Journal of Infrastructure, Policy and Development 2024, 8(8), 4656.
https://doi.org/10.24294/jipd.v8i8.4656

Policy Insight

Muddling from the middle out: Multi-scalar governance for place-based and adaptive sustainability in Texas

Steven M. Richter[1,*], **Jacob D. Petersen-Perlman**[2], **Katherine Lieberknecht**[3]

[1] East Carolina University, Greenville, NC 27858, United States
[2] Colorado State University, Fort Collins, CO 80523, United States
[3] University of Texas at Austin, Austin, TX 78705, United States
*** Corresponding author:** Steven M. Richter, richters22@ecu.edu

CITATION

Richter SM, Petersen-Perlman JD, Lieberknecht K. (2024). Muddling from the middle out: Multi-scalar governance for place-based and adaptive sustainability in Texas. Journal of Infrastructure, Policy and Development. 8(8): 4656. https://doi.org/10.24294/jipd.v8i8.4656

ARTICLE INFO

Received: 17 February 2024
Accepted: 15 April 2024
Available online: 14 August 2024

Abstract: Given the eclectic and localized nature of environmental risks, planning for sustainability requires solutions that integrate local knowledge and systems while acknowledging the need for continuous re-evaluation. Social-ecological complexity, increasing climate volatility and uncertainty, and rapid technological innovation underscore the need for flexible and adaptive planning. Thus, rules should not be universally applied but should instead be place-based and adaptive. To demonstrate these key concepts, we present a case study of water planning in Texas, whose rapid growth and extreme weather make it a bellwether example. We review historic use and compare the 2002, 2007, 2012, 2017 and 2022 Texas State Water Plans to examine how planning outcomes evolve across time and space. Though imperfect, water planning in Texas is a concrete example of place-based and adaptive sustainability. Urban regions throughout the state exhibit a diversity of strategies that, through the repeated 5-year cycles, are ever responding to evolving trends and emerging technologies. Regional planning institutions play a crucial role, constituting an important soft infrastructure that links state capacity and processes with local agents. As opposed to "top-down" or "bottom-up", we frame this governance as "middle-out" and discuss how such a structure might extend beyond the water sector.

Keywords: sustainability; place-based; adaptive management; regional water planning; climate adaptation; multi-scalar governance

1. Introduction

Sustainability is a flexible concept that resonates with a broad audience. It is alluring, having been described as leading to "chameleon-like opportunism" (Campbell, 2016, p. 394) where, sometimes, transformative goals are given a backseat to ulterior motives (Gunder, 2006). But such conceptual pliability differs from flexibility in how to achieve it. Even when the definition is standardized, implementation and practice should be far from uniform.

This was the consensus reached by the scientific community more than two decades ago, as articulated by the US National Research Council's (NRC) (1999) *Our Common Journey*. The report, an attempt to build from *Our Common Future* (UNWCED, 1987) and coalesce US scientific efforts toward sustainability, concluded that "the pathways of a transition to sustainability cannot be charted fully in advance. Instead, they will have to be navigated adaptively at many scales and in many places" (NRC, 1999, p. 3). The socio-cultural, environmental, political-economic, and technological aspects of planning for sustainability exhibit tremendous heterogeneity, specificity, and uncertainty (MacGillivray and Franklin, 2015). They are interactive and ever evolving, complicating the application of universal strategies to local contexts constituted by a distinct set of problems and capabilities (Wilbanks, 2015). This call for a context-dependent and flexible approach is echoed in the most recent Intergovernmental Panel on Climate Change (IPCC) (2023) report.

Given this pretext, it becomes essential to contemplate what it means to adaptively plan for sustainability "at many scales and in many places". Such an approach to sustainability is not only grounded in scientific rigor, per NRC (1999), but also remains an underdeveloped piece of transformative social justice and equity planning. Sometimes, universal solutions (e.g., densification, mixed use development) yield counter-productive outcomes (e.g., the displacement of poorer, transit-riding residents with affluent car users) (Oden, 2016). This is not to suggest that many of the concepts commonly linked with sustainability are destined to fail, but instead to emphasize the need for a different starting point.

This article seeks to address this weakness by re-engaging with the concepts outlined in NRC (1999). We focus more on the "how" than the "what" of sustainability and do so by applying multi-scalar analysis to two key concepts—1) place and 2) adaptive planning. After reviewing key literature, we leverage these concepts to conduct a case study of water planning in Texas. The case reveals that transformation is possible, but it requires continuous (adaptive) work empowered by regional institutions that facilitate interactions between local (place-based) and state actors.

Such interplay between scales is essential to accessing the dynamism and richness of place (Wilbanks, 2015). We call this approach a "middle out" governance strategy, one that explicitly hybridizes local (bottoms-up) and state/federal (top-down) scales. Our discussion highlights how middle-out governance could enable place-based, adaptive planning across key planning sectors, emphasizing the ripeness for innovation and the momentum of current and ongoing reforms. We find that planning for sustainability is less about the substance of any individual plan, and more concerned with empowerment of planning apparatus and institutions.

1.1. The receptive and complex nature of place

Despite the global or regional nature of systems or threats (e.g., climate change), planning problems manifest locally, often in response to a unique set of interactions among a variety of systems (MacGillivray, 2015). Social, ecological, and technological patterns and processes connect interactively, resulting in non-linear change, feedback loops, and a diversity of driving forces (Alberti, 2008; McPhearson et al., 2022). This shift from linear to complex causality requires an approach receptive to context and the particularities of place (NRC, 1999).

The concept of place has meanings derived from diverse epistemologies that include interpretive, phenomenological, positive, and mechanistic traditions (MacGillivray and Franklin, 2015). Place is essential to lived experience and intrinsic to cultural identity and human values (Tuan, 1975). Simultaneously, place represents a system coproduced by social, ecological, and technical structures (Picket et al., 2021). The two, though the subject of vastly different research traditions, are intertwined.

For example, Barton Springs Pool in Austin, Texas is both a singular experience for residents and a culmination of complex systems. The springs are the home to the

Barton Springs salamander, an endangered species. Development in the watershed was threatening the species; it also compromised recreating in the pool. Thus, different place-based mechanisms were engaged. First, a strong sense of place motivated local opposition and municipal action. Second, the highly connective karst geology, regional growth trends, and federal endangered species law gave a place-based mechanism for extending resistance beyond the confines of municipal boundaries (Lieberknecht, 2000). Today, a technically sophisticated salamander breeding program, exurban conservation funded by city residents, and a web of development regulations all combine to ensure both the salamanders and sunbathers remain… in place.

This example highlights how "place" might serve as an effective boundary object for integrating different types of knowledge (MacGillivray and Franklin, 2015). Yet, "putting place into a multiscale context … is emerging as a very practical need in addressing a number of salient issues for nature-society policy and action" (Wilbanks, 2015, p. 74). When applied strictly from a top-down perspective, "place" might just be a buzzword for used to describe spatially differentiated policy as opposed to the more receptive and holistic approach it implies (Randolph and Currid-Halkett, 2022). As such, it is necessary to consider how different governance structures empower, or hinder, place-based planning.

1.2. Adaptive planning as applied humility

There has, perhaps, never been a time when so much was changing so fast. Climate change, technological advancements, social and cultural trends, human migration, etc. have all picked up steam since NRC (1999), making their guidance as apt today as it was a generation ago (NRC, 1999, p. 3):

> The metaphors of 'journey' and 'navigation' in the work reported here were adopted with serious intent. They reflect the Board's view that any successful quest for sustainability will be a collective, uncertain and adaptive endeavor in which society's discovering of where it wants to go is intertwined with how it might try to get there.

Therefore, adaptive planning is a process, as opposed to the similar concept representing an outcome or characteristic (e.g. "adaptive capacity"). The expression of this process in environmental management—adaptive management—is no longer novel. It has been defined as an iterative process that involves continuous learning from implemented strategies and re-evaluation of external factors (Pahl-Wostl, 2008). Yet, it is increasingly clear that this concept needs to be extended from the programmatic or project-level toward institutional reform of governance structures, as is found in the call for further institutional response to climate change (Mach et al., 2023).

The transition from scientific management to adaptive institutions necessarily begins with humility. Instead of being a driver within decision structures, science becomes part of an integrated and open framework for policy and planning that is both incremental and iterative (Brunner et al., 2005). One crucial element is the realization that science possesses different levels of certainty, with more general and regional phenomena—e.g., drier conditions in Texas due to climate change—likely being more certain than local and place-based science—e.g., precise future conditions in a given river basin or aquifer. More importantly, how a community values or prioritizes those conditions is a normative, not scientific question. The multi-dimensional nature of "place" thus complicates the process of adaptation. Adaptive pathways (Haasnoot et al., 2013) are one process for bringing together place-specificity and uncertainty. Pathways combine discreet policy actions or scenarios with a description of iterative futures that allows policy makers to understand tipping points and path dependence while targeting both short- and long-term goals. The intricacy of adaptive processes may suggest the local scale to be the most appropriate as higher levels of governance may not possess sufficient flexibility or receptivity. Yet, the question of scale remains a highly debated aspect of governance, for water resources planning in particular (Woodhouse and Muller, 2017) and sustainability, in general (Wilbanks, 2015).

1.3. Scale and water governance

Gupta and Pahl-Wostl (2013) describe the debate about scale and water governance in terms of the subsidiarity principle, which refers to water governance at the most localized scale possible, and the universality of water-related problems, thereby pushing water issues to the highest possible level of governance. Often, the scale debate in water governance is often framed as "top-down" versus "bottom-up".

Top-down models of governance can be described as operating as a policy-centered, rational process with decisions made through senior officials, with decisions progressing downwards through relevant lower rungs of organizations and departments. On the other hand, bottom-up models operate through policies created on the ground through experiences of lower-level bureaucrats basing decisions on experiences and interactions with affected user groups (Watson, 2014).

Both approaches have strengths and weaknesses. Top-down approaches can be overly reliant on experts that can potentially dismiss knowledge from local actors and exclude them from decision-making, manifesting as overly paternalistic and alienating to local stakeholders. In contrast, participatory bottom-up approaches have been critiqued as promoting tokenism, representing communities and stakeholder groups as coherent and cohesive bodies, lacking resources, and lacking knowledge of the policy-making process and how to facilitate it (Smith, 2008).

Oftentimes, the top-down/bottom-up distinction in approaches is not so clear cut in practice, as many cases of collaborative environmental management highlight the diverse roles policymakers play in the crafting of policies (Koontz and Newig, 2014). The heterogeneity of water resources problems also implies different levels of governance. Given this complexity, water problems necessitate multiple simultaneous levels of governance (Gupta and Pahl-Wostl, 2013). This is seen in adaptive water governance, which prescribes polycentric governance across multiple centers of power and learning through co-management (Huitema et al., 2009).

Given its federalized system, polycentric governance is both prevalent and necessary in the US. Consequently, water management has become increasingly fragmented (Petersen-Perlman et al., 2018). There are over 100,000 local water-related organizations and more than 300 agencies and departments across all 50 states (Dworsky et al., 1991). Given the complexity of managing and governing water at all scales and the problems with top-down and bottom-up approaches, perhaps it is time to "meet in the middle".

2. Texas case study

2.1. Why Texas regional water planning?

Texas, with its rapid and diverse urban growth (Lieberknecht et al., 2019) and volatile, drought-prone climate (Nielsen-Gammon et al., 2020), has been a crucible of human-environmental stress in the realm of water supply. Texas' statewide water planning process has evolved significantly since its inception more than sixty years ago. A severe, six-year drought during the 1950s, which remains the worst multi-year event in the 125-year instrumental record (Nielsen-Gammon et al., 2020), led to the 1961 plan focused primarily on reservoir construction (Texas Board of Water Engineers, 1961). The State of Texas produced five more plans on an ad hoc basis by the end of the 20th century.

Following another significant drought in the 1990s, it was determined that a revision to the top-down, state-driven approach was necessary. In 1997, the Texas legislature evaluated and restructured the state water planning process in hopes of increasing effectiveness by switching from top-down to a regional planning process. The new process emphasizes greater participation and integration of local knowledge (TWDB, 2002). In a repeating five-year planning cycle, 16 Regional Water Planning Groups (RWPGs), each comprised of representatives from 11 different citizen groups (agriculture, industry, etc.), leverage technical support and financial resources provided by the statewide water office, the Texas Water Development Board (TWDB) to recommend water supply strategies for each region (TWDB, 2017). TWDB then compiles the regional water plans, including all relevant data (population, supply and demand projections, etc.), into the official State Water Plan (SWP). Only supply strategies approved by RWPGs and included in the SWP qualify for state funding.

This new process aligns with best practices outlined in literature on environmental governance as the regional ("meso") scale is considered the most tractable for integrated environmental governance (Wilbanks, 2015). Moreover, balancing between conservation and meeting society's demands requires significant capacity-building toward co-production of knowledge and governance (van der Molen, 2018). The RWPGs provide several key functions, including a steering mechanism, a nucleus for social learning, and the connective tissue (van der Molen, 2018) between individual/sectoral interests (e.g., irrigation, power-generation, etc.) and state administrative and regulatory processes.

Thus, the State of Texas has exhibited a robust planning response to issues of water supply (and more recently flooding). Texas water planning has been considered a model for other states due to its regional focus, statewide reach, participatory nature, and funding and implementation structure (English and Arthur, 2010). Its contemporary water planning legislation is among the most adaptive and supportive of local and regional water planning in the United States (Dyckman, 2016). This is not to suggest the process is perfect (as we will discuss), only that it aligns with an adaptive, place-based, and multi-scalar approach, and has done so for long enough (five plans since 2002) to provide a useful case study. As urbanization and climate change continue, other regions throughout the globe will begin to (or already do) grapple with similar issues, making this work both timely and relevant beyond the confines of the Lone Star state.

2.2. Case methods and data

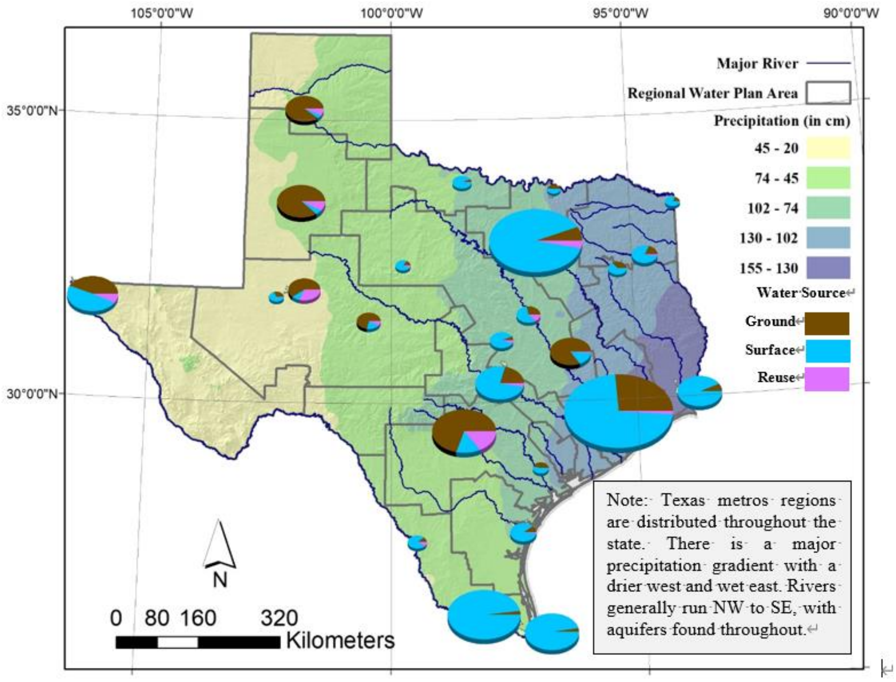
To understand the place-based and adaptive nature of water planning in Texas, it is necessary to examine how planning varies across time and space. This includes analysis of trends at both statewide and urban scales. The latter is operationalized not by individual municipality but by urban agglomeration, defined here using the 2020 US Census Metropolitan Statistical Area delineation ("metro regions" hereafter). We examine the statewide scale because this the source of formal planning water planning and funding processes. The metro regional scale provides insight into how social patterns like population and economic growth intersect with local physical and infrastructure dynamics, such as surface and groundwater availability or preexisting storage and distribution networks (Bixler et al., 2019).

We base our temporal analysis on historic use data, beginning in 1980, and the five SWPs published since the shift to a regional planning process: 2002, 2007, 2012, 2017, and 2022. Although much of the data and models used to produce the plans vary across plan year and RWPG, there are four standard data elements that allow statewide aggregation and comparison. These include 1) population forecasts, 2) projections of future water supply, 3) estimates of future water demand, and 4) strategies that fill the gap between future supply and demand (referred to as "needs" in the SWPs). Each plan includes 50-year forecasts for these four data elements. The '02 plan extends to 2050, the '07 and '12 plans target 2060, and the '17 and '22 plans include data through 2070.

Urban analysis is limited, in part, because there can be great variability within metro regions, but the data used here is consistent over time only at the county scale (counties are the basis of metro regions and have inconsistent relationships with municipalities). However, the county scale provides a useful basis for comparing different metro regions and provides a consistent base unit back to 1980. Figures have been selected that prioritize visualization of adaptive and/or locally differentiated patterns. Detailed data tables are available in the supplementary materials.

2.3. Study area and historic trends

Before applying the place-based and adaptive lens of analysis to the SWPs, it is helpful to first review the study area and historic water use. Texas encompasses diverse hydrological regimes, from over 150 cm of rain annually in Beaumont in the east to 25 cm annually in El Paso in the west (Nielsen-Gammon et al., 2020). The state contains 15 major river basins and nine major aquifers, with the 25 metro regions exhibiting a varied approach to water supply (see **Figure 1**). The 16 RPWG are distributed throughout the state and align with river basins, with larger basins being subdivided.



Note: Texas metros regions are distributed throughout the state. There is a major precipitation gradient with a drier west and wet east. Rivers generally run NW to SE, with aquifers found throughout.

Figure 1. Map of case study area. Circle and wedge size reflects total water use for individual metro regions, which include all major cities and their suburban and exurban areas.

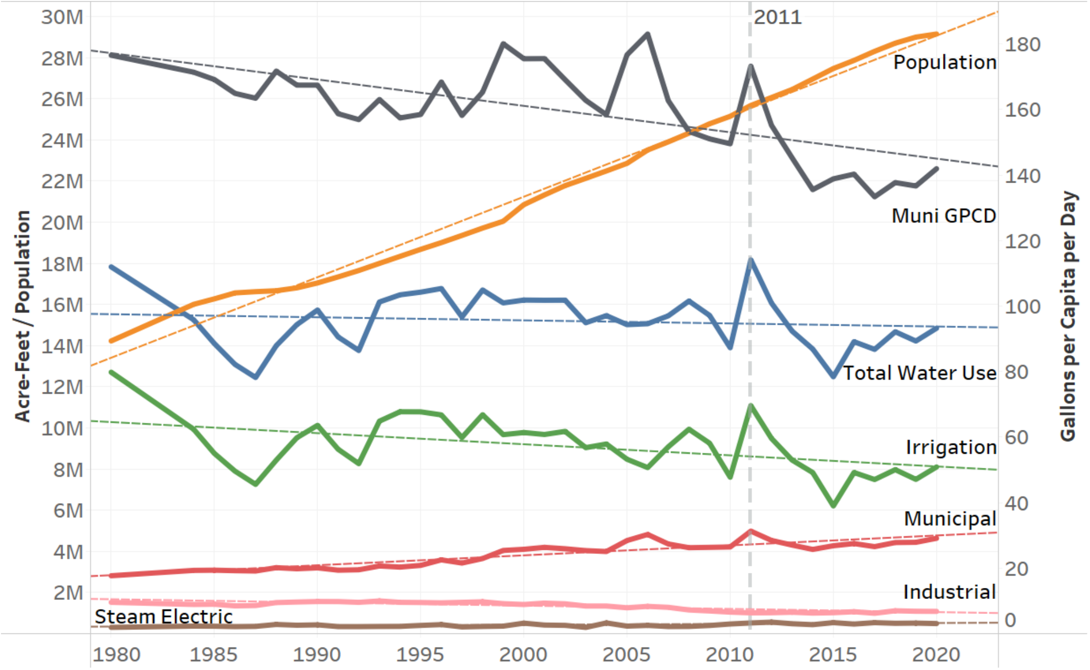


Figure 2. Summary of Statewide Population and Water Use. Population and Water Use on left axis, per Capita Use (GPCD) on right; linear trend as dashed line.

Since 1980, sectoral use has experienced significant change (**Figure 2**). Irrigation has declined from ~71% of total annual water use in 1980 to ~54% in 2020, with municipal and steam-electric use both doubling over the same period, from ~16% to ~31% and ~1.5% to ~3%, respectively. At the same time, manufacturing water use has slowly declined from ~9% to ~6%. Declines in irrigation have largely come from reductions in groundwater use (especially over the Ogallala aquifer in the northern Panhandle region). Municipal expansion has been supported by increased use of surface water that concentrates in the Texas Triangle and along the US-Mexico border. Manufacturing is primarily located along the Gulf Coast on the east.

Population growth is concentrated in metro regions (many rural areas are seeing declining population) and is a driver for rapidly expanding municipal water use. Metro region population more than doubled from 1980 to 2020, but municipal water use increased by only 73%. This corresponds to a significant reduction in per capita use from 180 to 140 gallons per capita per day (GPCD) (**Table 1**). Several smaller metro regions (e.g., Abilene, Corpus Christi) have managed to reduce overall water use despite population growth. Thus, municipal water use in Texas is characterized by concurrent expansion and increasing efficiency; however, this overall trend masks the impacts of individual drought years. For example, the 2011 drought, which remains the worst single-year drought (Nielsen-Gammon et al., 2020) had one of the highest rates of per capita municipal use since 1980 (**Figure 2**).

Table 1. Population and Municipal Water Use (Total and per capita/GPCD) for all Metro Regions.

Metro Region	**‘80 Population**	**‘20 Population**	**Pop Delta**	**‘80 Muni Use (Acre-Ft)**	**‘20 Muni Use (Acre-Ft)**	**Use Delta (Acre-Ft)**	**‘80 GPCD**	**‘20 GPCD**	**GPCD Change**
Abilene	139,192	176,579	37,387	32,111	29,424	(2687)	206.0	148.8	(57.2)
Amarillo	184,648	268,691	84,043	39,126	64,398	25,272	189.2	214.0	24.8
Austin-Round Rock-Georgetown	585,051	2,283,371	1,698,320	117,475	356,120	238,645	179.3	139.2	(40.0)
Beaumont-Port Arthur	373,210	397,565	24,355	55,640	64,407	8767	133.1	144.6	11.5
Brownsville-Harlingen	209,727	421,017	211,290	39,522	60,867	21,345	168.2	129.1	(39.2)
College Station-Bryan	120,554	268,248	147,694	24,582	43,569	18,987	182.0	145.0	(37.0)
Corpus Christi	340,488	445,763	105,275	74,889	60,888	(14,001)	196.4	121.9	(74.4)
Dallas-Fort Worth-Arlington	3,012,391	7,637,387	4,624,996	647,001	1,259,108	612,107	191.7	147.2	(44.6)
El Paso	482,627	868,859	386,232	103,174	131,729	28,555	190.8	135.4	(55.5)
Houston-The Woodlands-SugarLand	3,147,640	7,149,642	4,002,002	595,205	1,008,196	412,991	168.8	125.9	(42.9)
Killeen-Temple	226,592	475,367	248,775	38,997	74,403	35,406	153.6	139.7	(13.9)
Laredo	99,258	267,114	167,856	23,698	43,583	19,885	213.1	145.7	(67.5)
Longview	221,737	286,184	64,447	32,557	40,771	8214	131.1	127.2	(3.9)
Lubbock	262,506	351,268	88,762	48,764	61,305	12,541	165.8	155.8	(10.0)
McAllen-Edinburg-Mission	283,323	870,781	587,458	48,955	147,497	98,542	154.3	151.2	(3.0)
Midland	87,320	175,220	87,900	20,145	41,842	21,697	206.0	213.2	7.2
Odessa	115,374	165,171	49,797	24,549	25,791	1242	190.0	139.4	(50.6)
San Angelo	86,170	121,516	35,346	22,350	17,312	(5038)	231.6	127.2	(104.4)
San Antonio-New Braunfels	1,154,819	2,558,143	1,403,324	251,939	424,244	172,305	194.8	148.1	(46.7)
Sherman-Denison	89,796	135,543	45,747	16,750	19,638	2888	166.5	129.3	(37.2)
Texarkana	75,301	92,893	17,592	16,748	18,713	1965	198.6	179.8	(18.7)
Tyler	128,366	233,479	105,113	23,340	47,629	24,289	162.3	182.1	19.8
Victoria	74,000	98,331	24,331	11,099	16,578	5479	133.9	150.5	16.6
Waco	202,102	295,782	93,680	45,460	52,010	6550	200.8	157.0	(43.8)
Wichita Falls	137,930	148,128	10,198	26,897	16,644	(10,253)	174.1	100.3	(73.8)
All Metro Regions	11,840,122	26,192,042	14,351,920	2,380,973	4,126,666	1,745,693	179.5	140.7	(38.9)

2.4. Evolving planning outcomes

The increasing efficiency demonstrated by historic water use trends reflects collective adaptation. The extent to which this trend is driven by intentional planning rather than resulting from indirect pathways related to urbanization, densification, and technological change is unclear. However, examination of future water visions, as encapsulated in the five SWPs, provides some granularity into the adaptive planning process.

Longitudinal comparison of SWP outcomes illustrates multiple dynamics since 2002 (**Figure 3**). Population growth exhibits acceleration, which contrasts with decelerating demand, supply, and future strategies. The use of second-order descriptors (e.g., “accelerate” vs “increase”) is necessary because the general trends do not change across plans. For example, each plan shows a positive trend (or slope) in population, demand, and strategies and slight negative trend for supply. It is the rate-of-change (or slope) that requires further analysis.

Population exhibits the greatest acceleration during the 2007 cycle. The population slope, calculated using a simple linear model, increases 7% in the 2007 plan, then less so in subsequent planning cycles. Demand accelerates in the 2007 and 2012 cycles before reversing course in 2017 and eventually decelerating sharply in the 2022 cycle. The negative trend in future supply decelerates such that supply forecasts for 2050, a year which will be used throughout this analysis because it is the furthest into the future that all five plans share, increase by 4% and 3% in 2007 and 2012, but decline sharply during the 2017 cycle. Following a similar pattern, strategies accelerate through 2012 with downward revisions in both the 2017 and 2022 cycles.

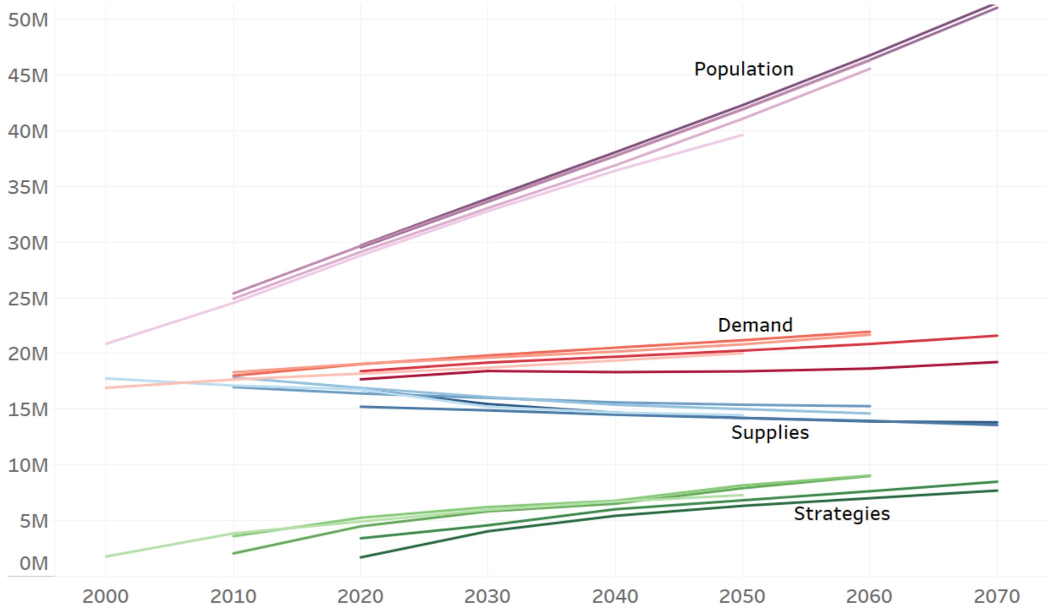


Figure 3. Comparative analysis of SWP outcomes. A summary of the four plan outputs for each SWP year, with earlier plans in lighter shade and more recent in darker. Units are in acre-ft except for Population.

These patterns become more nuanced when dissecting demand by end-use sector (**Figure 4**, panel A). Irrigation demand peaks in the 2007 plan, municipal and power generation demands begin their deceleration in the 2017 plan, and manufacturing demand peaks in 2017 then experiences the largest slowdown in any demand subcategory, accounting for 2/3rds of the overall demand deceleration in the 2022 cycle.

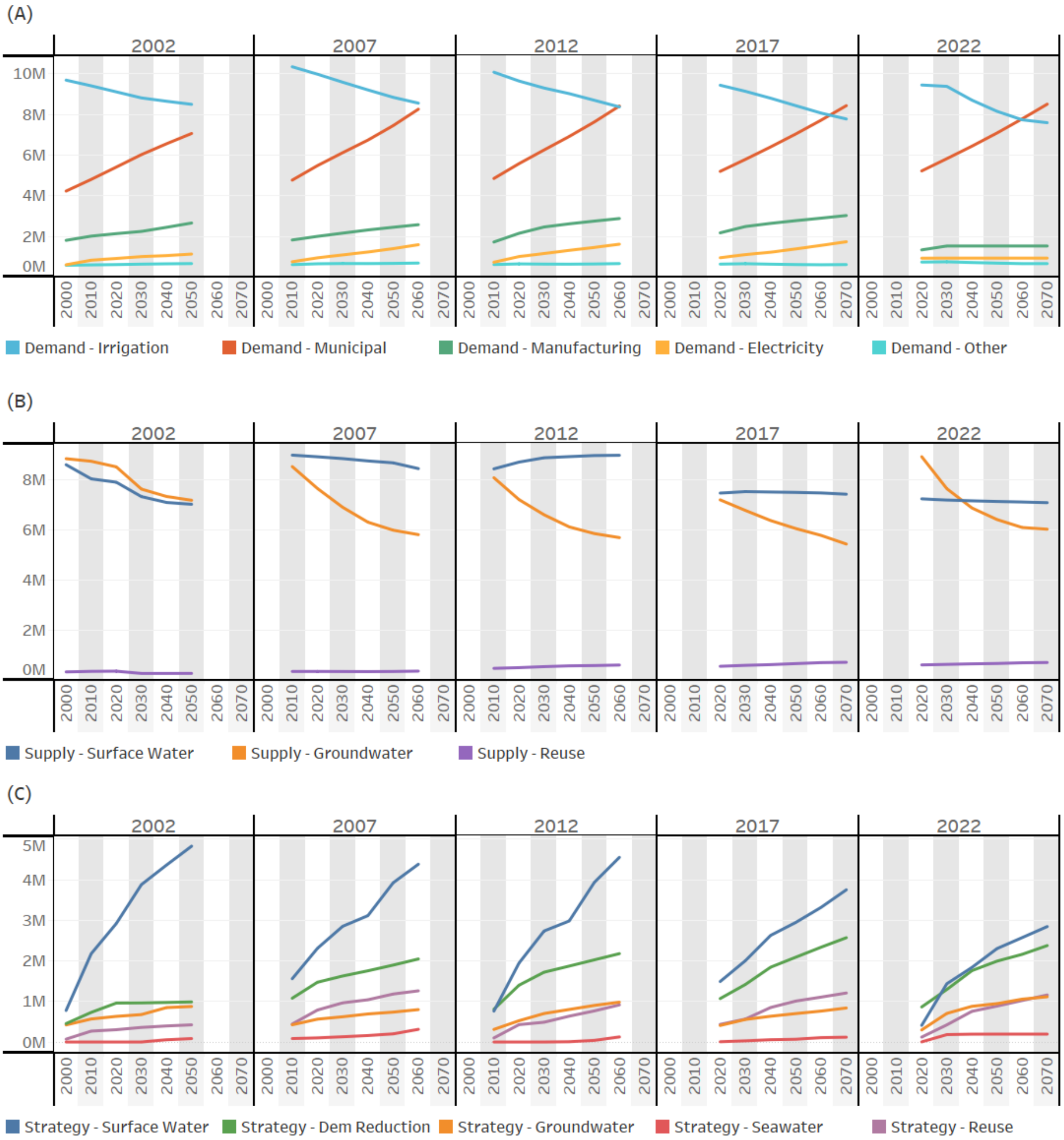


Figure 4. Sub Categorical Breakdown of SWP outcomes. **(A)** demand forecasts by sector for each SWP year; **(B)** supply forecasts by source for each SWP year, and **(C)** strategies forecasts by source for each SWP year. Units for all panels in Acre-Ft but Y-axis rescaled for each to optimize visibility.

Supply subcategories exhibit similar diversity (panel B). Surface and groundwater supply have a similar trajectory in the 2002 plan, then diverge over the next two cycles with surface water accelerating and groundwater dropping. These patterns switch over the 2017 and 2022 planning cycles, with the surface water trend flattening and shrinking in absolute terms. Groundwater forecasts drop in the 2007 plan, maintain relative stability through 2017, then undergo significant revision in the 2022 plan with a major acceleration in near-term supply followed by rapid decline. Supply from reuse slowly accelerates, with a cumulative increase in the 2050 reuse supply forecast of nearly 250% by the 2022 plan.

Analysis of strategies by source shows major shifts in how future needs will be met (panel C). The biggest shifts are the deceleration of surface water and acceleration in demand reduction (conservation). The former is nearly cut in half by the 2022 plan, dropping from 66% of all 2050 strategies in the 2002 plan down to 37% in the 2022 plan. Concurrently, the share of 2050 strategies that come from demand reduction more than doubles from the 2002 to 2022 plans. Reuse become a greater factor after the 2002 plan, groundwater maintains a similar share across plans between 12%–15%, and seawater is between 1%–3% of 2050 Strategies for all planning cycles.

This comparative analysis of the five SWPs shows how outcomes have changed in substantive ways over the five cycles. There are sometimes abrupt shifts, as with manufacturing demand in 2022, but more often trends progress over multiple plans. How strongly these changes reflect an adaptive planning process will be discussed in Section 2.6.

2.5. Manifestations of place

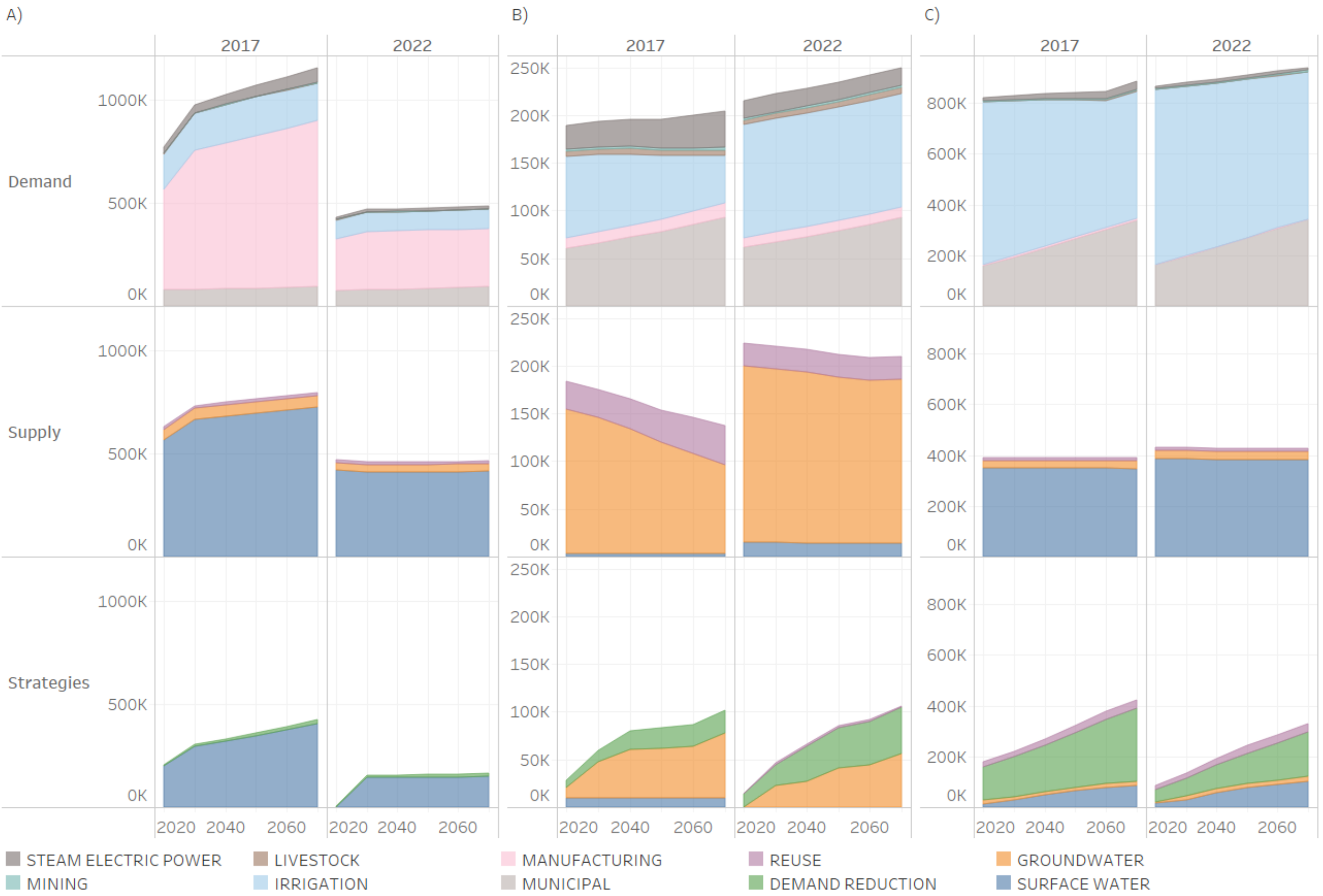


Figure 5. Sub Categorical Breakdown of SWP outcomes filtered for select Metro Regions. **(A)** Beaumont-Port Arthur; **(B)** Amarillo; **(C)** McAllen-Edinburg-Mission. Units for all panels in Acre-Ft but Y-axis rescaled for each to optimize visibility.

The local dynamics of water supply are evident in historic water use. For example, the Austin-Round Rock-Georgetown and San Antonio-New Braunfels metro regions are immediate neighbors of roughly the same size with a similar (rapid) growth trajectory, yet their supply profile is entirely different with the former relying primarily on surface water and the latter being groundwater dominant. Metro regions throughout the state display a variety of sectoral, source, and efficiency characteristics. The same is true when one looks forward, not just back.

Many of the broad, adaptive planning trends discussed in the previous section are not universal, but instead concretely link to different places throughout the state, as is evident in county-level data from the 2017 and 2022 SWP cycles (unfortunately, this level of detail is not available in early plans). In some cases, a single metro region drives the statewide trends, as is the case with the acceleration in population projections or seawater strategies—Dallas-Fort Worth-Arlington accounts for ~75% of the statewide population acceleration and Corpus Christi encompasses the entirety of seawater strategies in the 2022 SWP. But, in many cases, heterogeneity manifests in a portfolio of trends that bely the complexity and specificity of place; **Figure 5** provides three illustrative examples.

Beaumont-Port Arthur (panel A), a medium-sized and slower growing region, reveals itself as a driver of statewide deceleration in manufacturing demand. Supply, especially that coming from surface water, also sees a major decline. From the 2017 to 2022 SWP, manufacturing demand drops ~50% while surface water supply has a staggering 60% reduction. For context, the closest neighbor—Houston-TheWoodlands-SugarLand—also sees a significant drop in manufacturing (24%) but its surface water supply sees a slight change (3%). This highlights the crucial role played by river basins, as Belmont-Port Arthur is located in the Neches instead of the San Jacinto and Brazos. SWP data shows a major reservoir in the Neches (the Sam Rayburn-Steinhagen Reservoir system) drops from ~190 k to ~42 k acre feet of Supply, and Neches River water drops from 404 k to 242 k. There is a web of causes for these changes: new demand forecast methods, legal constraints due to subordination of Sam Rayburn and Neches water rights, a fixed error in ecological flows calculations, and hydropower supply requirements. It is uncertain if the 2022 SWP represents a robust forecast as a new set of models, required by House Bill 723, will inform the 2026 cycle (TWDB, 2022).

Amarillo (panel B) is a small rural metro region in the northern Panhandle, a region that relies on the declining Ogallala Aquifer. Demand sees modest deceleration in the steam-electric and manufacturing sectors, mirroring statewide trends. Similarly, the composition of strategies sees demand reduction increase in its relative share. But, irrigation demand in 2070 increases ~140% from 2017 to 2022 SWP. Mirroring this, groundwater supply in 2070 is approximately 90% higher in the more recent SWP. Both changes are contrary to statewide trends and are driven by the results of the 2016 Joint Groundwater Planning Process (TWDB, 2022). During this process, regional Groundwater Management Areas collectively determined their Desired Future Condition, a formal quantification of what the SWP refers to as “managed withdrawal” —in this case, 50% of remaining volume is to be used the next 50 years. So, the acceleration in irrigation demand and groundwater supply are not the result of new technology or different science, but instead reflect a formal willingness to deplete the resource more quickly than before.

McAllen-Edinburg-Mission (panel C) is the largest metro region in the growing Rio Grande Valley (RGV), which lies on the northern edge of the US-Mexico border. Recent international and interstate water conflicts along the Rio Grande River make the increase in irrigation demand (~15% in 2070) and surface water supply (~10%) a noteworthy outlier, especially with the adoption of a more stringent drought of record (from 2011) during the 2022 cycle. The two—demand and supply—both correspond to a hydrologic variance request that reflects a shift in irrigation timing and expands irrigation water rights. Though increased supply was formally acknowledged in the 2022 SWP, water supply in the RGV remains extremely stressed (Gonzalez, 2022).

These three vignettes highlight how state trends represent a different perspective than local and place-based realities, which are co-produced through physical and social processes. A common theme is the co-evolutionary nature of supply and demand, the significant role played by social and governance processes, and the applicability of physical units-of-analysis (river basins and aquifers).

2.6. Discussion

This case study examines historic and future water trends across Texas. Despite rapid population and economic growth, the state has seen relatively stable water use. Key factors include significant reductions in irrigation and growing municipal demand that is offset by a broad trend of increasing efficiency (lower per capita use). Next, a comparative analysis of the five SWPs since 2002 provides insight into the adaptiveness and place-based nature of water planning. This section serves to reflect on the case results and provide a brief assessment of planning outcomes.

2.6.1. Adaptiveness

SWPs are clearly dynamic artifacts that embody shifting assumptions and expectations surrounding water demand, supply, and future strategies. Perhaps nothing reflects this as meaningfully as the transition in how SWPs envision future supply—surface water dominated future strategies in 2002 but was halved in its share by the 2022 plan, with conservation making the biggest gains in its place.

This transition was not the result of an abrupt realization that water is a scarce resource in Texas, but instead reflects incremental improvement baked into the continuous planning efforts of the TWDB and RWPGs. Thus, the emphasis is on planning, not individual plans; a project continues eligibility for funding only if it remains in the next plan. This reduces path dependence and leaves room for revision and innovation.

Some planning changes occur over the course of a single planning cycle. The 2011 drought serves as a sharp inflection point for both demand and supply forecasts, with the previous accelerations reversing over the 2017 and 2022 cycles. Changes to forecast methods, like those used for manufacturing and steam-electric demand, also manifest abruptly. In the 2022 cycle, manufacturing demand forecasts became less speculative as only those user groups with supply contracts could get projects in the plan, while declines in steam-electric demand reflect the statewide shift toward renewable energy.

Planning outcomes driven by emerging water technologies tend to take multiple cycles. Two examples of this include brackish desalination (BD) and aquifer storage and recharge (ASR). The story of BD begins in 2004 with TWDB-funded demonstration projects and technical guidance materials. Since then, TWDB constructed a database on desalination plants, mapped groundwater reserves, and funded research that led to improved permitting. The 2022 SWP includes 26 new DB plants constituting 2% of future water strategies. ASR involves the use of wells in wet years to store water (ground or surface) in suitable aquifers. State intervention is more recent, with the Texas Legislature passing bills in 2015 and 2019 to simplify permitting and require TWDB to conduct a statewide survey and consolidate best practices. The 2022 SWP includes 27 new ASR systems or pilot projects that combine to form 2.5% of future water strategies. Both BD and ASR have become common strategies, and both will likely see their relative share of future supplies and strategies increase as they continue to mature.

There are several aspects of the Texas water planning process that are highly adaptive; however, the use of climate science is not yet among them. TWDB’s approach, as described earlier, relies on historic droughts to assess future demand and supply. Regarding climate change, the SWP states:

> “There currently isn’t much agreement among climate models (or scientists) about the nature of long-term changes to water resources in Texas and no forecasting tools capable of providing quantitative certainty about future water resources in Texas at the resolution needed for water planning.” (TWDB, 2022, p. 81).

There are certainly technical challenges with downscaling climate models, but it is highly likely that future droughts will be worse (Banner et al., 2010) and rainfall more intense (Nielsen-Gammon et al., 2021). Simply ignoring such a crucial influence on the future of water in Texas stains what is otherwise a strong record as an adaptive institution.

2.6.2. Place

Though many SWP trends align with general best practices—increasing efficiency, growth of conservation, integration of new technologies—the regional process grants meaningful legitimacy to local conditions and values, even when running contrary to best practice or overarching trends. For example, the deceleration in manufacturing demand in Beaumont-Port Arthur, large as it was, would have been greater had the region not revised it upward (TWDB, 2022). Local actors can and do have influence; there are several pathways through which place influences SWPs.

One means is the revision of data generated by the state. In the case of hydrologic models, regions submit variances that require state approval. A model that defies hydrologic reality would not pass muster, but there is room for different model parameters, input data, etc. For demand forecasts, state data relies not on complex methods but on simple yet defensible techniques that apply recent water and economic trends (e.g., the relative efficiency of renewable energy growth). Local communities often have more and better data on local water use and economics, and can readily improve on such forecasts. Local sponsors are also required to propose projects that accumulate to become SWP strategies. Unlike models, projects start with local agents but are still required to follow state process and requirements.

Not all local influences need to be defensible to the state. Normative decisions, as is perhaps best illustrated by the "managed depletion" (TWDB, 2022, p. 7) of the Ogallala Aquifer, are ultimately values-based. Though models are applied to the "Desired Future Conditions" to provide a supply estimate, the condition itself (50% of remaining volume) stems not from quantitative analysis but the collective identify and reality of farmers. It may be tempting to critique the decision to accelerate depletion of a critical and limited resource, but the stakeholders were well informed and are themselves in the best position to understand the implications of such a decision.

Some of the mechanisms described above provide clear examples of both socio-cultural and the systemic coproduction aspects of place. This does not suggest the outcomes are perfect. The depletion of groundwater likely reduces ecological flows downstream and new reservoirs displace residents. In theory, such stakeholders should have a place at the RWPG table, but local power-dynamics almost translate into winners and losers. How middle-out governance can diminish these inequities is an important consideration for future research.

3. Conclusion

Transformation is a lofty ambition, one that is often achieved not through grand gestures or projects but via "muddling through" (Lindblom, 1959). The NCR (1999) concluded that transformation toward sustainability requires an adaptive approach that contextually responds to different places. We find water planning in Texas to be an example of incremental, adaptive, and place-based transformation. Central to its success is a multi-scalar governance framework where regions provide the essential connective tissue between top-down and bottom–up processes. We call this "middle out".

The case and analysis presented here are relatively coarse and exploratory in nature. Both the place and adaptive concepts can and should be examined in greater detail. However, SWP outcomes show sufficient change across time and space to be evidence that the overall strategy is working. The emphasis is not on any single plan but on continuous planning with stakeholders working collaboratively across scales.

Other planning sectors seeking to replicate this process need to focus on institutional reform. Cities demonstrate vastly different land use trends (Richter, 2020) with significant process differentiation within regions (Richter and Bixler, 2022). Yet in the US, the focus remains on individual plans at the local scale, with regional governance struggling to find the "middle". A representative example are metropolitan planning organizations, a common regional institution marred by asymmetrical representation and insufficient links to local implementation (Sciara, 2017). Planning for Sea Level Rise is another example where place and uncertainty necessitate more robust and dynamic governance, something currently lacking in much of the United States (Grandage et al., 2024). Reform is needed for progress toward sustainability.

Sustainability began with the call for new institutions (UNWCED, 1987). Despite tremendous work in academia and by practitioners, governance innovation remains an area of need. This case study on water planning in Texas provides insight for policy makers on what "middle-out" looks like in practice. Some of the precise mechanisms (e.g. hydrologic variances) are sector specific, but at the core is regional governance empowered by state capacity and informed by a diverse set of local actors. Sustainability should not look the same everywhere but there are consistent means of achieving it.

Acknowledgments: This research was funded Planet Texas 2050, a research grand challenge at the University of Texas at Austin.

Conflict of interest: The authors declare no conflict of interest.

References

Alberti, M. (2008). Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems. Springer.

Banner, J. L., Jackson, C. S., Yang, Z. L., et al. (2010). Climate Change Impacts on Texas Water: A White Paper Assessment of the Past, Present and Future and Recommendations for Action. Texas Water Journal, 1(1), 1. https://doi.org/10.21423/twj.v1i1.1043

Bixler, R. P., Lieberknecht, K., Leite, F., et al. (2019). An Observatory Framework for Metropolitan Change: Understanding Urban Social–Ecological–Technical Systems in Texas and Beyond. Sustainability, 11(13), 3611. https://doi.org/10.3390/su11133611

Brunner, R., Edwards, C., Steelman, T., et al. (2005). Adaptive Governance: Integrating Science, Policy, and Decision Making. Columbia University Press.

Campbell, S. D. (2016). The Planner's Triangle Revisited: Sustainability and the Evolution of a Planning Ideal That Can't Stand Still. Journal of the American Planning Association, 82(4), 388–397. https://doi.org/10.1080/01944363.2016.1214080

Dworsky, L. B., Allee, D. J., & North, R. M. (1991). Water resources planning and management in the United States federal system: Long term assessment and intergovernmental issues. Nat. Resources J., 31, 475.

Dyckman, C. S. (2016). Sustaining the Commons: The Coercive to Cooperative, Resilient, and Adaptive Nature of State Comprehensive Water Planning Legislation. Journal of the American Planning Association, 82(4), 327–349. https://doi.org/10.1080/01944363.2016.1214537

Gonzalez, V. (2022). Squeezed dry: South Texas farmers face a possible future without water. MyRGV.Com. Available online: https://myrgv.com/local-news/2022/08/06/squeezed-dry-south-texas-farmers-face-a-possible-future-without-water/ (accessed on 19 January 2024).

Grandage, A. J., Hines, R. E., & Willoughby, K. G. (2024). Treading Water: Planning for Sea Level Rise in the Southeastern United States. Public Works Management & Policy, 29(1), 45–62. https://doi.org/10.1177/1087724X231178868

Gunder, M. (2006). Sustainability: Planning's Saving Grace or Road to Perdition? Journal of Planning Education and Research, 26(2), 208–221. https://doi.org/10.1177/0739456X06289359

Gupta, J., & Pahl-Wostl, C. (2013). Global water governance in the context of global and multilevel governance: Its need, form, and challenges. Ecology and Society, 18(4).

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global Environmental Change, 23(2), 485–498. https://doi.org/10.1016/j.gloenvcha.2012.12.006

Huitema, D., Mostert, E., Egas, W., et al. (2009). Adaptive water governance: Assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. Ecology and Society, 14(1).

Ibisch, R. B., Bogardi, J. J., & Borchardt, D. (2016). Integrated water resources management: Concept, research and implementation. Springer.

Intergovernmental Panel on Climate Change. (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Koontz, T. M., & Newig, J. (2014). From planning to implementation: Top-down and bottom-up approaches for collaborative watershed management. Policy Studies Journal, 42(3), 416–442.

Lieberknecht, K. (2000). How everything becomes bigger in Texas: The Barton Springs Salamander controversy. In: Clark, S. G., Clark, T. W., Willard, A. R., & Cromley, C. (editors). Foundations of Natural Resources Policy and Management. Yale University Press.

Lieberknecht, K., Oden, M., Leite, F., et al. (2019). People, land, & water: Stories of metropolitan growth. University of Texas at Austin.

Lindblom, C. E. (1959). The Science of “Muddling Through.” Public Administration Review, 19(2), 79–88. https://doi.org/10.2307/973677

MacGillivray, B. H. (2015). The position of place in governing global problems: A mechanistic account of place-as-context, and analysis of transitions towards spatially explicit approaches to climate science and policy. Environmental Science & Policy, 53, 8–17. https://doi.org/10.1016/j.envsci.2015.05.015

MacGillivray, B. H., & Franklin, A. (2015). Place as a boundary device for the sustainability sciences: Concepts of place, their value in characterising sustainability problems, and their role in fostering integrative research and action. Environmental Science & Policy, 53, 1–7. https://doi.org/10.1016/j.envsci.2015.06.021

Mach, K. J., Vallario, R., Arnold, J. R., et al. (2023). Sector interactions, multiple stressors, and complex systems. In: Crimmins, A. R., Avery, C. W., Easterling, D. R., et al. (editors). Fifth National Climate Assessment. U.S. Global Change Research Program. https://doi.org/10.7930/NCA5.2023.CH18

McPhearson, T., Cook, E. M., Berbés-Blázquez, M., et al. (2022). A social-ecological-technological systems framework for urban ecosystem services. One Earth, 5(5), 505–518. https://doi.org/10.1016/j.oneear.2022.04.007

National Research Council. (1999). Our Common Journey: A Transition Toward Sustainability. National Academies Press.

Nielsen-Gammon, J. W., Banner, J. L., Cook, B. I., et al. (2020). Unprecedented Drought Challenges for Texas Water Resources in a Changing Climate: What Do Researchers and Stakeholders Need to Know? Earth’s Future, 8(8), e2020EF001552. https://doi.org/10.1029/2020EF001552

Nielsen-Gammon, J. W., Holman, S., Buley, A., & Jorgenses, S. (2021). Assessment of historic and future trends of extreme weather in Texas, 1900-2036 (Document OSC-202101). Office of the Texas State Climatologist, Texas A&M University.

Oden, M. (2016). Equity the Awkward E in Sustainable Development. In: Moore S. (editor). Pragmatic Sustainability; Dispositions for Critical Adaptation, 2nd ed. Routledge, Taylor & Francis Group. pp. 30–47.

Pahl-Wostl, C. (2008). Requirements for Adaptive Water Management. In: Pahl-Wostl, C., Kabat, P., & Möltgen, J. (editors). Adaptive and Integrated Water Management: Coping with Complexity and Uncertainty. Springer. pp. 1–22. https://doi.org/10.1007/978-3-540-75941-6_1

Petersen-Perlman, J. D., Megdal, S. B., Gerlak, A. K., et al. (2018). Critical issues affecting groundwater quality governance and management in the United States. Water, 10(6), 735.

Pickett, S. T. A., Cadenasso, M. L., & Rademacher, A. M. (2021). Coproduction of place and knowledge for ecology with the city. Urban Ecosystems. https://doi.org/10.1007/s11252-021-01190-8

Randolph, G. F., & Currid-Halkett, E. (2022). Planning in the Era of Regional Divergence. Journal of the American Planning Association, 88(2), 245–252. https://doi.org/10.1080/01944363.2021.1935302

Richter, S. M. (2020). Revisiting urban expansion in the continental United States. Landscape and Urban Planning, 204, 103911. https://doi.org/10.1016/j.landurbplan.2020.103911

Richter, S. M., & Bixler, R. P. (2022). Complexifying urban expansion: An exploratory, gradient-based approach. Buildings and Cities, 3(1), Article 1. https://doi.org/10.5334/bc.226

Sciara, G. C. (2017). Metropolitan Transportation Planning: Lessons From the Past, Institutions for the Future. Journal of the American Planning Association, 83(3), 262–276. https://doi.org/10.1080/01944363.2017.1322526

Smith, J. L. (2008). A critical appreciation of the “bottom-up” approach to sustainable water management: Embracing complexity rather than desirability. Local Environment, 13(4), 353–366.

Texas Board of Water Engineers. (1961). A plan for meeting the 1980 water requirements of Texas. Available online: https://www.twdb.texas.gov/waterplanning/swp/1961/index.asp (accessed on 24 October 2022).

Texas Water Development Board. (2002). Water for Texas. Available online: https://www.twdb.texas.gov/waterplanning/swp/2002/index.asp (accessed on 24 October 2022).

Texas Water Development Board. (2007). Water for Texas. Available online: https://www.twdb.texas.gov/waterplanning/swp/2007/index.asp (accessed on 24 October 2022).

Texas Water Development Board. (2012). Water for Texas. Available online: https://www.twdb.texas.gov/waterplanning/swp/2012/index.asp (accessed on 24 October 2022).

Texas Water Development Board. (2017). Water for Texas. Available online: https://www.twdb.texas.gov/waterplanning/swp/2017/index.asp (accessed on 24 October 2022).

Texas Water Development Board. (2022). Water for Texas. Available online: https://www.twdb.texas.gov/waterplanning/swp/2022/index.asp (accessed on 24 October 2022).

Tuan, Y. F. (1975). Place: An Experiential Perspective. Geographical Review, 65(2), 151–165. https://doi.org/10.2307/213970

United Nations World Commission on Environment and Development. (1987). Our Common Future. Oxford University Press.

van der Molen, F. (2018). How knowledge enables governance: The coproduction of environmental governance capacity. Environmental Science & Policy, 87, 18–25. https://doi.org/10.1016/j.envsci.2018.05.016

Watson, N. (2014). IWRM in England: Bridging the gap between top-down and bottom-up implementation. International Journal of Water Resources Development, 30(3), 445–459. https://doi.org/10.1080/07900627.2014.899892

Wilbanks, T. J. (2015). Putting “Place” in a multiscale context: Perspectives from the sustainability sciences. Environmental Science & Policy, 53, 70–79. https://doi.org/10.1016/j.envsci.2015.04.009

Woodhouse, P., & Muller, M. (2017). Water governance—An historical perspective on current debates. World Development, 92, 225–241.