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Current Issues and Perspectives in Urban Water Demand Management: A Report on the 5th Urban Water Demand Roundtable April 8–9, 2019, Tempe, Arizona

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Abstract

The Urban Water Demand Roundtable (UWDR) is a convening of practitioners, consultants, and academics engaged in water demand research. The UWDR was initially organized in 2012 by a group of water professionals and academics to fill a need for a forum with a higher level of dialogue about the ongoing and unexplored changes in urban water demand than could be found at existing national conferences and professional association events. This report was written to capture, organize, and communicate important and interesting insights, questions, and opinions expressed by participants in the 5th UWDR held April 8–9, 2019.

Keywords: conservation, water management, drought, urban water, water demand, land use, community, water rates, urban growth

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This report seeks to capture those discussions. Any errors or inaccuracies are the authors'.
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Introduction

This report was written to capture, organize, and communicate important and interesting insights, questions, and opinions expressed by participants in the 5th Urban Water Demand Roundtable (UWDR). The UWDR is a convening of practitioners, consultants, and academics engaged in water demand research. The UWDR was initially organized by a group of water professionals and academics to fill a need for a forum with a higher level of dialogue about the ongoing and unexplored changes in urban water demand than could be found at existing national conferences and professional association events. The purpose of the UWDR is to provide an opportunity for academics, consultants, and practitioners to share their work related to urban water demand, discuss current policy challenges for water demand management, identify important long term and emerging critical research needs, and develop partnerships among the participants to further address these research needs. The results produced by the UWDR offer a unique synthesis and dissemination of expert knowledge, opinions, and insights and an increased awareness of urban water demand issues that require attention from researchers and practitioners.

The 5th UWDR was held April 8th and 9th, 2019 in Tempe, Arizona at Arizona State University. It focused on the following set of topics:

- Drivers of Water Demand and Water Demand Forecasting
- Land Use Connections to Demand Management
- Economics and Sociology of Water Demand
- Assessment of Water Demand Management Policies
- Drought Management Comparison Between States

These topics were covered by 36 presentations distributed within 11 sessions. Each session devoted at least as much time for discussion as was allotted for the presentations. These discussions covered the topics of the presentations as well as others that evolved from the focus topics. Throughout the two-day UWDR, discussions were centered most heavily on these three key themes:

1. Economics and Sociology of Demand
2. Challenges to Estimating and Forecasting Demand
3. Balancing Community Values and Institutional Priorities

This report summarizes the discussion across these three main themes as well as three cross-cutting themes that emerged from our analysis of those discussions:

1. The Importance of Multiple Kinds of Scale
2. The Behavior and Values—Sociology and Psychology—of Urban Water Users

3. Integrating Land Use and Water Planning

Table 1 demonstrates that most of the cross-cutting themes relate to the UWDR themes and manifest in diverse ways, which are further explored below. The synthesis reported here does not include the content of the presentations, rather it presents the discussion that occurred after each set of presentations.

Table 1: UWDR Discussion and "Cross-Cutting" Themes

Roundtable Themes	**Cross-cutting Themes**		
	Scale	**Behavior**	**Land Water Integration**
Economics and Sociology of Demand	• Economic upscaling and downscaling • Assess affordability	• Interest/ability to conserve water • Pricing/rate structures	No emergent themes
Challenges to Estimating and Forecasting Demand	• Estimates and forecasts at neighborhood, city, regional scale • Data collection, dissemination, and maintenance	• Population growth • Indoor and outdoor water conservation tolerances	• Uncertainty of land use • Residential density
Balancing Community Values and Institutional Priorities	• Cross-scale fertilization	• Values • Participation in turf removal programs • Combine messaging and pricing to make rate strategies more effective	• Gap between water management and land management activities • Social value of landscape and urban form • Water as limit to growth

Urban Water Demand Roundtable April 8-9, 2019

Major Themes of the 5th Urban Water Demand Roundtable

Theme 1: Economics and Sociology of Water Demand

The economics and sociology of demand was a programmed topic for the UWDR with seven presentations covering this topic. The discussion that followed expanded the presentation topic to a number of related topics including affordability, rate structures, revenue implications of declining demand, and the economics of water demand management programs. The sociology of demand was a key aspect of the discussion for several of these topics.

Water Affordability

During several sessions the issue of affordable water rates was raised. Many utilities representatives at the UWDR noted that there is an emerging concern among the community's water providers and that their rates may not be affordable for some of their customers. Participants expressed frustration with the lack of industry or academic consensus on the best affordability indicator. They agreed that standards such as AR20 (used by City of Phoenix) and percentage of median income (used by City of Seattle) inadequately address affordability issues. Several cities are experimenting with different ways of quantifying affordability, including the creation of assistance programs, but are not satisfied with the results. For example, the City of Seattle created a program with a threshold based on percentage of median income, but found it hard to get people to sign up for it. The issue is aggravated by the motivation behind utilities' rate increases: addressing rising fixed costs; addressing loss of revenue resulting from effective conservation programs and falling demand; and incentivizing customers to reduce their demand. Identifying a household or community's affordability level is a function of how much families can afford and how much they can reduce their water use without radically affecting quality of life. The issue involves users who cannot afford rate increases, and more affluent users whose demand does not respond to rate increases because they are willing to pay anything to maintain their irrigated landscapes.

There was discussion about whether or not a one-size-fits-all affordability standard was practical because of the context of economy and conservation in each community. One such example was the appropriate scale to employ to assess affordability: the whole community; census tract; block group; or individual customer scale. Another issue was which parameters to use to assess affordability. Median and average incomes and cost of living not only vary from community to community, but also in the shape and tails of their statistical distribution.

Participants arrived at a consensus that more research is needed to: 1) create a definition of water affordability; 2) create affordability indicators that reflect each community's unique context; and 3) identify effective education and communication methods with both lower- and higher-income families.

Water Rates

Various viewpoints about rate structures were discussed including the relative merits of different kinds of rate structures and the rationale for choosing one over another. Generally, academic and practicing economists alike suggested that simpler rate structures, such as blockrates with a small number of blocks, are easier to manage and deliver a more easily understood message to customers: reducing demand will reduce customer costs. In other words, reducing demand is needed because water supplies are constrained. Conversely, some water managers suggested that more complex rates structures, such as budget-based rates, provide water managers with greater flexibility to adjust the system to accommodate changing conditions, such as normal or drought stressed water supplies. There was discussion about the effect that some rate structures, proportional or progressive, have upon different customers such as low income and wealthy. However, a few participants said that the fact of whether a rate structure is regressive or progressive was not an important consideration for their decision-makers.

Participants generally agreed that they have a limited understanding of exactly how different rates and pricing structures affect customers' behavior. Water managers require more actionable social psychology research about attitudes and behaviors towards water use in order to develop polices to persuade people to conserve more. Furthermore, the group discussed how messaging combined with pricing might make rate strategies more effective in meeting water utilities' demand objectives.

Participants also talked about the importance of understanding the politics of water rate adoption. Sometimes water utility boards will be reluctant to raise water rates, rejecting proposals for rate increases. Water managers need to know the organizational and community risks and implications associated with not increasing rates and be able to communicate those risks with their proposed recommendations.

Revenue Implications of Demand Reduction for Water Utilities

During the discussion sessions, there was minor concern expressed about the revenue implications associated with demand reduction and various rate structures. This was based upon the general problem, or paradox, of water utilities in the midst of a funding crisis also wanting to reduce demand. Some indicated that this is an important issue for smaller and midsize utilities that struggle with funding for repairs and water loss projects; changes in revenues due to demand reductions can be at the expense of some of these projects. There was little discussion about reducing the operating costs associated with demand. Participants did consider the question of how utilities decide if there is too much focus on reducing demand, i.e., whether there is a tipping point.

Economics of Conservation Programs

There was general discussion about the need for greater knowledge about the costs of different water demand reduction initiatives and the factors that make them effective or ineffective. For example, some participants identified a need for more formal data and information on the "contagion effect"—such as the roles individual behavioral standards and shared social norms play in the increased participation in landscape change programs such as turf removal. There is an existing body of social science research, especially in energy sector and areas of environmental behavior, that would be salient to such practices.

Theme 2: Challenges of Estimating and Forecasting Demand

Ten presentations on "Estimating and forecasting water demand" focused on the challenges associated with those activities and generated several sub-themes around demand modeling and data needs.

Data Limitations

The need for data and lack thereof was a major theme across several sessions where topics related to forecasting, estimating, and evaluating demand and demand management programs.

The scarcity of geospatial demand data among municipal water providers and socioeconomic data about their communities were identified as limiting factors for forecasting demand.

In addition to uneven availability of datasets, participants raised the issue of the absence of national standards for how water utilities report data. This results in inconsistent data reporting and terminology, which makes it even more difficult to analyze future demand. Practitioners lamented the lack of incentives to report demand data consistently across institutions given there was no federal agency suggesting or requiring this. It was noted that the U.S. Environmental Protection Agency has done this for water quality data and the U.S. Department of Energy (DOE) has done it for energy end use.

An ensuing discussion about how to address this issue focused on creating a national water demand survey that would establish standards of data reporting. This was done for industrial water use, but that ended in 1982. There was some discussion about the Water Research Foundation's projects and the California Data Collaborative providing some guidance on possible standards. While there was no agreement on which agency could take the lead at a national level on such an effort, some participants suggested that the U.S. Geological Survey or DOE would be the most suitable. It was not clear how to move the issue forward; some participants felt that more research was needed to assess the local and national barriers to initiating data standards and a survey.

Modeling Challenges

Besides data issues, multiple discussions about aspects of water demand modeling centered around the issue of models being used for either forecasting or assessment. Academic research into demand modeling is largely conducted for assessment purposes. Some of these research efforts touched upon at the UWDR focused on understanding qualitative interactions or exploring uncertainties related to driving factors of demand. A few practitioner participants indicated that though this work is not practical to integrate into demand forecasting currently, it is nonetheless useful because it pushes practitioners to expand their thinking about developing new forecasting models. There was also discussion about suggestions from previous UWDRs that practitioners' research would benefit from demand models that include factors related to demand management policy, such as specific conservation methods or drought responses, as well as any number of important exogenous factors like heat related climate change. These models could be used in an anticipatory way: to assess different water demand policies prior to implementation; and to assess the long-term demand implication of uncertain factors such as climate change.

How Low Can Indoor Demand Go?

Another important variable for predicting demands is future indoor water use. As the participants discussed, this variable is hard to quantify because no one can determine how much people are willing, or even able, to cut back on their household water use. Some suggested that there might be a lower bound or floor to how much water demand per capita can decline. Currently in many communities the rate of decline in per capita water use has been close to the population growth rate, resulting in a relatively flat total water demand despite population growth. It was suggested

that as the rate of decline in water use starts to flatten out it will no longer offset population growth and total water demand will begin to increase. Participants pointed out that identification and response to those trends will be particularly important in such communities.

However, opinions differed about the ability to identify a floor for this trend. Some suggested that estimating a floor would be prohibitively difficult, while others suggested that although a precise floor may not be difficult to predict—due in part to changing technology—that a general floor could still be defined and useful, and could be adjusted as new technology comes on line.

There was also discussion about how this will be a technical issue with behavioral and values components as well. Although some UWDR participants anticipate that there are likely to be conservation severities and restrictions that communities and individuals will be unwilling to go below, there is currently little understanding of what those tolerances actually are or may be.

Outdoor Demand

As with indoor demand, outdoor demand is also subject to important uncertainties. Despite brief discussion of exogenous factors such as issues related to climate change adaptation, most of the discussion focused on the social science of behavior. Participants reached consensus regarding professionals and researchers limited understanding of the factors that really drive individuals' outdoor irrigation behavior and how those factors may change over time. One complicating factor was a growing emphasis in communities on shade, particularly from trees. The group acknowledged a shared lack of knowledge about the relationship between shade, water, and energy use in urban environments. This includes information about older versus newer vegetation, the effectiveness of higher canopies versus lower shrubs and turf, and community values towards desirability of different landscapes. There was brief discussion surrounding concerns about green infrastructure projects and the uncertainty of: 1) how these projects will be maintained; and 2) how their effectiveness will be measured over time as the climate changes. There was general agreement that more research is needed to understand the factors affecting behavior related to outdoor demand as well as understanding the relationships of shading landscapes and water and energy use over time.

Planning for Long-Term Trends and Uncertainty

Anticipated climate change is generating increased interest in extending planning horizons further into the future to incorporate long term (50 years-plus) water demand trends. Cities may recognize the need for longer-range planning and additional challenges and uncertainties associated with doing so. Discussion of this topic was spurred by a presentation about the City of Austin's adoption of a planning horizon to the year 2100 for its water resource planning. Such a long period is likely useful when planning for the ramifications of climate change; for example, if drought becomes a "new normal" rather than a short-term emergency condition. This prospect raised questions about the long-term demand dimensions of drought response. More specifically, although water use restrictions during drought can sometimes be quite draconian, the public may tolerate them because they have been characterized as temporary. This differs from water conservation in general, which is typically portrayed as a lifestyle change, raising a question that was not answered at the UWDR: what will be the implications for predicting water demand if

actions for drought that are now considered a temporary burden become long-term lifestyle changes?

Despite participants discussing implications of climate change on household water demand in the context of longer planning horizons, there was little discussion about how long-term climate change (e.g., towards increased heat and dryness) may transform landscapes, what impact this may have on demand, or how cities should be planning for this change. For example, there were a few comments that: balancing the urban heat island effect and water demand is next major issue for the Phoenix metro region; climate change may drive migrations from hotter areas to less hot areas; people's values about landscape may change as temperatures increase; and policies considered to be drought response could become the norm.

Lastly, another risk associated with such long-term planning views is that population growth in general can be fairly uncertain over such a long time span but still must be accounted for in water demand planning.

Quantifying Relationships Between Land Use and Water Demand

Future urban water demands are partly contingent on the future of land use. The main aspects of the relationship between land use and water demand were discussed by the group: the nature of buildout, and the density of development as cities move towards buildout.

Predicting Future Land Use

There was discussion about the issues of considering future urban forms and land use patterns in relation to water demand. Since each land use has a unique water demand associated with it, predicting future water demands requires the ability to predict future land use with a reasonable degree of confidence. A key challenge that participants highlighted relates to the reliability of different methods for quantifying this relationship.

Cities may use buildout as a standard for future land use and city form to gauge the maximum possible levels of water demand. However, they have begun to recognize the limitations of this method for considering the future of the city. A chief limitation raised during discussion was that buildout can mask or exclude changes within the existing city boundary, such as redevelopment to different uses (commercial to residential or vice versa), as well as increased density of commercial and residential land uses.

More commonly, approved zoning districts and comprehensive plan land use zones are used to estimate future land use, but these are unreliable indicators. A main source of uncertainty with this approach is the unpredictability of when and how zoning may change. For example, land can be re-zoned for both greenfield development and infill redevelopment projects, and the zoning standards for districts can also change. Such changes in turn require recalculation of water demand. It was discussed that backcasting analyses to understand the effects of past zoning changes might help with predicting what might happen in the future, but there is a research gap on the application and utility of this method. There was also discussion about using data besides, or in addition to, buildout and zoning for analysis of future land use, but these too have

limitations. Utility billing classes, for example, are not the same as general plan classes (i.e., they do not map together); this limitation would also be true of tax appraiser classes, a third and different kind of class.

Demand Implications of Densification

The issue of water demand being unique for different density levels of residential land use was also discussed. The trend of decreasing water demand as density increases was acknowledged, but questions were raised about when densification may reach an inflection point beyond which water use increases instead of decreases. The City of Colorado Springs was illustrative on this point because the city's water footprint for new development is going up instead of down. Although individual lots are denser than in the past, the total area of irrigated turf in planned communities is increasing, which is generally resulting in an overall increase in outdoor water use for new development rather than a decrease. Las Vegas has investigated this issue, but it is unclear whether there is adequate research at present to address it more broadly. Researchers, including a few at the UWDR, have recently conducted analyses with models to address this question. Participants discussed the question of the most appropriate scale for modeling work to study this issue. Researchers have looked at various scales such as block group, while others have used case studies of different segments of the community.

It was also observed that densification changes over time are not often accounted for in community plans and mapping. It is difficult to forecast where redevelopment may occur within a community, and even more difficult to estimate the type and density of redevelopment when it does occur. Water and land managers need to better understand and track the possibilities and uncertainties of redevelopment and the associated changes in water demand to better anticipate the impact of redevelopment on water demand.

Theme 3: Balancing Community Values and Institutional Priorities

A third theme of the UWDR discussion focused on how a community's various values and the priorities of the multiple institutions involved in supporting the community were not always aligned with regard to their relationship to water demand.

<u>Fragmentation of Functional Planning and Management</u>

The institutional fragmentation of water planning and management regarding demand forecasts was discussed from several angles. In many communities, planning for demand, supply, and infrastructure is done by distinctly separate groups, and for some communities by completely different organizations. The unfortunate result of this fragmentation is that decisions about demand management are often not coordinated with demand forecasting. Social and institutional barriers can limit the coordination or integration of planning between these various entities. In the worst case, different entities produce their own demand forecasts which do not align, and each makes decisions based on their particular forecast, creating conflicts in policy.

This lack of coordination exists not only among those traditionally water-related departments, but others such as departments that regulate land use and development. Often water demand

management initiatives started by a water department end up being enforced by another department. Issues of resource constraints are often at the heart of whether a demand management practice will be voluntary or mandatory because the implementing department's funding is separate from the utility's revenue stream. Frequently, informal or legal institutional constraints, such as inspections of property after occupancy has been approved, are not well understood and can result in reduced effectiveness or conflicts.

Two examples of good coordination and integration were discussed. The Truckee Meadows Water Authority in Nevada has a process where different departments reconcile their individual demand predictions and forecasts into one common set so that decisions in each are made based on a common forecast. San Francisco has three separate enterprise departments doing water related planning as well as other departments involved in enforcement and implementation. Their OneWater initiative has encouraged all city departments, including public health agencies, to work together and coordinate planning and implementation.

Despite these examples, the group agreed that more research and information was needed around this issue. Research on how to integrate multiple independent levels of government, including local, state and federal, into development of new water demand policies is needed. This research could include case study examples of where integration was attempted, and how others integrate near-term and long-term demand projections for use with demand management projects and financial and capital decisions. Unfortunately, the currently level of federal funding or direction available for such research is insufficient because of the perception that water is a state right and management is unique to each state with land use planning occurring at the local level. Of course, this explains why toilets are so radically different from one state to the next.

Overall, participants' discussions of this general topic indicated a need for additional research and knowledge about the relationships between different land uses and urban water demand to enable more informed and integrated management of both.

Trees and Shade

The issues of balancing the benefits of irrigated landscapes, particularly for heat mitigation, with demand management in response to stressed supplies was a hot topic during several discussions. Shade was recognized as a critical heat mitigation and adaptation strategy, particularly for semiarid and arid cities. Yet these same cities are experiencing stressed water supplies during drought. The irony of this is that climate change will increase the need for shade while decreasing available supplies. This issue of balance was characterized in two ways: understanding the physical dynamics of water and heat; and understanding the social value components of the issue.

Currently, there is little understanding of the complex relationships between landscapes and water use. Irrigating trees to increase shade can make outdoor environments more comfortable and cool buildings, which in turn may use less energy, which in turn may reduce the amount of water needed to produce energy. However, there is little knowledge about which landscapes are the most water efficient for reducing heat, or the dynamics of how much heat each gallon of water used can offset, and how that may vary over time as landscapes mature.

Further complications arise from drought and climate change. During hotter and dryer conditions, typical drought response actions include abandoning some landscapes, particularly turf. Yet we do not know how these actions contribute to increased heat island effects. This is particularly critical as climate change normalizes drought conditions. There is little information on how long-term, dry, and hot conditions will change landscape regimes. Cities like Austin are already experiencing challenges with preserving trees, and understanding how such efforts will have to change under hotter and dryer conditions.

There is also a value component to this issue. As communities begin reaching the limits of their water supply, the values a community places on how water is used will become important. How does a community value the benefit of irrigated landscapes, including heat adaptation, against other activities that could be supported by the same water? This is less of a technical issue than one of community values and priorities.

Water Limits and Growth

As communities approach their water limits, the connection between growth and water supply becomes critical to the long-term economic sustainability of the community. There was discussion about how this can be done, the barriers to doing so, and the long-term effectiveness. Historically, the unwritten rule among water managers was that not only were the assumptions and decisions about the future growth of the city not legally within the purview of the water utility, but it was also politically taboo for water managers to interfere in development decisions.

However, this viewpoint has changed and now it is common for utilities to be involved in development decisions from a facilities adequacy and cost of facility basis. UWDR participants briefly discussed who is responsible for paying for fixed costs of new and aging water infrastructure. Still, the group agreed that utility involvement in discussions of water supply limitations being part of development decisions is uncommon. However, the group recognized that the time has come for such discussions in many communities. More research and information about the different ways water management can be linked to development decisions, particularly to function as a controlling factor is required. Likewise, participants acknowledged that research was needed to explore the long-term, practical effectiveness of these various methods. Though there are currently examples of cities using these methods, there has not been any critical assessment of their short-term or long-term effectiveness.

Cross-Cutting Themes

A number of themes were entwined within a range of various topics of discussion, which when viewed together provide additional insights. These crosscutting themes suggest that the common elements of experience, opinions, research, and practice are relevant across number of topics. These themes represent opportunities for interdisciplinary sharing and collaboration.

The Role of Human Behavior

One theme that resurfaced repeatedly over the course of the UWDR across a variety of topics was the variable of human behavior—including water use habits, perceptions, and values—in relation to managing urban water demand. As shown in Table 1, behavior intersected with multiple UWDR themes through several different subtopics. These intersections resulted in the identification of key information gaps and unanswered questions.

First, there is a need for better evidence for cutting edge strategies for inducing people to conserve. Major unanswered questions include: how do different pricing structures affect behavior; how can managers most effectively combine water pricing with new messaging to users; and how can managers effectively use new understandings from social psychology to inform those decisions and strategies?

Second, although UWDR participants recognized the existence of something called the contagion effect that can account for the adoption of new water use behaviors, they also observed a gap in data and information about how the contagion effect actually works in a given case. One example raised was the question of how participation in turf removal and/or rebate programs increases among populations due to the behaviors and actions of participants. A better understanding of this would likely help managers design more effective programs for the removal of irrigated turf in urban environments.

Third, due to the importance of understanding and projecting future water demands, another area where individual behavior remains hard to predict and account for is outdoor irrigation. The general question of what really drives individuals' outdoor irrigation behavior is a critical social science research and data need.

Fourth, as noted in How Low Can Indoor Demand Go?, p. 5, participants noted the uncertainty associated with different community-level tolerances for conservation severities and restrictions. How willing are people to abide short-term, conservation restrictions becoming more permanent as climate changes and droughts increase in frequency and intensity?

Lastly, there was discussion about the uncertainty of future land uses within communities in existing and growth areas. This included the growing understanding and consideration of land use impacts on water demand. However, the limitations of using zoning or comprehensive/general plans were discussed in terms of uncertainty around politics and market dynamics. Both are issues that can change over time. Participants discussed that water managers need information or assessment tools to better understand these uncertainties.

Taken as a whole, analysis of the UWDR discussions indicates that there is a general need to better understand the complexities of human behavior within the larger topic of urban water demand.

The Importance of Multiple Scales

Within a number of discussions issues of scale—both geographic and administrative—seemed to be of concern for a specific topic.

Concerns or questions often arose about integrating management efforts across jurisdictional scales of local, region, and state. These ranged from issues of coordinating or aggregating demand forecasts to issues of centralizing or decentralizing services and capital infrastructure, to data collection and dissemination. This was particularly an issue with the decentralization of wastewater and water treatment in cities such as San Francisco.

There was also discussion about the viability of tools and practices at different jurisdictional and geographic scales, and variations in culture and values at these scales. This included understanding how local context can influence the effectiveness of regional or state approaches, and best management practices for water demand management, particularly for drought response.

The participants talked about how land and water issues can manifest differently at different scales, which is particularly important when applying research done at a regional scale to local management programs. Here again understanding local context was suggested as important both in terms of land use patterns and limitations in available data and organizational capabilities at different geographic scales.

Concern was expressed about the implications of scale for efficiency improvements that result in disparities between larger center cities and smaller outlying areas that cannot make major investments in efficiency. This also relates to how people perceive issues of water crisis when local needs vary widely across a common region.

During many different discussions it was agreed that more research and information about the implications of scale are needed, particularly as they pertain to the viability of regional approaches to address affordability beyond borders of any particular utility, and for advancing sustainability and resilience.

The Emergence of Land Use and Water Management Integration

The topic of "Land Use Connections to Demand Management" was new to UWDR and a session was devoted to presentations and discussion on it. Perhaps as a result of having it on the agenda, this topic emerged more prominently during the discussions within many of the other topics. In a way this confirmed the level of integration between land use issues and a wide range of traditional water demand issues. During these discussions several key themes emerged.

From the discussion on water demand forecasting and estimation, land use is emerging as an important factor (see Quantifying Relationships Between Land Use and Water Demand, p. 7). Predicting Future Land Use, p. 7 included discussion about the issues and uncertainty surrounding the forecasting and utilization of land use in demand forecasts. Additional discussion in Demand Implications of Densification, p. 8 focused on the implications of residential density and urban water demand, the uncertainty of these relationships, importance of local context, and the need for more research and application. Concerns were expressed about outdoor water demand related to green infrastructure and shade projects, such as maintenance and how their effectiveness will be assessed over time in light of climate change.

There were multiple discussions around the fact that water and land use management are operated by different agencies, which do not often coordinate or collaborate. This was seen as problematic when a water management objective is being implemented by a land use management agency or a land use planning issue is heavily influenced by water management policies. There was discussion on the lack of understanding within each of the agencies about the work and constraints of the others. The group suggested that there is need for research on the effectiveness of various approaches to bridge these gaps (see Fragmentation of Functional Planning and Management, p. 8).

Social values related to community form and amenities (such as trees), their impact on urban heat and water use, and the complications caused by drought and climate change were discussed. The group's discussion embraced the concepts that community and social values frame individual and community decisions about the types of landscapes and urban form that communities create and support. There is need for further research about these connections to help water and land planners understand implications of social and community values for public policy (see Trees and Shade, p. 9).

The discussion also reflected the emerging issue of water being a limiting factor to community growth. Although this was generally a politically taboo subject in the past, the attendees agreed that now is the time to start discussing this issue. Participants were aware of some examples of cities using methods to link an analysis water demand and supply as a key factor in the process of approving new development, but they pointed to the need for more research to assess the long-term and short-term effectiveness of these practices (see Water Limits and Growth, p. 10).

Opportunities for Future UWDRs

The final session of the UWDR was devoted to reflection on the two days of presentations and discussions, generating ideas and topics for future meetings. Participants identified what was most interesting as well as questions that were raised but not answered. Below is a summary of participants' unanswered questions with key topics and issues identified through analysis of the two days' worth of discussions. The topics and issues will inform future UWDRs and identify general avenues for relevant research.

- The role of agriculture, which strongly impacts how water management is playing out currently, was missing from the agenda. This includes transfers of agricultural water to

the urban sector and responsible management of the transfers since agricultural water is the future water supply for many communities.

- Reducing uncertainties that limit efforts to predict future water demand was a key issue, in particular, unanswered questions related to the floor of per capita efficiency: what it is, if and when it might be reached, and the implications for demand forecasting. Uncertainties could be addressed by research on household water use and conservation behavior; the water demand implications of different patterns and scenarios of land use; and better methods of predicting those patterns.
- Participants were interested in improving the coordination and integration of different aspects of water management; land use planning and management; and water and land use planning integration. This could be addressed by additional real-world institutional change, experiments, and sharing of existing case studies. For example, two good examples were shared in this UWDR (Truckee, Nevada and San Francisco).
- In part due to the prospect of climate change, planners have begun looking further into the future, but such efforts are limited by the unpredictability of human behavior with regard to a variety of aspects of water use. Consequently, there is a need for more social science in order to better understand individuals' values, behaviors, tolerances, etc. This may require looking for insights from fields not traditionally associated with land and water management, e.g., social psychology.
- There is a need to better understand equity and inclusion (and behavior) in relation to urban water demand and consumption. Notable examples were the City of Dallas and the poll and public awareness campaign implemented by the Water Conservation Program.
- The unanswered questions related to water rates included the problems of defining affordability and determining the optimum number of pricing blocks in progressive rate structures. There is a need for a new conceptual approach to thinking about water affordability that allows utilities to create affordability programs appropriate to their unique community needs and rate structures.
- There was interest in further exploration of how different organizations integrate their decisions about water demand management.
- Drought contingency planning was a missing topic that participants would like to address in a future meeting.
- The group was interested in identifying and understanding the role of federal, state, and local policies for relevant research.
- Suggestions were made that future meetings include a focus on regionalization of water utilities and infrastructure, which was seen as relevant for sustainability goals and to affordability issues for utilities; large utilities play a particularly important role in this issue.

Conclusion

The goal of every Urban Water Demand Roundtable has been to share cutting edge information across the research and practitioner communities, while uniquely fostering discussions, otherwise unlikely to occur, between these two communities about key issues and challenges. The participants of the 2019 UWDR concurred that the annual event is worthwhile and should continue; a steering committee was formed to shepherd it into the future. Given this, it seems appropriate to document and share the content of these discussions for both recent and future UWDR participants as well as the general public. This report on the 2019 UWDR is the first effort to do so. We hope that synthesizing and disseminating the expert knowledge, opinions, and insights of the participants to a larger audience will increase awareness of urban water demand issues in need of attention from researchers and funders and will incite innovation by practitioners.