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# Stressors and Strategies for Managing Urban Water Scarcity: Perspectives from the Field

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**Abstract:** Largely because water resource planning in the U.S. has been separated from land-use planning, opportunities for explicitly linking planning policies to water availability remain unexamined. The pressing need for better coordination between land-use planning and water management is amplified by changes in the global climate, which will place even greater importance on managing water supplies and demands than in the past. By surveying land and water managers in two urbanizing regions of the western United States—Portland, Oregon and Phoenix Arizona—we assessed the extent to which their perspectives regarding municipal water resource management align or differ. We specifically focus on characterizing how they perceive water scarcity problems (*i.e.*, stressors) and solutions (*i.e.*, strategies). Overall, the results show a general agreement across both regions and professions that long-term drought, population growth, and outdoor water use are the most important stressors to urban water systems. The results of the survey indicated more agreement across cities than across professions with regard to effective strategies, reinforcing the idea that land-use planners and water managers remain divided in their conception of the solutions to urban water management. To conclude, we recommend potential pathways for coordinating the fields of land and water management for urban sustainability.

**Keywords:** water managers; land-use planners; climate change; stressors; strategies; Portland; phoenix

## 1. Introduction

Despite the breadth and depth of the literatures on water supply and demand management, the operation of these systems have been viewed largely in isolation from land-use planning [1]. Residential development patterns, which in some cases are the direct and intentional outcome of land-use planning initiatives, are a potentially important exogenous influence on water management [2–4]. In fact, largely because water resource planning in the U.S. has traditionally been separated from land-use planning, opportunities to explicitly link planning policies with water availability have gone unexamined [5]. Further, the planning community has neglected the role of water supply, assuming it is readily available for urban (re)development. In short, integrated planning across the land and water sectors is rarely if ever practiced. To better coordinate planning for land and water resources, information about professional perspectives and practices is required. Such information can reveal areas of converging and diverging viewpoints, thereby identifying the potential for collaborations as well as for conflicts as efforts to integrate across sectors continue.

This paper seeks to characterize and compare perceptions among land-use and water-resource planners in two cities of the American West. Using humid Portland, Oregon and arid Phoenix, Arizona as case study samples, we surveyed professionals about various stressors and strategies for their local community water systems. In addition to identifying converging and diverging views, we also examined similarities and differences across the two metropolitan study areas, which may be important in signaling the unique effects of each regional context.

### *1.1. Pressing Challenges*

The pressing need for better coordination between land-use planning and water management is amplified by changes in population and the global climate, which present even greater challenges and uncertainties than in the past. Urban water managers—defined here as those public sector employees responsible for the allocation, administration, and budgetary aspects of water management—in Portland and Phoenix face the complexity of burgeoning growth, with the populations of both urban regions expected to double in coming decades [6,7]. This comes on top of the increasing growth rates of the last decade. Compounding the macro-scale pressures faced in both cities, recent evidence suggests that global climate change will have profound impacts on water resources in the West [8]. The Pacific Northwest (PNW) is experiencing more frequent winter floods and summer warming [9,10], while the American Southwest is currently experiencing a multi-year drought [11].

Long-term climate models project increasing annual temperatures and high precipitation variability (with generally less precipitation in summer) for the PNW [9]. Higher winter temperatures combined with more precipitation will lead to higher snow-line elevations, which in turn will affect the timing of snowmelt and summer flow, ultimately impacting the availability of water resources for the Portland region [12].

With respect to Phoenix, global climate models increasingly conclude the Southwest will likely be warmer and drier in this century than in the last. Regional climate models have recently indicated reductions in surface water runoff in regional watersheds serving metropolitan Phoenix [6]. A report by the National Research Council [13] shows that a warmer and drier future will reduce snowpack, Colorado River flows, and urban water supplies. According to the 5th IPCC assessment report, there is a broad consensus among models that the region will be drier during the 21st Century, and indeed, the transition to a more arid climate is already underway [14]. Although per capita water consumption has decreased since the 1990s in most municipalities in the American west [15–18], the expected combination of reduced water supply and increasing urban populations will likely create an unprecedented state of potential water scarcity.

### *1.2. Potential Strategies*

The process of coordinating water management still involves several policy actions enacted independently and jointly by multiple agents with different goals and objectives, as well as varying levels of influence on outcomes. Water managers have multiple options for adapting to the effects of water supply shortfalls, including taking actions to increase supplies or to decrease demands, both of which can have either short-term or long-term reach. The long-term options, while generally effective in engineering terms, are not always feasible for political and/or financial reasons. Building dams and reservoirs can be cost-prohibitive and requires localities and states to shoulder the burden alone, especially since the U.S. government appears disinterested in funding such projects. The communities designated as hosts often resist large-scale projects. As a result, augmenting supply increasingly does not provide a viable option for the long-term [19]. Rather, U.S. water managers are increasingly forced to use short-term measures that either augment supply or diminish demand [20,21]. These measures include tapping emergency water sources, trucking in water from outside locales, and imposing water-use restrictions on non-essential uses (e.g., lawn irrigation, car washing). We note that such short term measures can prove challenging due to the overall lack of precipitation, and the uncertainties about future rain events.

In the face of new and pressing challenges and a diminished ability to continue adding to the water supply, new solutions must be sought. One area of untapped potential is in collaborating with land-use planners. Earlier studies suggest that the nature of the built environment, landscape treatments, and short-term consumption behavior can also impact residential water use in urban areas [16,22–26]. This is particularly relevant to arid cities, such as Phoenix and Los Angeles, where an estimated 74% of residential water use is for outdoor purposes [27]. Wentz and Gober [22] demonstrated that residential outdoor water use increased with large lots, turf grass (as opposed to drought-tolerant landscaping), and the presence of pools. Similarly, Chang *et al.* [3] found that residential water use was higher in denser older neighborhoods close to downtown than in newer peripheral neighborhoods in the City of Portland, Oregon. House-Peters *et al.* [28] further reported that highly affluent newer neighborhoods had more seasonal water use than denser older low-income neighborhoods in Hillsboro, a suburban city of Portland. Sauri [29] found that demand management policies such as conservation and water pricing may not be sufficient for controlling water consumption levels when low-density urban development continues or income gains occur. In a study of annual residential water use in the Portland metropolitan area, Shandas *et al.*, [23] stressed the importance of investigating behavioral and land-use density barriers that limit the responsiveness of water use to varying climate conditions. Automated timers, for example, generally do not appear to be adjusted in response to weather conditions. The built environment of cities, which is largely controlled by land-use planning, combines with individual and group behaviors to mediate the extent of water consumption [30,31].

### *1.3. Integration Across Sectors*

To address calls for greater integration between water and land managers, many national organizations, professional journals, trade publications, and international conferences are bringing attention to highly inter-connected nature of water and land systems. The National Science Foundation, for example, recently released a call for proposals examining the water–land nexus, and the European Commission is hotly debating the future of this field [32]. Amidst the challenges for integrating water and land systems, little is known about the extent to which the people who are responsible for managing these systems view the same challenges and opportunities. To what degree do land managers agree with water managers in terms of the stressors on the urban water system? What are the similarities and differences between the two groups in terms of strategies for addressing future changes in water supply? These and other questions help to frame a critical issue in the management of water supplies because, arguably, if these two constituencies do not view the problem as the same, then their solutions will also face formidable challenges to implement.

By surveying both land and water managers in two urbanizing regions of the western United States, we sought to assess the extent to which their perspectives align or differ. We specifically focused on their perceptions of the problem (e.g., stressors) and potential solutions (e.g., strategies). While previous studies have looked at single regions [31,33] we sought to examine two regions—Phoenix, Arizona, and Portland, Oregon—that have different land-use policies, climate regimes, and population growth trends. By engaging water managers and land-use planners in these regions, we were able to address two research questions: (1) To what extent do urban water use managers and land-use planners share perspectives regarding the stressors to and strategies for water management both within and between the two locations and professional fields? (2) What factors might help to explain any observed differences and similarities in perspectives about the water management system?

## 2. Materials and Methods

Portland and Phoenix share the dual challenges of rapid growth and climatic uncertainty. The challenges however occur under different physical geographies, political cultures, and growth-management and land-use policies. These differences allowed us to study perceptions of land-use planners and water-resource managers in two distinct areas, by comparing factors that may exacerbate or mitigate future water shortages, and strategies for ameliorating potential water challenges.

### *2.1. Survey Design*

We used a cross-sectional survey design that was informed by existing literature on the challenges facing the regions [31,34]. An online survey of municipal water managers and land-use planning professionals in the Phoenix and Portland regions constituted the primary vehicle for the empirical assessment, resulting in four samples: Phoenix water managers, Phoenix land planners, Portland water managers, and Portland land planners. The survey was administered in the spring of 2010 to municipal professionals in both regions—32 in metropolitan Phoenix and 25 in the Portland area. By identifying all the municipal land use and water professionals in both regions, we identified nearly all of the potential recipients of the survey. For land planners, our priority was to survey planning directors/managers or the closest equivalent for each city within our study regions. If none could be found, the city/town manager was contacted instead. For water managers, our priority was to target water resource managers/directors or the closest equivalent. While the small number of municipalities in each region did not allow us to conduct statistical tests of inference, they did provide a descriptive assessment of the water scarcity strategies employed in each region, and patterns among survey respondents, comparing the land and water managers and the two study regions.

To address our research questions, we developed survey questions that consisted of two main points—stressors and strategies—with respondents rating a set of options on a scale of one to ten (from 1 = not at all significant to 10 = greatly significant). Twelve stressors and 13 strategies were developed for both potential risk factors and solutions based on a review of literature and discussions with professionals and among our research team. Following from Larson and colleagues [35,36] these items present a variety of natural and anthropogenic risk factors as well as potential voluntary and regulatory-based strategies in both the land and water sectors. For each of the possible factors representing a stressor, respondents were asked, "To what extent are each of the following factors important when considering the future of water supply." For each factor that represented a strategy, respondents were asked, "To what extent are each of the following factors important when considering strategies for addressing shortages in future water supply." Respondents had 12 stressors and 13 strategies to consider, relating to three sources of influence: environment and population, infrastructure and management, and end-user behavior, as shown in Tables 1 and 2. The three categories correspond to the generally accepted challenges facing water resource management, including a growing population and environment, combined with strategies facing the future, such as climate change, technological applications, and human or individual actions. We distinguish two aspects of climate change, namely natural climate variability and human-induced climate change in part because American public opinion continues to be divided about the causes for changes in climate conditions.

**Table 1.** Stressors listed for consideration in survey with descriptive statistics (Minimum, Maximum, Median, Standard Deviation).

| Category of Stressor | Stressor | Min. | Max. | Med. | SD |
|---|---|---|---|---|---|
| Environment and Population | Population growth | 1 | 10 | 7 | 2.89 |
| | Long-term drought | 1 | 10 | 7 | 3.08 |
| | Natural climate variability | 1 | 10 | 5 | 2.88 |
| | Human-induced climate changes | 1 | 10 | 4 | 2.68 |
| Infrastructure and Management | Inadequate access to water sources | 1 | 10 | 4 | 3.02 |
| | Infrastructure to store, treat, deliver water | 1 | 10 | 4 | 2.69 |
| | Land-use planning or development | 1 | 10 | 5 | 2.46 |
| | Water-resource planning or management | 1 | 10 | 5 | 2.66 |
| End-User Behavior | Indoor water uses | 1 | 8 | 4 | 2.06 |
| | Outdoor water uses | 1 | 10 | 6 | 2.57 |
| | Household or residential water use | 1 | 10 | 5 | 2.36 |
| | Industrial or other business water use | 1 | 10 | 5 | 2.52 |

**Table 2.** Strategies listed for consideration in survey with descriptive statistics (Minimum, Maximum, Median, Standard Deviation).

| Category of Strategy | Strategy | Min. | Max. | Med. | SD |
|---|---|---|---|---|---|
| Environment and Population | Planning for future climate changes | 1 | 10 | 5 | 2.74 |
| | Restricting new building permits | 1 | 10 | 4 | 2.56 |
| | Limiting new growth or development | 1 | 10 | 6 | 2.97 |
| Infrastructure and Management | More compact or dense communities | 1 | 10 | 5 | 3.08 |
| | Retiring agricultural land | 1 | 10 | 4 | 2.90 |
| | Acquiring new sources of water | 1 | 10 | 8 | 2.73 |
| | Building structures to store water | 1 | 10 | 4 | 2.94 |
| | Upgrading water delivery infrastructure | 1 | 10 | 7 | 2.53 |
| | Wholesale contracts with other providers | 1 | 10 | 5 | 2.93 |
| End-User Behavior | Restrictions or bans to limit water use | 1 | 10 | 6 | 2.50 |
| | Increasing the price of water | 1 | 10 | 7 | 2.96 |
| | Water conservation education | 1 | 10 | 8 | 2.49 |
| | New water efficiency technology | 1 | 10 | 8 | 2.53 |

### *2.2. Methods of Analysis*

Due to the small sample representing diverse municipalities in each region, we developed analytical techniques that emphasize the descriptive and qualitative patterns in the data. These included graphic depictions of the data, information from a series of workshops, and where available, using qualitative responses to flesh out responses to the survey. Specifically, for the purposes of data interpretation, we considered a rating of 7 or above to indicate the respondent considered the strategy or stressor to be important or very important. By looking only at those responses with a rating of 7 or higher we can effectively parse out the differences between the two professions and the two regions using descriptive means.

Across both regions and sectors, 57 surveys were completed and returned for a response rate of 50%—some municipalities had more than one respondent. For Portland, both surveys were returned from 7 towns, either the land or water survey was returned by 10 towns, and 7 towns did not respond at all. For Phoenix, both surveys were returned by 8 towns, one or the other was returned by 17 towns, and 7 towns were not represented in this study. While the response rate was similar across regions, land planners responded at a higher rate. For the water survey, respondents included Public Works Directors, City Engineers, Environmental Managers, and a Town Manager. The respondents from the land-use survey were mostly planners, but also included City Administrators and Community Development Directors from smaller towns. As a whole, the surveys represent a variety of towns across the study regions, ranging from small to large. In accordance with policies governing the ethical treatment of research participants, the survey results are presented anonymously.

## 3. Results and Discussion

Overall, the results of the surveys show significantly more agreement in identifying the most significant stressors—of which only two stood out—whereas there were many strategies identified as important and a wider range of opinion. There was also somewhat more agreement across cities than across professions, particularly for strategies.

### *3.1. Stressors*

Three stressors emerged as the most widely perceived as important in both cities and by both professions. These were, in ranked order, long term drought, population growth, and outdoor water use (Figure 1). The remaining possible stressors were not viewed as important by the majority of respondents, and there was general consensus that indoor water use is the least important stressor. Phoenix professionals were generally more focused on long-term drought than Portland professionals; 83% of Phoenix water managers identified this as an important contributor to water stress, and 62% of Phoenix land-use planners agreed (Figure 2). Two most widely identified stressors were related to the environment and population, while the third—outdoor water use—was an end-user behavior. Notably, professionals in both locations rated human-induced climate change low—and water professionals rated it very low—as a cause of stress, despite the direct connection between climate change and summer drought in both areas that is projected by current climate models [11,12,37]. While we are not able to discern the reasons for the low rating to human-induced climate change, we note that the term 'human-induced' may reflect the discomfort with the causal connection or attribution of drought events to human activities. These results would be consistent with the earlier point regarding the fact that U.S. public opinion is still divided regarding the causes for climate change.

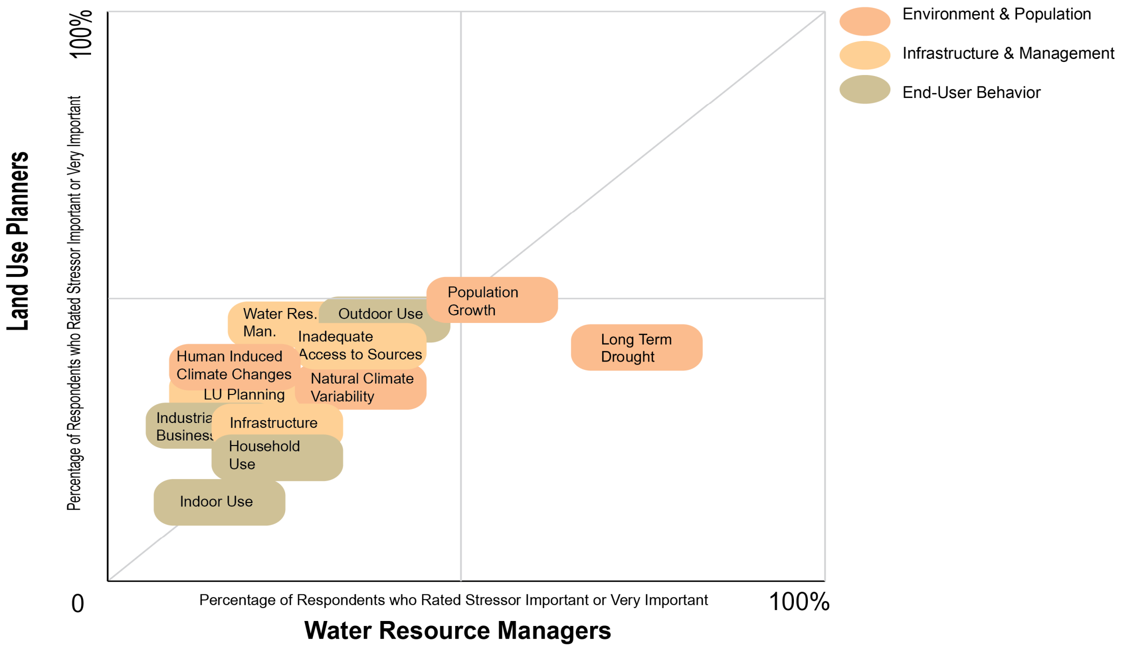


**Figure 1.** Water Resource Stressors rated at least 7/10 on a scale of importance, by profession.

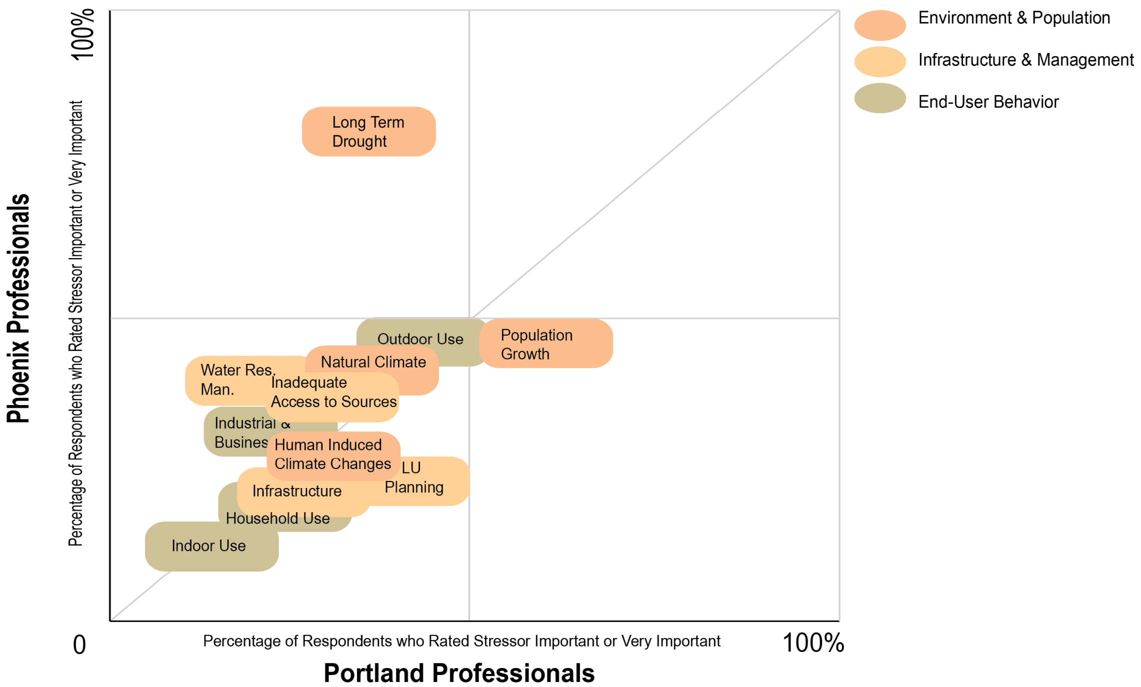


**Figure 2.** Water Resource Stressors rated at least 7/10 on a scale of importance, by region.

### 3.2. Strategies

Across both regions and professions, the results suggest greater variation in perspective on the effectiveness of potential strategies than stressors. Between both professions, four strategies were identified as somewhat effective by over 50% of respondents (as compared to only two stressors): water efficiency technology, water conservation education, acquiring new sources of water, and limiting new growth (Figure 3). Although the two biggest stressors are in the environment and population category, namely long-term drought and population growth, the corresponding strategies that directly addressed these stressors were generally not among the highest ranked.

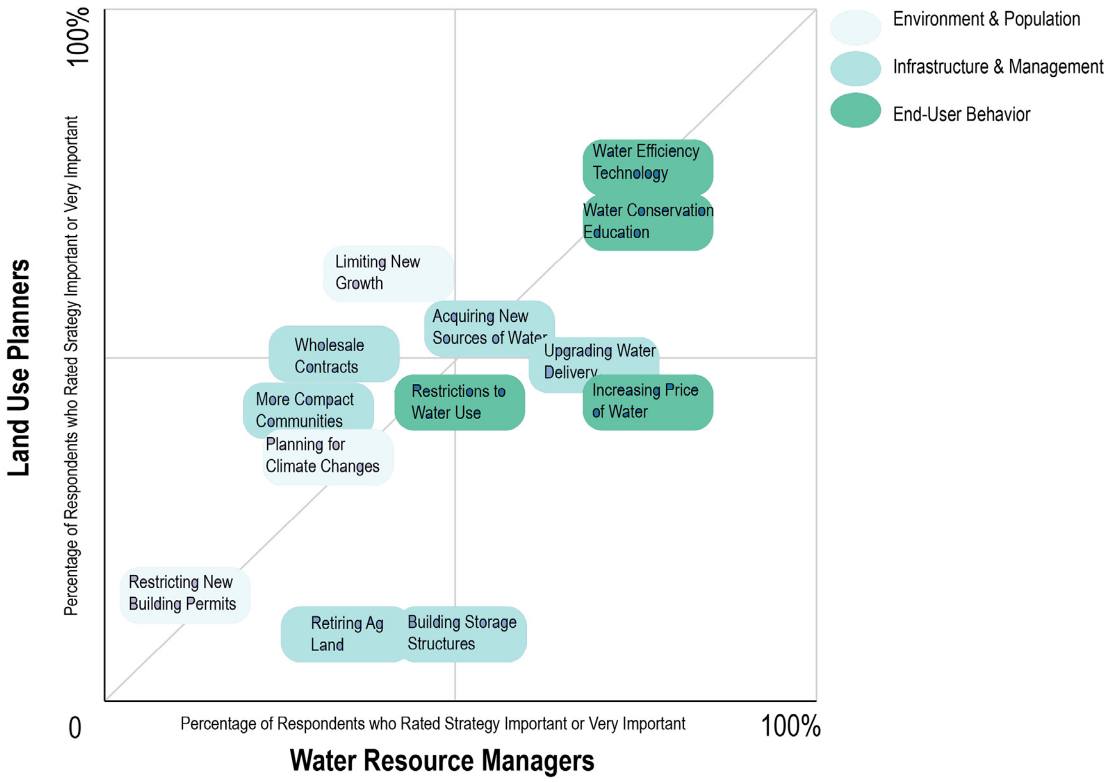


**Figure 3.** Water Resource Strategies rated at least 7/10 on a scale of importance, by profession.

The strategies relating to end-user behavior generated the most support. Specifically, new water-efficient technology had the most support and least variability of all the strategies in the survey across all categories of respondents. Among water managers, there was consensus that increasing the price of water would be effective, in Portland 70% of water managers ranked it 7/10 or above, and in Phoenix, almost 60% of water managers ranked it 10/10 (Figure 4). Water conservation education was also a highly ranked strategy, although land planners lagged water managers in their enthusiasm for its effectiveness. Outright restrictions to ban or limit water-use was split in among the Portland respondents and were ranked moderately in Phoenix. Although inadequate access to water sources was not rated highly as a cause of stress, there was general agreement in Phoenix that acquiring new sources of water would be a highly effective strategy: half of Phoenix water managers ranked this a 10/10. We note that while many of these strategies were supported, recent research from California suggest that applications of water efficient technology, increasing the prices of water and education [38], may not be highly effective.

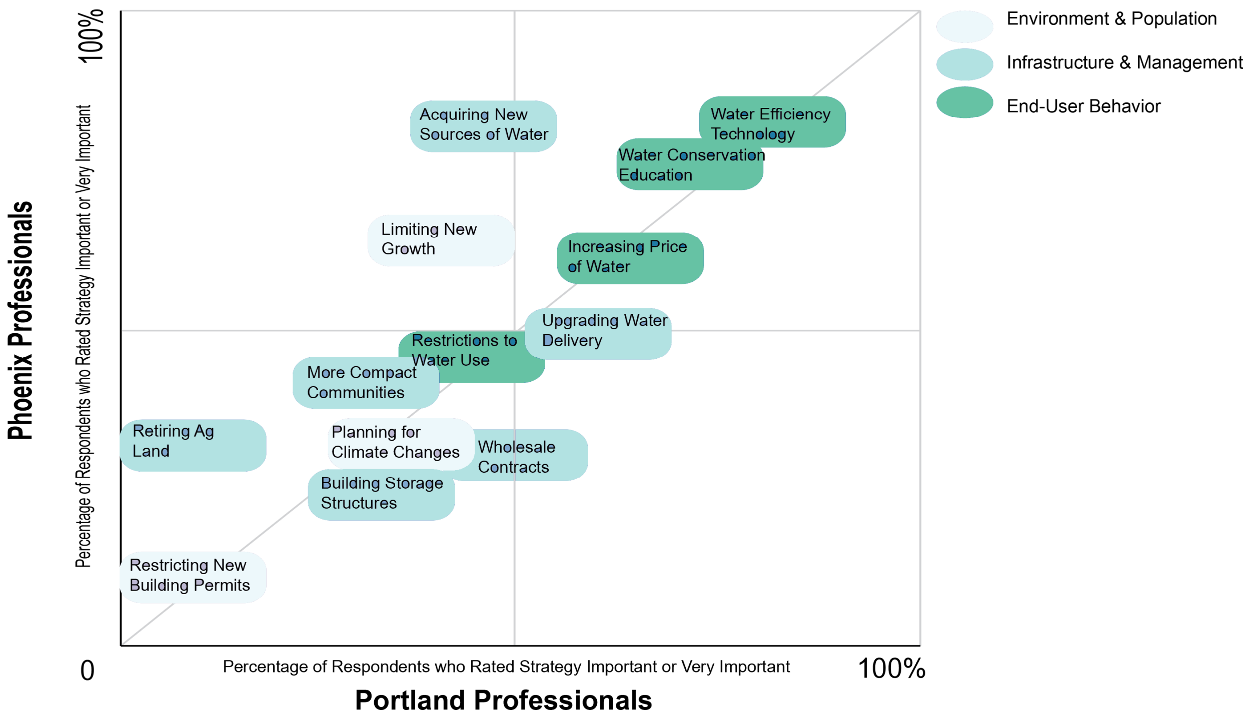


**Figure 4.** Water Resource Strategies rated at least 7/10 on a scale of importance, by region.

Generally, land-use planners were relatively more supportive than water managers of strategies in their field, such as limiting new growth, and more dense and compact communities. Similarly, water managers were more favorable towards upgrading water delivery systems and increasing the price of water. The main regional difference is that professionals in Phoenix were more likely to support acquiring new sources of water and limiting new growth than those in Portland. Generally, restricting new building permits was not identified but by a few land-use planners and water managers, while limiting new growth was somewhat more highly valued, particularly in Phoenix where a clear majority (75%) of water managers rated it 7/10 or above in effectiveness.

## 4. Discussion

Despite the sample size of the survey, we observed that across region and profession, survey respondents widely agreed on the sources of stress to urban water systems, while opinions on strategies were much less uniform and a wider array of strategies was identified as effective. The fact that only two stressors were identified by 50% or more of respondents as important while many strategies emerged could suggest that while stress to water resources comes from one or two causes, the solutions are less clear. This is logical because a suite of strategies for each specific region will be necessary, rather than a single silver bullet that fits every region. Alternatively, these results could suggest that the research team more successfully presented options for stressors with which practitioners agreed, while failing to include other important stressors.

While the top two stressors were related to environment and population, the majority of highly ranked strategies were related to end-user behavior. While understandable due to the challenge in the physical and political feasibility of other strategies, research by Lach and colleagues suggest that water managers are highly conservative when attempting to regulate end-user behavior [39]. Accordingly, while a strategy such as acquiring new sources of water might be highly effective, it is not worth consideration if there are no such new sources available or if this strategy would create negative environmental and social outcomes (e.g., on source ecosystems or communities from which water is withdrawn). Further, experiences in California suggest that water agencies are required to balance the cost of water to match what is required to address the demand, and the raising water rates must occur within limits. Local government bodies are much more likely to have the ability to enact policies related to end-use. A more positive finding is that the third most highly rated stressor was outdoor water use, which is highly likely to be impacted by land-use decisions, as described in Section 1.2. Indeed, water provides in both regions have introduced incentives for water conservation through landscape manipulation [40].

Distinctive perspectives were identified along both professional and regional lines. The biggest professional division relates to limiting new growth, which was much more highly ranked by land-use planners, and increasing the price of water, which was much more highly ranked by water managers. This is perhaps due to familiarity level—in that planners use growth measures (e.g., urban growth boundary in Portland) to reduce the physical growth of the urban area—while water manger in Phoenix use instruments such a pricing to mediate demand. The largest regional difference was that Phoenix professionals are much more worried about long-term drought, which is logical as their already arid region was in the midst of a significant drought period at the time of the survey. Professionals in Phoenix are also more optimistic about acquiring new sources of water as a solution.

The practicality of some of the highest ranked solutions is not yet clear. The two top strategies in both regions and professions are education and new technology. While these are important tools, hoped for technological solutions to environmental problems do not always materialize and often create negative, unintended consequences (e.g., dams, canalized water transfer systems, excessive ground water pumping). Conversely, some of the most aggressive strategies were not as highly ranked, perhaps because of perceived political feasibility issues. In particular, raising water prices and limiting growth may not be seen as popular choices by elected officials. Although it is important to remain critical of the practicality and feasibility of any solution, innovative ideas are already being generated, such as tiered water pricing, which was recently implemented in Santa Fe [41] This can also be seen in significant opposition to increasing the price of water in an earlier Phoenix-based survey, which demonstrated that planning professionals opposed those strategies more so than scientists as well as residents [42].

The practitioners' approach to global climate change is of particular importance for the long-term health of the water systems. Human-induced climate change was identified as an important stressor by a minority of water managers and land-use planners. Despite the fact that the two most commonly identified stressors are greatly exacerbated by climate change—long-term drought in Phoenix, and population growth in Portland—climate still is not considered unequivocally as the primary factor in addressing urban water scarcity. The related strategies showed slightly higher interest levels: planning for future climate changes was identified as an effective strategy by a third of Phoenix water and land practitioners, a third of Portland water managers, and almost half of Portland land-use planners.

The lack of recognition of climate change as an important stressor, and only moderate interest in planning for future climate changes as a strategy suggests a serious problem in resource management decision-making in Portland and Phoenix. The professionals most concerned with climate change are land-use planners in the Portland area, suggesting that they are a group to watch and may provide a model. This further suggests that there could be potential opportunities to use land planning to adapt to climate change as it relates to urban water resource management [4,23,24]. The recent experience of California's water management challenges, and the emerging field of 'climate attribution science' may offer many opportunities for further research into the linkages among climate, land use and water recourses planning.

To that end, four plausible directions emerge as a way to address the challenges facing water use in the midst of climate change. First, the gap must be closed between academic and federal concerns over climate change and the lack of concern reported by on the ground practitioners. Meeting mandates to provide water in the short run seems to be central to the administration of urban water resources. Yet, if the frequency of drought and magnitude of droughts are expected to increase in the future as projected by several studies [12,37,40] then engaging practitioners—both land-use planners and water managers—in developing climate sensitive strategies can provide effective guidance to reduce short and long term impacts. Second, a realistic understanding of the scale of the issue is required. Quantification, even as an estimate would help provide a realistic understanding of the improvements in conservation education and technology that would be necessary to offset the large-scale environmental and population challenges that are already emerging. Third, while the communities we surveyed had a high level of consensus regarding the problem (*i.e.*, stressors) and on the top strategies, assessing the effectiveness of those strategies is an area that requires further research and consideration. The consensus itself is a strong foundation for advancing greater coordination between the two fields, and provides an opportunity to build further cross-sector integration.

Finally, the continued rapid population growth that is forecasted for both study areas presents an opportunity to use land-use planning tools to lessen future stresses on urban water systems. The opportunity for linking existing land-use, housing, and transportation models that are common place in urban areas, with water demand models can help in cross-sector communication, particularly early in the land-use planning process in growing cities [43]. Integrating such models with downscaled climate system can also help to inform communities about the potential to greatly impact the stressor and strategies for managing urban water scarcity.

## 5. Conclusions

We set out to answer two questions. First, to what extent do urban water use managers and land-use planners share perspectives regarding the stressors to and strategies for water management systems both within and between the two locations and professional fields? Overall, survey responses were mostly consistent for the stressors (*i.e.*, problems) facing water resource management, while responses to the effectiveness of strategies were more varied by both region and profession. Professionals expressed the greatest concern about the impact of environmental and population stressors, while strategies related to end-user behavior were found to be the most effective, and there was general consensus that improved water efficiency technology and water conservation education would be effective strategies. Concomitant concerns about long-term drought seems to be pervasive among the respondents from Phoenix, perhaps since the region continues to undergo severe water shortages along with much of the Southwest. The general lack of concern about climate pressures on water resources by Portland respondents is also note worthy, and may suggest a need to further examine why climate concerns may not be central to current water management strategies.

The second research question was: what factors might help to explain any observed differences and similarities in perspectives about the water management system? The general consensus was that environmental and population factors are stressors, but that related strategies are not as effective, likely because these influences are difficult or impossible to control at the level of local government. Conversely, local government bodies may have greater ability and some certainty to influence end-user behavior, which is reflected in these strategies' high ratings. There were categorical divisions in assessing one stressor (long-term drought) and variation in the perceptions of many strategies, notably source acquisition and limiting new growth. The clear consensus that drought is a greater stressor in Phoenix than Portland is likely due to that region's significantly more arid climate with ongoing drought and to the projected impacts of climate change across the southwest. The professional divide between water managers and land planners concerning limiting new growth (favored by land-use planners) and increasing the price of water (favored by water resource managers) might be explained by their differential levels of involvement and knowledge of related programs. Fostering greater interaction between these two groups may be a timely, cost-effective, and prudent means of improving the opportunities for more effective management of this scarce resource.

Taken together, the present paper provides one perspective into the state of water resource management in two geographically diverse urban areas of the U.S. However, the local politics of water management is complex and is often based on accepted behaviors and organizational cultures [38]. The pressing challenges of climate change and precipitation uncertainty pose formidable challenges to traditional approaches. While our approach could not address the reason for specific responses, the summary of responses suggest aligned and divergence regarding the stressors and strategies by region and profession. Now more than ever we need research that articulates how current challenges to water resource management are created, in part, through the social systems we have created and enabled. Our research is one step in that direction, but additional research is needed to assess the extent to which administrative fragmentation of natural resource management is creating water scarcity. The future will require at once the need for collaboration among the diverse groups of interest managing water and land resources, and the sharing of effective strategies across jurisdictions.

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**Author Contributions:** Vivek Shandas, Kelli L. Larson, and Heejun Chang designed the research, including the development of survey questionnaire. Vivek Shandas and Kelli L. Larson implemented the survey. Rosa Lehman and Jeremy Bunn compiled survey questionnaire and analyzed the data. Vivek Shandas, Rosa Lehman, Kelli L. Larson, Heejun Chang and Jeremy Bunn wrote the manuscript.

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