The Water Supply Is fine: Decision-Maker Perceptions Of Water Quantity And Supply-Side Management

By: **Kristan Cockerill**

Abstract

Years of research have called for more science to be integrated into water management decisions and for a shift from supply-side to demand-side management; yet, there remains a strong emphasis on supply-side approaches and in many areas limited attention to hydrological data. A survey and interviews with decision-makers in western North Carolina reveal that there is only low-level concern about water quantity, and this drives a continued emphasis on supply-side management and no perceived need for hydrological data. The historical realities of low demand and abundant water have generated a perception of 'water supply' as disconnected from physical, hydrological systems and allowed for ad hoc decision-making processes to prevail. The lack of well-established processes may, ironically, provide significant opportunities for employing collaboration among researchers and decision-makers to develop policies and processes that integrate data into making water management decisions and thus prompt increased attention to water demand.

Kristan Cockerill (2014) "The Water Supply Is fine: Decision-Maker Perceptions Of Water Quantity And Supply-Side Management" *Water and Environment Journal* vol. 28 pp. 242-251 Version of Record Available From (www.onlinelibrary.wiley.com

Introduction

There is significant evidence that a growing population coupled with climate change will pose increasingly significant challenges to water managers, even in wet regions, and to address these challenges requires a shift in management philosophy towards reducing demand (Butler & Memon 2006; Bates *et al*. 2008; Kindler 2010; Kampragou *et al*. 2011; Traynham *et al*. 2011; Zetland 2011). Simultaneously, it is well established that despite decades of reports calling for a shift from supply-side to demand-side policies (cf. Sewell & Roueche 1974; Sawyer 1982), water managers, for a variety of reasons, continue to focus on supply-side management (Griffin & Mjelde 2000; Pirie *et al*. 2004; Lach *et al*. 2005; Rayner *et al*. 2005; Larson *et al*. 2009; Zetland 2011). This reality affects how decision-makers think about data, their water supply and what they perceive to be relevant to decision-making processes.

Research shows that one of the reasons for continued emphasis on supply-side policies is the lack of science employed in making water management decisions. Despite the plethora of ideas for integrating science, there remains a gap between hydrologically relevant science and water management decision making. Rayner *et al*. (2005) cite numerous studies in noting that, '. . . institutional decision makers have a generally positive attitude toward the use of scientific information in decision making, but rarely act on such information directly.' Clark & Dickson (1999) identified three interrelated characteristics that contributed to how influential science-based environmental assessments were in decision making: saliency (perceived relevance to decision-maker), credibility (believability of the data) and legitimacy (openness/fairness of the process). Having reviewed diverse studies from multiple disciplinary perspectives, McNie (2007) confirmed that these three characteristics remain core to determining whether scientific data are integrated into environmental decision making. Focusing on water management, Rayner *et al*. (2005) found that barriers to using climate forecast data include, 'traditional reliance on large built infrastructure, organizational conservatism and complexity, mismatch of temporal and spatial scales of forecasts to management needs, political disincentives to innovation, and regulatory constraints.' Driving several of these barriers is the stated goal of most water managers to remain invisible to the public by ensuring that water is available on demand without interruption. Kirchhoff (2010) provides a thorough overview of the literature related to the relationships between science and policy in water management and finds that research on this topic has focused on the need for accuracy and reliability as well as understanding the context for information use. The literature also stresses, however, that even when conditions for integration appear to be met (i.e. data seem salient, credible and legitimate), this does not guarantee that available data will be used in decision making. There is additional evidence, however, that employing collaborative processes involving data generators and potential users can bring research and application together in water resource management (Lowrey *et al*. 2009; Rice *et al*. 2009, Kirchhoff 2010).

Of course, in many cases, there is a paucity of data available to be integrated into decision making. Although climate change has prompted sophisticated modelling efforts, the Southeast United States is proving especially difficult to simulate (State Climate Office of North Carolina, http://www.nc-climate.ncsu.edu/climate/climate_change#Future) increasing the uncertainty in future water supply forecasts. Additionally, numerous reports conclude that current water quantity data in the United States is inadequate (cf. NSTC, Committee on Environment and Natural Resources 2007). This is perhaps especially true in humid, rural areas where there has been less perceived need to quantify water supplies. In response, a National Water Census (USGS 2009) is underway to gather water quantity data and work continues to refine computer-based climate models. Increasing the data will not guarantee their use in making water management decisions, but data absolutely cannot be employed if they do not exist.

Less prevalent in the literature are cases where data, regardless of type or source, holds little salience because water is not perceived as a concern. A lack of data is not lamented in many south-eastern communities because stakeholders and decision-makers are not concerned about water quantity as a policy issue (Feldman & Elmendorf 2000; Responsive Management 2003). In this paper, I present survey and interview results from decision-makers in Western North Carolina, United States that provides further evidence that there is a general lack of concern about water quantity. This study also confirms existing evidence that water management is based significantly on 'doing things as they have always been done' and in the rural, humid southeast (as in other places) that has meant tapping new water sources when needed. The results indicate that in the rare instances where hydrological data are sought, it is almost entirely in relation to justifying a new supply. Given the historic and current wet conditions in this region, there has been little sustained reason to consider water quantity an issue. This is now reflected in perceptions of what constitutes a water supply and hence what data are salient to making management decisions. While this study focuses on Western North Carolina, the findings are potentially pertinent to decision making in other places perceived to have abundant water.

Study area

The study area is in the mountainous region of Western North Carolina, United States (Fig. 1). This area is the headwaters for eight large river basins, and surface water is the primary supply source for the majority of residents served by water utilities. The fractured bedrock aquifer system supplies water to some smaller utilities and to all residents outside utility service areas. This region is classified as temperate rain forest, and although the terrain influences precipitation locally, the region averages between 100 and 150 cm of rain per year (Gaffin and Hotz n.d.). The higher altitudes (> 1200 m) routinely receive 127 cm or more snow per year (Ray's Weather Center 2012). The region experienced a serious drought in 2007–2008, and several communities implemented severe water use restrictions, including at least one case of a town requiring restaurants to use disposable tableware. This drought prompted changes to state regulations concerning drought planning and increased state authority in requiring conservation measures (General Assembly of North Carolina Session 2007).

The political jurisdictions include 22 counties and multiple municipalities (e.g. towns, cities) within each county. Within

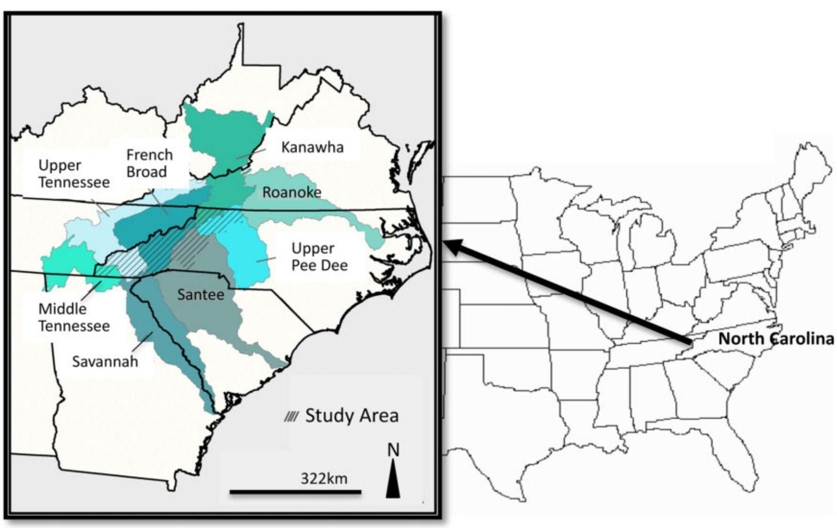

Fig. 1. The study area and affected river basins.

political jurisdictions are elected officials, managers, planners and utility personnel who have various responsibilities related to managing water supplies. Ultimately, elected officials have the authority for determining how water is allocated and otherwise managed within their jurisdiction. These individuals, however, rely on guidance from planners, managers and, when applicable, utility personnel. Managers are typically responsible for implementing the decisions made by the elected bodies and hence are familiar with the social, political and legal implications of water management decisions. The planners generate the plans for land use and economic growth management, which directly and indirectly impact water resources and drive demand. In those jurisdictions with water utilities, those personnel have day-to-day responsibility for managing water supplies and are often a key source of information about water for the planners, managers and elected officials. Additionally, utility personnel are often responsible for community education about water issues. In this region, there are planners, managers and elected officials who do not have any direct water management responsibilities because water users in their jurisdiction rely entirely on self-supplied sources, usually from groundwater. There are still, of course, impacts on the physical supply from these individual users as well as from land use and economic development decisions within these communities.

This is a rural area with a total population of about 1 000 000, and the largest municipality has a population of just under 85 000 (US Census Bureau 2010). The population, however, is increasing with many communities experiencing double-digit growth between 2000 and 2010. Since 2000, several communities in the region have had to identify a new water source to meet growing demand and avoid potential disruption from future drought. This has required increased attention to water among all decision-makers in these communities and provided the impetus for this project.

Method

A colleague, a graduate student and I drafted a 'Survey of City/County Planners, Utility Personnel, Managers, and Elected Officials' in September 2011. Appalachian State University faculty with expertise in planning and representatives from regional management organizations reviewed the draft survey in October. The final version included 31 core questions with up to 12 follow-up questions prompted depending on responses to core questions. The survey was posted online in November, and an email request to participate in the survey was sent to the 292 planners, managers, utility personnel and elected officials representing both county and municipality level jurisdictions in the region.

By late January 2012, we had received 85 completed responses, 68 from the initial list and 17 from governing entities just outside the originally designated area. Obviously, individuals on the initial email request forwarded it to others. This makes it difficult to calculate an exact response rate, as I do not know how many additional people received the request to participate. At a minimum, this reflects a 23% response rate from the initial list and a maximum 28% response rate if the 17 responses represent 100% of the additional potential respondents. Sheehan (2001) reported that online surveys of the general public average a 31% response rate, and Baruch (2008) showed that organizational surveys average a 36% response rate with a standard deviation of 18.8. Therefore, the 23–28% rate is within reported ranges for an online, non-random survey.

Between January and April 2012, a graduate student and I conducted in-depth interviews with 10 non-elected respondents from six different communities within the originally designated region. We conducted seven of these face to face in the offices of the interviewee and three by phone.

Results

Respondent characteristics

Respondents included 32 (38%) elected officials, 26 (31%) managers, 8 (9%) planners and 13 (15%) utility personnel. There were also six (7%) who identified as 'other' including environmental health professionals, an educator, a finance officer, a land manager and unspecified. When asked to characterize their water utility, about 78% said that their community/jurisdiction relies on a public, municipal supply, while a private provider serves almost 4%. Water associations that cross-political boundaries provide water to 7% of respondent communities, and 11% of respondents reported that this question was not applicable to them.

The majority of respondents (69%) spend 1–10 h per week thinking about their water supply. About 8% spend no time thinking about it, and 6% spend more than 25 h per week focused on the water supply. Additionally, 35 individuals (42%) noted that their community has a comprehensive plan that includes water management elements, and 66% have a drought plan. Interestingly, more than 15% do not know if their community/jurisdiction has a comprehensive plan or a drought plan (see Table 1).

Two broad and interrelated results relevant to future water management emanate from this data. First, the data make it clear that water quantity is not a serious concern for decision-makers in this region. Second, the idea of a 'water supply' is not directly connected to hydrological systems, but is focused on human systems.

Water quantity is not a serious issue

Agreeing with previous work in the Southeast United States, there is not a strong sense that water quantity is a serious issue in this region. As Table 2 shows, when asked to reflect on the perceived level of concern about water within their community/jurisdiction, 35% of the decision-makers reported that 'most people are not concerned.' To assess potential causes for concern, the survey asked about the impact of population growth and drought on water availability. Just over one third (31%) said that they are 'not at all concerned' about the potential for population growth to reduce the amount of water available to their community. Additionally, despite the seriousness of the 2007–2008 drought, only half of the decision-makers say that they are 'very concerned' about the potential for drought to reduce their water supply. In follow-up interviews, respondents all indicated that growth is what drives their management decisions, and interviewees were unanimous in expressing their confidence that any concerns about water quantity either have been or will be remediated by obtaining a new supply.

Table 1 Responses to survey questions about planning and management practices

Survey question	Yes	No	Do not know
Does your community/jurisdiction have a comprehensive plan? ($n = 84$)	51 (61%)	18 (21%)	15 (18%)
If yes, does it include water components? ($n = 50$)	35 (70%)	12 (24%)	3 (6%)
Does your community/jurisdiction have a drought plan? ($n = 83$)	55 (66%)	15 (18%)	13 (16%)
Does your community/jurisdiction have a specific policy/ordinance that guides water allocation decisions? ($n = 66$ only those communities that allocate water)	41 (62%)	25 (38%)	0
Has your community/jurisdiction implemented any water conservation measures? ($n = 85$)	53 (62%)	26 (31%)	6 (7%)
Non-drought driven measures ($n = 44$ open-ended follow-up; 27% indeterminate)	15 (34%)	17 (39%)	0
Has your community/jurisdiction implemented any public/school education campaigns/programmes related to the water supply? ($n = 85$)	16 (19%)	46 (54%)	23 (27%)
In the past 5 years has your community/jurisdiction consulted population growth or development forecast data? ($n = 85$)	53 (62%)	25 (29%)	7 (8%)
Has your community/jurisdiction initiated or participated in any scientific studies seeking to better understand the physical characteristics (e.g. seasonal flow rate, recharge rate) of your water supply? ($n = 85$)	26 (31%)	35 (41%)	24 (28%)

The lack of concern and a continued commitment to supply driven management are also reflected in the prevalence of conservation and education programmes. Only 19% of decision-makers reported that their communities have implemented any public education campaigns about water, while 62% indicated that their community has implemented some form of water conservation measure. Respondents were asked to describe the specific conservation measures in an open-ended question and 44 did so. Of those, 17 (39%) individuals reported measures that are applied only during declared droughts, while 15 respondents (34%) representing nine different communities reported measures that are not directly tied to drought conditions. The other 12 (27%) respondents did not give sufficiently detailed responses to determine when they applied (see Table 1).

Perhaps not surprisingly, respondents who expressed strong concern about the potential for drought to reduce water availability were more likely to represent communities with conservation programmes. High concern, however, does not contribute to implementing water education programmes (Table 3). There were no significant relationships between expressed concern for the potential for growth to impact water availability and the presence of conservation or education programmes.

Water supply is not hydrological

The data demonstrate that decision-makers interpret 'water supply' in terms of human systems, including legalities (e.g. permits, regulations) and infrastructure, not in terms of a physical system (e.g. discharge, recharge). This is reflected in responses to explicit questions about seeking hydrological information and perceptions of the available supply.

The survey section labelled 'Water Supply' included these questions:

> Has your community/jurisdiction initiated or participated in any scientific studies seeking to better understand the physical characteristics (e.g. seasonal flow rate, recharge rate) of your water supply?

Table 2 Responses to survey questions about concern for future water availability

Survey question	Not at all concerned	Somewhat concerned	Very concerned
Level of concern among the general public about the future water supply ($n = 84$)	29 (35%)	45 (54%)	10 (12%)
Potential for population growth to restrict/reduce the amount of water available ($n = 84$)	26 (31%)	48 (57%)	10 (12%)
Potential for drought to restrict/reduce the amount of water available ($n = 84$)	3 (4%)	39 (46%)	42 (50%)

Table 3 Correlation between the survey question, 'How concerned are you about the potential for drought to restrict/reduce the amount of water available (water supply) to your community/jurisdiction?' and the prevalence of conservation or education programmes

Concern about drought reducing available water	Has jurisdiction implemented conservation measures?*				Has jurisdiction implemented education campaigns?*			
	Yes	No	DK	Total	Yes	No	DK	Total
Not at all concerned	0	3	0	3	0	1	2	3
Somewhat concerned	21	15	3	39	10	24	5	39
Very concerned	32	8	2	42	5	21	16	42
Total	53	26	5	84	15	46	23	84

*Pearson's chi-square, $P \leq 0.05$.
DK, do not know.

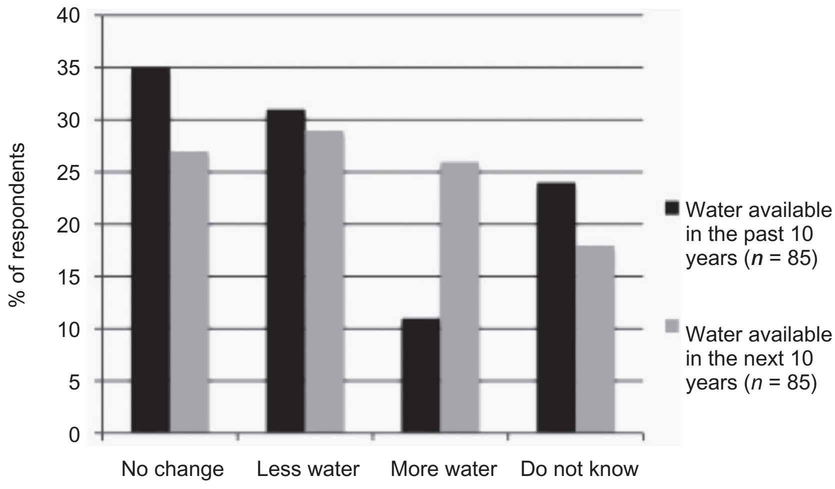

Fig. 2. Responses to the survey questions, 'Has the amount of water available (e.g. well level, river level) to your community /jurisdiction changed in the past 10 years?' and 'Do you anticipate that the amount of water available (e.g. well level, river level) to your community/ jurisdiction will change in the next 10 years?' Pearson's chi-square, $P = 0.01$.

> Has the amount of water available (e.g. well level, river level) to your community /jurisdiction changed in the past 10 years?
> Do you anticipate that the amount of water available (e.g. well level, river level) to your community/ jurisdiction will change in the next 10 years?

These questions were intentionally worded and ordered to encourage respondents to think specifically about hydrological data and available water. A literature search and conversations with hydrologists confirmed that there is little hydrological data available for this region. Therefore, the first question in this section was also intended to ascertain if there had been any localized studies done that are not represented in the literature. The results show that 26 respondents (31%) said that their community had conducted or participated in a scientific study (Table 1). An open-ended question about the types of studies conducted, however, revealed that only 12 of these responses, representing seven different communities, were definitively hydrological in nature. In five of these seven cases, the studies were focused on legal requirements related to a new supply source (e.g. flow rates determined as part of an environmental assessment). Six of the 'yes' responses to the question were not focused on assessing hydrological conditions, but rather on collecting customer usage data, assessing wastewater treatment capacity and/or using GIS to map sewer lines or other infrastructure. The remaining eight responses did not provide sufficient information to be certain of the nature of the studies referenced.

Despite the lack of data on hydrological conditions, 35% of the respondents indicated that there has been no change in the amount of water available in the past decade, while just over a third (31%) say that there is less water and 11% say that there is more water available. The remaining 24% responded that they do not know whether their water supply has changed (Fig. 2). Regional streamflow data from the US Geological Survey do not show any significant change in average discharge rates through this decade. There are no similar data available for groundwater.

In looking to the future, responses flatten a bit with 27% anticipating no change, 29% believing that there will be less water and just over one quarter (26%) saying there will be more water available. Fewer people (18%) said that they do not know if there will be a change in available water, despite

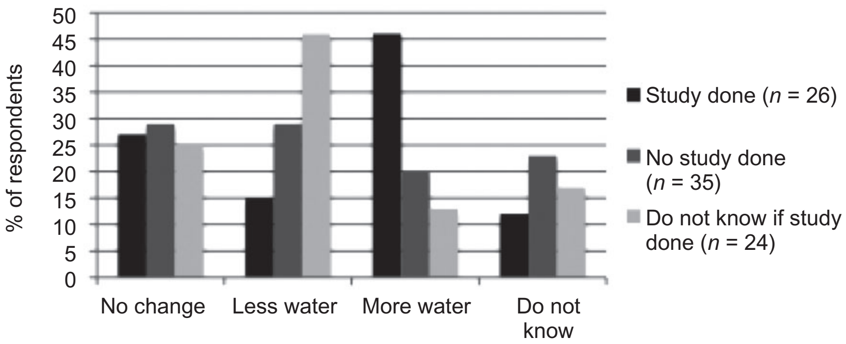

Fig. 3. Comparing responses to the survey questions, 'Has your community/jurisdiction initiated or participated in any scientific studies seeking to better understand the physical characteristics (e.g. seasonal flow rate, recharge rate) of your water supply?' and 'Do you anticipate that the amount of water available (e.g. well level, river level) to your community/jurisdiction will change in the next 10 years?' Pearson's chi-square, $P = 0.08$.

the need to predict future conditions. In the follow-up interviews, the shift in responses from past to future water conditions was clearly linked to increased demand and a subsequent need for a new supply. Five of the 10 interviewees indicated that there would be less water in the future because of population growth and subsequent increased demand. Of these, two simply said that growth and demand mean less water. One specifically mentioned increased private well drilling because of growth and one person said that stream flow is decreasing, but it would be a 'wild guess' as to why. Another interviewee said that he 'did not want to invoke global warming' but that the 'earth is dynamic.' This was the only reference to climate change in any of the interviews. The other half of the interviewees said that there would be no change or that there would be more water in the future specifically because new supplies are being or had been brought online. When asked about their community's response to a potentially decreasing supply, every interviewee said they would seek a new source.

While not strongly significant, the survey suggests that those who said that their community had participated in a scientific study were also more likely to say that there would be more water available in the future and less likely to say that they do not know what the future holds (Fig. 3). Although it is a small set, it is interesting that of the 12 respondents whose communities have participated in some type of hydrological study, six of them said that they will have more water in the future, likely because these studies are focused on obtaining a new supply.

The importance of perceived data salience and an emphasis on human systems is reflected through several additional survey questions. First, for issues that are perceived as salient (i.e. growth), the decision-makers do actively seek data, and 62% indicated that they have sought population growth or development forecast data in the past 5 years, mostly from the US Census Bureau (Table 1). Comparatively, when asked about primary data sources used to make decisions about water allocation, no respondent said they used scientific studies on water resources in the region. So, even those respondents who do have local hydrological studies do not use the findings when allocating water. Of the 66 respondents who reported that their community/jurisdiction does allocate water, two (3%) did say that US Geological Survey monitoring data is a primary source. The primary data source for 45% of respondents is locally collected data on customer water use. For 42%, allocation decisions are directed by state and/or local regulatory requirements and 9% use no data at all because any request for water is granted (Table 4).

Table 4 Responses to the survey question: 'What is the primary/most common data source that your community/jurisdiction uses in making decisions about allocating water?' ($n = 66$)

Source	Responses
Scientific studies on water resources in the region	0
USGS or other real time monitoring data	2 (3%)
Locally collected data on water use	30 (45%)
State/local regulations/guidance pertaining to water allocation	28 (42%)
No data needed – all requests granted	6 (9%)

USGS, US Geological Service.

The survey data indicate that the ability of the existing infrastructure to support any new water use is by far the most important variable in making decisions about water allocation, with a mean score of 2.44 on a 1–7 scale (Table 5). The ability to sustain the supply in the long term garnered a 3.44 mean score, a full point behind infrastructure. Interestingly, although regulations/guidance are noted as a prominent data source, they are not a leading influence on the decision-making process for these respondents. This may be, in part, because 38% of the respondents whose communities do allocate water indicated that there is no formal, established process for doing so. Interviews revealed that in communities that do have a formal process, this typically meant that an elected body (e.g. city council) needed to approve any significant allocation or service extensions and that it was rare to not grant requests for water.

As already noted, there is consensus that decisions are ultimately at the discretion of elected officials, with guidance from planners, managers and utility personnel. The survey data show that planners and elected officials are more likely to think that their community has conducted scientific studies, while managers and utility personnel are less likely to think that (Fig. 4). Despite survey language focused explicitly on hydrological conditions, more than half of the respondents who said 'yes' their community had participated in a scientific study, actually did not have any reference to hydrological studies. Further, of the eight respondents who indicated that their community had participated in scientific study but did not provide details on the type of study, five were elected officials. There are no significant differences in how these respondent groups answered the questions about past or future water availability or in their expressed levels of concern about the potential for growth or drought to affect the available water supply.

Table 5 Mean scores for the survey item: 'Rank from 1 to 7 (1 = most important; 7 = least important) the following in terms of their influence on your community's decision-making process for allocating water.'

Influence	Mean score
Ability of infrastructure to support new use (*n* = 70)	2.44*
Potential for economic benefits to the community (*n* = 69)	3.04*
Potential for drought (*n* = 75)	3.07
Ability to sustain the supply for the long term (> 50 years) (*n* = 72)	3.44
Compliance with state regulations (*n* = 70)	3.44
Environmental concerns (*n* = 71)	3.52
Other (*n* = 24)	6.75

*T-test, $P = 0.009$.

Discussion/conclusion

This project highlights several key ideas relevant to managing water for ourselves and the environment. First, these results demonstrate that there is not a sense of concern or urgency related to the water supply in this region and decision making is often ad hoc. Second, respondents confirm existing evidence that supply-side management is the norm and that science-based data are not core to local water management decisions. This project, however, also shows that some decision-makers perceive that they *are* using science-based data. This creates an additional challenge for integrating such data into decisions and for defending the need for a shift to demand-side management efforts. These results potentially provide fertile ground for researchers and policymakers to reconcile the 'supply' and the 'demand' for scientific data relevant to water management decisions (Sarewitz & Pielke 2007). Rather than waiting for potential data users to drive demand, there may be significant opportunities for researchers to leverage the lack of formal management infrastructure to catalyse data demand through collaborative approaches to water management.

(1) Figure 5 depicts a conceptual view of what has happened in Western North Carolina (and likely in other areas). There has been little concern about water quantity and therefore little data collected because there has historically been a low population base and plenty of water. Therefore, the prevailing decision has been to tap new water sources as needed. Now that population is increasing, there have been more formal planning and decision-making processes implemented in some communities, but the focus remains on establishing new sources.

(2) Because there still seems to be abundant water, there is little attention to assessing physical, hydrological conditions.

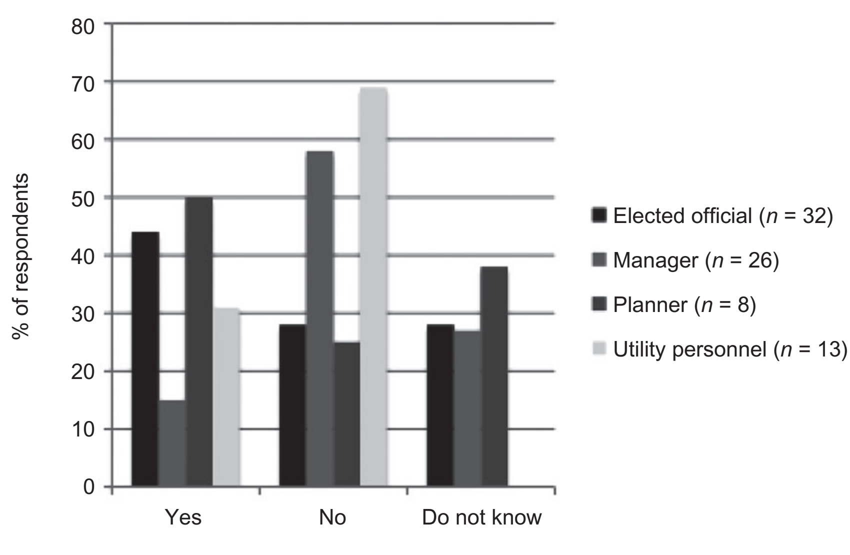

Fig. 4. Respondent type categorized by their response to the survey question, 'Has your community/jurisdiction initiated or participated in any scientific studies seeking to better understand the physical characteristics (e.g. seasonal flow rate, recharge rate) of your water supply?' Pearson's chi-square, $P = 0.002$.

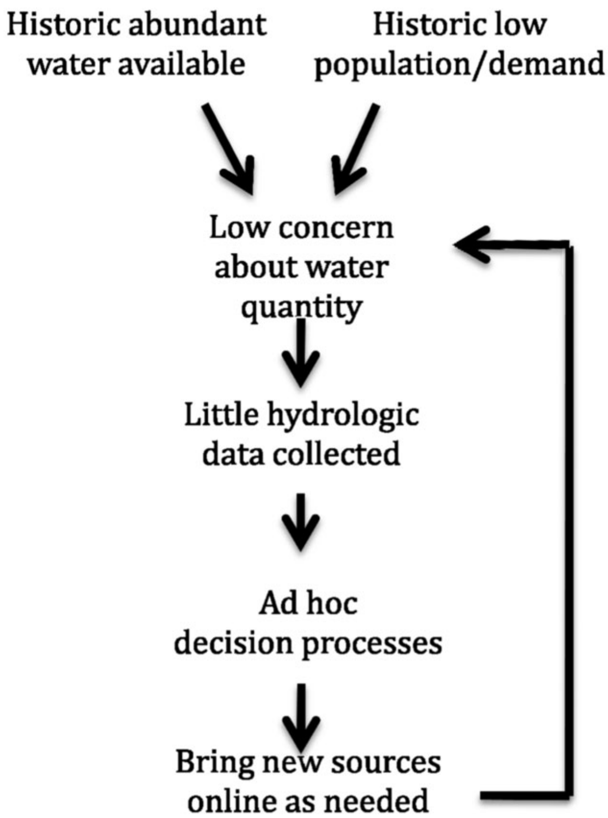

Fig. 5. Conceptual diagram of water management in historically wet regions.

Therefore, having one third of survey respondents report that they do have such data that presents potentially interesting issues related to how decision-makers think about data. First, it is feasible that ignorance about what constitutes hydrological data was manifested in some responses, so that the question's specific references to flow rate and recharge may not have been sufficient to guide respondents towards thinking hydrologically. More likely, the results simply reflect a management philosophy that is focused on providing a reliable supply. Therefore, in reading the question, respondents either assumed that there must be studies even if they could not articulate any specifics, or they interpreted data that they feel are most salient to their needs (e.g. usage, infrastructure) as being scientific. Given the lack of concern about quantity, hydrological data are not perceived as salient except as it is legally required to obtain a new supply. This is also reflected in the fact that the majority of respondents said that they did not know or that there had not been local studies completed, indicating that in these communities water management decisions are necessarily made without hydrological data. Thus, the idea of a 'water supply' is disconnected from physical, hydrological conditions. In this region, decision-makers think of water supply in terms of permitted use levels and infrastructure available rather than in terms of hydrology. Their predictions of future water availability reflect optimism about tapping new sources, and therefore, the future seems more certain than knowledge of past conditions. This subsequently contributes to the lack of concern about water quantity. This study suggests that these traits are perhaps particularly pronounced among elected officials, who are typically the final arbiters in making water management decisions. As is well documented, convincing decision-makers who are concerned about water quantity to begin using specific types of data is challenging. It is perhaps even more challenging to convince decision-makers who do not perceive a problem and/or who think that they are using appropriate data, to seek and use hydrological data or data emphasizing the benefits of demand-side management.

(3) Given rapid population growth and the uncertainty associated with climate change in this region, it is highly problematic for these decision-makers to continue to assume that the relationships shown in Fig. 5 will ensure a sustainable water supply. At some future point, it is realistic to expect that some communities will fail when they seek a new supply, as there will not be sufficient resources available or tapping them will be prohibitively expensive or ecologically devastating. Such a crisis scenario should trigger a change in decision-making focus. I say should, as experience in the Western United States demonstrates to what great lengths communities will go to secure a new water supply.

Although history suggests it is not the usual path, it is preferable to anticipate and avoid such a crisis driven change. Ironically, the lack of attention to water quantity and subsequent ad hoc decision making may offer the best rationale for optimism that perceptions of water supply can become more hydrologically based. When there are few existing decision protocols or firm data sources, there are fewer barriers to integrating hydrological data into decision making. There are still, of course, significant issues to address including the lack of concern that has perpetuated the ad hoc decision making without data and the emphasis on supply-side management as the norm.

(4) Current efforts focused on gathering additional water quantity data, such as improved climate models, a National Water Census or more local efforts, are relevant to addressing these issues. These data could, of course, reinforce a lack of concern if they show that the region is likely to continue to have abundant supplies *or* reflect a high level of uncertainty about future hydrological conditions. Subsequently, if there is not increased concern, there will not likely be a shift away from supply-side management or towards thinking of water supply in terms of its physical systems. If there are abundant supplies, however, then concern about water quantity may be unwarranted. Managing according to historical patterns (e.g. ad hoc, supply driven) under this scenario would be data based (even if unintentionally) and would set a precedent for using hydrological data in some fashion. This may influence how hydrological data are perceived, and therefore, if future data suggest cause for concern about water quantity, then that data may be more readily integrated into decision-making processes.

If, on the other hand, new data demonstrate that regional water supplies are diminishing, this could attract public and decision-maker attention. If there is increased attention to water quantity (I do recognize this as a significant 'if'), there arises an opportunity to address perceptions of water supply and the emphasis on supply-side management. Again, the ad hoc decision-making model may prove to be advantageous if increased concern catalyses policy change. Institutional conservatism is a strong barrier to changing how management is done (Lach *et al*. 2005). If there is not a well-established process or institutional 'norm' to be preserved *and* a desire to establish a process for making decisions, this institutional barrier should be lower.

(5) Any community that currently manages water in an ad hoc fashion is an excellent candidate for establishing collaborative processes that have been shown to successfully integrate science and policy. For example, Kirchhoff (2010) documents that formal programmes linking water managers with climate researchers to develop information relevant to the water manager needs are successful in integrating data into decision making. Even without the imprimatur of a formal programme, communities that are not currently utilizing data may offer a 'window of opportunity' (Kingdon 1984) to apply lessons learned from collaborative efforts to help decision-makers develop data gathering and decision-making processes that recognize a water supply as being dependent on the underlying physical, hydrological conditions. If data do show that supplies may be less abundant than previously assumed, local decision-makers may welcome overtures from scientists, advocates and others who have studied the physical system and are willing to work with decision-makers to find ways to integrate relevant data into decision processes.

Even if water remains abundant in humid regions, the evidence is strong that shifting from supply side to demand-side management can offer economic and environmental benefits to any region. This should also be a focal point for data integration within a collaborative process. Although changing the level of concern and perceptions of the water supply will not automatically mean a move away from supply-side management, it is a necessary first step. If water supplies are diminishing in historically wet regions, and if this does increase concern, then those communities that have not worried about their water may be promising locales to more thoroughly integrate hydrological, economic and environmental data into policy, and this could encourage a shift from supply side to demand-side policies to better manage the water that is available now and in the future.

Acknowledgements

Thanks to Christopher Badurek and Robin Hale for collaborating on the survey and to Robin for generating the map of the region's river basins, and coordinating and assisting with the interviews. Robin's work was funded through the Graduate Research Associate Mentor programme at Appalachian State University. Jana Carp, Rick Crepeau, Bill Eaker and Phil Trew all graciously reviewed a draft of the survey. Additionally, anonymous reviewers offered suggestions that greatly improved this paper.

References

Baruch, Y. (2008) Survey Response Rate Levels and Trends in Organizational Research. *Hum. Relat.*, **61** (8), 1139–1160.

Bates, B., Kundzewicz, Z.W., Wu, S. and Palutikof, J. (eds). (2008) *Climate Change and Water*. Intergovernmental Panel on Climate Change Technical Paper VI.

Butler, D. and Memon, F.A. (eds). (2006) *Water Demand Management*. IWA Publishing, London.

Clark, W. and Dickson, N. (1999) The Global Environmental Assessment Project: Learning Form Efforts to Link Science and Policy in an Interdependent World. *Acclimations*, **8**, 6–7.

Feldman, D.L. and Elmendorf, J.O. (2000) *Water Supply Challenges Facing Tennessee: Case Study Analysis and the Need for Long-Term Planning*. Prepared by the Energy, Environment and Resources Center, The University of Tennessee - Knoxville for the Environmental Policy Office, Tennessee Department of Environment and Conservation.

Gaffin, D.M. and Hotz, D.G. (n.d.) *A Precipitation and Flood Climatology with Synoptic Features of Heavy Rainfall across the Southern Appalachian Mountains*. National Weather Service Weather Forecast Office, Morristown, TN. http://www.srh.noaa.gov/mrx/research/climo/pcptxtnwd.php [accessed 25 January 2013].

General Assembly of North Carolina Session. (2007) Session Law 2008-143, House Bill 2499.

Griffin, R.C. and Mjelde, J.W. (2000) Valuing Water Supply Reliability. *Am. J. Agric. Econ.*, **82** (2), 414–426.

Kampragou, E., Lekkas, D.F. and Assimacopoulos, D. (2011) Water Demand Management: Implementation Principles and Indicative Case Studies. *Water Environ. J.*, **25**, 466–476.

Kindler, J. (2010) Water Demand Management. In: *A Review of Selected Hydrology Topics to Support Bank Operations*. HEF Technical Report 1. The World Bank.

Kingdon, J. (1984) *Agendas, Alternatives, and Public Policies*. Harper Collins Publishers, Michigan, USA.

Kirchhoff, C.J. (2010) *Integrating Science and Policy: Climate Change Assessments and Water Resources Management*. University of Michigan, Ann Arbor.

Lach, D., Ingram, H. and Rayner, S. (2005) Maintaining the Status Quo: How Institutional Norms and Practices Create Conservative Water Organizations. *Tex. Law Rev.*, **83**, 2027–2053.

Larson, K.L., White, D.D., Gober, P., Harlan, S. and Wutich, A. (2009) Divergent Perspectives on Water Resource Sustainability in a Public-Policy-Science Context. *Environ. Sci. Policy*, **12**, 1012–1023.

Lowrey, J.L., Ray, A.J. and Webb, R.S. (2009) Factors Influencing the Use of Climate Information by Colorado Municipal Water Managers. *Clim. Res.*, **40**, 103–119.

McNie, E.C. (2007) Reconciling the Supply of Scientific Information with User Demands: An Analysis of the Problem and Review of the Literature. *Environ. Sci. Policy*, **10**, 17–38.

National Science and Technology Council (NSTC), Committee on Environment and Natural Resources. (2007) *A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States*.

Pirie, R.L., Loe, R.C. and Kreutzwiser, R. (2004) Drought Planning and Water Allocation: An Assessment of Local Capacity in Minnesota. *J. Environ. Manage.*, **73**, 25–38.

Ray's Weather Center. (2012) Snow Totals Archives. Available at http://www.booneweather.com [accessed 7 June 2012].

Rayner, S., Lach, D. and Ingram, H. (2005) Weather Forecasts Are for Wimps: Why Water Resource Managers Do Not Use Climate Forecasts. *Clim. Change*, **69**, 197–227.

Responsive Management. (2003) *Understanding the Georgia Public's Perception of Water Issues and the Motivational Messages to Which They Will Respond: Focus Group Findings*. Conducted for the Georgia Department of Natural Resources, Harrisonburg, VA.

Rice, J.L., Woodhouse, C.A. and Lukas, J.J. (2009) Science and Decision Making: Water Management and Tree-Ring Data in the Western United States. *J. Am. Water Resour. Assoc.*, **45** (5), 1248–1259.

Sarewitz, D. and Pielke, R.A. Jr. (2007) The Neglected Heart of Science Policy: Reconciling Supply of and Demand for Science. *Environ. Sci. Policy*, **10**, 5–16.

Sawyer, S.W. (1982) Conservation Practices and Attitudes among Maryland Water Supply Managers. *Water Resour. Bull.*, **18** (5), 791–796.

Sewell, W.R.D. and Roueche, L. (1974) Peak Load Pricing and Urban Water Management: Victoria, B.C., a Case Study. *Nat. Resour. J.*, **14** (3), 383–400.

Sheehan, K. (2001) E-Mail Survey Response Rates: A Review. *J. Comput. Mediat. Commun.*, **6** (2), available at http://jcmc.indiana.edu/vol6/issue2/sheehan.html [accessed 25 January 2013].

Traynham, L., Palmer, R. and Polebitski, A. (2011) Impacts of Future Climate Conditions and Forecasted Population Growth on Water Supply Systems in the Puget Sound Region. *J. Water Resour. Plan. Manage.*, **137** (4), 318–326.

US Census Bureau. (2010) State & County QuickFacts. http://quickfacts.census.gov/qfd/index.html [accessed 5 June 2012].

US Geological Service (USGS). (2009) National Water Census. http://water.usgs.gov/wsi/ [accessed 7 June 2012].

Zetland, D. (2011) *The End of Abundance: Economic Solutions to Water Scarcity*. Aguanomics Press, California, USA.