Drought, Tree-Rings, and Water Resource Management:
Assessing the Scientific Outreach of the Western Water Assessment

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I. Project Description and Objectives

The purpose of this project is to evaluate the outcomes of ongoing scientific outreach efforts of the Western Water Assessment (WWA) related to the use of tree-rings and streamflow reconstructions for sustainable water resource management. This includes an evaluation of collaborative research conducted by Connie Woodhouse, Jeff Lukas, and Robin Webb (referred to as "tree-ring researchers") with water managers, consultants, and utility directors in Colorado, as well as an assessment of the Technical Workshops for Water Resource Managers facilitated by the WWA since 2006. In particular, we are interested in how water managers and utility directors are utilizing tree-ring data in their day-to-day operations, hydrologic models of water supply, resource planning and decision-making, in addition to any challenges they have encountered in using such data. We are also interested in how workshop attendees have utilized (or have not utilized) the information presented in the Technical Workshops.

General Research Objectives

- Obtain more detailed **background information** on individuals and organizations that have worked with tree-ring researchers and/or attended a WWA technical workshop, including what initially prompted their interest in tree-ring data and streamflow reconstructions. Also, consider what organizational characteristics, mandates, and/or cultures facilitate use of tree-ring data in water resource management.

- Determine **how tree-ring data and information have been utilized** by established research partners and workshop attendees (e.g. as data for quantitative/modeling analysis, as information to inform decision-making, planning, operations, and/or educating board/publics). Also, assess the degree to which acquisition of paleoclimate data influences organizational procedures or plans to cope with climate variability and uncertainty.

- Assess **general satisfaction** with the data/information established research partners and workshop participants were provided, as well as any future data/information needs. Determine what challenges (technical, political, other) exist in incorporating climate science/data into decision-making, as well as what aspects of scientific outreach have been most effective.

The intended use of data from this report is for internal use within Western Water Assessment, NOAA, the Climate Program Office, and other RISA programs to evaluate the success of scientific outreach, though subsequent stages will target a larger audience through publication of policy papers and journal articles for wider distribution. Ultimately, the results of this work will be used to improve the delivery of scientific information to users through the WWA and RISA programs more broadly.

In compliance with the University of Arizona's Human Subject's review, informed consent was obtained by all project participants. For the purposes of this report, all identifying names of individuals and organizations have been removed to ensure confidentiality. ***It is essential that any data used from this report retain and protect the confidentiality of all individuals and organizations involved. Please do not include any identifying information on any data used from this report.***

II. Data Collection

Data was collected in two research phases. The first phase consisted of five interviews with individuals associated with three different water utilities in Colorado (referred to as Organizations A, B, and C in Section III). The second phase involved an online survey of ten questions administered to all past Technical Workshop Attendees (whose email contact info was available). A Project Info Sheet (See Appendix A) and consent form were distributed to all interview participants before conducting the interview, while a confidentiality disclaimer was included at the beginning of the internet survey to ensure compliance with informed consent procedures before completion of the survey.

Phase One: Interviews with Established Partners (Collected January 2008)

To evaluate the outcomes of the tree-ring researcher's collaborations with its more established research partners, semi-structured interviews were conducted with individuals associated with three water resource organizations during January of 2008. Representatives from two municipal water providers (referred to as Organizations "A" and "B"), one water conservation district (Organization "C"), and two consulting firms (associated with Organization "B") made up the interview sample. Interview questions (included as Appendix B) were designed to elicit information regarding the integration of tree-ring data into water management by each of the organizations, the institutional context within which tree-ring data have been used, and each organization's general satisfaction of the tree-ring data they were provided. Furthermore, interviews were designed to be beneficial to both parties involved by allowing the participants to share any further data needs they may have or suggestions for future scientific outreach activities of the WWA. A semi-structured interview format ensured that a general set of topics would be addressed in each interview, without restricting the possibility for new discussion topics to emerge in conversation.

Qualitative textual analysis of interviews consists of two stages. First, analysis was performed on the interviews to produce a general summary of each organization's background and use of tree-ring data based on the information individuals provided in the interviews (Section III, A). The primary goal of this stage of analysis is to determine how each organization has come to understand the relevance and utility of tree-ring data in their operations and decision-making. A second stage of analysis was performed on interview data to decipher general topics or themes that occur in multiple interviews. The primary goal of this stage of analysis is to determine what broad concepts are present among the entire interview population or topics of divergence between different organizations (Section III, B).

Phase Two: Surveys with all WWA Technical Workshop Participants **(Collected March 2008)**

During the second phase of the project, we evaluated the outcomes of the WWA's Technical Workshops for Water Managers that began in 2006. A written survey, administered via the internet, was distributed to all previous workshop participants to determine if and how they have utilized the paleoclimatic information provided in the workshops (see Appendix C for complete list survey questions). The survey was sent to 71 individuals that have attended these workshops from a wide variety of public and private organizations (including the individuals interviewed in Phase One, since they have also participated in the workshops). The survey population offers a much larger and more diverse set of responses than was obtained from the interviews in Phase One, though the relationships with most of these individuals and organizations has not extended beyond the contact at the workshop they attended. Questions were designed to elicit basic background information on workshop participants, if and how tree-ring data have been integrated into the operations or decision-making of the organizations, what information from the workshops has been most or least useful, and what other paleoclimatic data might be of use to water managers, utility directors, or other related individuals.

Quantitative analysis was performed on the survey results to provide general summary statistics for each question and summary statistics for each occupation type (e.g. planner, researcher, or consultant). Qualitative analysis was performed on open-ended responses to survey questions to decipher prominent themes relevant to each question topic.

III. Results of Phase One: Interviews

A. Discussion of Each Organization's Use of Tree-ring Data

Organization "A" is a separate municipal water utility governed by a mayor-appointed manager and five-member board, which serves approximately 1.1 million customers with primary water sources on the Blue River (a tributary of the Colorado River) and South Platte River. Organization A has 684,315 million acre feet of reservoir storage over 4,000 miles, with its primary water source coming from mountain snow melt. Approximately, 65% of Organization A's water is used for single or multi-family domestic use, 20% for industrial/business use, and the remainder for public agency and other uses. Of domestic water use, it is estimated that more than 50% is for landscaping. Water rates are set by the five-member Board of Water Commissioners, whose professions and backgrounds include development and real estate, law and public service, as well as environmental consulting.

The following information about Organization A's use of tree-ring data was provided in the interviews. Specific quotes from interviews are included in italics where possible.

1. **The incorporation of streamflow reconstructions into Organization A's hydrologic model showed that the worst drought in the tree-ring record (1840s) *could* have been accommodated by current planning strategies if current plans for drought restrictions were used.** Before utilizing tree-ring reconstructions, Organization A was using an instrumental record [1946-1991] and the 1950's drought *without* restrictions for water supply models and planning. One interviewee indicated that they have determined, using their water model, that the 1840s drought may have been "slightly more severe" than the 1950s drought, but because the drought could have been

accommodated with current drought restriction plans, they have continued to use the 1950s drought in their water models. The importance of this finding is that Organization A's system performed through the 1950s without water use restrictions, but could only get through the 1840s with restrictions. As a result, Organization A is now considering is what changes need to be made in their system and/or operations to get through a 1840s drought without restrictions.

> *"So when we came in with the tree-ring information, what we learned was, in order to get through the 1840s drought at the same reservoir ending content levels we had to put restrictions on, and it was just a coincidence that we put on in the modeling the same level of restrictions as what we had in our drought response plan, and the 1840s with restrictions, you end up with the same emptiness as you do in the 1950s without restrictions. So right now we are just using that information kind of as a back-up to say it's reasonable to look at the 1950s, without restrictions, because when we look at worse periods with restrictions, we end up with the same answer."*

2. **Tree-ring data have been used to educate Organization A's Water Board about water supplies and to update drought plans**. The Water Board was happy to see that a longer record of streamflows from the tree-ring record could have been accommodated using current drought planning. Representatives from Organization A were pleased that tree-rings gave the Water Board a better sense of the frequency of drought and restriction events. They also have plans to incorporate information gained from analysis of the tree-ring record into the next Integrated Resource Planning Document of Organization A.

> *"So we took them [The Water Board] through part of the planning process to re-educate or educate them on what our planning approach was—the 1950s drought, without restrictions, what we learned from using the tree-rings—and we got a really positive favorable response that made them feel a lot better to see a longer hydrological period."*

> *"And what we did out of this longer period too is we could give them [the Water Board] a better idea of how often they would have to be on different levels of restriction of a Level 1, Level 2, Level 3. That was really important for them to go back. Roughly one out of every five years they would have to be on some level of restriction…versus, oh, it will never happen again, or it's an every year thing."*

3. **Organization A indicated that "giant leaps" have to be made to use yearly tree-ring data in daily water models, so it can be difficult to run water models with longer time periods.** Furthermore, using tree-ring data can open the organization up to questions about water supply during review and impact processes that cannot necessarily be answered directly from streamflow reconstructions. Although, Organization A was successful in developing a strategy for disaggregating the tree-ring data spatially and temporally to provide the necessary input into their water system PACSM model, they are still using the 1950s drought for planning, in part because EIS process requirements.

> *"Even if we have everything worked out on a [model] run and we are comfortable it and have confidence in it, you can't really use that model run so easily for an EIS [Environmental Impact Statement] process because people go 'well what happened in October of 1634…why in November of this did this happen'"*

Organization "B" is a municipal water utility governed by the City Council, with an appointed five-member Water Resources Advisory Board to oversee and advise the city council on more technical issues related to water supply and provision. Organization C's primary water sources come from mountain snow melt on both the East and West Slope, which is captured by a series of city-owned reservoirs. Of the nearly 25,000 acre-feet (7.8 billions gallons) of water provided by Organization B each year, more than 60% is used for domestic purposes. Organization B frequently utilizes consulting firms for special projects, including the creation of the 2003 Drought Plan.

The following information about Organization B's use of tree-ring data was provided in the interviews. Specific quotes from interviews are included in italics where possible.

1. **Consultants working for Organization B have known about tree-ring data since the 1990s and wanted to use information from the paleo record to lengthen the timeframe upon which their water models run.** Consultants that work with Organization B were interested in obtaining a better understanding of the amount of variability, including droughts more severe than the 1950s, so they sought out tree ring data from Connie after meeting her at a conference. A model using the tree-ring reconstructions was used to help develop the Organization's 2003 drought plan, which has been readily embraced by the City Council and wider community that Organization B serves. Furthermore, Organization B is now in the process of using tree-ring data in conjunction with climate change models for future planning efforts.

> *"And so, we had a limitation—an analytical problem in terms of only being able to look at the same historical trace over and over again. And people have done recombinations, you can do synthesized hydrology traces based on that, but early on I remember reading about the tree ring data that Stockton and Jacoby had done on the Colorado River Basin and I think that was done in the early '80s… and based on that they had cast some doubt as to… 'gee, we might actually be having a relatively wet century here.' I thought, gee, it would be fun to do that for Boulder some time."*

> *"The next thing they [Organization B's City Council] saw is the drought plan in 2003…at that time, they heard about tree rings and they were fascinated."*

2. **Tree-ring data have been used to create and justify Organization B's "Reliability Criteria" approach to water planning.** This approach differs from traditional "firm yield" approaches (determining the amount of water available to meet average water demand without the use of water restrictions) by determining a threshold of drought frequency (e.g. 1 in 20 year drought) that they would like their system to accommodate without any restrictions, followed by a series of increasingly strict restrictions for droughts of greater severity.

> *Organization B "has adopted reliability criteria. They say we'd like to have a water supply that's sufficient to meet everybody's needs, no matter how trivial, against droughts with severities of up to 1 in 20 year recurrence. At 1 in 20 year droughts, and getting more severe, then we will impose restrictions on citizens, but those restrictions shouldn't be so severe as to kill off permanent vegetation, trees, permanent landscaping, unless we hit droughts of 1 in 100 year recurrence, and that beyond that, we will suffer permanent*

damage to landscaping. But we want to at least be able to meet essential indoor uses against droughts as severe as 1 in 1,000 year occurrence."

3. **Organization B feels that the most important factor for using tree-rings in drought planning is how well the parameters of the water model, and in particular water rights, are specified.** User-defined tools, rather than generic tools to be used by multiple water providers, are better suited to examine tree-ring data in water models.

"Give people data, give people a simple tool kit, but don't design grand analytical tools because people with inevitably distrust them, find fault with them. You won't get them right because water allocation is very place specific."

Organization "C" is a publically owned water conservation district that sells water for agricultural, municipal, and industrial uses throughout seven counties in Colorado. Using a series of reservoirs and pipelines, the conservation district provides contract water to more than 750,000 people over 1.6 million acres. A twelve member board determines how much of each alottee's water quota will be delivered each year. District court judges appoint the Water Board, whose backgrounds include farming, ranching, engineering, business, and law. The Board determines water quotas each year based on snow pack, runoff, and estimated diversions, while balancing the water needs of individual contractors and the amount of water available in reservoir storage.

The following information about Organization C's use of tree-ring data was provided in the interviews. Specific quotes from interviews are included in italics where possible.

1. **The 2002 drought was particularly important in why Organization C began to use tree-ring data in water resource planning.** Historically, Organization C provides at least 50% of individual water quotas to users, though in 2002 they were only able to provide 30%, a level unprecedented in their history as a water conservation district. It was later suggested by Jeff that a drought of this magnitude may not be outside the range of natural variability, when considering paleoclimatic data.

Because when that [the 2002 drought] hit, when we pretty much figured out how much water we were going to end up having, it was a lot less than we had been forecasting and telling people. So we thought is was prudent to go back and just tell our allottees—our water users—that, 'hey, this year is going to be very bad and we don't know what the future is going to look like here.' We hadn't seen anything like that…I think Jeff was sitting in the back of the room and he came over and visited with us afterwards…and he said 'you know, this drought may not be that unusual in terms of a historic perspective.' So that's when we got a little bit more involved in what their research was doing… "

*"So we were contemplating a 30% quota, which was just unheard of and a lot of us here were really pretty worried about 30% of a full allotment…**We were water supply limited for the first time**"*

2. **Water managers at Organization C have used data from a tree-ring reconstruction to quantitatively assess what water quotas would have been over the entire paleo record.** Somewhat unexpectedly, the tree-rings demonstrated that quotas lower than 50% (what was generally considered the lowest allotment user would be given) would not be as unusual as they had previously thought. This was a very important finding for Organization C's water contractors who had previously thought they would always be given at least 50% of their water allotment, even in drought years. Organization C also has plans to use tree-ring data to construct a "quota-chronology" over the entire paleo record to help identify "trigger-points" for their drought plan. They would like to create a model that they can present to water users to provide a better picture of what water quotas may be under certain conditions. Organization C has also used data regarding quotas derived from the tree-ring record to educate its Water Board about the variability of water supplies that is present over a longer time period.

> *"So, I did this little study, just to kind of look at—it wasn't very sophisticated. It just kind of ran through our project under some different quota setting methodologies and I guess the result out of that study is that the 30% quotas really aren't that unusual when you have a longer time period to look at, based on the way that we set quotas at that time.. We had a few public meetings just to knock on people's doors and say, 'oh, by the way, you know that 50% you thought you might get, it's going to by 30%!'"*

3. **Organization C would like to gain a more complete understanding of the variability that exists in the tree-ring record as a way to begin assessing the impacts that climate change may have on their water supply.** Organization C is very cautious about including climate change in their current assessments of water supplies because they do not want to create fear that water supplies will decrease in the future and create the possibility that waster users would "hoard" water. An ongoing shift from agricultural water contracts to more municipal water contracts may also be creating new demands and potential vulnerabilities for Organization C, and as a result they are reconsidering the effects of climate variations on their water supplies. Importantly, however, tree-ring chronologies appear to be more credible to Organization C than climate change models.

> *I've been told by some researchers that …there are some things out there where folks want to take very high level global climate models and the information those models are generating, and downscale it down to Ft. Collins, Colorado… I am a little reluctant of taking that hydrology or what-have-you that comes out of that and saying, 'well, this is it…this is what its gonna be, this is the future.' But, we can't stand on the sideline…I think we ought to do something. And I guess my 'do something' would be to look at the chronologies we get out of the tree rings… you can look at the vulnerability that you are in those situations, and those will probably be as extreme as probably anything that a large climate change model might have for you."*

B. General Conclusions of Collaborations with Established Research Partners

1. **Given the perspective and mandates of the organization, tree-ring data often tell an organization what they want (or expect) to hear about their water supply/system.** In some cases tree-ring data "verifies" the variability they already thought existed, in other cases it "verifies" the modeling perspective they are already using. It is important to note, however, that these organizations have some of the most robust and reliable (e.g. senior water rights) water portfolios of

any Front Range providers, which may be part of the reason they were interested and willing to consider the tree-ring data. Occasionally, the tree-ring data do show something unexpected (as was the case for Organization C), in which case it has been very well-received and water managers have begun to incorporate the lessons learned from tree-rings into water management plans.

2. **The occurrence an extreme event, the 2002 drought, has contributed to the consideration and incorporation of tree-ring data into water management.** At the same time, increasing uncertainty related to climate change has also prompted the decision by water managers to consider more than the gage record in water planning. As water providers become more aware of their vulnerability to drought due to increased demands, they also recognize that water systems with supplies that can easily meet water demand are not as secure as once thought.

3. **Organizational structure and history greatly affect how tree-ring data are incorporated into planning and operations**. Organizations that are already interested in the effects of climate and climate change on water planning readily embrace the tree-ring record and use it to create new climate change models, while other organizations may take tree-ring data into consideration, but not necessarily change their planning or modeling procedures from the way they operated before using tree-rings.

4. **Constituencies also play a role in if/how tree-ring data are used and how it is communicated.** Some constituencies may be more willing/able to embrace tree-ring and/or climate change data in drought plans than others. Organization B, for example, is located in an area with several climate research centers and has established relationships between the water utility and climate researchers, while Organization C is concerned with the perceptions of their water customers related to the incorporation of climate and climate change data into water planning (which has been identified a reason they were more interested in tree-ring data rather than climate change information).

5. **Tree-ring data are often used to define and justify planning paradigms related to uncertainty and variability of streamflows.** Both Organization A and B utilized insights from the tree-ring record to support their planning approaches of firm yield and reliability criteria, respectively. This indicates that tree-ring data are gaining credibility for use in policy guidelines and under different management philosophies.

6. **All three organizations indicated that the tree-ring record was important for gaining a better understanding of sequences, spells, and persistence of drought**. This has shown all three organizations that using the 1950s as the most extreme drought may not be adequate for drought planning and that the tree-ring record has been an important aspect of testing water system reliability. The tree-ring record has also helped define breadth of uncertainty and helps some bounds on expectations for future based on the past.

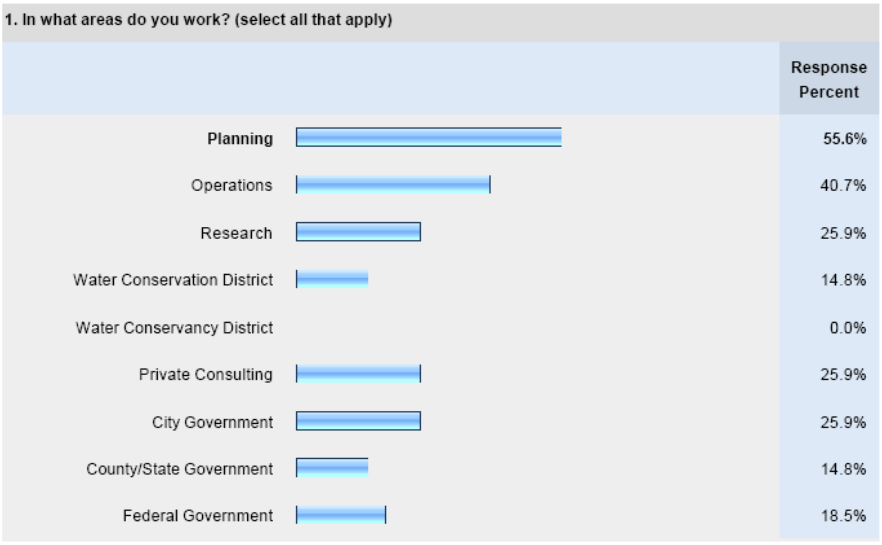
7. **All established research partners utilize tree-ring data in both quantitative and qualitative environments.** Organizations A and B use have used tree-ring data in water models, while Organization C has utilized tree-ring data in quantitative assessments of water quotas. All three organizations indicated that tree-ring data have also been used to qualitatively assess planning and decision-making procedures, as well as educate other members of their organization and general publics. This also indicates that the credibility of tree-rings for use in water management is increasing.

8. **"Data accuracy" means different things to different people.** Some organizations want better numbers (e.g. a chronology that captures low flows better), while other organizations are satisfied with the numbers in the chronology and are more interested in using the data in better models (e.g. a model that handles complex water rights).

IV. Results of Phase Two: Online Survey

The following reports the results of a 10 question internet survey administered to past Technical Workshop attendees. The response rate for the written survey was 39.4% (n=28) and one response was removed from the survey due to inconsistent responses to several questions. In many cases respondents were able to select multiple answers to survey questions, along with the option to provide written explanations or descriptions of answer choices. Graphs (and in some cases tables) are provided after a brief discussion of findings for each question.

A. Profile Information of all Participants (Q1): Most workshop participants are in planning and operations, followed by research, consulting, and government.

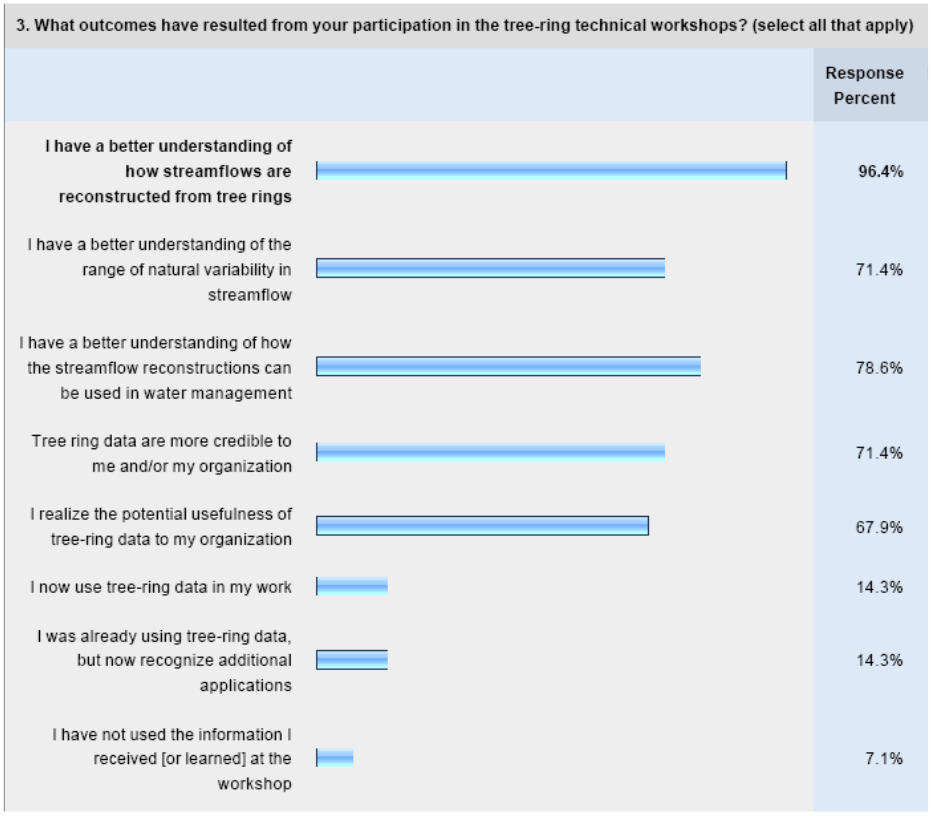


B. Circumstances or events that first motivated individuals to seek out tree-ring data vary widely (Q2). In general, the following represent many responses provided by survey respondents (provided as open-ended responses):

- The need to better forecast variability and/or assess the reliability of water supplies
- The need to improve planning for future water supplies
- The 2002 drought, sustained drought conditions
- Exposure to paleoclimate data in research or studies
- Email notification, PBS special on climate change

C. Current and Future Use of Tree-Ring Data (Q3, Q4,Q 5)

Almost all workshop attendees stated that the workshops provided them with a better understanding of tree-ring streamflow reconstructions and the range of natural variability in streamflow. Importantly, the workshops do appear to be successful at also communicating the applications of tree-rings for water management, while also increasing the credibility of tree-rings for use in water resources planning. Only a small portion of participants (7.1%) have not used the information from the workshops.



When broken-down by occupation, responses to Question 3 generally reflect the trends of the entire survey population, though some differences do emerge. Consultants, for example, have much lower positive response rates to the statement that “tree-rings are more credible to me and/or my organization” or “I now realize the potential usefulness of tree-ring data to my organization” than in other professions. The reason for this, however, is not known from the survey, though it could be speculated that consultants have already established credibility of tree-rings and their potential uses prior to attending the Technical Workshops, and therefore did not identify this as an outcome specifically from the workshops.

Percentages of Positive Responses to Each Answer Choice of Question 3 by Occupation Type.

	Streamflow Reconstruction	Natl. Variability	Management	Tree Rings More Credible	Potential Use	Use Tree Rings	More Applications	Not Used
Planners	100	73	80	73	60	20	20	7
Operations	100	73	91	100	82	36	27	0
Research	100	43	86	86	71	43	29	0
Water	100	100	100	100	100	25	0	25
City Govt	100	100	86	86	71	14	29	0
Fed, State, County Govt.	100	56	78	67	78	11	11	0
Consulting	86	57	43	43	29	14	14	0

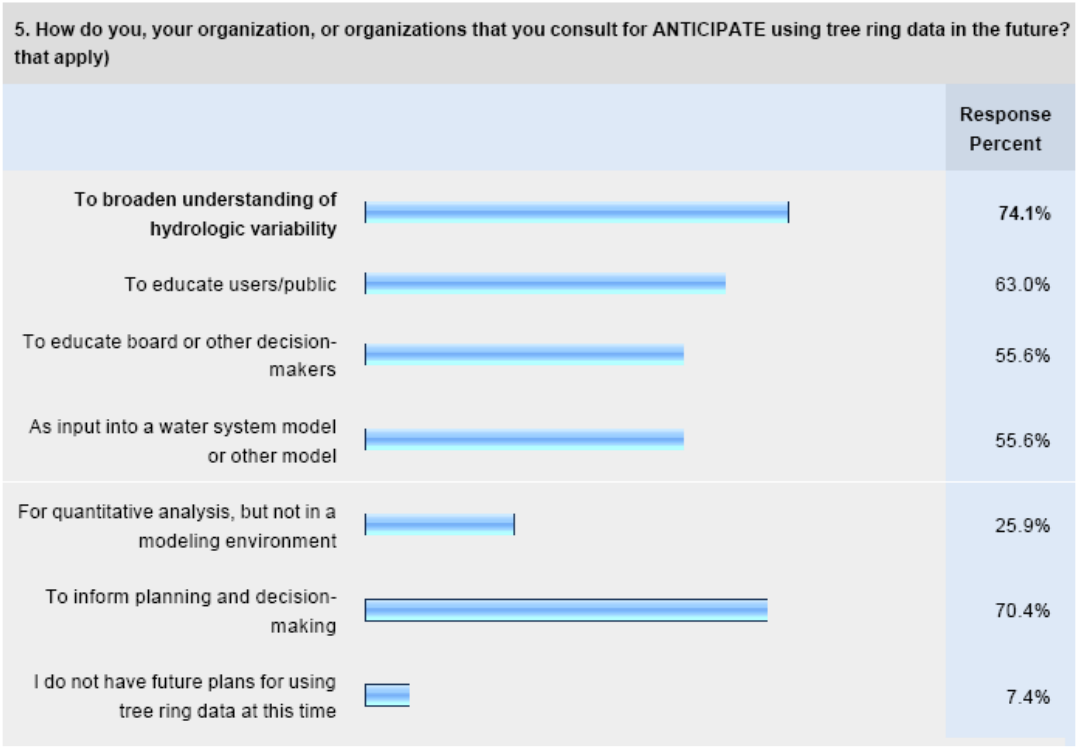
Furthermore, approximately 50% of workshop attendees have used the information they learned in the workshops to educate their boards, decision-makers, and/or publics. Up to one-quarter of workshop participants are using tree-ring data in water models and half of all workshop participants have used tree-ring data to inform planning or decision-making.

When broken down by occupation, it is revealed that the highest percentage (75%) of people that use tree-ring data to educate their board or other decision-makers are people from water conservation districts, while the lowest percentage (44%) are in Federal, State, or County government positions. Consultants most frequently use tree-ring data in a quantitative environment, but are among the lower percentage that use tree-rings to inform planning and decision-making.

Percentages of Positive Responses to Each Answer Choice of Question 4 by Occupation Type

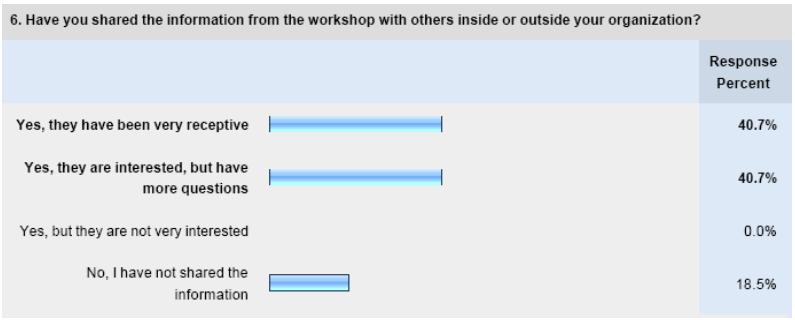
	Hydrologic Variability	Educate Users	Educate Board	Model Input	Quant Non-Model	Inform Planning	Not Used
Planners	87	53	53	33	7	73	13
Operations	73	55	55	36	18	73	18
Research	71	43	57	14	29	71	14
Water	75	50	75	25	0	75	25
City Govt	86	43	57	29	14	57	14
Fed, State, County Govt.	78	56	44	22	0	56	11
Consulting	57	43	29	43	29	57	14

When asked how workshop attendees a*nticipate* using tree-ring data in the future, the largest portion of workshop participants plan to use tree-ring data for education, modeling and quantitative analysis, and to inform planning and decision-making.



D. Communication of Data to Others (Q6 and Q7)

The majority of workshop participants have shared the information they learned in the workshop with others they work with, though half of those individuals do have their own questions about tree-ring data.

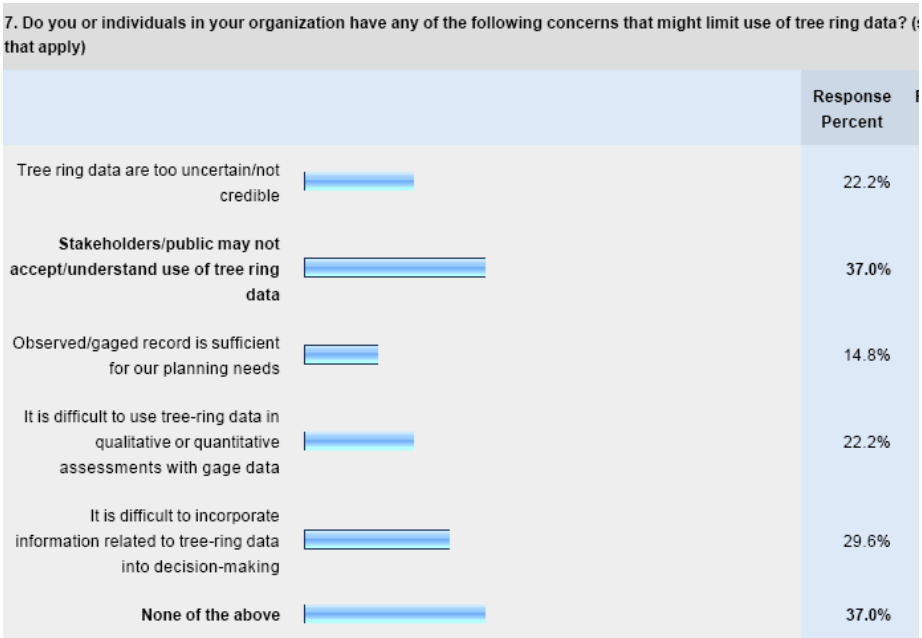


The most receptive communities have been in operations, research, and Federal/State/County governments. Planners, city governments, and consultants have the highest percentages of communication to individuals that still have more questions about the use of tree-ring data.

Percentages of Positive Responses to Each Answer Choice of Question 6 by Occupation Type

	Yes, Receptive	Yes, Have Questions	Yes, Not Interested	Not Shared
Planners	27	47	0	20
Operations	55	27	0	9
Research	57	14	0	29
Water	50	25	0	0
City Govt	29	43	0	29
Fed, State, County Govt.	56	22	0	22
Consulting	29	57	0	14

Most frequently, these concerns about the use of tree-ring data are related to the perception of tree-ring data by stakeholders or difficulty incorporating tree-ring data into water models or decision-making. A smaller portion of individuals believe tree-ring data is still to uncertain/not credible or feel that the observed record is sufficient for their needs.



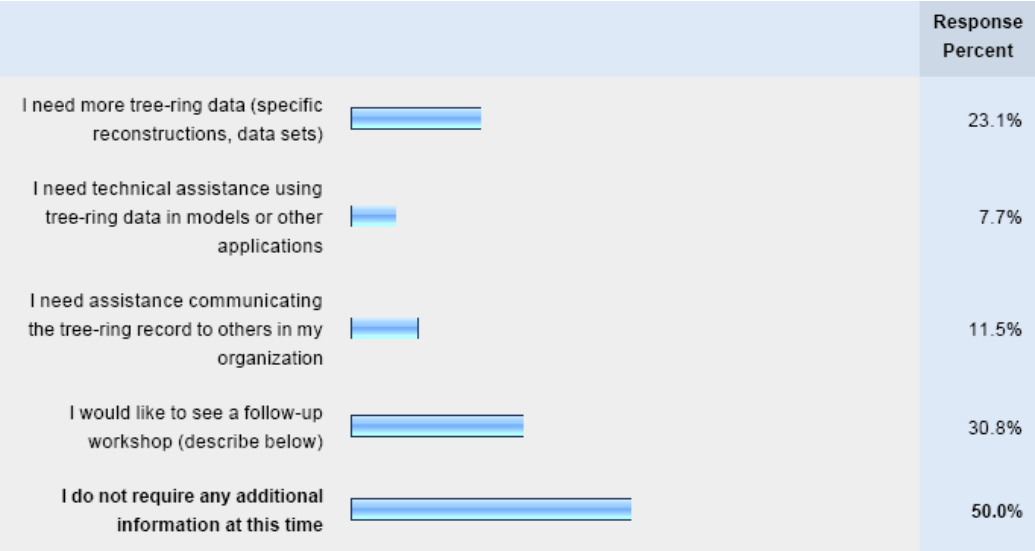
Consultants and federal/county/state governments tend to have the most concerns about their stakeholders/public perception of tree-ring data, while individuals working in water management have the highest percentage of concerns with the difficulty of incorporating tree-ring data into decision-making.

Percentages of Positive Responses to Each Answer Choice of Question 7 by Occupation Type

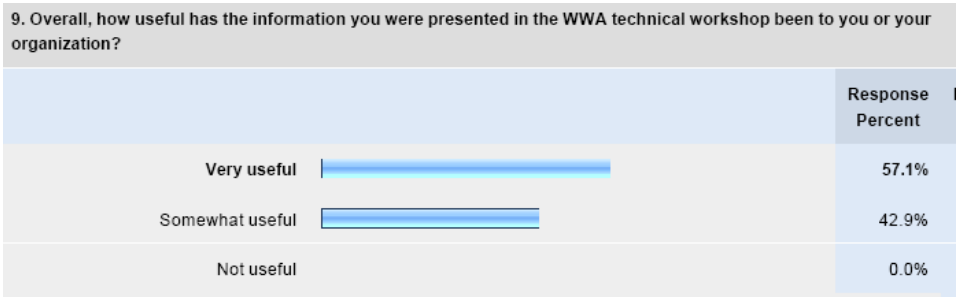
	Too Uncertain	Stakeholders	Observed Sufficient	Difficult to Use w/ Gage Data	Difficult for Planning	None
Planners	20	33	20	27	33	27
Operations	27	27	27	36	27	27
Research	0	14	29	29	29	29
Water	0	0	0	25	50	50
City Govt	14	14	0	29	29	57
Fed, State, County Govt.	22	56	22	22	22	22
Consulting	29	57	43	29	14	14

E. General Satisfaction with Technical Workshops (Q8 and Q9)

More than half of the workshop participants do not have any further informational or data needs at this time, but 30% of participants would like more follow-up workshops (though no one specifically described what they would like to see in a future workshop). Nearly a quarter of workshop participants would like to obtain specific tree-ring data, while a smaller portion of workshop participants need assistance communicating tree-ring data or using tree-ring data in quantitative/modeling applications.

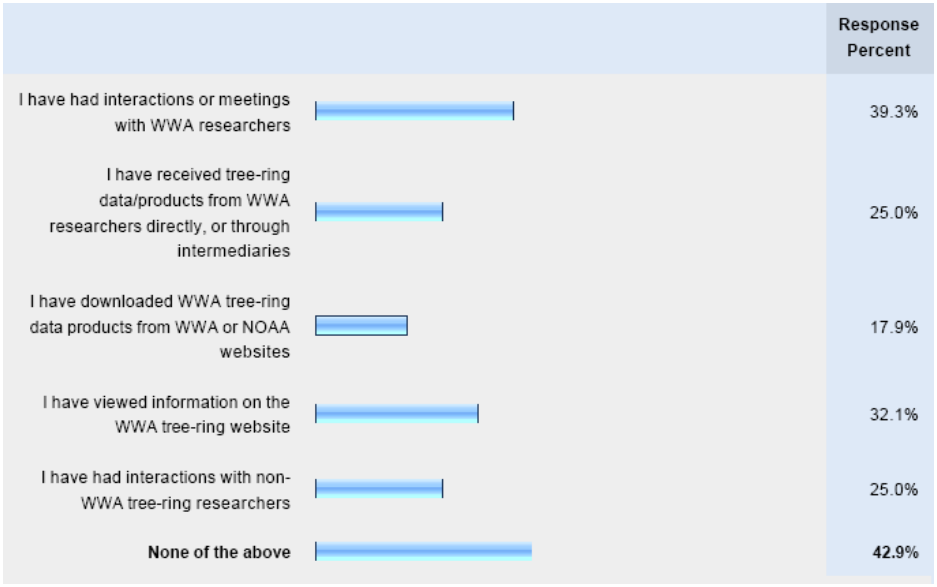


All workshop participants found the workshops to be at least somewhat useful, while over 50% found them to be very useful.



F. Other Interactions with WWA (Q10)

In general, less than half of workshop attendees have had any additional contact with WWA researchers or resources.



G. General Conclusions from Survey Results

1. **In general, there has been a high rate use and satisfaction among workshop participants regarding the information presented in the Technical Workshops.** A high percentage of workshop attendees indicated that they have a better understanding of tree-ring reconstructions, their applications, and the range of natural streamflow variability. Importantly, over two-thirds of workshop participants indicated that tree-rings are more credible and useful to them after attending the workshops. Other participants stressed the importance of obtaining a better understanding of the range and duration of dry and wet periods present in the paleo record after attending a Technical Workshop.

2. **There was a much higher than expected rate of use of workshop information to educate user, the public, board members, and decision-makers about streamflow variability.** This seems to have also started to affect planning and decision-making, though it is not clear from the survey how (e.g. what new policies or procedures are now in place). Less than one-third of workshop participants identified that they have experienced challenges in incorporating tree-ring data into decision-making, however, the survey does indicate that more needs to be understood about the relationship between the jobs (and associated actions) of workshop attendees and how policy and planning decisions are made in water management. Future WWA studies could examine this topic to obtain a better understanding of the role that tree-ring data have in actually influencing (and potentially changing) water resource management and/or policy, along with how these efforts can be made most effective.

3. **Some barriers related to the acceptance of tree-ring data by stakeholders and the public still exist in some sectors.** It is not clear from the survey what these are or how they could be addressed, but open-ended responses (Q7) indicate that improvements in communicating science to non-scientists and non-engineers can still be made, and that there can be hesitation in being among the early adopters of new scientific applications. WWA might consider addressing this issue in future workshops or activities.

V. Action Items for WWA

The following suggestions were made in interviews and surveys about how to improve collaboration efforts and/or the Technical Workshops:

1**. Develop a "tree-rings for board members" guide/presentation** to help workshop participants and other WWA collaborators better communicate the policy relevant aspects of using tree-ring data in water management.

2. **Provide online "updates" about tree-ring data and their applications** that will allow past workshop participants to stay up-to-date on any improvements that may occur in tree-ring research.

3. **Consider engaging a wider range of sectors in Technical Workshops.** One respondent indicated that transportation managers, for example, might be interested learning more about tree-rind data to allow them to better plan for future climate changes that may affect snow plowing, ice storms, or flooding.

4. **Provide more information about East vs. West Slope water supplies** to assist water managers in fine tuning water source issues when using tree-ring data in water management and modeling.