Assessing the need for fire-related decision-support tools for water management in the Pacific Northwest, USA

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I. OVERVIEW

Fire disturbances in the Pacific Northwest (PNW) are projected to increase with global change and are a major cause of increased erosion, runoff, suspended sediment, nutrients, and debris flows in forested watersheds. The risks associated with wildfires are believed to be of particular concern to water managers in this region, who historically may have been able to dedicate little, if any, resources towards predicting the impact of fire activity on source watersheds and water infrastructure. With growing regional attention being paid to wildfire activity in the PNW, among other fire-prone regions, water managers and researchers alike have been working to understand how a changing fire regime will impact existing forests and water resources. Through this needs assessment, initial focus group work with PNW water utility managers was conducted in 2019 and it was concluded that there is a lack of relevant information or tools available for guiding drinking water utility decision-making to prepare for or respond to wildfires. To more clearly identify what types of information and tools would be beneficial for water managers, an online survey was conducted in July 2020 to collect information from a wider representation of drinking water utilities and other types of water managers in the PNW. The goal of this survey was to identify what types of water manager needs might benefit from better accessibility to targeted information and decision-support modeling tools for managing wildfire impacts on water supplies. Results from the survey are summarized in this report.

II. SURVEY STRUCTURE

The Social and Economic Sciences Research Center (SESRC) was recruited to assist with survey generation and implementation. The SESRC provided guidance on the structure of the survey, developed the online survey tool, managed the distribution and participant follow-up, and compiled and provided the anonymized raw data to our research team (see Appendix for full set of survey questions). The survey consisted of 25 mainly close-ended questions grouped into four sections: 1) System Characteristics (Q1-5), 2) Concerns about wildfire (Q6-10), 3) Fire management strategies (Q11-21), and 4) Demographic questions (Q22-25). The survey was open from July 9 – Aug 27, 2020.

The research team was responsible for developing the survey questions and provided the SESRC with participant contact information (n=231) that included the names, emails, phone numbers, and organization names of surface water resource managers in WA, OR and ID whose organization either directly managed water or had a mission to protect source water quality. Participants targeted for this survey by the research team included managers from large water utilities (serving > 10,000 people), as well as state and federal fisheries and wildlife management agencies, and land and forest management agencies. In total, 104 of the 231 eligible respondents completed (n=78) or partially completed (n=26) the survey for a response rate of 45%.

III. SURVEY RESULTS

a. System Characteristics

Of the participants that responded, 53% (n=55) of these were from water utilities, with the remainder representing respondents from fish management agencies (16%), land/forest management agencies (16%), or other water management agencies (15%). Water utility respondents made up the largest percentage of respondents (over half of those sampled) (Fig 1A). In addition to characterizing those who participated in the survey, this work also sought to understand watershed management since many watersheds in the

western US serve multiple purposes, including water supply, wildlife habitat, timber production, recreation, or residential or agricultural development. As such, in watersheds where multiple entities are managing resources for different purposes, it is likely that more communication and collaboration will be needed to ensure any pre- active- or post-fire responses do not create significant management challenges for any entity in the watershed. For example, a watershed may act both as a water supply source for a drinking water utility and serve as a forested recreational area for the public. If a fire occurs, the recreational manager might call for fire retardants to be used to restrict the area burned to the smallest size possible; however, the water utility may be concerned that fire retardants could contaminate their raw water supply. Therefore, each respondent was also asked to approximate the number of other known landowners in their source watershed and their role in managing fire events to provide some context for how information might be used by respondents for decision-making purposes.

When asked about the systems they manage, most of the respondents were using water from one or two watersheds (73%). Across all respondents, it was most common for these source watersheds to be under the management of multiple entities (67%) (Fig 1B) and be open for public access or recreation (81%). While the majority of respondents had not recently experienced a fire event creating significant challenges for their operations (60%), 20% of respondents had endured three or more significant fire events in the last five years (Fig 1C). Interestingly, water utility respondents indicated they had relatively little experience with fire-induced challenges in their watersheds- only 8 of these 43 respondents had reported 1-2 problematic fire events in the past 5 years. In contrast, 20 of the 27 other water managers had experienced more than one such event in the same time frame. Finally, when asked about their role in responding to fire events, results indicate that most organizations play a passive role. Over 70% of respondents indicated they play no role in managing for fire in their watershed (Fig 1D).

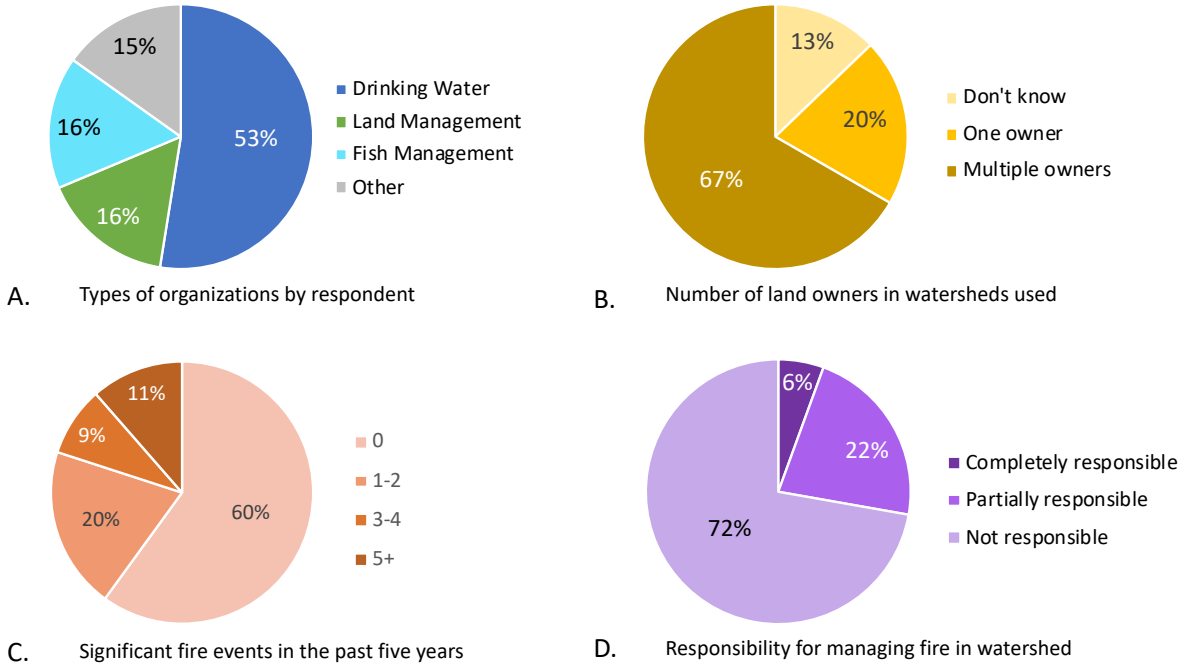

Figure 1. Survey respondent system characteristics, including respondent's organization type (A), the number of other landowners in the respondent's source watershed (B), the number of fire events

experienced in the watershed in the past five years (C) and the role the respondent's organization plays in responding to fire events (D).

Given the majority of respondents in this survey were representing water utilities, the remainder of this summary breaks participant responses into two groups: water utility respondents (the "Utility" group) and all other water management respondents (the "Other" group). In doing so, we provide additional insights into unique concerns and needs of those providing drinking water as compared to those who manage forests or fish but have missions or needs for high quality water from the source watershed.

b. Wildfire Concerns

In an effort to understand what fire-related risks or impacts are worrying water managers in the PNW, we asked respondents to assess the degree and types of concerns their organizations (henceforth "they") face regarding impacts of fires on their water-centric operations. When asked to rate the degree to which they were concerned about fire, only 11% of respondents (n=9), split roughly equally across the Utility and Other groups, indicated they were unconcerned about wildfire or fire impacts. However, most respondents (~90% regardless of group type) indicated some level of concern, with more Utility respondents reporting moderate levels of concern compared to Other respondents (Fig 2A).

When asked to identify which specific types of fire-related impacts were the biggest concern (Fig 2B), both groups of respondents identified water quality (e.g., turbidity, ash, nutrients, dissolved oxygen, algal blooms, etc.) as their top concern (Utility = 100%, Other = 78%). The rank of other priorities differed by respondent type. For instance, the Utility group ranked hydrologic impacts (e.g., channel scouring or sedimentation, timing or volume of runoff, etc.), infrastructure impacts (e.g., damage to equipment, reservoirs, etc.) and forest impacts (e.g., changes in biodiversity, species recovery, soil water retention, etc.) as their second, third and fourth highest concerns, respectively. In contrast, respondents from the Other group ranked forest impacts, hydrologic impacts, and infrastructure impacts as high to low priorities, respectively.

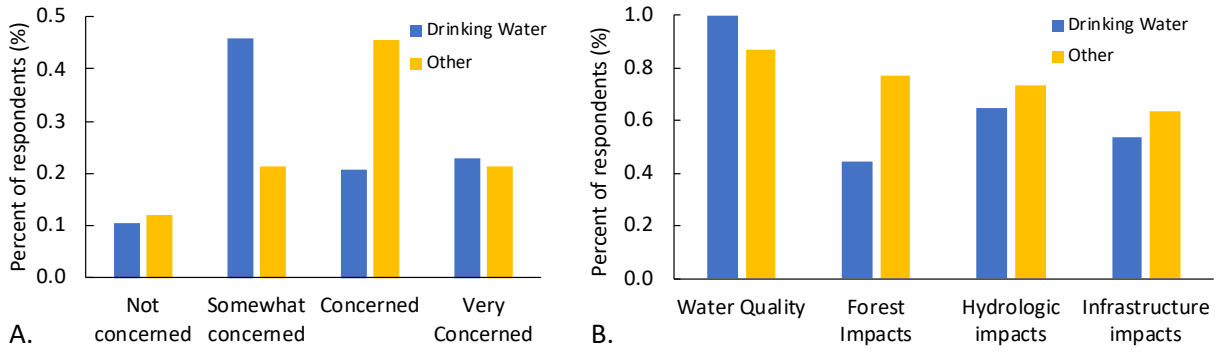

Figure 2. Level of wildfire concern (A) and type of fire-related impacts causing concern (B) across water utilities and other water managers response groups.

Participants were also asked to rank, from low to high priority, what types of decision making they were most focused on with respect to wildfire impacts (Fig 2). The types of decision-making choices presented were based on core themes identified by our focus group work earlier in 2019 and included 1) assessing

where fires would be most likely to occur within a watershed, 2) understanding how watershed dynamics (e.g., streamflow, species diversity, water quality) change after fires, and what 3) pre-fire and 4) post-fire management actions would be effective in protecting or mitigating impacts to operations, respectively.

Nominally stronger preferences for information that could help assess change in watershed dynamics and in pre-fire mitigation actions emerged across both respondent groups. Both the Utility (59%) and Other (50%) groups indicated that being able to understand watershed dynamics was a top priority (Med-High or High) for management. For instance, 37% and 22% of respondents in the Utility group and 25% and 25% of respondents in the Other group indicated watershed dynamics as a medium-high or high priority, respectively. There was less clarity as to how useful information that could help managers better detect likely fire locations or assess post-fire mitigation actions would be, with a relatively equal number of responses associated with generally higher and lower priority rankings for each information need type in each respondent group.

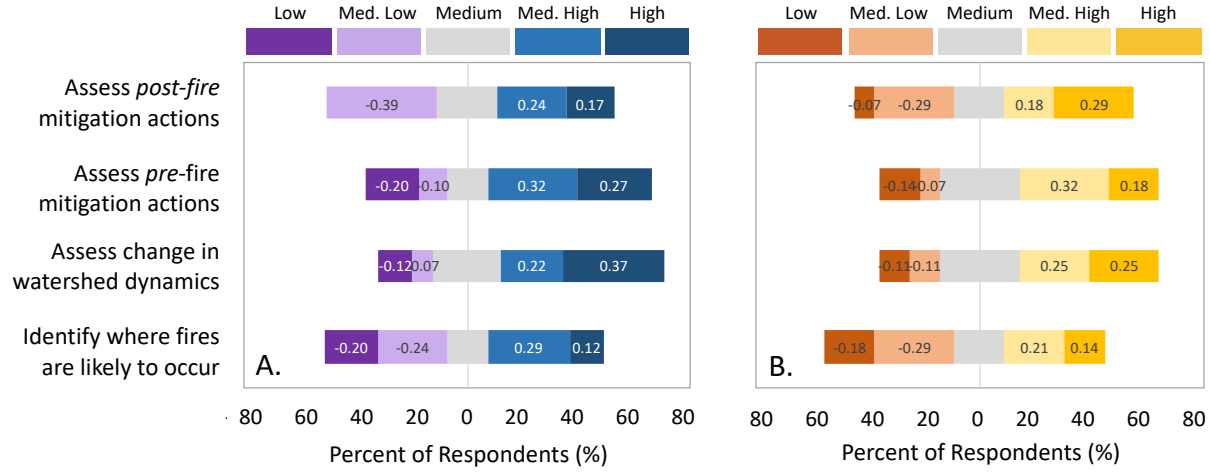

Fig 3. Priority levels identified by water utility (A) and other (B) respondents for different types of information needs when considering wildfire impacts to operations.

Managing water for wildfire impacts can mean more than just dealing with changes in water quality. Water managers need to be able to make decisions about how operations may need to change to respond to fire impacts, but also need to consider how to adapt both in the short- and long-term for best management. This means not only understanding how vulnerable their operations may be to fire but understanding what they can potentially do about it. Respondents shared their thoughts on how well they felt their organization was prepared for fire impacts by evaluating a set of statements reflecting some of the key short- and long-term outcomes highlighted in the 2019 needs assessment focus group work (Fig 4). Both groups had a sizeable portion of respondents indicate that they did not feel (or know) that they had the right information available to make decisions about managing operations for wildfire impacts and expressed concerns about how well their current operational infrastructure could handle substantial changes to water quality or water quantity. For both groups, there was generally strong agreement across respondents that fire would impact their operations, there would likely be more fires in the future, and that others stakeholders with interests in the source watershed were also concerned about fire impacts.

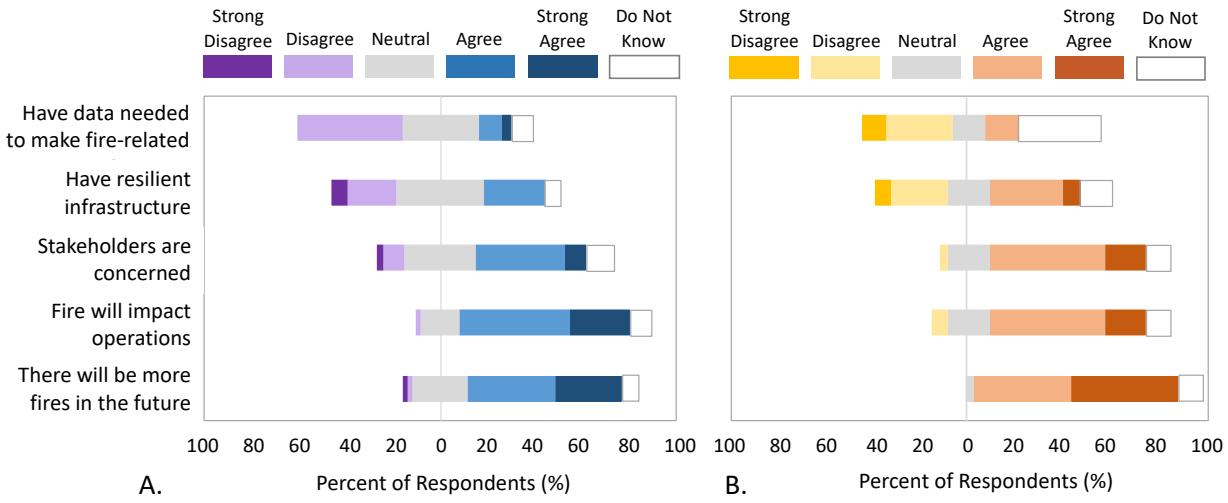

Fig 4. Degree to which a respondent felt their organization was successfully managing for fire-related water management issues for water utility (A) and other types (B) of water managers.

c. Strategies for Managing Fire Impacts

As part of this needs assessment, our goal was to both identify where there were gaps in understanding or capability in water manager operations and decision-making. Being able to understand the plans managers were making, and information they were using to make decisions is important. This survey therefore asked respondents for information about how they are actively planning for and communicating with others about fire response, what types of information they use or need to make decisions, and how an online decision-support tool might assist them in their fire-related decision-making processes.

In most source watersheds, water managers are relying on water that is generated in or passes through the domains of one or more other entities or landowners (Fig 1B). The expectation that all entities within a watershed would have the same priorities and goals related to water management during and after a fire event is therefore assumedly not high. This means that being able to work with other entities, whether it is to communicate organizational needs related to water quality or quantity or to participate in the planning or response effort to a fire occurance, is important. Respondents were asked to evaluate how well they believed their organization communicated about fire risks and impacts with other entities with management goals in their source watershed (Fig 5). While the number of respondents who were unsure about this type of interaction were relatively high, both groups had a majority of respondents indicating that, at minimum, they knew that other watershed entities were at least concerned about fire. Fewer respondents in both groups felt that their organization's management goals were in line with those of other watershed owners when it came to agreeing on how to manage fires, and what pre-, during- and post-fire actions should be taken. There was significantly more uncertainty- both in the reported numbers of "Do Not Know" responses and in ranked responses- about how well other entities would manage for water quality or quantity concerns when fighting against or preparing for fire, or when communicating with other entities about wildfire responses if a fire were to occur.

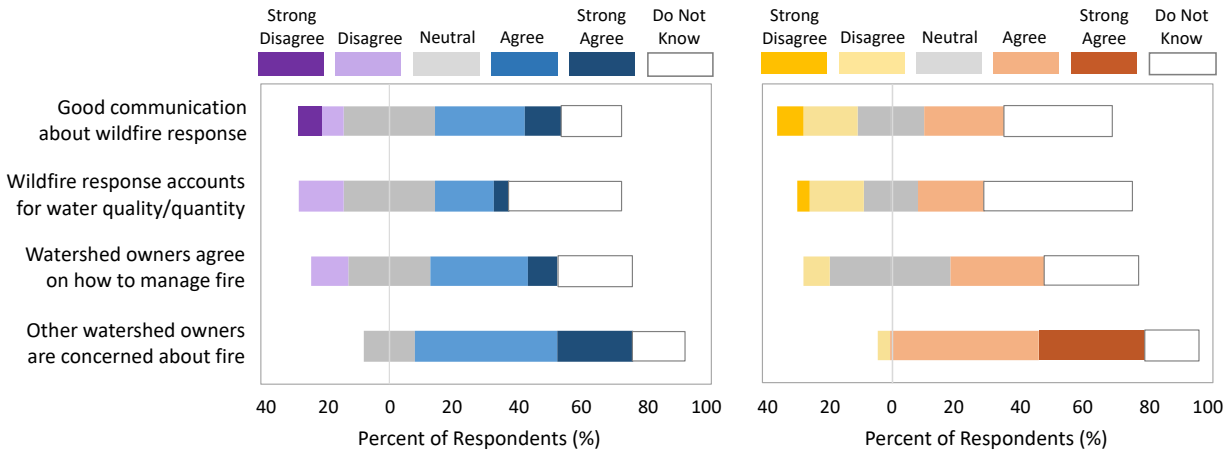

Fig 5. Level of agreement about cooperation between the respondent's organization and other land-owners in the source watershed for water utility (A) and other types (B) of water managers.

Respondents were also asked to provide information about any types of near-term future management strategies they were aware of that were related to either reducing the impact of fire or being able to mitigate fire impacts in their source watersheds if a burn did occur. Fig 6 shows the results for six management strategies likely to be implemented in a source watershed. Respondents in both the Utility and Other respondent groups both indicated that pre-fire mitigation efforts were a high priority, as both indicated the use of mechanical fuel load reduction (e.g., thinning, pruning) the most frequently (Utility = 59%, Other = 76%). However, the two groups showed different priorities for the other types of fire-related management strategies presented. For instance, Utility respondents indicated that new infrastructure (e.g., new treatment technology, new locations for intakes, new sources of water) was a high priority future management initiative (49%), followed by the creation and maintenance of fire breaks (38%), and use of prescribed fire (31%) with lower priorities currently assigned to strategies related to detecting fires in the field (23%) or using computer modeling to predict fire impacts (28%). In contrast, Other respondents placed higher priority on prescribed fire (64%), computer simulation modeling (60%), and fire breaks (52%), with slightly lower priorities on fire detection (48%) and developing new infrastructure (44%).

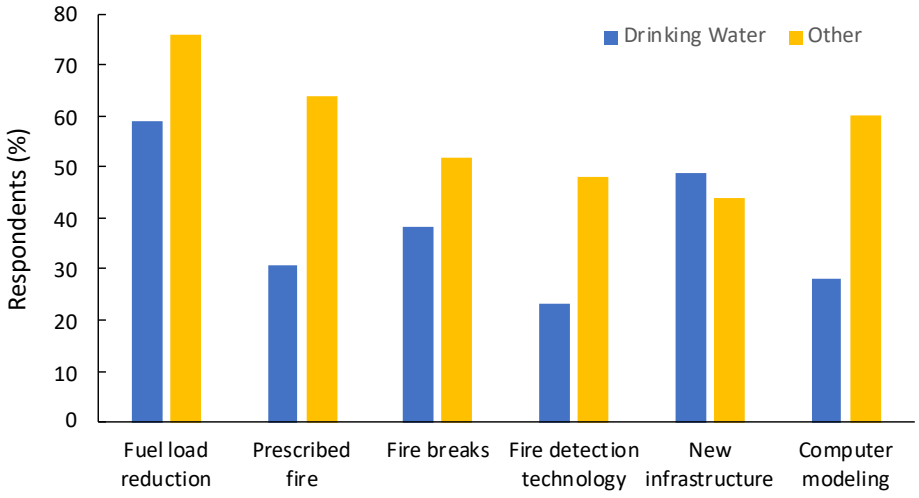

Fig 6. Types of technological/physical fire management strategies to be implemented in the source watershed in the next 5-10 years.

Respondents were also asked to comment on the types of information they were using to make decisions about fire risk in their source watersheds. These responses provide insights into the spatial and temporal resolution of data being used, the complexity of the information accessed, and their current use or potential familiarity with simulation models as a mechanism for interpreting or synthesizing data. For both groups, very simple information sources (e.g., smoke detection, Utility = 23%, Other = 32%) and very complex sources (e.g., satellite-based monitoring of vegetation or soil moisture, Utility =18%, Other =24% and watershed simulation models, Utility = 13%, Other = 48%) were reported as less commonly used in the decision-making process (Fig 7). Rather, data that captured some environmental complexity (e.g., nationally or regionally produced drought indices, Utility = 82%, Other = 80% or fire risk forecasts, Utility = 67%, Other = 68%) and easily accessible local data such as local weather information (Utility = 87%, Other = 80%) were more commonly reported by respondents as typical information sources for assessing fire risk in their source watersheds.

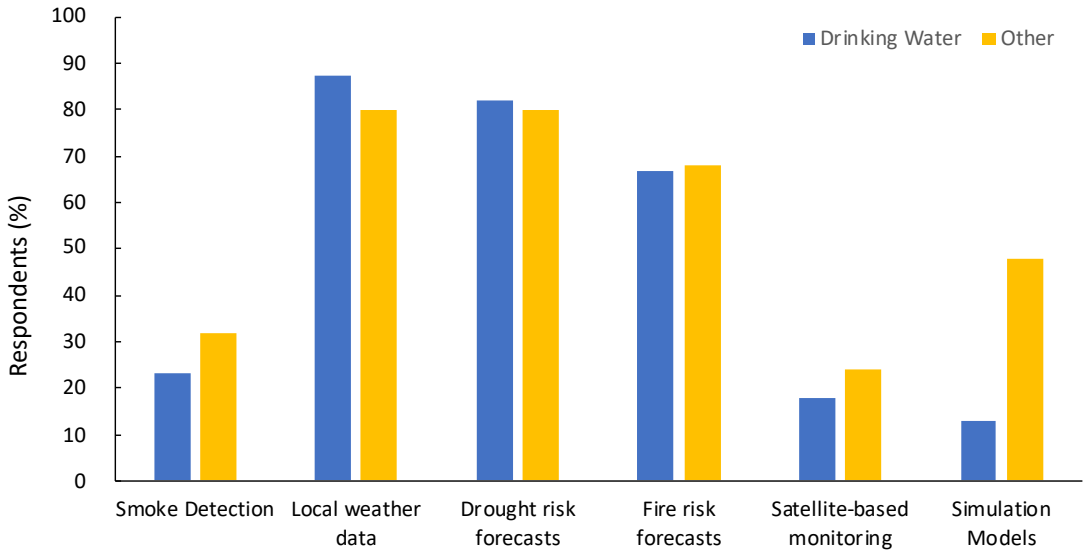

Fig 7. Types of information currently being used by a respondent's organization to assess fire risk in source watersheds. Information types (x-axis) are arranged according to their relatively complexity from relatively simple (left) to complex (right).

When considering the future information needs of water managers, it is useful to have an idea of what specific types of information would be additionally helpful to managers making decisions about fire risk. Fig 8 shows responses indicating the perceived usefulness of other types of information that are available via satellite or remotely sensed data at potentially finer spatial and temporal resolutions than the data they are currently using. Interestingly, the Utility group indicated mixed feelings about whether they did (or would) find little value in metrics such as vegetative stress (e.g, degree to which unfavorable conditions are affecting a plant's growth or survivability), soil moisture, or smoke detection, potentially reflecting the fact that many utilities do not have the mandate or right to manage fire events in their source watersheds. While few Utility respondents reported using information on fuel loads, they did show strong interest in

having access to information about this metric. And even though roughly 40% of Utility respondents indicated they already use precipitation and temperature forecasts to make decisions about fire risk, they showed strong agreement that these types of data could potentially offer better insights, presumably if available with refined precision. In contrast, the Other respondents reported a relatively small percentage of organizations were using any of the information identified, but indicated an even stronger interest than the Utility group in accessing some of these types of data, especially those related to vegetative stress, soil moisture, precipitation forecasts, and temperature forecasts. It was less clear whether fuel load and smoke detection data would be valuable to this group, however.

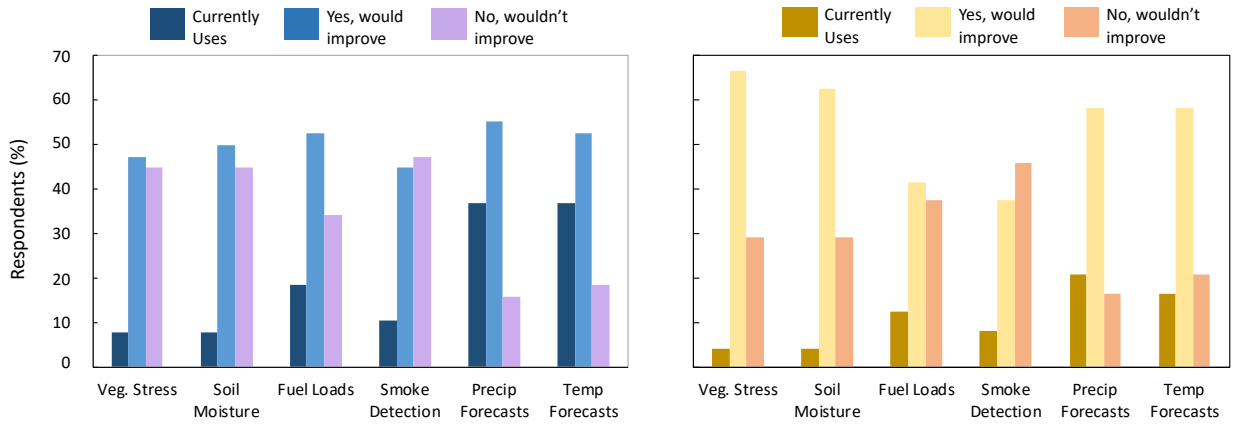

Fig 8. Types of information and their usefulness to the respondent's organization in the decision-making process about fire risk or response for water utility (A) and other (B) types of water managers.

Finally, we directly asked respondents about their interest in an online decision-support tool that would allow managers to easily input local information about their watershed and automatically download relevant satellite-based data to allow them to explore various potential fire impacts to water quality and quantity in their specific watershed. As such, we asked respondents what they might explore using a hypothetical tool like the one described above in relation to their water operations management. Utility respondents showed strong interest in an online tool that could help them understand streamflow changes, water quality changes (inc. nutrients and turbidity), and how changes may impact their water supply intakes or storage reservoirs under different fire regimes. Utility respondents only showed slightly less interest in understanding how fire may impact soil erosion, or in how vegetative stress might make forests more vulnerable to fire activity. These priorities differed from those in the Other group, who indicated great interest in using the hypothetical tool to explore changes in streamflow and turbidity, with moderate interest in changes to water quality (e.g., nutrients, turbidity) and vegetative stress, and a less clear interest in infrastructure impacts (e.g., to intakes or reservoirs). This latter result is not surprising, as not all those in this "Other" group would be necessarily withdrawing water for their operations.

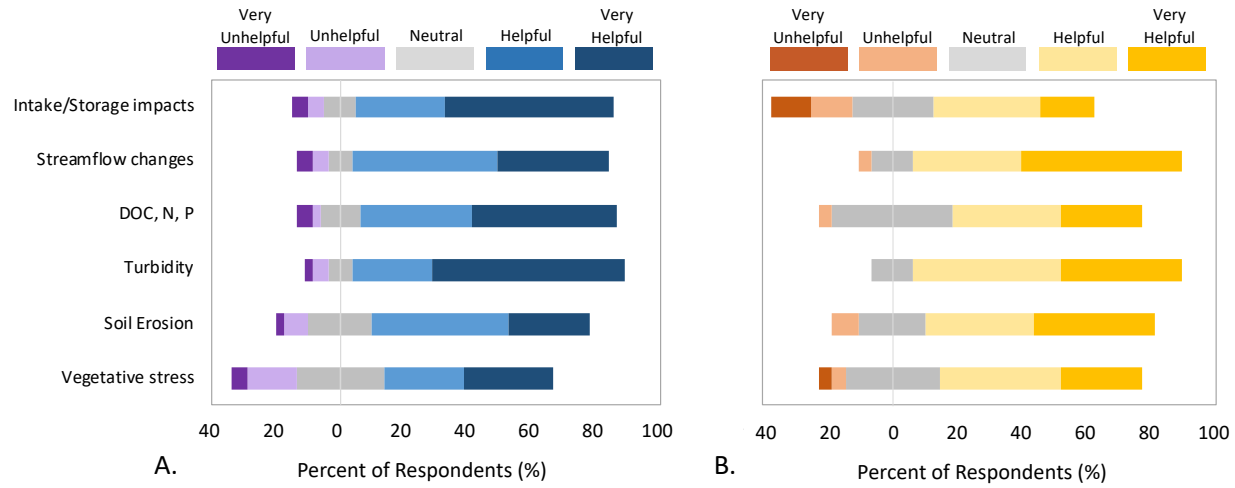

Fig 9. Types of fire impacts respondents would like to be able to assess using an online decision-support tool for water utility (A) and other (B) types of water managers.

Since we assumed that not all water managers would use such a tool to make decisions about how to directly manage a watershed for fire (an assumption confirmed by our survey – Fig 1D), we also asked respondents about other ways they may use a hypothetical tool that would allow users to explore "what-if" scenarios about fire risk and impacts to water operations. Utility respondents widely showed interest in the tool for understanding local watershed dynamics and how aspects of the physical environment may change post-fire. There was also substantial interest expressed by the Utility group in using the tool for understanding post-fire mitigation responses, and in being able to better communicate the potential short- and long-term fire risk threats and needs facing utilities with customers. Nominally less Utility respondents were interested in using the information directly for operations management, pre-fire mitigation, or for communicating fire-related information to other landowners in the watershed. When assessing responses from the Other group, results showed a very strong interest in using the tool to better understand fire-induced dynamical changes in their watershed. The Other group also placed substantial weight on using the tool for communication purposes (either with landowners or customers), and nominally less interest in using it for operations management or pre- or post-fire mitigation planning.

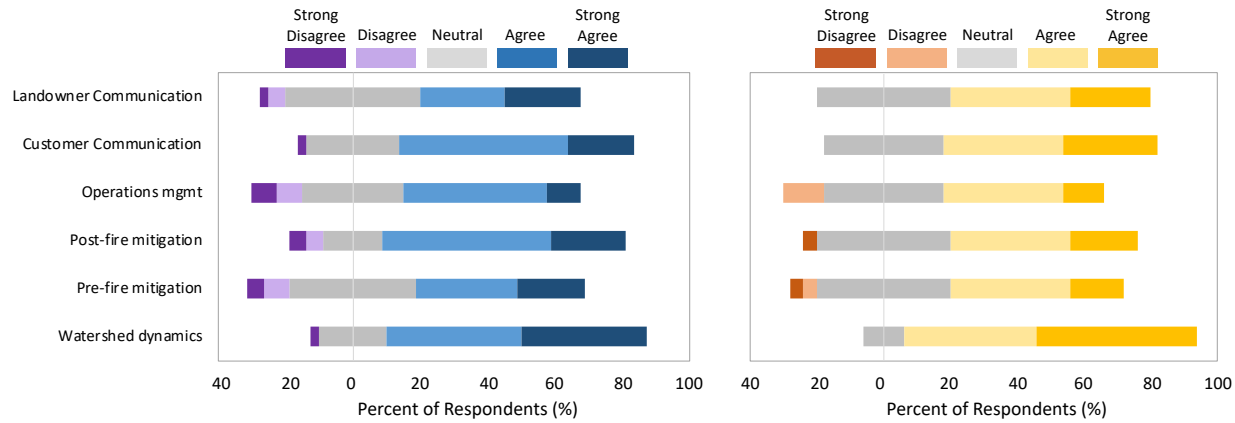

Fig 10. Decision-making applications respondents would like to be able to make using an online decision-support tool for water utility (A) and other (B) types of water managers.

IV. CONCLUSIONS

Climate change is altering the timing, frequency, extent, and severity of fire regimes in the Pacific Northwest (PNW). Fires can profoundly impact the environmental dynamics of a watershed, including creating substantial, negative consequences for water managers who rely on forested watersheds for clean supplies of water. Our needs assessment study, conducted between 2019 and 2020, aimed to better characterize the concerns of water managers in the PNW and identify what data or tools would be helpful for making decisions about managing water as fires and fire impacts become more likely. This report summarizes an online survey that was sent to over 200 water managers- including representatives from water utilities, fish and aquatic resource management entities, and land and forest management entities. Results here were analyzed for water utility respondents (Utility group) and all other respondents (Other group). Findings indicated that fire-related concerns are pervasive across all types of water management organizations and center on uncertainties about how water quality and watershed dynamics may change during and after fires. And while there was variation in the ways each group responded to the survey questions, there was often agreement between the two groups on where gaps in knowledge exist, what data or information would be valuable for filling these knowledge gaps, and what role decision-support tools could play in helping in the decision-making process.

In general, water managers in the PNW use fairly coarse, disparate data when making decisions about fire risk and managing water operations in the face of fire. The data used tend to not be watershed-specific and provide piecemeal, versus, more integrated knowledge about fire risk and fire impacts. For example, while local weather data may provide valuable information about local temperature, precipitation, or wind conditions, a water manager must integrate this knowledge with information about fuel loads and soil moisture to understand fire risk and be able to combine knowledge about topography, soils, and hydrology to predict the extent and magnitude of soil erosion expected after a burn. Currently, there are few options or resources available to managers to integrate this information to make such fire-related decisions. This lack of resources was highlighted by results showing there was substantial interest from respondents in data relevant at the watershed scale and tools that could help managers synthesize this information to understand how watershed dynamics (e.g., streamflow, species diversity, water quality) may change after fires and with different pre-and post-fire management decisions. Addressing these knowledge gaps is particularly important, as indicated by respondents who generally agreed that they are actively moving forward with management strategies designed to tackle issues related to fire, despite clearly indicating in the survey that they do not believe or know if they have the right data to be making informed decisions about whether new management solutions will be effective or useful.

The idea of an online, decision-support tool that could incorporate local data and updatable, remotely sensed information for fine-scale analyses of potential fire impacts in source watersheds was very favorably viewed by most respondents. Interestingly, this favorable view of the tool occurred despite the fact that most of the respondents worked for organizations who don't directly play a role in watershed management for fire. Rather, responses indicate that regardless of whether an organization could make decisions about watershed management, there was value in being able to understand what potential watershed changes their organization should be aware of during and after fire events and in being able to use that information to communicate organizational needs and concerns to other stakeholders and landowners using the same watershed.