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Stakeholder collaboration in the forecast-informed reservoir operations (FIRO) pilot project at Lake Mendocino, California

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Abstract

Purpose – Water is a critical and contentious resource in California, hence any changes in reservoir management requires coordination among many basin stakeholders. The Forecast-Informed Reservoir Operations (FIRO) pilot project at Lake Mendocino, California explored the viability of using weather forecasts to alter the operations of a United States Army Corps of Engineers (USACE) reservoir. The pilot project demonstrated FIRO's ability to improve water supply reliability, but also revealed the key role of a collaborative Steering Committee. Because Lake Mendocino's Viability Assessment did not explore the features of the Steering Committee, this study aims to examine the relationships and interactions between Steering Committee members that supported FIRO's implementation at Lake Mendocino.

Design/methodology/approach – The project identified 17 key project participants who spoke at a FIRO workshop or emerged through chain-referrals. Using semi-structured interviews with these participants, the project examined the dynamics of human interactions that enabled the successful multi-institutional and multi-criteria innovation as analyzed through text-coding.

Findings – The results reveal the importance for FIRO Steering Committee members to understand the limitations and constraints of stakeholder counterparts at other organizations, the importance of building and safeguarding relationships, and the role of trust and belonging between members. The lessons learned suggest several interventions to support successful group collaboration dynamics for future FIRO projects.

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Originality/value – This study identifies features of the Steering Committee that contributed to FIRO's success by supporting collaborative negotiations of infrastructure operations within a multi-institutional and multi-criteria context.

Keywords Stakeholder group dynamics, Water resources management, Semi-structured interviews, Text coding

Paper type Research paper

1. Introduction

This project explores the Steering Committee attributes that supported the success of the Forecast-Informed Reservoir Operations (FIRO) pilot project at Lake Mendocino, California. FIRO uses improved weather forecasting to implement more flexible reservoir operations while maintaining or improving flood risk management. FIRO can increase water supply reliability for multiple uses, however, changing reservoir operating rules requires stakeholder feedback and institutional knowledge to ensure that operational changes continue to serve the basin's diverse needs. The FIRO pilot project at Lake Mendocino assembled a functional and productive collaboration between stakeholders despite competing interests over water resources. This paper examines the stakeholder group dynamics within the pilot project to identify features that contributed to FIRO's success and should be replicated at other FIRO sites.

Local stakeholders bring expertise about the watershed's dynamics, needs and vulnerabilities, and can help researchers characterize opportunities and basin-specific limitations for FIRO. For example, reservoir water releases that halt too quickly can imperil protected fish by stranding them in elevated parts of the riverbed. To support implementing FIRO at Lake Mendocino, the project formed a stakeholder coalition to represent the diverse interests and obligations that the reservoir serves. The Steering Committee for FIRO's Lake Mendocino included members from the US Army Corps of Engineers, the Center for Western Weather and Water Extremes (CW3E) at the University of California San Diego, Sonoma Water, National Marine Fishery Services of the National Oceanic and Atmospheric Administration (NOAA) and others. Together these stakeholders determined the framework for FIRO's successful application at Lake Mendocino.

At the conclusion of the FIRO pilot project at Lake Mendocino, stakeholders observed that FIRO's successful implementation owed in part to successful collaboration. However, collaboration was not examined in FIRO's Final Viability report for Lake Mendocino. This study fills this gap by exploring the human connections between key Steering Committee participants. The study found that Steering Committee members took care to understand the limitations and constraints of their counterparts at other organizations. The stakeholders' operations were distinguished by the intentional efforts to build and safeguard relationships. These relational considerations fulfill the concept of belongingness. Trust also emerged as important to project success and can be built over time if it is not present at the beginning of the project. Survey results indicate that it is possible for the Steering Committee to take active measures to foster the important prerequisites to trust. If positive emotions, optimism and anticipation are present, there is room for trust to grow between stakeholders. These insights will help the FIRO program support successful collaboration at reservoirs implementing FIRO in the future.

This paper will provide an overview of the science of FIRO before introducing the propositions related to stakeholder collaboration, followed by the sections describing the study's methodology, results and discussion.

1.1 Scientific details of the FIRO Lake Mendocino project

Nationally, as development increases, water needs also increase and studies have indicated that climate change will produce more droughts in California (AghaKouchak *et al.*, 2014; Diffenbaugh *et al.*, 2015). These changes can exacerbate apparent and actual tensions

between goals like flood management, increased storage for water supply and ecosystem uses. The risks and benefits associated with water resource management make altering the water resources management paradigm a complex undertaking that must involve many stakeholders, including the federal entity that operates the reservoir.

The USACE dam operators at Lake Mendocino are legally obligated to follow rules from the reservoir's Water Control Manual, which specifies monthly maximum water levels to determine when to store or release water, based on historical weather patterns. During the winter, typically a time of rain events, this is meant to ensure that the reservoir has space to retain runoff from a rain event and to prevent downstream flooding. However, Lake Mendocino's 2012–2013 water year demonstrated limitations in using the guide curve for reservoir operations. In December 2012, a large rain event raised the reservoir volume above the maximum allowed in the guide curve, and the USACE operators subsequently released 25,000 acre-feet of water in anticipation of additional rain events. Defying probability, no further rain events occurred for the remainder of the wet season. Without this expected replenishment, the December releases set the reservoir on a trajectory for extremely low storage levels in the summer and fall of 2013, with negative effects for all the downstream stakeholders dependent on the water. In contrast, had the Lake Mendocino guide curve allowed the USACE reservoir operators to hold the December 2012 runoff until another storm forecast necessitated its release, the additional water could have mitigated the 2013 summer drought. However, the USACE operators had no legal flexibility to deviate from the rule curve for December water storage, even without rain predicted in the forecast.

Forecasting capabilities have advanced since the USACE Lake Mendocino Water Control Manual was written and adopted in the 1950s (with minor amendments in 1989 and 2004). The science for predicting atmospheric rivers, which drive the most significant rain events in the region, can provide reservoir operators with greater certainty about the location, extent and timing of future precipitation. Researchers at the Center for Western Weather and Water Extremes at Scripps Institution of Oceanography, University of California San Diego are expanding atmospheric science while modelers construct and interpret sophisticated simulations of reservoir operations according to environmental parameters collected from the region. The FIRO project posits that improved forecast information can give reservoir operators flexibility to hold more water in the winter without fears of increasing flood risks. A full summary of the FIRO project at Lake Mendocino is available in the Final Viability Assessment (Jasperse *et al.*, 2020).

Yet, such innovation can understandably be perceived as risky for those governed by institutional public safety mandates to avoid flood damages downstream. Likewise, fisheries managers, responsible for the restoration of three endangered salmonids, were concerned about implications of the FIRO project and the effects of downstream release decisions for critical habitat conditions. Willingness to assume voluntary risk is not a scientific question, but a human one.

It was under these conditions that researchers at CW3E began discussions with water managers at Sonoma Water and the Army Corps of Engineers to explore a project to evaluate the application of FIRO. The research and development (R&D) project assembled stakeholders with various legal mandates and asked them to collectively envision a new way to manage the reservoir. Some agencies took on more risk than others: in particular, USACE assumed significant risk because of its obligations to follow the Water Control Manual rule curve with potential legal consequences if flooding results from any deviations from these rules.

The success of FIRO has been documented in different years as the amount of additional water withheld in the reservoir was subsequently available in the dry summer months. FIRO's pilot application at Lake Mendocino's required a functional collaboration to enable stakeholders to agree on changes to improve water management. The section below provides three propositions for the success of the Lake Mendocino stakeholder collaboration.

1.2 Theoretical propositions for group functioning

The study's theoretical propositions for the project's stakeholder collaboration considered aspects of the group's structure. Firstly, each stakeholder represented specific expertise. Social science has explored the value of uniqueness in group settings, which is met when a group acknowledges individual talents and hears and appreciates individuals' voices (Barak, 1999; Hope Pelled *et al.*, 1999). Uniqueness can co-exist with another important social dynamic: belongingness, commonly viewed as an individual's perceptual assessment of relational value in the eyes of others (Jena and Pradhan, 2018). In the context of working groups, Shore *et al.* (2011) define belongingness as being accepted and defines inclusion by belongingness: "the degree to which an employee perceives that he or she is an esteemed member of the work group through experiencing treatment that satisfies his or her needs for belongingness and uniqueness." Belongingness can create a secure base for exploring differences (Wang and Mallinckrodt, 2006), such as the uniqueness of the FIRO stakeholders.

P1. A sense of belongingness within the group supported the project's successful collaboration.

Next, this study considers the potential role of place-based attachment in helping a diverse group labor towards a common goal. Studies have connected a sense of place with successful collaboration (Thompson and Prokopy, 2016). Place-based attachment comprises the bonds people form with places and the meaning they ascribe to them (Altman and Low, 1992). Place-based attachment can alter individual behavior (Lee, 2011; Sfair Kinker, 2021; Marques *et al.*, 2020), for example, the meaning attached to places can help instill a sense of stewardship and motivation to collaborate in the development and management process (Mohapatra and Mohamed, 2013). Within inclusive planning processes for natural resource management, place-based attachment can mediate civic engagement and develop trust between individuals (Payton *et al.*, 2005). Furthermore, the positive effect of place-based attachment is stronger when there is trust between the different actors involved, in terms of supporting pro-environmental behavior (Song *et al.*, 2019).

P2. Place-based attachment of the participants to Lake Mendocino helped build relationships that enabled successful collaboration and innovation.

Finally, collaboration requires functional relationships and trust. Fulmer and Gelfand (2012) define interpersonal trust as "a shared psychological state among team members comprising willingness to accept vulnerability based on positive expectations of a specific other or others." According to Mayer *et al.* (1995), trust in an interdependent relationship enables risk-taking behavior that leads to the desired outcomes. This may be because trust provides *intragroup safety*, an atmosphere within the team that is characterized by trust and mutual support (Hülsheger *et al.*, 2009), which may in turn increase individual risk tolerance necessary for creativity and innovation (Kim, 2015). Morrissette and Kisamore (2020)'s meta-analysis of teams found that trust between stakeholders can determine their collective group performance, although trust is mediated by the size of the team, as documented by Mueller (2012). The role of trust within the relationships in the Lake Mendocino FIRO project's stakeholders was thus examined.

P3. Trust was a key feature in the relationships between participants that enabled successful collaboration and innovation.

Using these propositions, this paper characterizes the interactions between the Lake Mendocino stakeholders, describes the qualitative lessons learned and suggests potential points of intervention to support success in future FIRO projects.

2. Methodology

The study used semi-structured interviews to explore the conditions that supported successful collaboration among Lake Mendocino's stakeholders during the FIRO project. This qualitative research design allows for open-ended questions and queries (Adams, 2015) that researchers could then analyze for themes. This methodology follows other studies exploring collaboration like Rahman *et al.* (2014), Graci (2013) and Paju *et al.* (2022). The researchers coded the resulting text (Popping, 2015; Vaughn and Turner, 2016) using the constant comparative method (line-by-line analysis) to code survey participants' responses (Boeije, 2002; Glaser, 1965) to one or more themes. This was compared to computer-generated topic modeling, which produces lists of words, or topic groups by detecting clusters in recurring words. The study team selected a popular topic modeling technique called Latent Dirichlet allocation, as first described in Blei *et al.* (2003).

Initial interview participants were selected from speakers at the 7th Annual Forecast-Informed Reservoir Operations Workshop, which was held virtually over three days in August 2020. Speakers at the workshop were assumed to be taking an active leadership role at the time of this study. Participants were contacted over email by the researchers, with supporting emails from the study facilitator as necessary. Participation in the study was voluntary and scheduled at the convenience of the participant.

The participant list was expanded during the interview process. At the end of each interview, the researchers asked the participant to list any people important to the execution of the project who had not been mentioned during the interview, to ensure a full picture of the FIRO project. If these additional people were not already on the interview list, the researchers added them. This adaptation of the chain-referral method (Kalton and Anderson, 1986) both verified and expanded the initial list. In total, the researchers interviewed 17 leaders.

Project leaders were predominantly executive-level professionals, often with decades of experience in water resources management. The junior professionals interviewed mainly consisted of postdoctoral researchers who grew into significant leadership roles within the project. Some stakeholders had been involved in FIRO at Lake Mendocino since its inception, while others had joined later to fill in for departing colleagues.

A semi-structured interview process (Adams, 2015) was developed to gather the information that describes stakeholders' relationships within the Lake Mendocino FIRO project.

The semi-structured interview had seven main questions. The components of the first question captured professional experience, authority in the water resources domain and specific questions about Lake Mendocino meant to elicit any aspects of place-based attachment (Question 1e). The remaining six questions sought to characterize connectedness and dynamic relationship qualities, such as frequency of contact, changes in level of formality and conflict resolution. These led respondents to reflect upon belongingness and trust, especially Questions 2g, 3 and 4, while other questions provided context for the researchers. The instrument was reviewed by the ERDC Institutional Office of Human Research Protections.

The researchers asked the following questions:

(1) Tell me your previous work experience.

- Tell me what led to you working with water.
- Tell me how you see your role in the Lake Mendocino project.
- Tell me about Lake Mendocino.
- How much of your typical work week is spent on your Lake Mendocino work right now?

- What drew you to working with Lake Mendocino specifically, and how does that connect to your previous work experience?

(2) Walk me through a typical day at work.

- Who at your organization comes to mind when you think about your work with FIRO? Did you work together? How?
- Who at other organizations come to mind when you think about your work with FIRO? Did you work together? How?
- Of those, who would you say you communicated with most? Least?
- Of those (outside organizations), who would you say were most important (regardless of communication frequency) to your Lake Mendocino work? Why?
- How has that interaction (with the important person) changed over time? [over the course of the FIRO project?]
- Any other important interactions that have changed over time?
- Describe a challenging interaction you have had during your FIRO work, and what contributed to its successful or unsuccessful resolution?

(3) What has been helpful to you in building the most important relationships?

(4) How have any other stakeholders affected your FIRO work?

(5) Is there anything you didn't know, or tools you didn't have at the outset that would have improved the process of building your most important collaborative relationships?

(6) How has the pandemic affected this work?

(7) Anything else you'd like us to know?

(8) Any people you haven't had an opportunity to mention yet that were very important to this work?

Since each participant was interviewed at the end of the Lake Mendocino project, this study does not address changes in perceptions over time.

Interviews were conducted remotely during a three-week period in autumn of 2020, due to both the geographic distribution of the leadership team, whose home organizations spanned the continental US, and due to precautions regarding the COVID-19 pandemic, which was ongoing at the time of the study. Each participant was interviewed individually. The interview team consisted of the primary interviewer and a note-taker. The note-taker was invited to ask clarifying questions at the end of the interview period. In eight cases, researchers required clarification by email on missing or indeterminate responses. Each interview took approximately 20–60 min, depending on the extent to which interviewees expanded on their answers, and all interviews were conducted in single-sessions. During the interviews, the researchers employed "adjusted conversational interviewing" to follow-up on the responses. The follow-up method is conversational in nature and based on study participants' responses. This approach, borrowed from Grounded Theory (Charmaz, 2009), balances the researchers' interest in pursuing specific questions while also encouraging the emergence of participant-generated themes.

First, the researchers coded interview transcripts to identify themes and count how often each theme is mentioned. Then themes were summarized and aggregated ("aggregated thematic groups") to maximize the salience of the thematic groups.

This human coding was then compared with an automated text analysis technique called topic modeling. The convergence between grounded theory and topic modeling, which is the basis for topic modeling's usage in this study, was first discussed in Baumer *et al.* (2017). Latent Dirichlet allocation (LDA) estimates each topic as a set of potentially overlapping words, and LDA can also treat each document as a set of words. Due to interest in themes across study participants, the former approach was applied. The number of desired topic groups is user-selected, and the analysis used the R package *topicmodels* (Grün *et al.*, 2021).

From the set of emergent thematic groups, the groups relevant to characterizing the relationships within the project were identified ("relational thematic groups"). The relational thematic groups were then categorized in the following ways. First, sentiment polarity categories identified practices that help (positive sentiment), hinder (negative sentiment) and otherwise contextualize (mixed sentiment, e.g. conflict resolution) multi-institutional innovation. Second, relational thematic groups were categorized by organizational scale, recognizing that multiple levels of government and multiple agencies at each level, were represented in efforts of this type. Text analysis techniques can perform the sentiment analysis. One form of sentiment analysis classified study participant statements as positive, negative, or neutral using the R package *tm* (Feinerer and Hornik, 2020). An additional, more nuanced sentiment analysis was obtained using the R package *tidytext* (Silge and Robinson, 2021) that classified sentiment according to the National Research Council (NRC) emotion lexicon described by Mohammed and Turney (2013). The NRC lexicon produced eight categories: anger, anticipation, disgust, fear, joy, negative, positive, sadness, surprise, trust.

3. Results

3.1 Frequency of themes and aggregation using human text coding

The researchers found 16 unique themes in their analysis of the survey responses. Table 1 summarizes these themes and the frequency with which they were mentioned. The researchers grouped the themes by commonalities.

The most frequently discussed themes fell into two categories, which became the first two aggregated thematic groups: closeness with frequent collaborators and knowledge of others' concerns and constraints, where "others" refers to people involved in the FIRO project as collaborators or stakeholders. Coders developed aggregations based on thematic similarity of individual themes and finalized aggregated thematic groups by resolving differences in their aggregations.

3.2 Frequency of themes and aggregation using automated topic modeling

Automated topic modeling similarly produced lists of words, or topic groups which can be compared to the human-aggregated thematic groups. The automated topic analysis uses base words, or stems (the word minus prefixes, suffixes and singular vs. plural versions, etc.). An example of a stem is "peopl" (shown near the top left in Figure 1) rather than considering variations, such as "people," "peoples," and "peopled," as separate words. This method produces fewer redundancies and more coherent topics, and the "stemming" process is considered an important pre-processing step in topic modeling. Figure 1 shows the R output of the automated topic modeling when researcher specified the generation of four topic groups. The researchers named the groups (Figure 1) according to their themes.

The researchers' empirical evaluation of the topic group results indicated general agreement with human coding, and no significant new or different aggregated thematic groups. Topic groups appear in similar forms even as the researcher varied the number of topic groups generated. Those that continue appearing after varying the number of topics are designated "persistent topic groups." Persistent topic groups are then compared to human-

Aggregated theme	Theme	Ct	#P	Aggregated theme	Theme	Ct	#P
Knowledge of others' concerns and constraints	Knowledge of collaborators' concerns and constraints	29	11	Place-based attachment	Place specialness	3	3
					Concern about possible mismanagement of natural world	8	5
	Knowledge of stakeholder concerns and constraints	13	8		Personal connection to nature	5	4
Closeness with frequent collaborators	Social attachment to collaborators	21	11	Personal morale and being valued	Statements about personal morale and being valued	11	5
	Comfort with collaborators	18	12				
	Collaboration	15	10		Enthusiastic participation	12	11
Leadership and connections to other water resources groups	Leadership	17	8		Behaviors showing investment in FIRO activities	5	4
	Transparency between committee members	4	3				
				Identity ties to a natural resource	Identity as a water resources professional	4	3
	Connections to other water resources groups	6	4		Length of experience in water resources field	7	7

Source(s): Table by authors

Table 1. Human coding: aggregated themes encompassing the themes that emerged from the constant comparative method of interviews, the counts for each time a theme was mentioned and the number of participants who mentioned the theme

aggregated thematic groups (Table 2). As expected in a summarizing tool, topic modeling was less nuanced than human coding, but was useful for verifying overall themes identified by human coders.

Table 2 shows approximate matches between persistent topic groups (R-generated) and human-aggregated thematic groups. This matching process serves as a check on human coding and aggregation.

3.3 Sentiments expressed in the relational thematic groups

The thematic groups relevant to relationships within the project comprised the most referenced thematic groups in the human coding, the persistent thematic groups in the automated coding and the groups that corresponded to each other in human and automated coding. These relational groups characterize the overall Steering Committee functioning. Using R, a sentiment polarity model assigns positive, negative, or neutral sentiments for the relational thematic groups to examine the sentiments characterizing the most-mentioned relationship dynamics in the interview responses. Figure 2 summarizes sentiment polarity for the three thematic groups relevant to characterizing relationships.

Figure 3 expands the sentiment analysis to include eight sentiments.

The statements made by study participants are overwhelmingly classified as containing positive sentiment. In addition to overall positive sentiment, *trust* and *anticipation* are both identified frequently.

3.4 Statements addressing government entities

Organizations named by study respondents are summarized in Table 3. Most statements (positive, negative, or neutral) discussing agencies are within the relational thematic group:

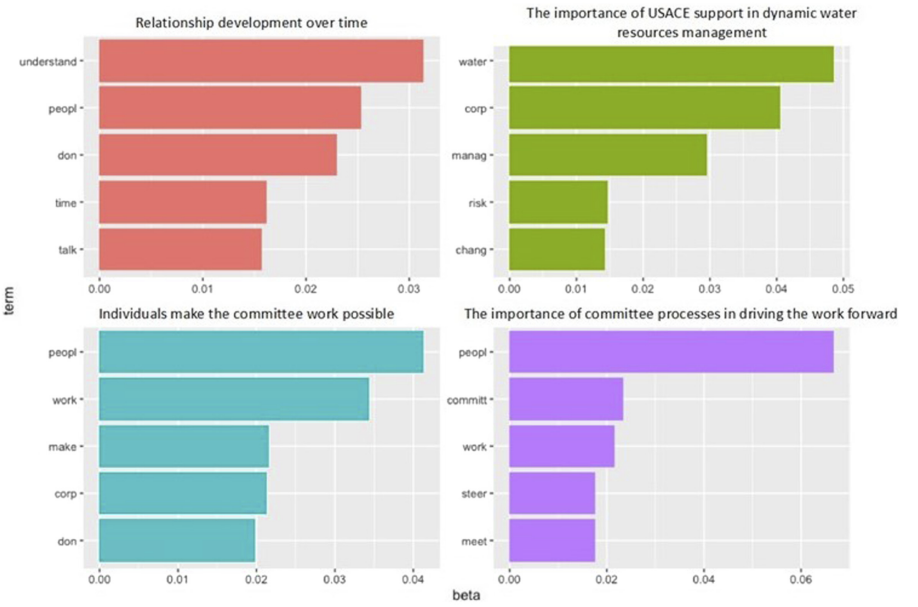


Figure 1.
Researchers examined topic groupings that included anywhere from two to eight topics

Note(s): When four topics are generated, relationships, membership, and commite* are several of the important words in the set of topics that result
Source(s): Figure by authors

Human-coded thematic groups	Similar persistent topic group from R coding	Similarity
Closeness with frequent collaborators	The role of relationships in driving the committee's work forward *(water, peopl*, time, relationship, manag*)*	Aspects of work (*water, manag**) and relationships (*people*, relationship)* suggest that this refers to collaborators and their working relationships
Knowledge of others' concerns and constraints	The role of USACE in managing water risks in a changing world (*Corps, water, manag*, risk, chang**)	Risk came up frequently in terms of actions that would be difficult to take, suggesting concerns or constraints of other professionals (*Corps, water, manag**)
Leadership and connections to other water resources groups	The importance of committee processes in driving the work forward *(peopl*, work, committee, steer)*	The emphasis on roles (*committee, steer*) and working with other people (*people*, work*) parallels group roles (leadership) and colleagues or collaborators
Personal morale and being valued	–	–
Place-based attachment	–	–
Identity ties to a natural resource	–	–

Table 2.
Human coded thematic groups compared with persistent topic modeling counterparts

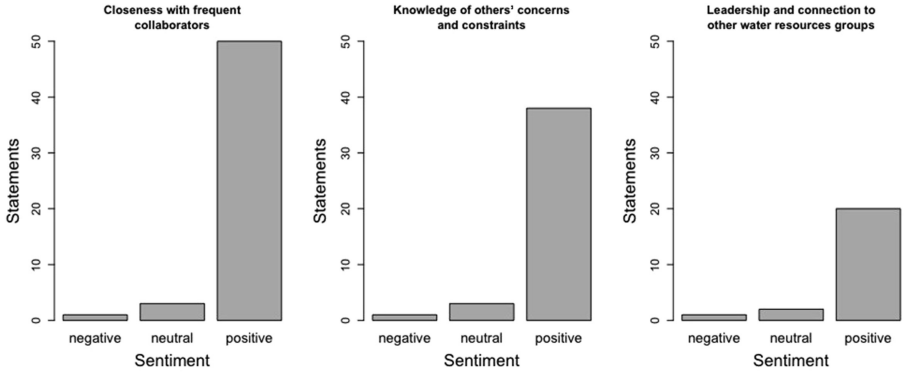
Note(s): Aggregated thematic groups consisting of relatively few statements were less likely to have corresponding persistent topic groups
Source(s): Table by authors

Knowledge of others' concerns and constraints. The agencies mentioned were Sonoma Water, the local government, the State of California (including the governor's office), USACE, NOAA, NWS and Congress.

When examining only the subset of statements that included mentions of agencies (local, federal, or state), the sentiment classification remained mostly positive. There are 35 statements classified as positive that included mentions of agencies. Many of these statements exemplify the collaborative character of the FIRO steering committee. One example statement reads, "[Two non-Corps participants] have done a great job of bringing their expertise to the table and respecting the bounds of the process that the Corps has to follow."

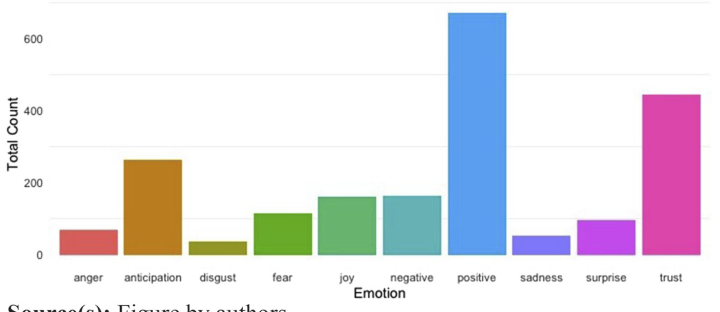
There were also four statements mentioning agencies that were classified as neutral within the three relational thematic groups. An example of a neutral statement is, "NOAA is facing that challenge [about balancing risk with geographic coverage]." Neutral statements typically involved the speaker acknowledging someone's constraints within their role.

There were only two negative statements within the three relational thematic groups, such as, "Early on also the Corps was very hesitant, and suspicious." Note that this apparently negative and subjective statement implies a significant change from skepticism to a current-day role of strong support that is reflected in the majority of other comments made about USACE. An additional 14 statements classified as positive sentiment directly mention USACE. USACE received more mentions than any other agency, followed by Sonoma Water. The other statement classified as containing negative sentiment was less focused on problems with agencies or organizations, and more focused on encouraging additional interest and participation by those agencies.



Source(s): Figure by authors

Figure 2. The three relational thematic groups are overwhelmingly populated with statements classified as positive sentiment



Source(s): Figure by authors

Figure 3. Sentiment analysis that can provide insight beyond polarity confirms mostly positive expressions by study participants: anticipation, joy, surprise and trust predominate

Table 3.
Within the relational thematic groups, several organizations were named by study participants

	Organization	Positive	Neutral	Negative	Number of mentions	Percent positive
Non-governmental	CW3E	1	–	–	1	100%
	Scripps	2	–	–	2	100%
Local government	Sonoma Water	7	–	–	7	100%
	Local government	2	–	–	2	100%
State government	State of California	2	–	–	2	100%
Federal government	USACE	14	2	1	17	82%
	NOAA	2	1	1	4	50%
	National Weather Service	1	–	–	1	100%
	Congress	2	–	–	2	100%

Note(s): These organizations, including government entities, ranged from the local to national levels
Source(s): Table by authors

4. Discussion

4.1 Testing the propositions

4.1.1 Proposition 1: Sense of belongingness. An important thematic group to emerge in the analysis was closeness with frequent collaborators. Study participants made comments about closeness with frequent collaborators, including, "We're friends, [we] go back ten years in completely different capacities." On the other hand, many members of the leadership were unknown to one another; "We had to learn about each other, and who we were and what our interests were." Such statements relate to an individual's perceptual assessment of relational value to others in the group, fulfilling the definition of belongingness that helped formulate Proposition 1.

To understand one's relational value in a group, a person must also understand the other members of the group. The theme of leadership and connections to other water resources groups emerged strongly in the analysis. Study participants made statements like, "Having a partner like Sonoma Water, they're technically savvy and also have a great relationship with the Corps," and "He understands the issues that I have to deal with . . . [h]e worked for . . . [an organization]. He understands, and he is also an excellent communicator."

Proposition 1 examines belongingness as related to collaboration. In the literature, group belonging and the internalization of social identity provides a platform for a sense of commonality and connectedness, as well as the ability to influence and coordinate thinking and actions of fellow in-group members (Haslam *et al.*, 2018). Groups and group processes in which members feel connection or belonging can promote and nurture personal change like gambling recovery (Penfold and Ogden, 2023), participation in therapeutic behavior by incarcerated people (Shukar, 2022), or adopting healthy lifestyles (Hystad and Carpiano, 2012). Belongingness can also play a key role in broader social change; Phillips *et al.* (2016) writes that "a sense of belonging . . . may be a requisite step to mobilizing citizens in collective action for social change on a larger scale." In the case of FIRO, it is not self-improvement or habit-breaking that is needed, but reconsideration of professional practices; this amounts to a personal change in perspective that enables professional innovation. Like this study, studies on impacts of belongingness within innovative professional settings are mediated by collaboration (D'Amour *et al.*, 2008; De Faria *et al.*, 2010), rather than a direct connection.

In this project's interviews, belongingness is not specifically mentioned, but its importance is implied within the stakeholder group as mutual respect, understanding and appreciation. Its presence in the relational themes and the positive emotions associated with those themes through the sentiment analysis, support Proposition 1.

4.1.2 Proposition 2: Place-based attachment. Proposition 2 was not supported; although the human-coding process identified place-based attachment as a theme in survey responses, it was not frequently referenced in discussions and the automated-coding did not identify it as a persistent topic group. Overall, these place-based identity and attachment factors did not appear to be consequential in project success. Most respondents were not local and the open-ended questions about the site elicited generally short responses that were only rarely in the affirmative. Thus, this study was not able to examine the role of sense of place in collaboration because it the interviewees did not particularly relate to the area, either individually or as a group. Professional working groups, even in an environmental context, may not benefit from place-based attachments.

4.1.3 Proposition 3: Trust. Trust, the topic of Proposition 3, emerged strongly in the sentiment analysis, along with anticipation and positive emotions. The theme of knowledge of others' concerns and constraints emerged frequently in the analysis as participants encountered constraints and reckoned with their implications for project goals: "I understand now why the Corps made the decisions and policies in place." or "Sometimes the answer is simply, 'We can't . . . that sounds great, we are not allowed to do it.'" Conveying such constraints asks others to incorporate them in their broaden vision for FIRO, an act of trust. Study participants also broadly described a process of listening to their counterparts at other agencies, observing and communicating frankly with one another about their authority in their various roles. Ultimately, this led not only to a successful project, but created an opportunity to intervene or advocate on behalf of one another: "Our partner needed me to be a voice about shutting off the water because of their very real concerns about liability." In still other cases, new information motivated further study of a participant's home agency: "I had to learn and gain some perspective about how my own agency deals with water." Such introspection underscores the value the participant placed in the information that inspired it, again speaking to trust between the participants.

Also underscoring trust, study participants described a process of accumulating and maintaining social capital with one another. Interest in maintaining that capital became particularly evident when discussing the pandemic: several study participants expressed concern that remote communications were drawing down the store of social capital.

The importance of trust in collaboration and innovation is well-documented in the literature, particularly for professional settings (Salampasis *et al.*, 2014, Bulińska-Stangrecka and Bagieńska, 2019; Oliver *et al.*, 2020), which was less true for belongingness and place-base attachment. The study's confirmation of Proposition 3 reflects these prior findings in the scholarship of organizations.

4.2 Implications: what strategies can support multi-institution innovation for water infrastructure management?

The newly evolving field of Water Infrastructure Asset Management (WAIM) recognizes the challenges and opportunities arising from changing environments, aging assets, increasing values of efficiency and improvements of technical knowledge (Pathirana *et al.*, 2021). FIRO uses meteorological advancements to make a case for changing operations in ways that respond to changing water availability due to climate change. FIRO's operation innovation augment the services provided by the reservoir, but such innovation can only be possible with agreement between stakeholders. Herein we examine strategies to support such collaboration, which can facilitate WAIM and FIRO projects in the future.

"FIRO runs on good will," said one study participant. Another stated, "I got comfortable sharing my opinion[.]" "Just about everyone here is a wonderful human being. Dedicated, principled, articulate, collaborative," said a third. These results indicate that high trust is a major factor in the project's success, according to participants. Trust, by definition, allows group members to assume voluntary risk for uncertain benefits, which was necessary for the project's success.

The interviews also suggest that the Lake Mendocino FIRO project stakeholders built mutual trust over time, starting from initial attitudes that ranged from skeptical to enthusiastic. The analysis of the relational themes reflected overwhelmingly positive sentiments (Figure 3). The FIRO project participants at Lake Mendocino characterize the work as a successful and exciting project, so this discussion assumes that the type and proportion of sentiments and the key lessons summarized earlier are broadly reflective of what is needed for a successful FIRO project at other locations. This assumption is likely a simplification because positive feelings may both result from group successes *and* contribute to group successes. A positive feedback loop may be present.

Therefore, low trust between project participants in a new FIRO application can simply indicate growing (rather than deficient) trust, provided sentiment is generally positive and anticipation, especially in the form of enthusiasm, is present. Low trust scores suggest that additional time and effort is needed to cultivate trust through strategies such as building in time to socialize, which would likely also help with belongingness.

Red flags in an infrastructure management innovation project might therefore be (1) lack of positive sentiment in a new FIRO project and (2) the presence of non-collaborative behaviors. Both individual behavior ("Some people are more likely to set up obstacles") and lack of project norms, such as effective facilitation, can lead to interactions that can erode positivity, anticipation and trust. By inverting some of the factors that led to success at the Lake Mendocino FIRO project, potential issues might include:

(1) The presence of adversarial relationships

(2) Zero sum thinking (the conviction that one person's gain can only be secured with another person's loss)

(3) Unresolved frustration because of mismatches between mission or authority

(4) Lack of outreach to collaborators or stakeholders

(5) Lack of common language

(6) Technical setbacks during testing

The relational thematic groups described in the Results section can provide a baseline for other FIRO projects to use as comparison. Additionally, the presence, effectiveness and organizational roles of laws, rules, norms and *ad hoc* relational strategies described in the Results can be assessed using Likert-type survey instruments (Croasmun and Ostrom, 2011; Likert, 1932). Low scores compared to the FIRO benchmarks could attempt improving working relationships. Such issues should be addressed rapidly and thoroughly to ensure goodwill. Additionally, because goodwill is difficult to restore, stakeholders should prioritize preventing behaviors that erode social capital and supporting ongoing maintenance.

Finally, the lack of evidence supporting place-based attachment as critical for FIRO's application at Lake Mendocino suggests that infrastructure projects are not limited to places where stakeholders or experts possess strong attachments. This broadens the potential reservoirs where FIRO might be applied in the future.

5. Study limitations

There are several limitations in this study. For one, the interviews were administered as the project was concluding with favorable results. This outcome could affect participants' recall of their experiences of the process and positively bias memories of formative events. Further study could include interviews conducted at different times in the project to capture social perceptions in real time.

The study used participants' self-reporting, which in addition to relying on memory accuracy, also risks missing unacknowledged and unstated interpersonal dynamics. Additionally, the stakeholders of this study display homogeneity in terms of being well-educated (post-secondary levels of education), which may have influenced relationships. Data on race or class was not collected, but future work could examine absence or presence of types of homogeneity to understand their relationship to group collaboration and cohesion.

6. Conclusions

The FIRO project assembled stakeholders with many different agendas around a common goal: increasing supply reliability for the Lake Mendocino watershed. The risks inherent in this endeavor were primarily flooding, but the benefits of reliable water supply are evident to all parties, regardless of institutional mandates. Stakeholder collaboration was critical to ensuring that the project benefits could be fully realized without increasing risks of reservoir management. This study used semi-structured interviews and text coding to examine common themes related to the project's successful collaboration. The findings include characterizations of belongingness by understanding of others' constraints and closeness with frequent collaborators, and evidence of positive emotions throughout the project, even before trust is present, as an indicator that trust can be built. Evidence of place-based attachment supporting Lake Mendocino's FIRO application did not emerge. Future FIRO projects can structure stakeholder collaboration to maximize trust-building and belongingness to best support FIRO's innovation at other reservoirs.

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