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Structuring the water quality policy problem: Using Q methodology to explore discourses in the Brantas River basin

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Recognizing the interrelatedness of water use and conceptual value of IWRM, progressive water resource management systems are moving beyond hierarchical arrangements toward more integrated networks. Increasing calls for participation recognize the value of broadened perspectives that provide both technical expertise as well as social, cultural, and administrative knowledge. Moreover, the call for evidence-based policy of '00s has been tempered by recognition of the political nature of data and science. As such, water decision-makers striving to coproduce and employ shared knowledge must grapple with integrating inputs from diverse participant groups to characterize policy problems and identify effective and feasible solutions. Participatory mandates, coordination bodies, and collaborative networks have emerged to facilitate such integration, and their effective cooperation and alignment relies upon some degree of shared purpose, rather than command and control. But guidance is limited with respect to how to accomplish such integrative aims, including how to support discussions across sectors and silos of practice in order to foster better understanding regarding the problems a policy network collectively aims to address. Motivated by observations within the discourse on water quality in the Brantas River basin in Indonesia, this research explores alternative concepts and problem structures regarding river health via Q methodology. Q methodology, an approach that uses factor analysis to explore human subjectivity, is applied to explore conceptualizations of water quality and the structures of the "water quality problem" in the Brantas. The results show that different groups of perspectives emerge regarding the concept itself, as well as characterization of the current condition of the Brantas. Surprisingly, these variant perspectives do not follow oft-cited government-business-civil society divisions. Moreover, the emergent perspectives demonstrate which aspects of the policy problem are consistent and which are contested, suggesting several starting points for early collaboration and several areas that require further research and facilitated deliberation. The results also offer participants in the collaborative network greater appreciation of the various perspectives and definitions in use, within and across organizations, when discussing water quality.

KEYWORDS

water quality management, problem structuring, Q methodology, river health, policy framing

Introduction

Social-ecological policy issues such as water pollution and river health are characterized by high complexity, deep uncertainty, and broad intersectional relevance, with component problems, root causes, and effects that extend across geographies, layers of society, and extended time periods. In response to the recognized interrelatedness of water use and conceptual value of integrated water resources management (IWRM), water resource management systems are increasingly shifting from hierarchical governance arrangements toward more decentralized networks involving large numbers of actors across scales and sectors of government and society (Gupta and Pahl-Wostl, 2013), who must grapple with both short-term needs and the long-term demands of water resource quality.

The growing number of actors formally involved in river management is also a response to recognized gains associated with integrating technical expertise with other kinds of social, cultural, and administrative knowledge. Participatory mandates, coordination bodies, and collaborative networks have emerged to facilitate knowledge integration, promote adaptive capacity, resolve conflict, and align policy-making and implementation in poly-centric systems. The maintenance and effectiveness of such systems is often as (if not more) dependent on strategic alignment, shared vision, negotiation, and competency to collaborate, as opposed to traditional command-and-control types of management.

Guidance is limited, however, with respect to how managers and actors within a river governance network might accomplish such integrative aims, including forging some degree of goal convergence regarding problems at hand and their most appropriate solutions. Moreover, growing recognition of the political, discursive, and constructed aspects of science means that diverse stakeholders may not only debate the appropriateness of solutions, but also employ different viewpoints regarding the nature of problems themselves—in this case, related to water quality. Diverse stakeholders apply different knowledge sets, methods, experiences, and values to characterize the "problem space."

The problem with "problem space" is that it is difficult to formulate targeted interventions, especially when implementation depends on the willing support of numerous institutional stakeholders. Good policy problem definitions entail moving from states of "inchoate expressions of collective unease" (Hoppe, 2018) toward some set of more specified conditions that can be realistically matched with available solutions (Dery, 1984). These processes of "problem structuring" (Franco, 2006; Dijk et al., 2017), "problem framing" (Peters, 2005), "problem setting" (Ackoff, 1974), or "problem finding" (Hoppe, 2018) are not often straightforward considerations of observations, measurements, and ideas. Actors involved apply their own viewpoints that integrate facts, values, theories, and interests to construct multiple problem realities themselves (Rein and Schön, 1993). This phenomenon of "multiple ontologies" (Mol, 1999)—here observed with respect to river health—is the focus of this paper.

Reflecting on these frames can be helpful, especially for policy planning in collaborative policy networks, wherein stakeholders must convene around some set of common goals to which their collective actions may be directed (Dijk et al., 2017). These involve questions about prioritized sub-problems and tradeoffs between economic development and environmental sustainability. Rather than specifying particular policy interventions and water management functions, however, this paper explores general perspectives on "the water quality problem" in the Brantas River basin of East Java, Indonesia, as expressed in real discourse. Q methodology, an approach that combines quantitative and qualitative methods to systematically explore perspectives on an issue, is applied to examine the framing of water quality and river health by stakeholders in the water quality issue network.

This Q-methodological research serves practical, theoretical, and methodological purposes. With respect to the first, the work aims to inform a joint problem analysis performed by participants in the issue network. These participants share a general interest in strengthening water quality management and reducing river water pollution, but do not necessarily "see" the same issue. The goal is to offer an explicit review of alternative viewpoints in order to encourage the kind of empathizing needed to sustain commitment to the difficult, and sometimes contentious, processes of joint knowledge-making and problem-solving and to avoid the pitfalls of narrow, standardized approaches in contexts where many stakeholders with diverse perspectives are involved (Rein and Schön, 1993; Bosomworth et al., 2017; Herrera, 2017).

Theoretically, the research discussed in this paper considers how actors bring multiple perspectives to the table in problem-setting, both with respect to what the water quality problem "is about" and how it can be characterized. Water quality, which may sound fairly clear-cut, is actually a complex problem space for three reasons. First, many inputs, processes, and actors affect water conditions, especially in river basins subject to both natural processes, such as geomorphic events or fluctuating seasonal flows, and multiple human impacts, such as urban or agricultural runoff or industrial water pollution. This is particularly pronounced in large and densely-populated basins like the Brantas, where there are many users and uses of the river, and when the river and its tributaries cross administrative boundaries. In these cases, the river is an ever-changing sink to many inputs, derived from many kinds of human activities, governed by many different individuals and organizations, and with impacts that are often difficult to measure and assess.

Second, dynamic river conditions are appraised with respect to a variant set of ideal states that account for different ways of valuing the river resource in terms of economic, social, symbolic, and recreational values. In other words, a water quality problem implies the deviation of current river conditions from some set of ideal conditions that characterize "good water quality," where quality may be judged, sensed, and measured quite differently. For example, if quality is associated with spiritual, cultural, or recreational uses, it may be appraised by the odor or clarity of water or the density of foliage on river banks, whereas if quality is associated with the river's capacity to support economic activities, it may be assessed according to a set of chemical parameters that must land below a concentration threshold for agricultural or industrial use or by way of an economic appraisal of ecosystem services and the societal value of improved water quality (Loomisa et al., 2018; Choe et al., 2019; Hatamkhani et al., 2022). As such, conceptualizations of water quality are neither uniform nor uncontestable.

Third, water quality, however conceptualized, is typically moderated by a number of governing mechanisms across sectors, levels of government, and geographical jurisdictions. The actors that perform the governance in such networks may hold different problem perspectives based on their knowledge bases, scopes of allowable action, and the availability of solutions to each (à la Maslow's hammer). The framing of a problem may be driven by epistemic communities who focus on specific sub-problems within the greater issue space, or by "instrument constituencies"—perspective holder united by common promotion of particular policy instruments as solutions to general sets of abstract policy problems (Voß and Simons, 2014; Béland et al., 2018). The alternative frames they adopt may also be interest-driven. For example, a particular problem framing may be employed to acquire more budget, power, or other resources. For these reasons, it can be expected that actors may not be discussing the same problem when referring to water quality, with differences that may be surprising to water scientists otherwise expecting fairly consistent conceptualizations.

Finally, the paper makes a methodological contribution by exploring the application of Q-methodology in an innovative two-stage approach that examines both perspectives within and between related discourses. The paper examines both the concepts that participants refer to when discussing water quality—i.e., what water quality is—as well as perceptions on current conditions and concerns. The paper proceeds with a review of relevant literature on problem framing in policy networks, followed by background on the Brantas River basin case. Thereafter, we present an overview of Q methodology and the results and analysis of the Q study, followed by discussion of the findings and recommendations, both for the Brantas and for further research related to policy problem framing for collaborative governance.

Policy problems, policy frames, and network steering

Structured policy problems are the "elements of problem situations that have been abstracted" through analysis (Ackoff, 1974, p. 21), and which better prepare the problem for the application of solutions (Peters, 2005). In his early work on agenda-setting, Dery proposes three criteria for defining workable policy problems, namely that problem definitions should fit a reasonable solution; be geared toward some actors' intervention capacity; and offer a realistic opportunity for improving the situation (Dery, 1984; Hoppe, 2018).

The process of moving from problem state to policy problem is active and involves observation, analysis, and argumentation regarding the current state of affairs and some desired state. As Hoppe describes it, the current state—or "is"—can be represented by a stock of available knowledge applied to understand the problem, where as "the 'ought' is represented in answers to questions about the set of norms, values, principles, ideals, interests and emotions at stake in tackling the problem" (Hoppe, 2018)—issues that can be contentious and ambiguous. But there can be as much debate over the current state and defining "what the problem is about" (Peters, 2005).

Indeed, representations of the problem may be many, particularly for "wicked problems" that are complex and interconnected, relentless (i.e., never fully and permanently solved), and whose causes and effects are difficult to identify or model (Rittel and Webber, 1973; Harmon and Mayer, 1986; Weber and Khademian, 2008; Dunn, 2018)—as is the case for many social-ecological issues for which the number of representations may be large.

Some scholars propose the application of Design Theory as a means of dealing with such complexity, as captured in the literature on policy design (Howlett, 2014a,b; Hoppe, 2018) and policy innovation (Van der Bijl-Brouwer, 2019; Pluchinotta et al., 2020). Here, the process of policy design sees problem finding and structuring as important and central tasks in design (Hoppe, 2018; Van der Bijl-Brouwer, 2019), largely in tune with the notion of "empathizing" in design thinking (Carlgren et al., 2016). The iterative nature of design thinking and policy design involves circling between considerations of problems and solution and is a constant process of problem structuring (Hoppe, 2018). In Bacchi's words, the key question is "What's the problem represented to be?" (Bacchi, 2009).

Progressing a policy problem from an ill-defined, wicked state to a more structured "tame" state (Rittel and Webber, 1973) involves consideration of, competition amongst, and some reconciliation of alternative *policy frames*—knowingly or unknowingly—by stakeholders involved in problem-setting, who often hold different constructions or interpretations of the world. A frame is perspective based on a set of principles or patterns used delimit, interpret, organize and make sense of a complex situation, so that the problematic situation can be understood, analyzed, and acted upon (Rein and Schön, 1993; Van der Bijl-Brouwer, 2019).

In policy processes, participants such as interest groups, policy analysts, policy-takers, bureaucrats, and decision-makers are likely to employ "different frames that lead them to see different things, make different interpretations of the way things are, and support different courses of action concerning what is to be done, by whom, and how to do it" (Rein and Schön, 1993). As such, policy movements and policy projects often start without clear formulations of the problems they are intended to solve (Van der Bijl-Brouwer, 2019). Moreover, different actors within the issue space will take on different framings driven by their particular roles—for example, as scientists driven by analyzing sub-problems or as policy entrepreneurs seeking to promote particular policy tools (Béland et al., 2018). This can be easily seen when large, complex, and complicated issue such as river health is at hand, because so many specific sub-issues are involved, each of which may be assessed and related to others in various configurations.

This can be particularly challenging in the context of governance networks, which have become more prominent arrangements for service delivery (Eggers and Goldsmith, 2004), common pool resource management (Ostrom, 1990), and policy-making (Klijn and Koppenjan, 2000). Such networks require "steering" vs. "rowing" (O'Toole, 1997; Agranoff and McGuire, 2003; Peters, 2011)—a type of coordination based on convergence around a common policy vision rather than traditional, hierarchal command-and-control government. Questions remain, however, about how to effectively steer these networks, including how to sufficiently align participants viewpoints to both set and solve the problems they are intended to address.

Frame alignment has been proposed as a necessary condition for collective action (Snow et al., 1986), though it has been demonstrated that deviating frames can still convene actors, as long as there is some alignment developed through interactions (Brugnach and Ingram, 2012; Pluchinotta et al., 2020). Through active deliberation focused on problem conditions, "individuals participating in the conversation engage in the sense-making of the problematique and may change their understanding of it; and as changed understanding is achieved, individuals engage in further structuring" (Franco, 2006). Such interactions are important to reframing the problem by arranging and rearranging particular elements of an issue (Dewulf and Bouwen, 2012).

While these processes may occur spontaneously and without intentional facilitation, a body of work on frame-critical policy analysis and problem structuring methods has developed to aid practitioners in processes of intentional problem structuring for policy design and to avoid what Dunn terms "Type-III error"—i.e., solving the "wrong" problems (2018). Traditional reductionist, rationalist approaches are often incapable of offering sufficient analysis for complex, wicked problem contexts, especially when it comes to problem-setting (Snowden and Boone, 2007; Van der Bijl-Brouwer, 2019). Rather, "meta-methods" that assist argumentation or generate mutual understanding are needed to delineate the problem space (Dijk et al., 2017).

With this goal in mind, this research examines how systematic, intentional appraisal of problem structuring can help network participants identify feasible policy sub-spaces on which to anchor collaborative work, in this case, to improve water quality conditions in the Brantas River basin, Indonesia. Whilst the large number of actors in the Brantas express general interest and support for improved river health, early experiences in a collaborative water quality management project in the basin suggested divergent conceptualizations of water quality as well as varying deep-seated perspectives of what the river is and what river conditions matter.

Water quality in the Brantas River basin

Brantas River overview

The 320-km Brantas River winds in a clockwise spiral from Mount Arjuno in East Java, Indonesia, emptying via its lower tributaries to the Madura and Surabaya straits to the north. After passing through large swathes of agricultural land and a number of medium-sized municipalities, the Brantas forks in the lower reaches at Mojokerto into two branches, the Surabaya and Porong Rivers (Figure 1). The Porong flows east to the Madura

Strait, while the Surabaya flows north and again divides into the east-flowing Wonokromo and the north-flowing Mas River, which runs north through Surabaya, the capital of East Java and Indonesia's second most populous city of 2.87 million people (Badan Pusat Statistik Jawa Timur, 2021).

The Brantas River basin—or Wilayah Sungai Brantas (WS Brantas) in Bahasa Indonesia—is one of Indonesia's largest basins, draining ∼14,000 square kilometers, an area that accounts for about a quarter of the province of East Java (Pola, 2020). This area is also home to around half of the province's population, some nearly 18–25 million people.[1] WS Brantas contains most of East Java's fresh water reservoir capacity, with an annual water potential of about 12 billion m^3 and is the most important source of raw water supply for domestic consumption, industrial use, and agricultural irrigation (Sudaryanti et al., 2001; Jennerjahn et al., 2004; Adi et al., 2013; Handoyo and Said, 2020).

The basin is an important economic, agricultural, and manufacturing region that generates around 59% of the province's GDP and 6–10% of Indonesia's rice crop. Agriculture accounts for over half of the basin's land use (Badan Pusat Statistik Jawa Timur, 2018), and aquaculture and fisheries account for a large percent of the region's protein availability (Badan Pusat Statistik Jawa Timur, 2017; Badan Pusak Statistik Jawa Timur, 2019). The river and its tributaries also provide raw water for domestic and industrial use, supplying ∼300 million m^3 of water each year to six regional water supply enterprises (Perusahaan Daerah Air Minum, or PDAMs) and about 191 million m^2 per year to 143 industries. For these users, water quality must be sufficiently acceptable for use, requiring pre-treatment by the raw water supplier, Perum Jasa Tirta 1, to meet minimum standards.

Brantas River basin management

Because of its economic, social, and agricultural importance, WS Brantas was designated as a National Strategic River in 2006. This designation means that, despite being located entirely within the bounds of the province of East Java, management of the Brantas falls largely under the national government via the Ministry of Public Works and Public Housing's Directorate General of Water Resources.[2] Balai Besar Wilayah Sungai (BBWS) Brantas, the river basin agency established to manage the basin, is responsible primarily for developing water infrastructure, managing riverbanks, and supervising the activities of its delegated operator, a state-owned enterprise called Perum Jasa Tirta 1 (PJT1). PJT1 was established in 1990 to deliver a corporatized approach to the operations and maintenance of water infrastructure, including reservoirs, dams, and hydropower stations, in order to deliver raw water for PDAMs and industry, manage water supply for irrigation, and maintain water flow for electricity generation.[3]

While BBWS Brantas and PJT1 provide most of the functions of water resource management related to development, utilization, irrigation, and flood control, they play secondary roles in water quality management. Both are obligated to monitor water quality, and BBWS Brantas also oversees planning and the functioning of the Tim Koordinasi Pengelolaan Sumber Daya Air (TKPSDA), or Water Resources Coordination Team, an intergovernmental coordination body charged with coordinating the multiple agencies involved in IWRM.

Provincial and municipal agencies provide many functions of water quality management, including water pollution control, spatial planning, development of wastewater treatment facilities and sanitation services, and provision of solid waste management. The provincial environmental protection agency, Dinas Lingkungan Hidup Jawa Timur (DLH Jatim) and the regency and city environmental agencies (DLH kota/kabupaten) control pollution from industrial sources and provide solid waste management policy and services (Table 1).

Brantas water quality

Development of the Brantas River basin dates to the mid-1800's with Dutch colonial development of irrigation and flood control infrastructure. Water quality management did not become a notable policy focus until the 1970's, when drinking water sources were found to be heavily polluted and a number of high-profile fish kills focused attention to industrial pollution (Lucas and Djati, 2007). Thereafter, national and local regulations to control water pollution and protect natural resources were drafted, and the fourth and fifth Brantas Master Plans incorporated IWRM and conservation initiatives.[4]

Attention to water quality and pollution within development and academic circles produced a growing number of studies reflecting deteriorating water conditions, high levels of measured contaminants, and decreasing health of aquatic species (Marini and Weilguni, 2003; Harnanto and Hidayat, 2004; Jennerjahn et al., 2004; Bhat et al., 2005; Fulazzaky, 2009;

1 Reported figures in the Brantas River basin 2020 Pola are 18,166,066 in 2015, where as a summation of the populations listed in the Pola kotas and kabupaten and reported by Pusat Badan Statistik Jatim (the East Java statistical agency) yields an estimated 25.1 million residents in 2015 (Badan Pusat Statistik Jawa Timur, 2021).

2 Government Regulation of Public Works No.11A of 2006.

3 Government Regulation (Perpem) 46/2010 concerning Perusahaan Umum (Perum; General Company) Jasa Tirta.

4 These legislative instruments included Regulation 20 of 1990 on Pollution Control, Regulation 5 of 1990 concerning the legal basis of PJT-1, Regulation 20 of 1990 concerning Water Pollution Control, and Law 5 of 1990 concerning Conservation of Biological Natural Resources.

TABLE 1 Key functions of water quality management in the Brantas River basin, by agency.

BBWS Brantas	PJT-1	DLH Jatim	District government
Water quality monitoring Strategic water resource planning Enforcement of wastewater regulation Riverbank management	Flushing of river to maintain ecosystem services/water quality Water quality monitoring	Pollution control Issuance and supervision of wastewater discharge permits Enforcement of wastewater regulation	Pollution control Issuance and supervision of wastewater discharge permits Enforcement of wastewater regulation Compiling and maintaining inventories of pollution industries

Source: Author's compilation based on doctrinal review of legal tasks and functions.

Yetti et al., 2011; Hakim and Trihadiningrum, 2012; Jänen et al., 2013; Gnadl, 2017; Roosmini et al., 2018; Mariyanto et al., 2019; Hendriarianti et al., 2019a,b; Risjani et al., 2020; Sartono et al., 2020). The Brantas has also regularly fallen short of meeting environmental water class standards set by government (Fulazzaky, 2009; Yetti et al., 2011; ADB, 2016; Amalia and Soedjono, 2019).[5] Rapid urbanization, concentrated industrial activity, runoff from agriculture, and natural processes have all introduced pollutants that compromise biological health, increase costs of water treatment for water supply, limit opportunities to develop tourism, and increase health and livelihood risks for riverside residents, fishermen, farmers, and other direct users.

As stipulated in regulation, the impacts on water quality are assessed by government agencies via calculation of a Water Quality Index based on such methods as STORET, the Water Pollution Index, or other scientific approaches more suitable to the context (Damayanti et al., 2021).[6] Similar approaches to building water indices have been used in many other locations to capture the parameterized state of water quality, often with reference to some acceptable threshold.

There is, however, no obvious consensus on the relative impacts of various pollution sources and management practices on overall river health.

Sources of pollution

Estimated pollution loads from various point and non-point sources vary both across studies, seasons, and segments of the river. A number of studies suggest that domestic wastewater is the highest contributor of pollution (Harnanto and Hidayat, 2004; Perum Jasa Tirta, 2014; Arum et al., 2019)[7] or at least focus most on the effects of high volumes of untreated wastewater (Simon, 1978; Jänen et al., 2013; Bekti et al., 2018; Hendriarianti et al., 2019b), whereas other studies focus on the impacts of agricultural runoff (Adi et al., 2013), industrial wastewater discharge (Marini and Weilguni, 2003; Aldrian et al., 2008; Fulazzaky, 2009; Schroeder et al., 2013), natural sedimentation (Omachi and Musiake, 2004; Jennerjahn et al., 2013; Mariyanto et al., 2019), and solid waste (Irawan et al., 2019; Visser, 2019).

Despite the lack of consensus on the relative severity of pollutant sources, it is generally accepted that urbanization and intensive agricultural and industrial development continue to drive anthropogenic pressures. The river and its tributaries run through 16 regencies (kabupaten) and six cities (kota) home to between 18 and 25 million people (Badan Pusat Statistik Jawa Timur, 2020; Pola, 2020). Facilities to treat wastewater and manage solid wastes are grossly insufficient, however. Centralized collection is limited to urban areas with partial coverage, household septic tanks often overflow into groundwater and drainage channels, and many households discharge directly to the river (Gnadl, 2017; Zulfi et al., 2018). Moreover, solid waste collection and management is limited, landfills are at near-full capacity, and open dumping is common practice. As such, the Brantas suffers high levels of organic and plastic waste and is one of the largest contributors to global marine plastic (Lebreton et al., 2017; Lestari and Trihadiningrum, 2019; Purba et al., 2019; UN ESCAP, 2020; World Bank, 2021).

5 As per Regulation of the Governor of the Province of East Java No. 61/2010 concerning Determination of Water Classes in Rivers, much of the Brantas is specified as Class II or Class III, indicating sufficient quality for recreational use (II) or at least for cultivation of freshwater fish and use for livestock watering and crop irrigation (III).

6 As per the Decree of the State Minister of the Environment Number 115 of 2003 concerning guidelines for determining the status of water quality.

7 Harnanto and Hidayat, for example, estimated in 2004 that the total daily domestic pollution load was ~515 ton/day of BOD in the basin, and that agriculture accounted for an ~2,500 tons per day. This was followed by estimated loads of 125–155 tons per day from the ~483 industries discharging effluent to the Brantas and its tributaries, and 100 tons per day from natural sources, such as mud flows (2004).

With respect to industrial pollution, somewhere between 300 and 500 registered industries discharge wastewater into WS Brantas (Aldrian et al., 2008; Schroeder et al., 2013; Septiono et al., 2016). Limited funds and human resource capacity for wastewater treatment plants (WWTPs), low and inconsistent enforcement of standards by government, and limited awareness regarding the ecological hazards of water pollution are all purported to contribute to industrial contaminants (Bruijns, 2018). The Brantas also serves as sink to pesticides, fertilizers, and livestock runoff from the farms and plantations that cover well over half of the land area of the basin. The basin is also subject to significant seasonal fluctuations, geomorphic activities, riverbank development, and land use changes that contribute to high sedimentation (Harnanto and Hidayat, 2004; Fulazzaky, 2009; Jänen et al., 2013; Sulistyaningsih et al., 2017).

Institutional and management challenges

The anthropomorphic nature of water pollution means that water quality is mediated by water and waste management practice and policy. In WS Brantas, as in many basins, a number of institutional, administrative, cultural, and resource-related issues have hindered efforts to implement IWRM and reduce ecological impacts of settlements, industry, and agriculture. A first category of challenges often cited in literature and reporting relates to the legal and regulatory determination of roles and responsibilities in water quality management and pollution control. While Indonesia and the province of East Java have a well-developed body of water and environmental law, some commonly-cited institutional challenges include the presence of overlapping government agency mandates that lead to duplicated activities (Rahmawati et al., 2014; Turner et al., 2019); confusion over responsibilities for industrial pollution control, including permitting and oversight, across levels of government (Nugroho et al., 2017); undeveloped implementation guidelines for the 2019 national Water Resources Law (UNEP, 2020); tenuous links between water policies and budgeting; and unspecified responsibility for removing wastes that enter water resources.

A second group of challenges relates to administrative capacity and political support. With respect to administration, there are noted coordination problems, insufficient expertise for implementing IWRM, and limitations with respect to administrative capacity to deliver some functions of water quality management, such as pollution control, integrated planning, and community engagement (ADB, 2016; Kösters et al., 2020; UNEP, 2020). So-called "sectoral egos" hinder effective cooperation (Mulyana and Prasojo, 2020; Waskitho et al., 2021), and a lack of socialization and "short-termism" prevents efforts to implement long-term river basin plans and programs (Sulistyaningsih et al., 2017). Lastly, water quality is simply of lesser political importance than water issues that are perceived as more urgent—namely, flood control and allocation.

A third set of common institutional challenges concerns availability of financial and informational resources. There is generally insufficient funding for developing infrastructure and services related to management and pollution control (Rusfandi, 2003; Subijanto et al., 2013; ADB, 2016). While river management budgets are supposed to follow priorities set out in basin plans, allocated funds for annual work are often cobbled together on an *ad-hoc* basis, and many agency managers do not know how to tap into available national funding for conservation and environmental management (ADB, 2016). There is also noted uncertainty regarding the availability and use of water quality data for planning and water quality management (Fulazzaky, 2009).

A fourth commonly-cited class of concerns relates to community awareness of river health and public behavior related to managing solid waste and domestic wastewater. Community awareness regarding river ecology and pollution is purportedly lacking, resulting in low levels of concern for the river and poor problem-solving skills related to wastewater management (Rusfandi, 2003; Sulistyaningsih et al., 2017; Handoyo and Said, 2020).

Conceptualizing water quality

Both the aforementioned studies of the Brantas River basin and interviews conducted with government and community stakeholders demonstrate a diversity of thought and opinion about the relative severity of pollution sources and the best approaches to improving river health. But more fundamentally, stakeholder discussions and interviews revealed divergent conceptualizations of the concept of water quality itself. Most of the studies of water quality referenced above take a technical parameterized approach, where water quality is defined in terms of measures such as dissolved oxygen, pH, conductivity, phosphates, etc. But there are multiple possibilities for how one perceives, sees, experiences, or thinks about water quality, and the notion may vary across user groups (see, for example, Pramana and Ertsen, 2022). For residents directly using the river for washing, for example, water quality may be judged by the smell or look of the water, whereas fishers and aquaculturists may judge quality in terms of fish stocks. There are also important cultural and spiritual ties to water and river health, exemplified in Javanese proverbs and concepts such as "Ibu bumi, Bapak aksa" ("Mother is earth, Father is sky") and Maununggal ("becomes one") that stress the oneness of humanity and nature and deep respect for tradition and ancestry, which may be employed to describing water quality in terms of harmony (Nugroho, 2016).

Specifically in the Brantas, Visser notes that some ecologists judged water quality by the presence of certain species or evidence of wetland preservation efforts, whereas various engineers viewed water quality as a concept tied to the calculated

Water Quality Index, measured chemical parameters, or the costs of raw water treatment (2019). Even amongst scientists and engineers using the same parameters, there is diversity in approaches to measuring and interpreting data, so that various assessors of water quality may perceive very different rivers. In reference to the Brantas, Fulazzaky points out that the individual interpretation of water quality data depends on the particular experiences and knowledge of each expert (2005).

Thus, instead of taking hydrological, chemical, or other ecological data as the sole starting point to investigate Brantas water quality, this study first investigates the water quality problem structure, including what perceptions various stakeholders in the policy system hold regarding water quality and water quality problems.

Q methodology

To explore alternative problem structures, this research employs Q methodology to identify how respondents bundle specific "attitudes, beliefs, and understandings" (Ward, 2013) into general perspectives or viewpoints, in this case regarding the problem structures related to water quality in the Brantas basin. Q methodology is a "quali-quantilogical" approach that employs factor analysis to study human subjectivity (Watts and Stenner, 2005). Respondents model their points of view on an issue by systematically rank-ordering a sample of statements from a larger discourse via a survey tool called a Q-sort (Brown, 1996; McKeown and Thomas, 2013).

Unlike surveys that ask participants to respond to isolated statements or questions, the Q-sort allows respondents to react to statements in the context of all others, and the analysis preserves responses (the rank orderings) as a whole in analysis. By-respondent factor analysis is used to identify groups of participants who organize the relationships between statements in similar ways. The underlying factors are interpreted by the researcher to represent viewpoints within the discourse (Webler and Tuler, 2001; Watts and Stenner, 2005).

It is important to note that Q methodology is not designed to represent all of the discourses across groups in a population or to what extent any one viewpoint is held; rather, it allows the researchers to determine the perspectives held by the participants in the study (Restrepo-Osorio and Brown, 2018). In this way, it does not privilege the opinions held by the majority and allows the researcher to identify perspectives that may otherwise be overlooked in R methodological research. It is also a powerful tool to tease out areas of particular contention or consensus. In this case, Q demonstrates the ways in which the concept of water quality and attendant problem structures are consistent, based on statements that are ranked similarly across groups, and how they are contested, based on statement rankings that distinguish factors.

This methodological contribution in this study is in employing two separate Q-sorts performed in sequence to consider both conceptualization of water quality and participants' problem structuring related to water quality. The first Q-sort, termed *Concept*, includes statements that are largely conceptual and definitional in nature and reflect what people may feel water quality "is about," whereas the second Q-sort, termed *Conditions*, includes statements that reflect positions regarding the causes of water quality problems and characterization of Brantas River health.

Building the concourse and developing the Q set

The set of statements included in a Q-sort—i.e., the Q set or Q sample—is selected to provide broad representation of the diversity of opinion within a greater discourse regarding an issue (Watts and Stenner, 2012, p. 58). A structured sample is composed to avoid bias due to over- or under-selection of sub-issue components (McKeown and Thomas, 2013). The Q samples in this study were extracted from a larger concourse of statements recorded from academic literature, news media, organizational reports and publications (including many that included interview data from communities), and interviews. An initial set of 301 statements was recorded and considered for inclusion in the sorts.

This concourse was manually organized, first by separating out statements about the conceptualization of water quality from statements about the current status of water quality. Thereafter, the statements were grouped into categories based on similar themes or content, thus naturally reducing the statements to a more condensed set. In line with the advice of Watts and Stenner, the size of the sorts—i.e., the number of statements in each—was limited in order to reduce the burden on respondents (Watts and Stenner, 2012). A structured sample of statements was selected for both Q-sorts, as recommended by Dryzek and Berejikian, in order to balance descriptive, factual, value judgements, and normative prescriptions (Dryzek and Berejikian, 1993).

Q-sort 1, *Concept*, included 23 statements (see Appendix 1), and Q-sort 2, *Conditions,* contained 34 statements about current conditions of water quality and water quality management (see Appendix 2). These statements were reviewed during the piloting of the survey tools and refined for language by native Bahasa Indonesia speakers to ensure clear language and terminology.

Conducting the Q-sorts

The respondent set, or P set, included 32 respondents from government, water user groups, NGO and community representatives, and academia. The respondents included 21

TABLE 2 Summary of respondents.

Government	17	Male	21
State-owned enterprise or water user	6	Female	11
NGO or community	6		
Academic	2		

men and 11 women from the upper, middle, and lower reaches of the Brantas River area (Table 2). Responses were anonymous, but a limited set of identifying data was gathered, including affiliation (government, GO, etc.), gender, and general area of residence, via a small survey questionnaire between the first and second sorts. Eight-digit identifying tags were also issued in order to link respondents' first and second sorts during analysis.

In each sort, participants were asked to rank statements from "least agree" to "most agree," and to organize these rankings on a forced quasi-normal distribution (Table 3). Least and most agree corresponded to rankings of−3 and +3 in Q1 and−4 and +4 in Q2.

The Q-sorts were performed in one of two ways. The first was via online Q-sorts developed using open-source Easy-HtmlQ software (https://ken_q_tools.gitbooks.io/ken-q-analysis-reference-guide/content/1-3-easyhtmlq-file-import.html) and hosted on the Netlify application platform. These sorts were actively facilitated during video calls via Zoom in order to answer respondent questions and encourage careful reflection and participation. Data gathered via the online Q-sorts were recorded to a Google Firebase database. The second data collection approach was via manual (hard-copy) versions of the same Q-sorts, facilitated in-person by research assistants in the Brantas. For the manual sorts, the results were photographed and recorded onto scoresheets. Data was subsequently entered by the research team into the Google Firebase via the Netlify app in order to combine the data sets.

The approaches and procedures for online and in-person sorts were the same and supported by a written data collection protocol to ensure comparable collection conditions. For each sort, respondents first grouped statements into three categories: agree, disagree, and neutral. Thereafter, they placed tiled statements onto the provided plots to designate relative agreement and disagreement with the statement. They were given the opportunity to rearrange tiles until they were satisfied with the resultant rankings.

Analysis and interpretation

Analysis of the Q-sorts was performed via the *KenQ Analysis* web application (https://shawnbanasick.github.io/ken-q-analysis-beta/index.html#section1). For both sorts, seven centroid factors were extracted. In deciding how many factors to retain for rotation in the factor analyses, three considerations were applied. First, Kaiser's rule states simply to retain factors whose eigenvalues are >1 (Kaufman and Dunlap, 2000). Second, Cattell's scree test requires that the plotted eigenvalues are subject to visual inspection and that factors that demonstrate no marked change in slope are dropped from further analysis (Cattell, 1966). Third, a retained factor should have at least one distinguishing statement.

For Q1, *Concept*, three factors were retained for rotation, and for Q2, *Conditions*, four factors were retained. Varimax rotation was applied to maximize the total amount of variance explained by the extracted and retained factors. In Q1, the first factor C1 accounted for 27% of the variance, whereas the second (C2) and third (C3) accounted for 21 and 15%, respectively. In Q2, the first factor (N1) accounted for 17% of the variance, whereas N2, N3, and N4 accounted for 15, 7, and 14%, respectively.

Thereafter, idealized sorts for the extracted factors were considered and interpreted using the crib sheet method, based on Stephenson's worked and further developed and described by Watts and Stenner (2012; see, for example, Table 4). In this approach, the researcher considers, by factor, the statements ranked highest and lowest and the statements ranked higher or lower than in other factors. The factors were also examined with respect to distinguishing statements in the full set of results for each sort.

Results

Three related enquiries are made in considering the results of this analysis. First, what perspectives on water quality as a concept and current state emerge? Second, what are the areas of agreement or general consensus amongst respondents, and what components distinguish alternative viewpoints? And finally, is there a relationship between a respondent's conceptualization of water quality and their structuring or framing of the water quality problem or a relationship between their affiliation and position? The results of this two-part Q methodological study are presented first and then discussed in terms of these questions.

Concept Q-sort results

Q1 analysis resulted in three emergent factors presented in Table 5, which shows the idealized sorts for each factor, noting distinguishing and consensus statements.

TABLE 3 Q-sort summaries.

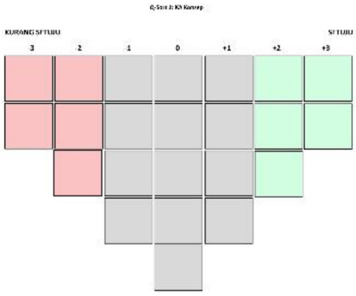
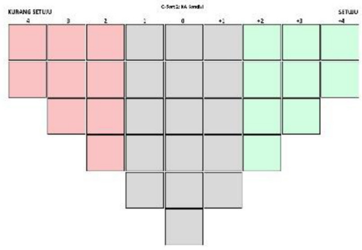
	Concept sort (Q-sort 1)	*Condition* sort (Q-sort 2)
Total statements	23	34
Q-sort plot distribution		
Number of respondents	32	32

TABLE 4 Example crib sheet for Q1, *Concept*, factor 3.

		C3		C1	C2
	Highest ranked statements				
11	The quality of river water is important for the daily lives of people in the watershed.	3	D*	0	1
1	Water quality can be judged by the number and diversity fish, insects, and other aquatic species.	3	D*	1	1
	Positive statements ranked higher in factor C3 than in others				
4	I think water quality matters largely with respect to how it affects people's livelihoods.	2	D*	1	−1
5	Maintaining water quality is primarily a matter of controlling and reducing pollution from factories.	2		−2	2
17	Women play a central role in managing and safeguarding water quality.	2	D*	0	−2
12	Water quality is truly known by directly engaging with the water—smelling it, seeing it, touching it.	1	D**	−1	−2
6	Water quality is important because of recreation. People should be able to swim safely.	0	C	−1	−1
	Negative statements ranked lower in factor C3 than in others				
18	River management should be based on a participatory approach that involves users and policy makers at all levels.	0	D*	3	3
14	We and the river are one and should be in harmony.	0		2	0
9	Water quality is largely a concern related to environmental conservation and preserving biodiversity.	0	C	1	0
22	Reliable water quality data is needed to support water management decisions.	0	D**	3	3
20	Water quality begins and ends with communities, since they have the most direct experiences with problems and solutions.	−1		0	−1
13	Water quality is a measure of how scientific measurements meet water standards set by government.	−1	D**	0	0
19	Flood control and water allocation are priorities. Water quality is nice, but it is a secondary issue.	−2	C	−1	0
10	Water quality is a technical issue that should be assessed by experts.	−2	D*	−1	1
16	Water quality may be important to scientists and environmentalists, but it is not a concern for most people in their everyday lives.	−2		−2	−1
	Lowest ranked statements				
23	Water quality is only a seasonal issue.	−3	C*	−3	−3
7	The river is useful to dispose of domestic waste.	−3	C*	−3	−3

Consensus statements: Do not distinguish between any pairs of factors, noted if statements were non-significant at $p > 0.01$; those flagged with * are also non-significant at $p > 0.05$.
Distinguishing statements: *indicates significance at $p < 0.05$ and **indicates significance at $p > 0.01$.

Interpreted idealized *Concept* Q-sorts

The interpretation of factors resulted in three overarching conceptualizations: C1, Harmonist-holist; C2, Technical-regulatory; and C3, Engaged. Factor C1 has an eigenvalue of 8.64 after rotation and explains 27% of the study variance. Fourteen respondents were significantly associated with the Harmonist-holist viewpoints, which can be described generally as follows, with direct reference to statement rankings:

C1, Harmonist-holist: *A clean Brantas River is both a source of national pride (8:+2) and economic value (3:+2), but it is most important that we maintain a harmonious relationship with the river and each other (14:+2). Water quality is also not just a matter of controlling industrial pollution (5:-2); it is about broader efforts to promote biodiversity and environmental conservation (9:+1) that depend the involvement of users, communities and policy makers at all levels (18:3). It is a matter of value to all*

TABLE 5 Q-sort statement rankings for idealized *Concept* factor statements.

	Statement	Factors			*Z*-score variance	Distinguishing and consensus
		C1	C2	C3		
1	Water quality can be judged by the number and diversity fish, insects, and other aquatic species.	1	1	3*	0.093	Distinguishes C3
2	I notice that the river is clean or dirty by whether it makes people in my community sick after using water for bathing, cooking, washing, or swimming.	0*	−2	−1	0.095	Distinguishes C1
3	Clean water has an economic value.	2	2	1	0.036	Consensus
4	I think water quality matters largely with respect to how it affects people's livelihoods.	1*	−1**	2*	0.507	Distinguishes all
5	Maintaining water quality is primarily a matter of controlling and reducing pollution from factories.	−2**	2	2	0.938	Distinguished C1
6	Water quality is important because of recreation. People should be able to swim safely.	−1	−1	0	0.053	Consensus
7	The river is useful to dispose of domestic waste.	−3	−3	−3	0	Consensus
8	The cleanliness of our river is a matter of national pride.	2	1	1	0.036	Consensus
9	Water quality is largely a concern related to environmental conservation and preserving biodiversity.	1	0	0	0.041	Consensus
10	Water quality is a technical issue that should be assessed by experts.	−1*	1**	−2*	0.257	Distinguishes all
11	The quality of river water is important for the daily lives of people in the watershed.	0**	1*	3*	0.742	Distinguishes all
12	Water quality is truly known by directly engaging with the water—smelling it, seeing it, touching it.	−1**	−2**	1**	0.808	Distinguishes all
13	Water quality is a measure of how scientific measurements meet water standards set by government.	0	0	−1**	0.134	Distinguishes C3
14	We and the river are one and should be in harmony.	2**	0	0	0.253	Distinguishes C1
15	Water quality can be likened to a potential hazard, where managing water quality is a kind of damage control.	1	2	1	0.073	
16	Water quality may be important to scientists and environmentalists, but it is not a concern for most people in their everyday lives.	−2	−1*	−2	0.098	Distinguishes C2
17	Women play a central role in managing and safeguarding water quality.	0*	−2**	2*	0.44	Distinguishes all
18	River management should be based on a participatory approach that involves users and policy makers at all levels.	3	3	0**	0.337	Distinguishes C3
19	Flood control and water allocation are priorities. Water quality is nice, but it is a secondary issue.	−1	0*	−2	0.079	Distinguishes C2
20	Water quality begins and ends with communities, since they have the most direct experiences with problems and solutions.	0**	−1	−1	0.12	Distinguishes C1
21	Maintaining water quality is a government responsibility.	−2*	0	−1	0.209	Distinguishes C1
22	Reliable water quality data is needed to support water management decisions.	3	3	0**	0.47	Distinguishes C3
23	Water quality is only a seasonal issue.	−3	−3	−3	0.031	Consensus

Consensus statements: Do not distinguish between any pairs of factors, noted if statements were non-significant.
Distinguishing statements: * indicates significance at $p < 0.05$ and ** indicates significance at $p < 0.01$.

groups and is not solely the responsibility of governments (21:-2). It can been seen that water quality is poor when people are sickened after using the water for bathing, cooking, or washing (2:0), and communities play a role in water quality management since they have the most direct experiences with problems and solutions (20:0). Nevertheless, water quality itself is not terribly important to the daily lives of people in the watershed (11:0).

Factor C2, termed the Technical-regulatory viewpoint, has an eigenvalue of 6.72 and explains 21% of the study variance. Eight respondents were significantly associated with this factor, summarized as follows:

> **C2, Technical-regulatory:** *Water quality is a technical issue that should be assessed by experts (10:+1) and is not generally judged by simple means—for example, by touch, sight, or smell (12:-2;2:-2) or through observation of sickness (2:-2). Rather, reliable water quality data is needed to support management (22:+3), which is largely a responsibility of government (21:0) with respect to controlling industrial pollution (5:+3) and is less so an issue for communities (20:-1).It should nevertheless still be based on a participatory approach that involves users and policy makers at all levels (18:+3). Water quality is somewhat relevant to the daily lives of people in the watershed (11:0) and has economic value (3:+2), but it is a secondary issue to flood control and allocation (19:0) and does not have a very important effect on livelihoods (4:-1) or a significant interaction with considerations of gender (17:-2). Rather, it can be likened to a hazard, where water quality management is a form of damage control (15+2).*

Last, factor C3, the Direct Engagement viewpoint, has an eigenvalue of 4.8 and explains 15% of the study variance. Five respondents were significantly associated with C3, whose perspective is interpreted as follows:

> **C3, Direct Engagement:** *Water quality is important to the daily lives of people in the watershed (11:+3) and an important issue relative to others such as flood control and allocation (19:-2). It matters with respect to how it affects livelihoods (4:+2) and is also somewhat important because of its recreation value (6:0). Water quality can be readily observed by the number and diversity fish, insects, and other aquatic species (1:+3) and may also be observed by directly engaging with it—by smelling it, seeing it, touching it (12:+1). Women play a central role in managing and safeguarding water quality (17:+2). Managing water quality isn't just a measure of how scientific measurements meet standards set by government (13:-1) and needn't only be judged by scientists and experts (10:-2). In fact, scientific water quality data is not of central importance to making water management decisions (22:0).*

Consensus and distinguishing statements

An examination of *Z*-score variance and significance of statement in each idealized factor is helpful to consider areas of consensus by way of statements that do not distinguish any factor, as well as sub-components for which perspectives differ most. Perhaps unsurprisingly, all factors strongly disagreed that the river is useful to dispose of waste (7:−3,−3,−3) or that water quality is a seasonal issue (23:−3,−3,−3). Similarly, all factors agreed on the economic value of clean water (3:+2,+2,+1) and the river's position as a potential source of national pride (8:+2,+1,+1). Two other statements of consensus (6 and 9) are less powerful in terms of finding meaningful space for cooperation, because, while they do not distinguish factors, all factors ranked them neutrally.

An examination of distinguishing statements shows a high degree of differentiation across user groups, particularly for those statements with highest *z*-score variances (Table 6). It is also interesting to note where one factor differs significantly from the other two. Some of the most differentiating conceptualizations relate to the notion of water quality management as industrial pollution control, the ability to measure water quality in non-technical ways, and the importance of water quality to the every-day lives of people and to livelihoods. The Technical-regulatory (C2) and Directly Engaged (C3) perspectives both believe water quality to be largely a matter of industrial pollution control—a conceptualization not held by Harmonist-holists (C2). Similarly, the Directly Engaged agree that water quality is truly known by direct contact, that the quality of the water is important to everyday lives of citizens, and that women are important to safeguarding water resources—notions the other factors either disagree with or feel neutral about.

Conditions Q-sort results

For the second Q-sort regarding concerns and perceptions of current conditions of water quality, results similarly showed a high degree of differentiation across the four factors that emerged, but far less consensus than in the conceptualization of water quality. Q2 results are presented in Table 7, which again presents the idealized sorts for the four factors.

Interpreted idealized *Conditions* Q-sorts

After rotation, *Conditions* Factor N1—termed General Reformers—has an eigenvalue of 5.44 and explains 17% of the study variance. Eight respondents were significantly associated with this factor.

> **N1, General Reformers:** *Despite the fact that government and communities are working together to keep the river clean (23:+4) and sufficient data is available to support decision-making (28:+4), the watershed has become increasingly polluted (12:+2) and rivers are generally unsafe (13:-4; 14:-3). Agricultural runoff is a significant concern (7:+3), as are deforestation, sand mining, and riverbank erosion (1:+2). It can be agreed that and that factories are not the primary source of pollution (2:-2), but are one of many. Indeed, our water quality problem is also largely a problem of*

TABLE 6 Q1 *Concept* distinguishing statements in order of highest to lowest *z*-score variance.

		C1	C2	C3	*Z*-score variance
5	Maintaining water quality is primarily a matter of controlling and reducing pollution from factories.	−2**	2	2	0.938
12	Water quality is truly known by directly engaging with the water—smelling it, seeing it, touching it.	−1**	−2**	1**	0.808
11	The quality of river water is important for the daily lives of people in the watershed.	0**	1*	3*	0.742
4	I think water quality matters largely with respect to how it affects people's livelihoods.	1*	−1**	2*	0.507
22	Reliable water quality data is needed to support water management decisions.	3	3	0**	0.47
17	Women play a central role in managing and safeguarding water quality.	0*	−2**	2*	0.44
18	River management should be based on a participatory approach that involves users and policy makers at all levels.	3	3	0**	0.337
10	Water quality is a technical issue that should be assessed by experts.	−1*	1**	−2*	0.257
14	We and the river are one and should be in harmony.	2**	0	0	0.253
21	Maintaining water quality is a government responsibility.	−2*	0	−1	0.209
13	Water quality is a measure of how scientific measurements meet water standards set by government.	0	0	−1**	0.134
20	Water quality begins and ends with communities, since they have the most direct experiences with problems and solutions.	0**	−1	−1	0.12
16	Water quality may be important to scientists and environmentalists, but it is not a concern for most people in their everyday lives.	−2	−1*	−2	0.098
2	I notice that the river is clean or dirty by whether it makes people in my community sick after using water for bathing, cooking, washing, or swimming.	0*	−2	−1	0.095
1	Water quality can be judged by the number and diversity fish, insects, and other aquatic species.	1	1	3*	0.093
19	Flood control and water allocation are priorities. Water quality is nice, but it is a secondary issue.	−1	0*	−2	0.079

*Indicates significance at $p < 0.05$ and **indicates significance at $p < 0.01$.

garbage (6:+1). It can also be agreed that communities need more education about water quality and the environment (33:+3), but the under-representation of women is a concern that others may not sufficiently share (25:-2).

Moreover, there are just too many laws and regulations that affect how water quality is managed. Since many agencies are responsible for water quality, no one knows whose responsibility it is (26:+2). It's difficult to know who is supposed to do what (31:+2), and coordination mechanisms are not effective (34:-1). It is also unclear how to report pollution (22:0) or how government controls pollution and responds to complaints (30:-2).

Q-sort Factor 2, the Government Optimists, has an eigenvalue of 4.8 and explains 15% of the study variance. Eight respondents were also significantly associated with this factor.

N2, Government Optimists: *While pollution is, indeed, a concern (14:-3), many parts of the river are not polluted (13:0), and government and communities are working together hand in hand to keep the river clean (23:+4). Moreover, while many government agencies and organizations are involved in managing water quality, coordination mechanisms seem effective (34:+3), and responsibilities for maintaining water quality are clear (26:-2). It is clear how and to whom pollution incidents should be reported (22:+3), and it is transparent how government controls pollution and responds to complaints or incidents (30:+4).*

Factories should be held to standards if they are found to be polluting (32:-3), even at the expense of preserving harmonious relations (15:-1). In fact, regulations on industrial pollution are generally enforced (20:0). Businesses are also generally interested to improve wastewater

TABLE 7 Q-sort statement rankings for idealized *Conditions* factor statements.

	Statement	Factors				Z-score variance	Distinguishing and consensus
		N1	N2	N3	N4		
1	The river is silty and muddy-looking. Deforestation, sand mining, and riverbank erosion should be a focus for managing water quality.	2	1	−2**	1	0.379	Distinguishes N1
2	Factories are the primary source of river pollution.	−2	−2	−2	0*	0.162	Distinguishes N3
3	Communities are a significant source of water pollution through wastewater and garbage.	3**	1	4**	0	0.569	Distinguishes N1 and N3
4	Industries are often held as a scapegoat to put off dealing with waste from domestic sources.	0**	−1	0	−1	0.158	Distinguishes N1
5	Micro-plastics in the river present health risks for humans and wildlife.	1	1	0	3**	0.33	Distinguishes N3
6	Water quality in our river is largely a problem of garbage.	1**	−1	−3	−2	0.445	Distinguishes N1
7	Agricultural runoff from livestock and pesticides is a worrisome source of pollution.	3	2	1	1	0.111	
8	Agriculture is a minor issue. There's not really any indication that it is affecting the river.	−3	−1	−3	−1	0.312	
9	Garbage affects the way the river looks more than it really affects the water.	−2	−3	−4**	−3	0.171	Distinguishes N3
10	The river is the only reasonable place to throw away some kinds of household waste.	−4	−4	−4	−4	0.105	Consensus
11	Communities use the river to dispose of garbage, because it's the only convenient option.	−3	−4	−1**	−4	0.22	Distinguishes N3
12	Over the years the watershed has become more polluted. It's not what it used to be.	2	1	3	3	0.135	
13	Some rivers in the area experience pollution, but the majority are actually quite safe.	−4	0*	−1*	−3	0.587	Distinguishes N2 and N3
14	Most of the rivers are in fairly good shape. A lot of the discussion about water pollution is just hype.	−3	−2	−2	−2	0.095	Consensus
15	A harmonious and supportive approach is preferred to strong enforcement when it comes to managing pollution from factories.	−1	−1	1*	2*	0.32	Distinguishes N3 and N4
16	Most people in communities value clean water and understand that it is important to care for the river.	0	2**	0	0	0.281	Distinguishes N2
17	Businesses are generally interested to improve wastewater management, since clean water is an input for their business.	0	2**	−1	−1	0.169	Distinguishes N2
18	Water quality is significantly impacting the livelihoods of many people that live near the river.	−1	0	1	2*	0.292	Distinguishes N4
19	If the river is deteriorated, it limits opportunities to develop tourism.	0*	2	2	2	0.112	Distinguishes N1
20	Factories regularly get away with illegal dumping. Regulations should be more firmly enforced by government.	1	0**	2	4**	0.433	Distinguishes N2 and N4
21	There are community activities, but they rarely involve decision-making about water quality.	−1	0	−3**	2**	0.62	Distinguishes N3 and N4
22	I know how to report pollution if I see it—where to go or who to call.	0	3**	1	0	0.283	Distinguishes N2
23	Government and communities are working together hand in hand to keep the river clean.	4	4**	2	4	0.18	Distinguishes N2
24	Managing water quality requires quite local knowledge. Solutions transferred from other contexts are unlikely to work here.	0	1	4**	1	0.659	Distinguishes N3
25	Women in are fairly represented in decisions about the river.	−2	0**	−1	−1	0.138	Distinguishes N2
26	Since many agencies are responsible for water quality, no one knows whose responsibility it is.	2**	−2	−1	−1	0.477	Distinguishes N1

(Continued)

TABLE 7 (Continued)

	Statement	Factors				Z-score variance	Distinguishing and consensus
		N1	N2	N3	N4		
27	Solutions to water quality problems and responsibilities are clear and well-known; there just isn't enough money to improve them.	1	0*	1	−2*	0.254	Distinguishes N2 and N4
28	There is enough data on water quality to support decision-making.	4	−1	3	0	0.565	
29	There is lots of water quality data and studies, but nothing seems to be done with it. No follow-up action is taken.	1	−3**	3	1	0.939	Distinguishes N2
30	It is transparent how government controls pollution and responds to incidents or complaints.	−2*	4**	0	0	0.655	Distinguishes N1 and N2
31	There are too many laws and regulations that affect how water quality is managed. It's difficult to know who is supposed to do what.	2	−2	−2	1**	0.55	Distinguishes N4
32	Even if their activities don't yet meet pollution standards, factories must keep running so that jobs aren't lost.	−1**	−3*	0	−2**	0.296	Distinguishes N1, N2, and N4
33	Communities need more education about water quality and the environment.	3	3	2	3	0.066	Consensus
34	While many government agencies and organizations are involved in managing water quality, coordination mechanisms seem effective.	−1**	3**	0**	−3	0.987	Distinguishes N1, N2, and N3

Consensus statements: Do not distinguish between any pairs of factors, noted if statements were non-significant.
Distinguishing statements: * indicates significance at $p < 0.05$ and ** indicates significance at $p < 0.01$.

management, since clean water is an input for their business (17:+2).

We need more data and research to support decision-making (28:-1), but what information is available is applied and followed-up on (29:-3). Most people in communities value clean water and understand that it is important to care for the river (16:+2), though communities can always use more education about water quality and the environment (33:+3). Essentially, things are going well enough with respect to governance: we just need to keep generating knowledge, working together, and finding new sources of finance.

Conditions Factor 3 has an eigenvalue of 4.48 and explains 14% of the study variance. Only four respondents were significantly associated with this factor.

N3, Community-focused Pragmatists: *Responsibilities for water quality management are quite clear (26:-1; 31:-2); government coordination isn't a significant problem (34:0); and information is available to address water quality. In fact, there are lots of studies, but nothing seems to be done with them; no follow-up action is taken (28:+3). The real issues are financial resource limitations (27:+1) and implementation.*

A particular interest is solid waste management and community empowerment to bring local knowledge to solve domestic waste-related problems. Communities are a significant source of water pollution through wastewater and garbage (3:+4), and garbage is affecting river health beyond just aesthetic impacts (9:-4). Managing these and other water quality problems requires local knowledge, and solutions transferred from other contexts are unlikely to work here (24:+4). As such, government and communities could do better to work together (23:+2) in order to bring a harmonious approach to enforcement (15:+1) and build on the established patterns of community participation in decision-making about water quality (21:-3).

The fourth *Conditions* Factor has an eigenvalue of 5.44 and explains 17% of the study variance. Six respondents were significantly associated with this factor.

N4, Industry-focused Reformers: *Water quality is poor and worsening across the basin (13:-3; 12:+3) and is significantly impacting the livelihoods of many people that live near the river (17:+2). Micro-plastics in the river, which present health risks for humans and wildlife, are a particular concern (5:+3). That said, while domestic waste is a source of pollution, it is less worrisome than industry and of lesser importance than other groups believe (3:0;6:-2). Factories are a significant source of water pollution (2:0) and regularly get away with illegal dumping (20:+4). Regulations should be more firmly enforced by government (20:+4), though a harmonious and supportive approach is still preferred when possible (15:+2). There are also too many laws and regulations that affect how water quality is managed, and it's difficult to know who is supposed to do what (31:+1). Coordination across agencies is not effective (34:-3), and communities are rarely involved in decision-making about water quality (21:+2). Moreover, solutions to water quality problems are still not known (27:-2).*

Consensus and distinguishing statements

For the *Conditions* sort, three statements drew consensus across all four factors, and with relatively strong (positive and negative) rankings. First, all factors agreed strongly that communities need more education regarding water quality and water environmental issues (33:+3,+3,+2,+3). Second, all factors disagreed that discussion about water pollution is merely hype (14:-3,-2,-2,-2), confirming that river health is, indeed, a concern for perspective types. Third, all factors disagreed strongly (10:-4,-4,-4,-4) that the river is currently the only reasonable place to dispose of some kinds of household wastes.

With respect to distinguishing statements (Table 8), in some cases, one perspective differed from all others. For example, all factors *except* Industry-focused Reformers (N4) disagreed that factories are the primary source of river pollution (2:-2,-2,-2,0), distinguishing N3 as the only perspective type focused largely on manufacturers as a key component of the water quality problem. Similarly, Community-focused Pragmatists (N3), unlike all other factors, believe that effective water quality management depends on applying local knowledge (24:0,+1,+4,+1), and Government Optimists (N2) is the only viewpoint that agreed strongly that most people value clean water (16:0,+2,0,0) and that pollution reporting methods are clear (22:0,+3,+1,0).

In other cases, two factors align in opposition to the other two. For example, N1 and N3 show significant concern regarding agriculture as a pollution source, whereas N2 and N4 are far more neutral (8:−3,−1,−3,−1). Similarly, N1 and N3 see communities as a significant source of pollution, whereas N2 and N4 are neutral on this issue (3:+3,+1,+4,0).

For some statements, rankings demonstrate neutral stances for one or two factors and divergent opinions from the other two. For example, Government Optimists (N2) disagree strongly that there is no follow-up action to water quality studies, whereas Community-focused Pragmatists (N3) strongly agree, and the others are fairly neutral (29:+1,-3,+3,+1). Similarly, N2 and N4 stand in direct contrast on whether government coordination is effective, which Government Optimists landing on the positive side, Industry-focused Reformers on the negative, and others neutral (34:-1,+3,0-3).

Comparing *Concept* and *Condition* Q-sorts

It might be expected that one's conceptualization of water quality and characterization of current conditions would be correlated to one's affiliation—government, NGO, etc.—and that alternative viewpoints would emerge to reflect a purported government-user-community divide. A look at the factor loadings by respondent type is surprising, however, with respect to the conceptualization of water quality, in that—while government respondents largely assumed the Harmonist-holist viewpoint, they were also relatively distributed over the other two factors. This same is observed for NGO/Community, and SOE/User respondents (Table 9). This is interesting, because it suggests that across all user groups, there is a diversity of conceptualization of water quality itself.

In the case of the *Conditions* sort, Government respondents overwhelmingly associated with N2, Government Optimists (eight of 18 government participants were flagged N2). This is unsurprising, perhaps, since they are the respondents likeliest to see, experience, and know ongoing work in government agencies that deals with water quality management. This is also likely due to the self-referential nature of Q methodology. It is more interesting note that nine of the government respondents were associated with other perspectives more pessimistic about government coordination, clarity of responsibilities and roles, etc., and that no respondents from other groups—NGO/Community, SOE/User, or Academic—were associated with Government Optimists. This shows (for this respondent set) a diversity in opinion regarding current conditions across respondent types, but that non-government respondents were at least aligned in terms of *not* assuming a Government Optimist perspective.

Another interesting finding from this analysis relates to the potential relationships between conceptualization of water quality and perceived conditions. It would be reasonable to expect one's conceptualization of water quality would mediate one's characterization of current conditions and concerns. While the P-set size is relatively small for correlation analysis, a simple frequency table shows that there is no apparent strong link between conceptualization of water quality and the set of concerns that respondents feel are most important to the structure of the water quality problem (Table 10). For example, the three respondents with a Direct Engagement (C3) conceptualization, who were also significantly associated with one of the Conditions factors, were evenly distributed across General Reformers (N1), Community Pragmatists (N3), and Industry-focused Reformers (N4). Similarly, respondents with Harmonist-Holist (C1) conceptualizations were distributed across problem structure viewpoints.

The notable exception to this apparent delinking of conceptualization and problem structure are observations that *no* respondents with a Direct Engagement (C3) conceptualization were associated with Government Optimists (N3) and that *no* respondents with a Technical-regulatory (C2) conceptualization were also associated with Community-focused pragmatists (N3). Rather, only respondents with Harmonist-holist (C1) or Technical-regulatory (C2) conceptualizations were also associated with the Government Optimists (N2) problem structure perspective in Q-sort 2; and only respondents with a Harmonist-holist (C1) or Direct Engagement (C3) conceptualizations were also associated with a Community-focused pragmatist (N3) perspective. These results suggest that, while conceptualization is not a strong determinant

TABLE 8 Q2 *Conditions* distinguishing statements in order of highest to lowest *z*-score variance.

		N1	N2	N3	N4	*Z*-score variance
34	While many government agencies and organizations are involved in managing water quality, coordination mechanisms seem effective.	−1	3	0	−3	0.987
29	There is lots of water quality data and studies, but nothing seems to be done with it. No follow-up action is taken.	1	−3	3	1	0.939
24	Managing water quality requires quite local knowledge. Solutions transferred from other contexts are unlikely to work here.	0	1	4	1	0.659
30	It is transparent how government controls pollution and responds to incidents or complaints.	−2	4	0	0	0.655
21	There are community activities, but they rarely involve decision-making about water quality.	−1	0	−3	2	0.62
13	Some rivers in the area experience pollution, but the majority are actually quite safe.	−4	0	−1	−3	0.587
3	Communities are a significant source of water pollution through wastewater and garbage.	3	1	4	0	0.569
31	There are too many laws and regulations that affect how water quality is managed. It's difficult to know who is supposed to do what.	2	−2	−2	1	0.55
26	Since many agencies are responsible for water quality, no one knows whose responsibility it is.	2	−2	−1	−1	0.477
6	Water quality in our river is largely a problem of garbage.	1	−1	−3	−2	0.445
20	Factories regularly get away with illegal dumping. Regulations should be more firmly enforced by government.	1	0	2	4	0.433
1	The river is silty and muddy-looking. Deforestation, sand mining, and riverbank erosion should be a focus for managing water quality.	2	1	−2	1	0.379
5	Micro-plastics in the river present health risks for humans and wildlife.	1	1	0	3	0.33
15	A harmonious and supportive approach is preferred to strong enforcement when it comes to managing pollution from factories.	−1	−1	1	2	0.32
32	Even if their activities don't yet meet pollution standards, factories must keep running so that jobs aren't lost.	−1	−3	0	−2	0.296
18	Water quality is significantly impacting the livelihoods of many people that live near the river.	−1	0	1	2	0.292
22	I know how to report pollution if I see it—where to go or who to call.	0	3	1	0	0.283
16	Most people in communities value clean water and understand that it is important to care for the river.	0	2	0	0	0.281
27	Solutions to water quality problems and responsibilities are clear and well-known; there just isn't enough money to improve them.	1	0	1	−2	0.254
11	Communities use the river to dispose of garbage, because it's the only convenient option.	−3	−4	−1	−4	0.22
23	Government and communities are working together hand in hand to keep the river clean.	4	4	2	4	0.18
9	Garbage affects the way the river looks more than it really affects the water.	−2	−3	−4	−3	0.171
17	Businesses are generally interested to improve wastewater management, since clean water is an input for their business.	0	2	−1	−1	0.169
2	Factories are the primary source of river pollution.	−2	−2	−2	0	0.162
4	Industries are often held as a scapegoat to put off dealing with waste from domestic sources.	0	−1	0	−1	0.158
25	Women in are fairly represented in decisions about the river.	−2	0	−1	−1	0.138
19	If the river is deteriorated, it limits opportunities to develop tourism.	0	2	2	2	0.112

TABLE 9 Distribution of factor loadings by factor and respondent type.

	Q1 *Concept*				Q2 *Conditions*				
	C0	**C1**	**C2**	**C3**	**N0**	**N1**	**N2**	**N3**	**N4**
Government	3	9	4	2	1	3	8	2	4
NGO/Community	0	3	1	2	3	1	0	0	2
SOE/User	1	2	2	1	1	3	0	2	0
Academic	1	0	1	0	1	1	0	0	0
Total	5	14	8	5	6	8	8	4	6
Male	2	10	6	3	2	5	6	4	4
Female	3	4	2	2	4	3	2	0	0
Total	5	14	8	5	6	8	8	4	4

TABLE 10 Frequency table of respondent Q-sort pairings.

Q1 *Concept*	Q2 *Conditions*	Frequency
C0	N0	0
C0	N1	2
C0	N2	1
C0	N3	2
C0	N4	0
C1	N0	3
C1	N1	3
C1	N2	4
C1	N3	1
C1	N4	3
C2	N0	1
C2	N1	2
C2	N2	3
C2	N3	0
C2	N4	2
C3	N0	2
C3	N1	1
C3	N2	0
C3	N3	1
C3	N4	1

of problem structure for this group of respondents, at least some conceptualizations leave little space for the adoption of some problem structures—and the results hint at the likelihood that Technical-regulatory conceptualizations may be less likely to link to Community-focused Pragmatist problem structures—and the same for Direct Engagement conceptualization and the Government Optimist viewpoint.

Discussion

This analysis of conceptualization and problem structuring aims to better locate hydrological and ecological science in the socially-constructed problem space, inform discussion amongst network participants and managers, and help identify feasible starting points for early collaboration and network-building around issues of consensus. The results show that there is, indeed, a great diversity amongst the stakeholder respondents regarding what water quality discussions "are about" or what water quality is, as well as what the most relevant, challenging, urgent, etc. physical and institutional component sub-problems make up the greater "water quality problem."

Conceptualizations and characterizations of Brantas water quality

The results of the *Concept* Q-sort show that discussions about water quality amongst and between participants in the water management policy network may seem quite straightforward to the participating individuals but can actually involve exchanges of quite dissimilar compositions of the concept itself. The three *Concept* perspective groups in this study, for example, hold different values of water quality and ideas about the ways in which it may be assessed, measured, observed, et cetera. As such, in a deliberation on river health, a holder of the Technical-regulatory perspective would likely appraise water quality with a parameterized approach and consider it largely in terms of governmental pollution control, whereas a Harmonist-holist may be judging water quality by broader considerations that also include biodiversity, economic, and cultural aspects, where "good water quality" is related to harmony amongst elements. In the same discussion, a holder of the Direct Engagement perspective may be more focused on lived experience with the river, livelihoods, and observation of river species. As such, each may bring to the discussion table a similar, but importantly *not* same, construction of water quality that will undoubtedly affect their ideas about both current and desired states of water quality.

Similarly, the results of the *Conditions* sort reflect different perspectives on the state of water quality,

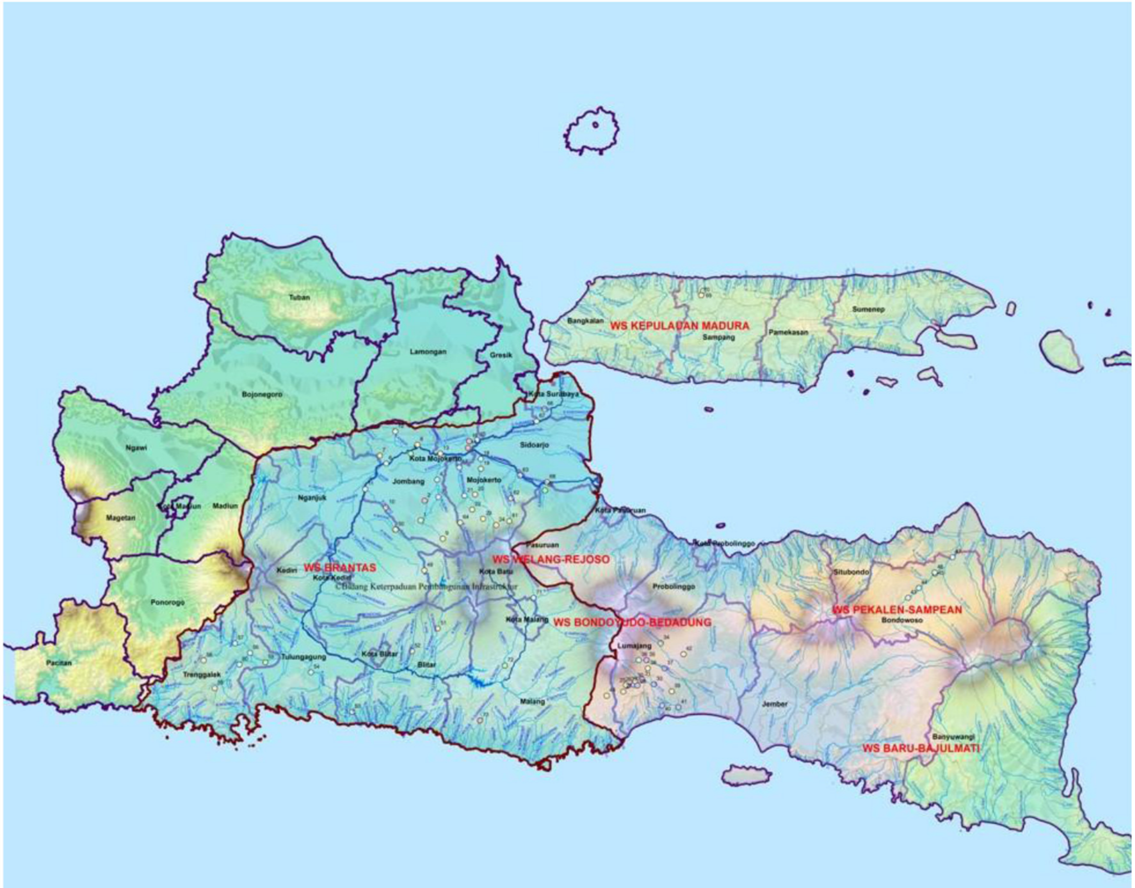


FIGURE 1
Map of WS Brantas within province of East Java. Source: BBWS Brantas Hydrology Information System, 2020, https://sda.pu.go.id/balai/bbwsbrantas/page/sih3/hidrologi.

as well as divergent ideas regarding the impacts of physical pollution sources and institutional, management, informational, and social factors on river health. Notably, some perspectives—General Reformers and Industry-focused Reformers—perceive significant problems in the institutional and management arrangements that suggest a need for focused improvements related to the governance regime, including the allocation of responsibilities and coordinating mechanisms for water management. But even these two perspectives have different ideas about where such efforts should be focused—e.g., at a broader system level for General Reformers or with a more targeted approach to industrial pollution management for Industry-focused Reformers. Government Optimists and Community-focused Pragmatists, on the other hand, are far more positive with respect to current policies and procedures. Both lean toward a focus on improved data collection and application, collaboration, and resource allocation—but the Community-focused Pragmatists are both less positive about standing institutional arrangements and more focused on community-level implementation and experiences with water quality management.

These alternative perspectives are important, because they demonstrate that participants in the policy network engage in decision-making, advocacy, negotiation, cooperation, daily work, discussion, sense-making, et cetera, with standing and constantly developing viewpoints that undoubtedly shape what they consider to be the most important sub-problems related to river health. As such, they will hold different structures of the "water quality problem"—but structures that may change through interactions and deliberations. Explicit consideration of these alternative structures and subsequent deliberation can help drive some convergence in problem definition and support more ready steering of the network toward acceptably shared solutions and, in the case of the Brantas water quality issue network, a potentially more harmonized and coordinated strategy for integrated water quality management.

The results also challenge the common assumption that variant perspectives are reflective of oft-cited government-business-civil society divisions. This finding may be taken both negatively and positively. On the one hand, the finding demonstrates how much conceptualizations and problem structures vary within all groups, which makes water quality management not only complex, but also very complicated. On the other hand, there is an optimism that, if positions are not in fact strongly tied to affiliation, then barriers to cooperating across government and community may be less insurmountable than is often assumed.

Implications for water quality management and policy

This research has several interesting implications for policy makers in the Brantas and other watersheds that involve large numbers of networked actors in water resource management. For one, a better understanding of the diversity of perspectives and viewpoints can inform policy-makers and collaborators regarding the various values and beliefs that may be brought to the table in prioritizing problems and solutions. Because the effective collaboration and coordination across groups depends on effective discussion, negotiation, and deliberation, a more informed deconstruction of water quality as a concept can help participants consider whether they are, indeed, considering, arguing over, agreeing with, questioning, etc. the same issues, or whether they may be talking across purposes about related but not identical constructions of an issue. Moreover, the Q methodological analysis can help challenge or verify assumptions about what water quality conditions are, what more specific sub-issues should be attended to, and what actions are desired.

In the Brantas case, where water quality is rising to the agenda as an issue of increasing concern, and for which networked water quality management arrangements are continuously developing, the results are helpful to identify areas of consensus wherein new collaborators may find common spaces in which to cooperate. The results of this Q study, for example, show that all perspective groups agreed strongly that a clean river is a source of national pride and that communities need more education regarding water quality. For a new integrated water quality management network aiming to foster cooperation across agencies, community education programs that draw on values of national pride and harmony may be easy spaces for early collaboration to develop growing relationships and a sense of common purpose and to legitimize the network itself.

Similarly, areas of great divergence may require more research, evaluation, deliberation, and consideration by larger stakeholder groups in order to narrow the divides amongst participants with respect to their alternative problem structures. In the Brantas, this is the case for such sub-issues as the clarity of responsibilities amongst institutions for water quality management; the effectiveness of coordination mechanisms for implementation of IWRM and planning; the relative severity of industrial vs. domestic and agricultural sources of pollution; and the most appropriate approaches to industrial pollution control and planning for water quality. For these issues, there is a need not only for more research and evaluation, but also for more collective deliberation of research and evaluation findings, desired states, and priorities for improving water quality.

The results also have interesting implications for communication both between government and the citizenry as well as within government, in that they inform communications professionals about the concerns, worries, and cares of various user groups. This is interesting when considering how to promote an issue like water quality that is often relegated to a lower status as compared to water allocation or flood control. Q methodology can also illuminate minority perspectives that may not be widely held, but may nevertheless be important to consider in the interests of both effective policy-making and social justice. These lesser-held perspectives, which might otherwise be ignored in R-methodological research, may nevertheless be important, for example, to understanding how small but powerful perception groups could block policy implementation or to better consider low-power stakeholders' perspectives that may be less apt to be revealed via more typical large-N surveys.

In terms of informing integrated water quality management, remaining questions for follow-up work include the testing of methods to utilize perspective analysis in collaborative and coordinated planning; further research regarding to what extent consensus in problem structuring is necessary to identify policies acceptable to competing viewpoints; and lesson-drawing with respect to negotiating coordinated problem-setting and solution-finding in manners that deal with alternative problem frames. Moreover, the specific consensus and distinguishing statements in the problem structures may be used to set agendas for further scientific and social research in the basin—for example, to add further research where viewpoints strongly diverge—as well as to inform the selection of early topics on which to build cooperative activities and cross-agency collaborations This research posits that systematic (but not necessarily convergent) problem structuring can be informed by Q methodology to support the forming, reordering, and cohering of collaborative networks, especially for issues as complex as river water quality management.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Delft University of Technology Human Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RH and ME contributed to conception of the study. RH designed the study (the Q-sorts), built the online Q-sort surveys, prepared the manual materials for in-person data collection, managed the database, performed the Q methodology analysis, and wrote the manuscript. RH and KP contributed to the research protocol. KP translated Q-sorts and the research protocol and facilitated the online Q-sorts. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2022.1007638/full#supplementary-material

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