

Situating Hydrological Modeling

A Proposal for Engaging With the Power of Models

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Situating Hydrological Modeling: A Proposal for Engaging With the Power of Models

Rossella Alba^{1,2}  | Rozemarijn ter Horst^{3,4}  | Bich Ngoc Tran^{5,6}  | Anja Klein^{2,7,8}  | Krystin Unverzagt²  | Jonatan Godinez-Madrigal⁵  | Andres Verzijl^{4,9}  | Maria Rusca¹⁰  | Jeroen Vos³  | Jean-Philippe Venot¹¹  | Margreet Zwarteveen^{4,9}  | Tobias Krueger^{1,2} 

¹Geography Institute, Humboldt-Universität zu Berlin, Berlin, Germany | ²Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Humboldt-Universität zu Berlin, Berlin, Germany | ³Water Resources Management Group, Wageningen University and Research, Wageningen, the Netherlands | ⁴Water Governance Department, IHE Delft Institute for Water Education, Delft, the Netherlands | ⁵Land & Water Management Department, IHE Delft Institute for Water Education, Delft, the Netherlands | ⁶Delft University of Technology, Delft, the Netherlands | ⁷Institute for European Ethnology, Humboldt-Universität zu Berlin, Berlin, Germany | ⁸TUM School of Social Sciences and Technology, Technische Universität München, Munich, Germany | ⁹University of Amsterdam, Amsterdam, the Netherlands | ¹⁰Global Development Institute, University of Manchester, Manchester, UK | ¹¹UMR G-EAU, IRD, University of Montpellier, Montpellier, France

Correspondence: Rossella Alba (rossella.alba@hu-berlin.de)

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ABSTRACT

A growing scholarship suggests hydrological models have political power as they embed and reinforce specific understandings of water and society relations which, in turn, shape future visions of how and for whom water is to be managed. In this commentary, we explore how the power of models can be explicitly and constructively engaged with, thereby expanding their potential to support transformations to water justice and sustainability. To achieve this, we suggest understanding, analyzing, and doing hydrological modeling as a situated knowledge practice. We take inspiration from feminist scholarship that emphasizes that all forms of knowledge are inherently partial, situated within specific contexts, experiences, and circumstances, and shaped by power relations. Situating hydrological modeling, we argue, requires opening up modeling processes to ask where, how, for whom, and by whom models are developed and used, and how outcomes influence water distributions and conditions of access for different social groups. Situating also opens opportunities to explore what it would take for hydrological modeling to explicitly pursue justice and sustainability goals in context-specific and tangible ways. We present initial insights and invite further experimentation towards making models active agents of a more inclusive, transparent, and transformative water management.

1 | Hydrological Models Are Powerful

Hydrological models are powerful tools that influence how water is known, represented and managed. The power of models lies in their capacity to simplify, represent, and predict,

offering a means to engage with both measurable phenomena and aspects that are uncertain or unknown (Alba et al. 2025). Models simulate complex interrelations between water and society at multiple temporal and spatial scales with the objective of supporting policy makers, researchers, government

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officials or local communities to assess and manage the distribution of and access to water in terms of quantity and quality. Models are for instance mobilized to help solve infrastructural design controversies (Godinez Madrigal et al. 2020), or to assess aquifer conditions (Sanz et al. 2019). Because modeling requires selecting variables, defining conceptual and mathematical relationships, and making assumptions, it is inherently involving choices about what aspects of a hydrological reality to highlight or ignore. Hence, the models have also a political power that lies in their capacity to promote specific understandings of water and society relations (Krueger and Alba 2022), to support particular policy and economic agendas (Budds 2009), and influence imaginaries of the past, present and future (Melsen et al. 2018).

While the political power of hydrological models is increasingly being recognized (Budds 2009; Jensen 2020; Rusca et al. 2023; Alba et al. 2025) and new sets of ‘good’ practices are being proposed (Jakeman et al. 2024; Saltelli et al. 2020; ter Horst et al. 2024; Yalaw et al. 2024), explicitly and constructively engaging with this power remains an open challenge. It is a challenge that unfolds differently each time, depending on the model, the context in which it is developed and the actors involved. In this article, we propose understanding, developing and using hydrological models as situated knowledge practices as a useful way to deal with this challenge. We take inspiration from feminist assertions that all knowledge comes from specific places, experiences and people—in Donna Haraway’s words, knowledge is situated (Haraway 1988). This means knowledge production is also shaped by power relations, by geographical contexts and by histories. Thinking about and doing modeling from such an approach, for us, means first better understanding and openly discussing how hydrological models are developed, where, by whom, for whom, and what the implications are for distributions and qualities of water. Second, it entails an invitation to explore possibilities to model differently, with the explicit goal of fostering transformations to water justice and sustainability (Sultana 2018; Zwartveen and Boelens 2017). In what follows, we offer some insights on how this could be done by drawing from our own experiences in engaging in and researching hydrological modeling.

We are a group of disciplinary and interdisciplinary researchers with diverse backgrounds including human geography, hydrology, anthropology, development studies and water governance. We are based in different European universities and conduct research on water and/or models across different localities in the global North and South. We are involved in various collaborative experimentations with diverse practices of modeling in the context of water governance and beyond. Some of us are experts in hydrological modeling, others focus (among other things) on researching modeling practices with ethnographic and other qualitative methods, and some do both. We share a concern for how conventional hydrological modeling—and other ways of quantifying water—all too often have the effect of channeling water to the most powerful (Molle et al. 2024; Zwartveen et al. 2018; Budds 2009). We also share an interest in exploring the potential that hydrological modeling offers for fostering more just and sustainable water distributions (Krueger and Alba 2022; Rusca et al. 2023; Alba et al. 2025). To us, this starts

by recognizing, documenting and engaging with the power dynamics that shape how water is known and managed through models (ter Horst et al. 2024). It also entails recognizing, valuing and constructively weaving together the many different ways of knowing water that different people and communities carry (Zwartveen 2024). This commentary originates from exchanges and interactions we initiated in 2021 during a virtual workshop (Alba and ter Horst 2022), continued during a summer school on ‘Situating Hydrological Modelling’ we co-organized in 2023 in Berlin and that have been on-going since then.

In what follows, we first briefly describe the political power of hydrological models and then explain how situating them allows for productively engaging with such power. We suggest two ways through which situating models can improve accountability for the power of models and contribute to mobilizing their powers of simplification, representation, and prediction in support of social justice and sustainability.

2 | Acknowledging the Politics of Hydrological Models

Conventional hydrological modeling practice and related scientific literature tend to present models as mere tools to make complex hydrological and hydraulic dynamics legible to researchers and decision-makers. The often-implicit assumption is that models provide an objective and rational way to simplify and represent complex hydrological realities, generating the kind of information that can support decision making. A main concern of those involved in modeling is to make these simplifications ever more accurate and precise, with their models becoming ever better at representing such realities. Yet, a growing scholarship demonstrates that hydrological models and modelers do not simply reveal a water reality that exists independently of the model(ler)s (Lane 2014; Melsen 2022; Rusca and Mazzoleni 2025; ter Horst et al. 2024). Models actively help bring about—or enact—specific versions of such hydrological realities that is they shape how water is actually controlled, distributed, and accessed (Krueger and Alba 2022; Alba et al. 2025).

This is because models rely on and consist of simplifications: their very *raison d’être* is to simplify in order to make complex realities legible and actionable. Simplifications inevitably entail choices about what matters and what does not for a specific modeling purpose and therefore result in foregrounding some relations and not others. Simplifications also reflect and embed specific computing capacities, data availabilities and uncertainties that shape decisions about, for instance, model structure, numerical methods, data handling, and validation procedures. Thus, such decisions are shaped by the historical, geographical and institutional contexts in which models are developed, as well as by the values, worldviews, experiences and pragmatic considerations of those involved in the modeling process (Addor and Melsen 2019; Melsen 2022; Melsen et al. 2018), including their relations with colleagues and more coincidental encounters (Babel et al. 2019). For instance, based on 14 interviews with modelers developing hydrodynamic decision support models in the Netherlands, Remmers et al. (2024) found that modeling choices are largely influenced by modelers’ personal experiences and insights and by institutionalized predefined decisions

including the vision of the organization (in their case a water authority or a consultancy) or the infrastructure provided.

Seemingly technical decisions in modeling do not only make one world visible at the expense of others. They are also infused with ideas and principles about how the world works that precondition how people make the world intelligible, understand the interrelationships of water and society, and recognize knowledge, subjects, issues, and politics as legitimate. Models thus contribute to stabilizing certain regimes of intelligibility, of structuring water and society relations, and of ethics (Unverzagt 2023). For instance, they might assume particular societal goals and action priorities and for whom and how they should be known, measured and achieved. One example is provided by Krueger and Alba (2022) who reflect on an hydrological model developed to inform decision-making about aquatic pollution in the UK. Developed by a hydrologist, the initial version of the model neglected land management effects on aquatic pollution focusing rather on land use changes. Doing this meant, in turn, prefiguring a future where changes in land use were the only possible pollution mitigation strategy, a suggestion that was not well received by the farmers whose land was to be used differently. Another example is a model commissioned by the government of Mexico to the UNOPS (United Nations Office for Project Services) to guide decision-making and resolve the conflict around the Zapotillo dam and water transfer project (Godinez Madrigal et al. 2020). The model results importantly shaped water allocation between the Rio Verde and the cities of Guadalajara and León, co-determining the future of communities living around the dam. Indeed, based on the model results for the reliability, vulnerability, and resilience indicators of the whole water transfer, it was decided that the most suitable height for the Zapotillo dam would be 105 m—the highest possible option. Constructing such a high dam, however, implied the flooding of three rural communities in the Rio Verde basin. The model did not identify this as problematic, as the chosen indicators narrowly considered the interests of urban actors to the neglect of those of rural actors (ibid.). Eventually, the intervention of UNOPS did not yield the intended outcome of generating trust to resolve the water conflict that continued for another six years. This example is illustrative of how models play a key role in shaping not only imaginaries but actual infrastructural interventions (Melsen et al. 2018).

A growing scholarship within the water sector (Jakeman et al. 2024; Molle et al. 2024; Rusca and Mazzoleni 2025; ter Horst et al. 2024; Yalaw et al. 2024) and beyond (Rivadeneira and Carton 2022; Saltelli et al. 2020) is acknowledging and analyzing the political power of models and modeling. We find this encouraging. However, we believe further steps are needed to devise ways of doing modeling that more explicitly account for, and more consciously engage with, the distributive effects and the power in and of modeling.

3 | Engaging With the Power of Hydrological Models Through Situating

One way of embracing the power of hydrological models is to engage with them as situated knowledge practices. This draws on feminist water (Acevedo-Guerrero et al. 2024) and philosophy

of science scholars, particularly Donna Haraway (1988) who argues that detachment and universality are unachievable and politically problematic norms of scientific objectivity. As an alternative, Haraway proposes defining objectivity as partial situatedness. Haraway invites researchers to acknowledge and critically navigate the fact that all scientific knowledge is shaped by their positionalities and the socio-political and cultural contexts in which knowledge-making takes place. Doing this also entails cultivating awareness of and reflecting on the origins of concepts and frameworks used, especially those that present themselves (or are presented) as universally valid (Zwartveen 2024). Acknowledging that the preference for certain approaches and methods is always also social opens the door to questions about whose knowledges, expertise, values, and interests count (most) and directs attention to how different knowledges can be integrated or about how knowledges can be translated across contexts (Acevedo-Guerrero et al. 2024). Situating hydrological modeling, we believe, implies developing an approach where the organizational principles, assumptions, contexts, people, and choices that underpin a modeling process are made explicit and open for discussion. Bringing together our experiences in researching modeling in sustainability science (Klein et al. 2024), in hydrology (ter Horst et al. 2024) and in groundwater governance (Verzijl et al. 2023), we suggest that thinking and doing modeling as always partial and situated has at least three implications.

First, situating models is an invitation to trace how modeling is intimately tied to social, epistemic, material, institutional, political, historical, and ethical contexts. Second, it questions who is (or should be) involved and who instead is excluded from the development of a model, and how. This includes explicitly reflecting on the role of modelers, their choices, perspectives, values, and interests, as well as critically scrutinizing those who commission, develop, use, or disseminate models. It also includes reflecting on the role and stances of other researchers, social scientists in particular, in critically scrutinizing hydrological modeling practices and in exploring novel productive ways to work with models and modelers. Third, situating models creates space for considering more than one model or more than one way of knowing in understanding a specific hydrological reality and for critically (re-)considering the relative usefulness of models for answering specific research and societal questions. This in turn creates useful possibilities for comparison and conversation between different models and between models and other forms of knowledge-making. This can, for instance, lead to changing initial assumptions, dealing differently with uncertainties, choosing different methods or validation procedures, or inviting different actors to join the modeling process.

Situating models entails asking questions such as: What and whose concerns does a hydrological model make visible? How do choices on model structure, calibration, validation, and data management shape outcomes? Who funds the model, and why? Which discourses and interventions does a model afford or foreclose? What role do technologies play in shaping the development and use of models? What happens when a model developed from/for a specific context is transferred elsewhere? What are past or potential effects of the application of the model, and what do these mean for different actors-human and other-than-human? How does a different set of assumptions change model

outcomes? By responding to questions like these, modelers can explicitly trace and reflect on their choices as they go about modeling by keeping notes, discussing influential modeling junctures with colleagues, or more elaborately through autoethnography. For instance, Eitzel (2023) uses autoethnography as a way to find out if following a specific set of best practices results in her own modeling practices being more relevant, trustworthy, and just than they would be otherwise.

Alternatively, modelers and commissioners could invite researchers with different disciplinary backgrounds (Rusca et al. 2023; Unverzagt et al. *in press*) and/or publics to follow the modeling process (Klein et al. 2024; Melsen et al. 2018; ter Horst et al. 2024). Such collaborations could take the form of ethnographic research as in the tradition of laboratory studies in Science and Technology Studies (Latour and Woolgar 1986) where ethnographers spend considerable time observing, interviewing and informally talking with modelers (as well as other people involved in modeling processes) as a way to document their everyday modeling practices (see for instance, Unverzagt 2023). This is an approach that is also useful for illuminating the role of tacit knowledge, routines, improvisation, emotions and values in mundane modeling decisions and actions. Collaboration could also take the form of involving the broader public in the modeling process, as in the case described by Lane and colleagues (Landström et al. 2011; Lane et al. 2011; Whatmore and Landström 2011). They used hydrological modeling as a tool to engage communities in two English towns that had experienced severe flooding. People from these communities expressed a general lack of trust in science and local governance. A team of researchers from the natural and social sciences collaborated with volunteer residents in an experiment to develop alternative approaches to flood risk management. By using local experiences and understandings of floods and the local environment as the starting point, the experiment usefully redistributed expertise among participants and challenged some of the assumptions of modelers. Together, scientists and residents produced a model that integrated diverse knowledges. The modeling process transformed a knowledge controversy on flood risk management into a “generative event in which expert reasoning was forced to ‘slow down’ and a space for reasoning differently opened up, involving those affected in new political opportunities and associations” (Whatmore and Landström 2011, p. 604). Or, yet again, social scientists could take a more proactive role in working with models and modelers to develop methodological approaches and formats to accompany models, for instance by narrating the development of a model—as it is done in policy narrative analysis (Roe 1994)—or through storytelling methods.

4 | Situating Hydrological Models for Just Transformations

Understanding models as partial and situated knowledge practices offers opportunities for more explicitly mobilizing modeling in support of transformations towards sustainability and justice in at least two ways. First, if modelers and non-modelers work to explore and make transparent models’ ontological, epistemic and normative underpinnings, it becomes possible for them and others to ask which changes in model assumptions

would allow pursuing concrete and case-specific social justice and sustainability goals. In this way, models can become catalysts for developing new imaginaries, exploring possibilities for radical change and gauging which alternative futures are desirable (Rusca et al. 2023). If, as Beck and Krueger (2016, p. 639) observe, models possess “moral agency” and, they function as a world-making practices (Alba et al. 2025), then they can potentially also “proliferate rather than foreclose possibilities for transformative change” (Rusca 2024, p. 6).

Going back to the Zapotillo dam case described above, a study critically analyzing the composition of the model realized that the recommendations of the UNOPS team in terms of the dam’s height and water allocation did not consider future water demands in the donor basin, nor the impact of climate change on water availability in the region. Neither did the model allow for any other infrastructure than a large-scale water transfer project (Godinez Madrigal et al. 2020). As a follow-up, that same research team, therefore, developed a new model. This time, the missing variables were included, and the interests and claims of marginalized grassroots groups—especially those communities that were at risk of being flooded by the reservoir—were taken into account (Godinez Madrigal et al. 2022). The new results pointed to previously disregarded strategies such as demand management, which together with grassroots mobilization and the election of a new president of Mexico contributed to the possibility of a different configuration of the dam (with a lower reservoir height thus avoiding flooding of communities) and alternatives urban water supply strategies to be considered and eventually implemented (Godinez Madrigal et al. 2024).

Second, understanding modeling as a partial and situated way of knowing opens up spaces to explore if and how modeling compares with and can be complemented by other ways of knowing water. Contrasting the practices of predicting groundwater flows through modeling with local expertise on dowsing, for instance, pluralizes understandings of groundwater flows and governance (Verzija et al. 2023). Similarly, iterative exchanges between hydrologists and communal water stewards not only allow for more robust knowledge of aquifer recharge but also facilitate the emergence of new research questions (Saidani et al. 2024). In a slightly different vein, social scientists could collaborate with modelers and non-modelers in the development of a narrative, for example in the form of a text, that could accompany the model. Such an accompanying narrative could go beyond a mere description of the modeling process (e.g., a protocol), to include reflections about the limits and opportunities afforded by the model in terms of understanding a specific water-related issue. Participatory modeling approaches such as serious games or agent-based models (ABMs) created as part of simulation exercises are yet another approach to open up models and modeling expertise for critical questioning. Such approaches provide a forum for experts, policymakers, farmers and fishermen, for example, to learn, explore and speculate together about alternative landscape scenarios (Venot et al. 2022a). For hydrological modeling, examples of this are offered by Whitman et al. (2015) and by McDonald et al. (2022). The first example presents a case of collaboration between physical geographers and a UK Rivers Trust in researching farm slurry pollution in the UK. The authors show how participatory action research is a helpful approach to recognizing that “expertise can be ‘certified’

in multiple ways” (p. 635) and this in turn “has the potential to produce both innovation and more egalitarian research relations” (p.635). The latter example documents how close engagement between researchers and indigenous communities in the co-creation of an ABM contributed to integrate community needs and cultural traditions in understanding and addressing water-related risks. Overall, we believe, comparing and complementing hydrological modeling with other methodological tools and forms of knowledge-making helps appreciating the plurality of water worlds and generates useful questions about other possible ways of understanding and managing water (Saidani et al. 2024; Venot et al. 2022b).

5 | Conclusion: Towards New Practices of Modeling

In this commentary, we suggest situating hydrological models as a way towards more explicitly mobilizing modeling for just water transformation. For us, this is an invitation to, first, trace how modeling practices are shaped by their social, epistemic, material, institutional, political, historical, and ethical contexts. Second, it entails questioning who is involved in modeling processes and how these processes unfold. Third, it calls for attention to the specificities of each water issue, asking whether, and in what ways, hydrological modeling can serve as a meaningful knowledge-making practice to support transformations towards justice. By engaging with, taking, and sharing responsibility for how a model is partial and situated, different modeling routines can begin to be developed, those that encourage more open debate about which and whose political concerns the model addresses, and which futures the model makes (or ought to make) possible. These new routines adopt a new definition of objectivity, one premised on recognizing that all knowledge is shaped by positionalities and contexts. Situating models accepts that results will always be local, preliminary, and partial, and that the solutions supported by models are tentative and temporary yet have the political power to have socially and ecologically differentiating effects in the real world.

A shift towards situating hydrological modeling is no small feat, as it entails (un)learning and unsettling entrenched research practices and ways of understanding knowledge production. It calls upon modelers to further engage in forms of reflexivity and critical analysis. Simultaneously, it calls upon social scientists to make their critiques of models more productive, something that may include ‘stepping into’ the modeling process, for example by contributing to develop narratives that can accompany modeling. Doing this is likely to be uncomfortable for some (modelers and non-modelers), and help others to shift perspectives (Riaux et al. 2023). Acquiring the skills to conduct autoethnography and engaging in critical analysis requires effort, especially for those not trained in social science methods. Translating findings of ethnographic research and critical social science insights on the politics of modeling into productive propositions that are understandable and helpful for modelers likewise entails the willingness to delve into the numbers, equations, and mathematical formulations that modellers use, something that many social scientists may not find easy. Rather than as individual efforts, we see potential in inter- and transdisciplinary collaborations where social and natural scientists, modelers and

non-modelers, commissioners and affected communities jointly engage in developing and reflecting about modeling practices (Krueger et al. 2016). Hence, situating hydrological modeling is also an invitation to devise new forms of collaborations to effectively engage natural and social sciences in the processes of developing, using, and critiquing modeling. We recognize some may fear that our proposal might threaten the public acceptance and social relevance of hydrological modeling and more broadly scientific knowledge production at a time when “alternative truths” multiply (this point is further elaborated in Alba et al. 2025). Yet, we believe that by strengthening communication and collaboration between research, policy-making, and on-the-ground realities, situating models will more strongly anchor them in real-world contexts which in turn will provide different, yet stronger, grounds for judging their acceptance and relevance.

We have sketched some first promising attempts towards situating hydrological models, showing how these can contribute to much needed reflexivity and pluralization of approaches to understand and manage water and society relations (Macpherson et al. 2024; Venot et al. 2022b), while opening up their potential to contribute to just transformations. Yet, the new political, epistemological, and ethical modeling routines required are in no way settled. Developing such routines will likely be a dynamic process, one that is difficult to capture in a set of defined procedural guidelines. Following feminist scholars (Zwarteveen 2024), we believe that more than one way of situating hydrological modeling is possible and desirable, each depending on the specific context and the people involved and/or excluded. Ultimately, situating models is about engaging with a diversity of practices as part of on-going, open-ended and always partial attempts of reflecting and doing modeling. We invite the community of water researchers from all traditions to creatively engage with our proposition and join us in modeling differently.

Author Contributions

Rossella Alba: conceptualization (equal), writing – original draft (lead). **Rozemarijn ter Horst:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Bich Ngoc Tran:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Anja Klein:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Krystin Unverzagt:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Jonatan Godinez-Madriral:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Andres Verzijl:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Maria Rusca:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Jeroen Vos:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Jean-Philippe Venot:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Margreet Zwarteveen:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal). **Tobias Krueger:** conceptualization (equal), writing – original draft (equal), writing – review and editing (equal).

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

References

- Acevedo-Guerrero, T., L. Bossenbroek, I. Leonardelli, M. Zwartveen, and S. Kulkarni. 2024. *Routledge Handbook of Gender and Water Governance*. Taylor & Francis.
- Addor, N., and L. Melsen. 2019. "Legacy, Rather Than Adequacy, Drives the Selection of Hydrological Models." *Water Resources Research* 55, no. 1: 378–390.
- Alba, R., and R. ter Horst. 2022. "Towards a Reflexive Approach: Connecting Critical Research on Water Modelling." <https://flows.hypotheses.org/7300>.
- Alba, R., T. Krueger, L. Melsen, and J. P. Venot. 2025. "Modelling Water Worlds." *Water Alternatives* 18, no. 2: 214–239.
- Babel, L., D. Vinck, and D. Karssenbergh. 2019. "Decision-Making in Model Construction: Unveiling Habits." *Environmental Modelling & Software* 120: 104490.
- Beck, M., and T. Krueger. 2016. "The Epistemic, Ethical, and Political Dimensions of Uncertainty in Integrated Assessment Modeling." *Wiley Interdisciplinary Reviews: Climate Change* 7, no. 5: 627–645.
- Budds, J. 2009. "Contested H₂O: Science, Policy and Politics in Water Resources Management in Chile." *Geoforum* 40, no. 3: 418–430.
- Eitzel, M. 2023. "Autoethnographic Assessment of a Manifesto for More Trustworthy, Relevant, and Just Models." *Environmental Modelling & Software* 164: 105690.
- Godinez Madrigal, J., N. Van Cauwenbergh, and P. van der Zaag. 2020. "Unraveling Intractable Water Conflicts: The Entanglement of Science and Politics in Decision-Making on Large Hydraulic Infrastructure." *Hydrology and Earth System Sciences* 24, no. 10: 4903–4921.
- Godinez Madrigal, J., N. Van Cauwenbergh, H. Ochoa-Garcia, and P. van der Zaag. 2024. "Can Grassroots Movements in Water Conflicts Drive Socio-Technical Transitions in Water Management Systems?" *Environmental Innovation and Societal Transitions* 51: 100837.
- Godinez Madrigal, J., N. Van Cauwenbergh, J. Hoogesteger, P. Claire Gutierrez, and P. Van Der Zaag. 2022. "The Limits to Large-Scale Supply Augmentation: Exploring the Crossroads of Conflicting Urban Water System Development Pathways." *Hydrology and Earth System Sciences* 26, no. 4: 885–902.
- Haraway, D. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective 1." *Feminist Studies* 14, no. 3: 575–599.
- Jakeman, A. J., S. Elsawah, H.-H. Wang, S. H. Hamilton, L. Melsen, and V. Grimm. 2024. "Towards Normalizing Good Practice Across the Whole Modeling Cycle: Its Instrumentation and Future Research Topics." *Socio-Environmental Systems Modelling* 6: 18755–18755.
- Jensen, C. B. 2020. "A Flood of Models: Mekong Ecologies of Comparison." *Social Studies of Science* 50, no. 1: 76–93.
- Klein, A., K. Unverzagt, R. Alba, et al. 2024. "From Situated Knowledges to Situated Modelling: A Relational Framework for Simulation Modelling." *Ecosystems and People* 20, no. 1: 2361706.
- Krueger, T., and R. Alba. 2022. "Ontological and Epistemological Commitments in Interdisciplinary Water Research: Uncertainty as an Entry Point for Reflexion." *Frontiers in Water* 4: 1038322.
- Krueger, T., C. Maynard, G. Carr, A. Bruns, E. N. Mueller, and S. Lane. 2016. "A Transdisciplinary Account of Water Research." *Wiley Interdisciplinary Reviews: Water* 3, no. 3: 369–389.
- Landström, C., S. J. Whatmore, S. N. Lane, N. A. Odoni, N. Ward, and S. Bradley. 2011. "Coproducing Flood Risk Knowledge: Redistributing Expertise in Critical 'Participatory Modelling'." *Environment and Planning A* 43, no. 7: 1617–1633.
- Lane, S. N. 2014. "Acting, Predicting and Intervening in a Socio-Hydrological World." *Hydrology and Earth System Sciences* 18, no. 3: 927–952.
- Lane, S. N., C. Landström, and S. J. Whatmore. 2011. "Imagining Flood Futures: Risk Assessment and Management in Practice." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369, no. 1942: 1784–1806.
- Latour, B., and S. Woolgar. 1986. *Laboratory Life: The Construction of Scientific Facts*. Princeton University Press.
- Macpherson, E., R. I. Cuppari, A. Kagawa-Viviani, et al. 2024. "Setting a Pluralist Agenda for Water Governance: Why Power and Scale Matter." *WIREs Water* 11: e1734.
- McDonald, G. W., L. Bradford, M. Neapetung, et al. 2022. "Case Study of Collaborative Modeling in an Indigenous Community." *Watermark* 14, no. 17: 2601.
- Melsen, L. A. 2022. "It Takes a Village to Run a Model—The Social Practices of Hydrological Modeling." *Water Resources Research* 58, no. 2: e2021WR030600.
- Melsen, L. A., J. Vos, and R. Boelens. 2018. "What Is the Role of the Model in Socio-Hydrology? Discussion of Prediction in a Socio-Hydrological World." *Hydrological Sciences Journal* 63, no. 9: 1435–1443.
- Molle, F., B. Lankford, and R. Lave. 2024. "Water and the Politics of Quantification: A Programmatic Review." *Water Alternatives* 17, no. 2: 325–347.
- Remmers, J., A. Teuling, and L. Melsen. 2024. "A Modeller's Fingerprint on Hydrodynamic Decision Support Modelling." *Environmental Modelling & Software* 181: 106167.
- Riaux, J., M. Kuper, S. Massuel, and I. Mekki. 2023. "Riding the Waves of Discomforts: Reflecting on the Dialogue of Hydrologists With Society." *Journal of Hydrology* 626: 130189.
- Rivadeneira, N. R., and W. Carton. 2022. "(In)justice in Modelled Climate Futures: A Review of Integrated Assessment Modelling Critiques Through a Justice Lens." *Energy Research & Social Science* 92: 102781.
- Roe, E. 1994. *Narrative Policy Analysis: Theory and Practice*. Duke University Press.
- Rusca, M. 2024. "Towards a Future-Oriented Political Ecology of Climate Change." *Geoforum* 153: 103921.
- Rusca, M., and M. Mazzoleni. 2025. "The Interface Between Hydrological Modelling and Political Ecology." In *The Field Guide to Mixing Social and Biophysical Methods in Environmental Research*, edited by R. Lave and S. Lane, 247–278. Open book Publisher.
- Rusca, M., M. Mazzoleni, A. Barcena, E. Savelli, and G. Messori. 2023. "Speculative Political Ecologies:(Re) Imagining Urban Futures of Climate Extremes." *Journal of Political Ecology*, no. 3: 581–608.
- Saidani, M. A., C. Leduc, P. Baudron, and M. Kuper. 2024. "Weaving Different Forms of Knowledge of Managed Aquifer Recharge in a Saharan Oasis (Algeria)." *Journal of Hydrology* 642: 131895.
- Saltelli, A., G. Bammer, I. Bruno, et al. 2020. *Five Ways to Ensure That Models Serve Society: A Manifesto*. Nature Publishing Group.
- Sanz, D., J. Vos, F. Rambags, J. Hoogesteger, E. Cassiraga, and J. J. Gómez-Alday. 2019. "The Social Construction and Consequences of Groundwater Modelling: Insight From the Mancha Oriental Aquifer,

- Spain." *International Journal of Water Resources Development* 35, no. 5: 808–829.
- Sultana, F. 2018. "Water Justice: Why It Matters and How to Achieve It." *Water International* 43, no. 4: 483–493.
- ter Horst, R., R. Alba, J. Vos, et al. 2024. "Making a Case for Power-Sensitive Water Modelling: A Literature Review." *Hydrology and Earth System Sciences* 28, no. 17: 4157–4186.
- Unverzagt, K. 2023. "Enactments of Knowledge and Social Order in Participatory Modelling. An Ethnographic Perspective on the Relationship between Science and Democracy [PhD dissertation]. Humboldt-Universität zu Berlin."
- Unverzagt, K., T. Krueger, A. Klein, S. Somogyváry, and R. Alba. In press. "Situating Bayesian Knowledge: A Case Study of Modelling Pollutant Transfers from Land to Water." *Computational Culture*.
- Venot, J.-P., C. B. Jensen, and E. Delay. 2022a. "Mosaic Glimpses: Serious Games, Generous Constraints, and Sustainable Futures in Kandal, Cambodia." *World Development* 151: 105779.
- Venot, J.-P., J. Vos, F. Molle, et al. 2022b. "A Bridge Over Troubled Waters." *Nature Sustainability* 5, no. 2: 92–92.
- Verzijl, A., M. Vivek, A. Prayag, V. Srinivasan, C. Domínguez-Guzmán, and M. Zwarteveen. 2023. "From Divine to Design: Unearthing Groundwater Practices in Tamil Nadu, India." *Water Alternatives* 16, no. 1: 153–170.
- Whatmore, S. J., and C. Landström. 2011. "Flood Apprentices: An Exercise in Making Things Public." *Economy and Society* 40, no. 4: 582–610.
- Whitman, G. P., R. Pain, and D. G. Milledge. 2015. "Going With the Flow? Using Participatory Action Research in Physical Geography." *Progress in Physical Geography* 39, no. 5: 622–639.
- Yalew, S., P. Prasad, M. Mul, and P. van der Zaag. 2024. "Integrating Equity and Justice Principles in Water Resources Modeling and Management." *Environmental Research Letters* 19, no. 11: 111001.
- Zwarteveen, M. 2024. "Feminist Contributions to Water and Development Scholarship." In *Routledge Handbook of Water and Development*. Routledge.
- Zwarteveen, M., and R. Boelens. 2017. "Defining, Researching and Struggling for Water Justice: Some Conceptual Building Blocks for Research and Action." In *Hydrosocial Territories and Water Equity: Theory, Governance, and Sites of Struggle*, edited by R. Boelens, B. Crow, J. Hoogesteger, F. Lu, E. Swyngedouw, and J. Vos, 8–23. Routledge.
- Zwarteveen, M., H. Smit, C. Domínguez Guzmán, et al. 2018. "Accounting for Water. Questions of Environmental Representation in a Nonmodern World." In *Rethinking Environmentalism: Linking Justice, Sustainability and Diversity*, edited by S. Lele, E. S. Brondizio, J. Byrne, G. M. Mace, and J. Martinez-Alier, 227–249. MIT Press.