CRISIS INFORMATICS IN THE ANTHROPOCENE:

DISASTERS AS MATTERS OF CARE

by

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Crisis Informatics in the Anthropocene: Disasters as Matters of Care

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The information technologies that experts use to make sense of environmental challenges like disasters and climate change increasingly determine how we plan and execute responses. Alongside the rise of computing over the past half century, we have also witnessed the development of tools like satellite imagery, GPS, and environmental modeling. These tools now intervene in our understanding the world and our place in it with a depth and influence that was previously unimaginable. We might be forgiven for expecting that such changes would lead to a radically new relationship with the environment and an ability to finally and permanently vanquish disasters. Unfortunately disasters persist and our environmental problems are more challenging than ever.

In this dissertation I show that the technologies deployed to understand and enact responses to environmental challenges frequently serve to reinforce or exacerbate the factors that create these problems. I use qualitative and design research across three field sites and engage with literature in human-centered computing and science and technology studies to account for this situation and illustrate some of the specific mechanisms by which this occurs. Against arguments that would blame this situation on characteristics essential to either technology or human nature, I instead identify a series of recurring configurations of information technology and social life that systematically produce troublesome understandings of nature-society relations.

I argue that attending to the ways technology shapes our relationship to the environment is, in the language of feminist scholars of techno-science, an act of care. Practices of care are necessary to navigate the current upheaval along the nature/culture

divide and provide a departure from past approaches to dealing with disasters characterized by relations of domination, exclusionary notions of expertise, and reductive epistemological stances. By surfacing the ways that our information systems that sustain problematic approaches and identifying tactics within the toolbox of design research and practice to resist them, I raise the opportunity for alternative approaches to developing environmental information systems. In doing so, I provide the theoretical and conceptual foundations, as well as practical suggestions, for a crisis informatics that can achieve safety, justice, and sustainability in the Anthropocene.

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CHAPTER 1: THE ANTHROPOCENE GAZE

Introduction

My goal for this dissertation is to develop a critique of the new information and communication technologies (ICTs) that have reshaped how experts understand environmental problems over the past five decades. For better or worse, the technologies and socio-technical practices used to understand environmental issues in turn shape the kinds of responses we can imagine. In my career as a software developer, data analyst, and cartographer prior to beginning my PhD studies, I often felt that the kinds of information products my colleagues and I were producing failed to adequately capture the real issues at stake in the disaster response, environmental conservation, and international development contexts that I was working in. I witnessed how our maps, models, and statistics privileged the powerful perspectives of the government, international organizations, and large non-profit organizations, or served to limit discussion of complex multi-faceted issues to the aspects that could be most easily quantified. I saw that if we weren't careful, the tools and technologies we were developing to understand the world, could be used to exacerbate the very problems we were hoping to address. I wanted to understand more about the specific ways in which these issues worked, and what options there might be for envisioning alternatives.

I use the term "the Anthropocene gaze" to describe the set of epistemological and ontological (onto-epistemic (Chandler 2018)) commitments that shape the design and utilization of contemporary environmental information systems. The Anthropocene gaze is a vision of global crisis driven by exponential and unrelenting growth of the scale and reach

of human activity. Human exceptionalism, liberal individualism, and techno-scientific progress combine and collide with the material limits of a finite earth to provoke ever-more desperate efforts to calculate, manage, and rationalize nature/culture relations (Crist 2016). At the same time, participants in this discourse are struck by the disorientation and the foreshortened view of the future horizon characteristic of moments when, in Marx's phrasing, "all that is solid melts into air". Crises function as breaks in discourse, periods of transition during which old concepts and ways of thinking and being seem to fail and potential replacements aren't yet able to bear the weight we need them to. Our means of apprehending contemporary crises are increasingly mediated by information systems and infrastructures that are sometimes global in scale. As this dissertation will show, the tools shaped by the Anthropocene gaze respond to contemporary environmental crises by doubling down on 20th century efforts to discipline human relations with the environment through ever more precise and granular datasets, more powerful models, and more panoptic real-time sensing techniques.

The influence of the Anthropocene gaze on our environmental information systems has in many ways had unfortunate effects on how we respond to environmental crises like disasters and climate change. Many of these systems portray disaster as being temporally limited, extraordinary events triggered by external causes, directing attention away from the longer arcs of vulnerability (Blaikie et al 2015). Information systems used to guide response activities cast disaster-affected populations as helpless victims, if not predatory mobs, a portrayal that legitimates a disaster response focused as concerned with securing private property, investigating aid requests for possible fraud, and controlling

violence as supporting the recovery of those affected (Fassin 2012, Tierney et al 2006). Environmental models used in planning and mitigation efforts frame disaster risk as something ultimately quantifiable, leading to questionable attempts to tame danger through schemes such as actuarial models and insurance pools. Though these perspectives have been critiqued in the social sciences for decades (Lupton 1999, Perry 2007, Tierney 1999, Watts 1983), they persist in new forms, shaped, aided, and abetted by the tools we use to understand disasters and other environmental challenges.

To understand the specific ways that the Anthropocene gaze influences our information systems, this research uses qualitative research methods such as participant observation, semi-structured interviews, and careful analysis of information technologies. I also draw on design research to probe the information systems surrounding disasters and experiment with alternatives. In Boulder, CO one of the most flood-prone areas in the country and the birthplace of contemporary approaches to flood management, I examined the work that goes into the production of the 100-year floodplain map and some of the ways it contributes to ongoing risk in the area. In Nepal, site of one of the most devastating earthquakes in recent memory, my research shows how approaches for measuring damage serve to enable some kinds of disaster recovery while disabling others. My research in the San Francisco Bay area examined the intersection of sea-level rise models with competing visions of the future of the region. Through bringing together these diverse examples into a multi-sited research project, I illlustrate the common logics at work, those of the Anthropocene gaze, and explore the alternatives that new sorts of crisis informatics might offer.

The overarching research questions that guide this work are:

1 - What discourses of crisis do contemporary practices of informating disasters and climate change support?

2 – How do these discourses enable certain approaches to coping with crisis while foreclosing other possibilities, and with what effect?

3 – What, if any, possible alternative information practices do the traditions of critical and participatory research and design suggest?

I begin this chapter by discussing the Anthropocene, and the sorts of relationships with the world that the Anthropocene gaze might yield. As the dominant narrative about contemporary nature/society relations, this interwoven set of ideas, concepts, and methods of sense-making shapes the information technologies we use to interpret the world, and in turn is buttressed by them. With this foundation, I then provide an overview of my research approach, which draws heavily on concepts from human-computer interaction and science and technology studies. I then turn to a short discussion of my field sites, their settings, and my particular research questions and methods in each. Finally, I close this chapter with a map of the rest of the dissertation.

The Anthropocene Gaze

The present epoch has been named, though not uncontroversially, the Anthropocene. Subscribers to this designation characterize the "age of man" as a period of great upheaval and uncertainty as humanity comes to grips with the planetary impact of our activities. The concept provokes not only alarm at the existential consequences of runaway climate change, widespread species extinction, and a terrifying litany of damage and loss that scientists have observed and predict to worsen, but also an increased sense of responsibility for the state of the what used to be understood as the "natural" world (Purdy 2015). For if we have such great effect, should we not seek to better understand and in turn alter our behavior to ensure these effects accomplish ends we find more desirable? Rather than raising more fundamental questions about our approach to understanding environmental issues, such thinking has supported even greater efforts to calculate, quantify, and rationalize relations along the nature/culture divide. Advances in information technology in recent years have both enabled and emboldened such thinking. In this section I develop the idea of the "Anthropocene gaze" as a way of describing the imbrication of information technology and this relationship to environmental issues.

Some critics of the term Anthropocene point out that its usage has the effect of naturalizing a historical mode of relating to the world and each other, capitalism, and have suggested "Capitalocene" instead (Haraway 2016, Moore 2016). Others have taken issue with how the "anthropos" here is undifferentiated, mute on the linkage between colonial histories of oppression and environmental degradation, and serves to mask deep inequalities both in terms of who is benefitting from environmental change and who is

experiencing its negative effects (Yusoff 2019). The Anthropocene is also a profoundly pessimistic story, and indeed one of its most powerful evocations is that of a sense of crisis. The world seems to stagger from one calamity to the next, as an ever-growing catalog of loss accumulates and the future order of things growing ever more difficult to discern. The Latin roots of the word crisis meant "turning point," or "decision," or "judgement." In this vein, Haraway writes that the Anthropocene "is more of a boundary event than an epoch... What comes after will not be like what came before. (Haraway 2016: 101)." The Anthropocene, then, is a story about a planetary crisis and, as such, provides limited conceptual tools for navigating the contradictions of this liminal period or imagining what might come after.

In this dissertation I treat the Anthropocene as just one, though currently ascendant, of the many possible ways of comprehending our current situation. Environmental historian William Cronon has argued that any discussion of human relations with the environment is inherently driven by choices about narrative, drama, and actors that emphasize some phenomena over others (Cronon 1992). Paul Voosen noted the constellation of concepts and assumptions that usage of the term Anthropocene invokes when he wrote that it "is an argument wrapped in a word" (Voosen 2012, cited in Moore 2017). I want to understand the particular epistemological and ontological commitments of the Anthropocene narrative, their entanglements with developments in contemporary information technology, and tease out their assumptions and consequences for policy without treating any of this as in any way being natural or inevitable. To do this, I use the term *Anthropocene gaze.* The phrase highlights both the particularity of this constellation of

ideas and their importance in shaping the way we understand the world and our place in it. The Anthropocene gaze is a mode of identifying and reckoning with contemporary environmental issues that responds to the crisis in modernity by doubling down on modernist assumptions about the role of expertise and information and environmental issues.

If the Anthropocene gaze is the dominant approach to understanding the relations between humans and nature, then climate change and natural disasters are some of its main characters, the charismatic megafauna in the ecosystem. As edge cases, they illustrate facets of more widespread, if sometimes difficult to discern, phenomena that occurs as part of human interaction with our environment. Disasters have long been objects of study in the social sciences. Contemporary approaches are often traced to the 1755 Lisbon Earthquake, which is cited as both the first major disaster in which the state took responsibility for recovery and that was systematically studied through the lens of science (Coen 2012, Dynes 1999). In a letter to Voltaire, Rousseau penned the first arguments in the Western Canon that disasters were social constructions and that vulnerability to naturally occurring hazards was unevenly distributed across society and intimately connected with our economic and political systems (Dynes 1999). Despite the awareness across many areas of disaster research that "there is no such thing as a natural disaster", and that disasters are, in fact, the result of complex interactions between environmental hazards and socially produced vulnerabilities to such hazards, much of contemporary policy and planning fails to account for this fact.

Disaster and climate risk in late modernity is associated with increased "anxiety" as risks become more globalized, harder to assess and manage (Beck 1999, Lupton 1999), and as risk science itself has been driven by capitalist logics to become more ambitious in its attempt to discipline the future through the calculative rationalization of threat (Beck 1999, Boyd 2014). At the same time, critiques of disaster response have illustrated the way in which compassion for the suffering of "distant strangers (Corbridge 1993)," mobilized through the logic of humanitarian rationality, has reproduced undesirable power relations between affected communities and those seeking to assist them (Fassin 2011, Ticktin 2011, Tierney et al 2006). The high-tempo spectacle of humanitarian response also diverts attention from the ways in which vulnerability to disasters is created over much longer-time scales, and the ways that the impacts of large disasters reverberate through generations (Fassin 2011, Nixon 2011). Despite significant successes in reducing disaster mortality in wealthy countries over the last century (ICRC 2018), overall progress in reducing or eliminating disaster impacts lags far behind what would seem to be the potential offered by science and technology (Knowles 2012). Overall exposure is increasing (GFDRR 2014). In the United States, a world leader in disaster research across many fields of physical and social sciences, dominant approaches to disaster recovery have been shown to increase social inequalities (Howell and Elliot 2018) and efforts to build community resilience to disaster have, in the words of a recent report published by the Federal Emergency Management Agency, "failed miserably" (FEMA 2019).

The frustrating gap between the powerful tools created by scientists, engineers, and technology experts to understanding the causes of disaster and how to prevent them,

and the effects of these tools on reducing disaster impacts in an equitable and sustainable manner is one of the most important sources of inspiration for this dissertation. There are many reasons for this gap, in particular late capitalism and the structures of entrenched power that it enables. As a computer scientist with professional experience working on issues of international development, humanitarian response, and environmental conservation, I want to understand the specific role of my discipline and profession in contributing to, or sustaining problematic approaches to disasters and climate change. New technologies like satellites, GPS, crowdsourcing, actuarial risk models, and multi-media enabled smartphones have led to an increase in the creation of information that describes disaster risks, response, and recovery. We might anticipate that this information might produce substantively new stories about disasters and ways of addressing their challenges yet in each of my research sites, we can see the recurrence of older, problematic discourses in new forms. These new technologies seem to have entrenched, rather than disrupted, prior discourses around disaster. We have been creating new data when what we really needed were new understandings of the problem. What role can crisis informatics play in creating this new understanding?

Research Approach and Sites

In this research I draw on diverse theoretical traditions including human-centered computing, science and technology studies, and human geography in order grapple with the complex issues at stake. As will be discussed in Chapter 2, I rely on a rereading of the term "informating", initially used by Zuboff and Fortune, to help bring these different approaches together and position my research approach within the field of crisis

informatics, the area of HCI research most focused on disasters. Importantly, informating recasts informatics as a verb, highlighting the situated practices involved in creating, managing, distributing, and using the representations of the environment provided by emerging technologies. In addition, I argue that it also turns our attention toward how disasters, as complex worldly phenomena, are enrolled in broader social networks of management and governance through information technologies. Together, these factors create the possibility of a more critical perspective on crisis informatics that allows for interrogation of the relationship between the design of information systems and the politics of disasters and climate change. This is the perspective that I used to guide my dissertation research and writing. This chapter was initially published in 2018 with co-author Leysia Palen (Soden and Palen 2018).

The three sites that comprise this dissertation are flood risk mapping in Boulder, Colorado (Chapter 3), post-earthquake damage assessments in Langtang Valley, Nepal (Chapter 4), and sea level rise modeling in the San Francisco Bay Area, California (Chapter 5). Independently, each of these locations provides illustrative and compelling cases of the ways in which changing computing and information technologies are intervening in societal response to disasters and climate change. Boulder has been the site of influential advances in flood management and is known for having a highly educated population who is actively engaged in local environmental politics, yet still faces challenges in dealing with flooding. Nepal is struggling through a protracted government-led reconstruction effort following one of the most devastating earthquakes in recent memory, leaving its communities to manage their own recoveries. The San Francisco Bay has been constructed

and reconstructed through deeply contentious processes of shoreline expansion and retreat for almost two centuries, and the prospect of as much as six feet of sea level rise by the end of the century will sharpen already intense debates over the future of the region.

Together, these sites present a diverse set of geographies, hazards, social and political contexts, and temporalities that allow this research to demonstrate the remarkable reach of the Anthropocene gaze and the diversity of contexts in which it has effect. Though my research clearly doesn't encapsulate the full range of phenomena at work in such stories, bringing these sites into conversation with each other does allow me to bring to the surface the logics of bureaucratic rationality and techno-scientific optimism, and other characteristics of the Anthropocene gaze, at work in similar ways in the knowledge politics in each site. Together, they surface the ways in which the approaches to informating deployed in each site legitimate some visions of the nature/culture divide, while rendering others unthinkable. They show that the Anthropocene gaze to be a consistent, if not complete project, that influences the kinds of technologies that are developed to understand disasters, and the resulting understandings of disasters we gain through them.

The different sites also build on each other in a progressive fashion that has followed my own process of unpeeling the challenges and controversies inherent in the knowledge politics of disasters. My research on floods in Boulder was my first opportunity to study the phenomena outside of what data standards about flood hazard encapsulated, what some of the consequences were, and to start to experiment with alternatives. While

working in Nepal I had a similar reaction to the ways that data standards related to the post-earthquake damage assessment failed to capture critical aspects of what occurred during the earthquake. It also became apparent at that time that the measurement of damage following a disaster, despite on the surface being a way of representing the past, served the function of making arguments about what the future should be like. This in turn led me to want to ask the questions about how disputes over competing visions arose and are contested through and with information technologies. The long-term, slow-onset character of sea-level rise in the resource and expertise-rich region of the San Francisco Bay area provided an ideal context in which to pursue this line of questioning.

Chapter 3 - Flood Mapping In Boulder

Chapter 3 centers on the practices surrounding techno-scientific delineations of danger by national bureaucracy and what happens when these understandings travel beyond that context and into the wider public imagination. Through an investigation of the data standards underlying flood mapping in the United States, I show how current practices reinforce efforts to control nature in ways that have proven to be untenable. The 100-year floodplain, as delineated according to the standard defined by the US Federal Emergency Management Agency (FEMA), provides the expert knowledge necessary to discipline, at a national scale, the threat posed by flooding in the US. However, as the chapter shows, hazard has a way of resisting being standardized and when our understandings of hazard are tightly coupled with these standards new, and sometimes surprising, vulnerabilities can result. Using design tactics including a tabletop strategy game and an interactive website, I explore opportunities for preserving complex

understandings of threat and how Deweyan notions of public can emerge in productive

response to complex or uncertain knowledge controversies.

The 100-year floodplain standard emerged in the late 1960's from amongst a

number of competing ideas about how to assess and manage riverine flood risk at a

national scale (Robinson 2004). Properties within its boundaries are mandated, at

significant costs, to purchase flood insurance through the United States National Flood

Insurance Program (NFIP). Some communities, as part of participation in NFIP, limit

development in the floodplain altogether or require that construction within it meet

various safety standards. The binary nature of this approach to modeling risk – space is

either in the floodplain and therefore at risk or not and therefore safe – creates an illusion

of control that fits the logics of state bureaucracy and engineering expertise but has led to

unexpected problems. For example, floodplain delineation has been shown to increase

development in adjacent areas where it may be unsafe, discourage homeowners just

outside of floodplain boundaries from purchasing insurance or taking other precautions, or

blighting areas within flood-prone areas that are deemed risky (Gandy 2014). These issues

are central to ongoing debates over the future of the controversial NFIP.

The research into flooding issues in Boulder is based on a combination of

ethnographic and design methods. Following the September flooding events, I began

attending public meetings related to flood recovery and resilience in the area. From Fall

2015 through Spring 2016, I conducted participant observation of flood modeling in a

Colorado-based engineering firm contracted by FEMA to update flood map boundaries, and

provide consultation on development and construction projects that take place within floodplain. I attended team meetings, assisted with data preparation and modeling tasks, and observed the work of experienced engineers. In addition, I conducted over a dozen interviews with staff and consultants of Colorado's FEMA Region VIII Office, engineers and project managers employed at consulting firms hired by FEMA to conduct flood mapping work, and staff of the City of Boulder and other local governments in the region. This data collection was supplemented with analysis of government documents related to the NFIPS program and archival flood documents at the Carnegie Center for Local History in Boulder, Colorado.

In addition to the fieldwork discussed above, I also worked with collaborators to develop and deploy two design exercises that draw inspiration from these approaches to create thoughtful encounters for members of the public with flood information and the 100- year floodplain standard. The first is a tabletop game that encourages participants to collectively reflect on flood risk and options for mitigation. The second is a website that provides information to homeowners about flood insurance. In both cases, participants were given information about the 100-year floodplain as well as shown the extent of the September 2013 flood events, which diverged significantly from the floodplain as demarcated. Participants were then asked to make decisions about purchasing insurance, investing in flood mitigation, or to assess other issues related to flood risk. In total, we recruited 43 participants to take part in either the game or the website tasks from University of Colorado students and the Boulder community. The differences between the two approaches allowed us to explore both collective as well as individual encounters with

flood information as well as staged activities like the game and intervening in routine interactions with government websites using frictional design techniques.

This chapter was first published in 2017 with co-authors Leah Sprain and Leysia Palen. We argue that the 100-year floodplain acts as a problematic closure in the knowledge politics surrounding flood risk. As a standard, the floodplain facilitates Latour's "action at a distance," allowing a large federal bureaucracy to manage flood risk across the United States in a uniform manner. However, in spite Modernist efforts in this regard, the standards developed by risk science are unable to fully encapsulate the phenomena they aim to describe, which leads to a range of problems when they are presented to the public with a certainty and solidity that the underlying science gives them no epistemic claim to. The floodmaps, when taken out of context, of without the benefit of intimate knowledge or their production, present a deeply misleading view of flood risk as a result. The gap between the standards developed for assessing flood risk and the phenomena they are meant to encapsulate has real world consequence, shaping how individuals and communities protect themselves, or fail to, from flooding in the Colorado and around the United States.

The problematic closure that is enacted by the 100-year floodplain can be resisted through design tactics that support closer engagement with the uncertainties that are constitutive of any formulation of risk. Given this, those who design and enact risk standards can expose uncertainties in ways that encourage people to explore them as a means of resisting the reductive character of the Anthropocene gaze. Encounters with

uncertainty, whether through websites that trouble fixed notions of hazard, collective games that yield deliberative understanding, or other means, provide new surfaces for the attachments necessary for public formation. Through supporting public formation in this fashion, designers can in turn help create the necessary scaffolding for collective action and deliberation around complex and uncertain environmental challenges where there are no straightforward technical fixes. This configuration raises a number of questions for designers that I take up in Chapters 4 and 5. How do the ways in which environmental issues are staged by information technologies give rise to different kinds of publics? How are the choices made by designers of information technologies implicated in debates over environmental issues? In addition, this work has also inspired a future work agenda related to envisioning the kinds of standards that would support, rather than foreclose, productive encounters with uncertainty.

Chapter 4 - Post-Earthquake Damage Assessment in Nepal

Chapter 4 explores the role that informatics play in narrating damage and loss and legitimating particular forms of recovery in the aftermath of a disaster. In April 2015, a major earthquake struck central Nepal. The Nepal government, with financial and technical assistance from the World Bank and other donors, designed a damage assessment to understand the impacts of the earthquake and inform recovery planning This assessment was made possible by emerging technologies including tablet computers, open source data collection software, and wireless cellular networks. Inspired by approaches used following other recent large earthquakes in the region (i.e. Gujarat 2001 and Pakistan 2005), the assessment relies heavily on the expertise of civil engineers to determine which

homeowners receive government reconstruction funds. It also represents a major shift in responsibility for recovery work to individual homeowners and away from state and civil society groups. My research in Nepal examines the ways in which these assessments provide one understanding of the disaster, the number of houses damage and destroyed, deprecating alternate narratives and limiting the extent to which communities can take the lead in recovery processes. In partnership with a local organization, I also assessed the role that participatory tactics such as oral history and community mapping can play in countering or supplementing official discourses of damage.

The Government of Nepal's housing damage assessment took place in early 2016 for the 14 most-affected districts of the country. This assessment was conducted by a workforce of over 1700 engineers, trained in Kathmandu and sent into the rural areas with tablet devices to record detailed engineering data on the condition and level of damage faced by private houses along with comprehensive demographic data of the residents. The tablets transfer the survey results to government servers in Kathmandu, where they were used to assess individual's eligibility for official reconstruction assistance. The initial assessment of each home was completed roughly 16 months after the earthquake, after which eligible households received the first tranche of payments. The damage assessment, designed with expert technical advice from local and international agencies, provides a particular way to make sense and respond to the Nepal earthquakes. Research in other disasters have shown that, over time, official statistics come to dominate the discourse and memory of what happened during the disaster in the popular imaginary (Simpson 2013, Liboiron 2015). When such processes are designed to support the needs of wider

bureaucratic processes around recovery and reconstruction, as was the case in Nepal, they may highlight different priorities or come into conflict with community-driven progress towards disaster recovery.

The fieldwork for this research was two-part. The first was based on participant observation during the planning stages of the Government of Nepal housing damage assessment conducted between May and August 2015, during which time I worked for the World Bank's office in Kathmandu as a consultant on a related project. With partners in Nepal, I also conducted a series of focus groups and interviews in May of 2016 with engineers who participated in the assessment to understand their approach and interactions with the communities where they were working. In total, nearly two-dozen individuals were involved in these activities. I relied on these activities, supplemented by a review of various project documents and participant observation conducted in my role with the World Bank during this time, to understand the logics at work in the design of the damage assessment as well as the practices surrounding its implementation. This work captured the state-led damage assessment, the narrative of the earthquake it produced, and the approach to recovery it dictated.

To supplement these observations, I also conducted field research in a remote and hard-hit community in the northern part of the country called the Langtang Valley. This research was facilitated through partnering with Austin Lord, a PhD student in Anthropology at Cornell University. Prior to the earthquake, Langtang was home to around 600 people and an important site of Tibetan Buddhist culture within Nepal. During the

earthquake, the steep walls of the valley gave way to as many four major landslides, destroying several villages and killing as many as 300 residents and visiting tourists. Funding from the government recovery program, which the damage assessment was designed to inform, took over 26 months to arrive. In the absence of formal government assistance, the communities in Langtang Valley had to rely largely on their own resources and networks to plan and enact an essentially local vision of recovery. By conducting detailed study of both the formal damage assessment and people's lived experience of disaster in Langtang, we were able to surface the some of the very different perspectives that the tools used in the damage assessment provided as opposed to the survivors.

In the Langtang Valley, we worked with participants to include a mapping component within their already ongoing activities such as oral histories, photography exhibitions, and documentary filmmaking. In two separate research trips to Nepal in May 2016 and January 2017 we conducted a series of mapping workshops and map-based semi-structured interviews. 42 participants, about one fifth of the surviving residents of the valley representing a diversity of age, gender, and livelihoods, were involved in 25 hours of mapping activities. The mapping workshop focused on themes such as the history of the valley, participants' experience of the earthquake, progress and challenges towards recovery, and their hopes for the future. The research took place in the Langtang Valley, and in Kathmandu, with residents of Langtang who were still displaced and unable to return to their homes. The maps were used to both gather information as well as structure conversations about historic landslides in the valley, perceptions of future risk, long-term settlement patterns, religious and cultural sites, the impact of tourism on development,

hopes for the future, and challenges during recovery. All activities were audio recorded and transcribed and the data was analyzed in a collaborative manner with my co-author.

Chapter 4 was published in 2018 with my co-author Austin Lord (Soden and Lord 2018). This chapter examines how practices of damage assessment construct particular, reductive understanding of past conditions that aligns with state priorities and engineering expertise. It shows how they value scale and homogeneity over particularity. The narratives created by damage assessments in turn operate to focus attention and resources on some futures over others. The chapter thus highlights the gap between the standard measures of memory and loss and people's lived experience in a disaster and how this gap was important in Langtang. Sletto writes that memory is not "simply a retelling of the past but an iterative and unstable co-production of identity and landscape (Sletto 2014:362)." Mapping can thus be a means of performing alternate or emancipatory memory that undermines official histories. In this view, mapping can be understood as situated practice, equally as important for its performative qualities as any map or information artifacts it may yield. Tactics like participatory mapping or oral history thus provide opportunities to raise alternative ways of enacting memory.

Chapter 5 - Sea level Rise in the San Francisco Bay Area

Chapter 5 examines the ways in which different ways of creating and utilizing sea level rise models support alternative understandings of crises. Building on questions raised in Chapter 3 about the relationship between information systems and collective action around environmental issues and the concern in Chapter 4 with competing understandings

of disaster, I work here to delve further into some of the specific mechanics of how these debates are shaped   In the case of this long-term, slow onset disaster, the connection that competing approaches to informating sea-level rise have to particular visions of disasters become accessible in ways that can be more difficult to study in more acute forms of crisis. The extensive financial resources and technical expertise of the region also offer the opportunity to examine the current "state of the art" in terms of approaches to modeling sea level rise and planning long term protective strategies.

Human settlements have long been entangled with the chain of wetlands and shallow estuaries that comprise the San Francisco Bay. For at least two centuries, that relationship has included the effort to create more land to accommodate increasing population and high demand. Over 400 square miles of land was produced in this manner between 1850 and 1950[1]. In response to increasing infill in the mid-twentieth century, local activists formed the Bay Conservation and Development Commission (CDEC) to advocate for conservation of the Bay and support coordination between the 20+ government jurisdictions that manage the territory. Today, with climate-change driven sea level rise, the Bay is expanding again. The BCDC anticipates as much as 24" before 2050 and 60" before 2100, which could put at least 270,000 people at risk of flooding and cause up to $86 billion dollars in property damage across the region (BCDC 2011). There are a number of efforts underway involving local and regional government as well as civil society organizations to plan for and develop responses to the problem. At the same time,

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[1] http://www.bcdc.ca.gov/history.html

community activists focusing on social and environmental justice issues, real estate speculators, agricultural interests, and tech companies are all engaged in ongoing struggles over the direction of future development in the region.

To understand how information systems are bound up in, and contribute to, the politics of coastal planning in the region, I draw on Jasanoff and Kim's concept of socio-technical imaginaries. Socio-technical imaginaries are "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of advances in science and technology" (Jasanoff and Kim 2015:4). In the fieldwork for this chapter, we identified three distinct approaches, imaginaries, for addressing sea-level rise in the Bay Area. The first, grey infrastructure, assumes a command and control relationship to coastal flooding. Water is assumed to be a problem, to be disciplined or kept out through sea-walls, levees, or pumping systems. The second, green infrastructure, draws on ecology and coastal restoration practice to design interventions that accommodate or even leverage natural systems and flows. We call this "living with water". Finally, environmental justice advocates, the third imaginary, work to decenter the technical expertise of both the gray and green imaginaries and reassert the fundamentally political character of sea-level rise information and planning. Critically, each of these three imaginaries have distinct relationships to the information infrastructure that supports sea-level rise modeling in the Bay Area.

To study the ways in which information infrastructures shape the imaginaries at work in the Bay Area I conducted 18 months of research using qualitative methods. The first 12 months consisted of observation by the first author of numerous public and invitation-only meetings, events, and workshops where sea-level rise and climate change adaption were being discussed. In total, I estimate that I conducted about 60 hours of observation during this period. The field notes from these events focused on how different actors relied upon information products such as maps, projections, and data in the discussions, and capturing insights from informal conversations with other participants. During this period I focused especially on the differences between expert discourse on sea level rise and the ways in which community activists and environmental justice groups framed the problem. These observations were complemented by numerous informal conversations and close review of technical reports, scientific studies, and software packages related to predicting the impacts of sea level rise in the region and weighing various approaches to mitigation.

In the second phase of the research, I worked with a collaborator to conduct 19 semi-structured interviews with individuals working on sea level rise modeling or mitigation from across the three imaginaries. We developed two different interview schedules based upon the results of the first research phase. The first was for usage with technical experts – scientists, engineers, spatial data analysts – and focused on the details of their work. With this group, we sought to understand how they produced their models, what information sources they relied on, and the challenges they encountered. We used the second interview schedule during interviews with staff of community-based organizations.

This set of interviews focused on how these organizations engaged with data and information about sea level rise, how they deployed it in their planning and advocacy efforts, and their views of its contributions and limitations. All interviews were recorded and transcribed. I then collaborated with my co-author to develop a coding schema based on issues surfaced during the first phase of research. This schema was used to code interview and observation data and develop the arguments presented in the chapter.

This chapter was published in 2019 with co-author Nate Kauffman (Soden and Kauffman 2019). It argues, first, that the information infrastructure that currently supports sea-level rise modeling in the Bay Area is far from being a neutral actor in debates between proponents of the different imaginaries. On the contrary, we find a clear bias toward the grey imaginary – the one most closely aligned with Modernist efforts to command and control nature. That is, advocates of this approach to managing coastal flooding find it much easier to gather necessary data, develop their models, and have their arguments accepted by policy-makers and regulatory agencies. Research in the area of critical data studies has explored questions of algorithmic bias in order to show how information systems can be designed, often unintentionally, to support the worldview of dominant interests or contribute to the marginalization of vulnerable communities. Based on this study we argue that efforts to understand or address such biases would benefit from adopting the infrastructural perspective adopted by HCI and STS.

In addition, we show that environmental justice advocates work to resist or undermine the sorts of technical approaches that both the grey and green imaginaries. In

doing so, they seek to reassert the fundamentally political character of sea-level rise information and planning. We identify a number of tactics that these groups deploy to decenter technical expertise and instead center values of justice and advocate for their own perspectives and material interests in debates over how to address sea-level rise in the region. HCI research that seeks to engage with local communities or support efforts toward social justice should be aware of these dynamics when developing their partnerships. They hold the potential to derail well-intended projects, or provide tactics that could be designed for as part of attempts at resisting or providing alternatives to the Anthropocene gaze.

Toward Disasters as Matters of Care

In Chapter 6, the conclusion, I present an approach to thinking about and designing environmental information systems that I believe represents a viable and necessary alternative to the Anthropocene gaze. Drawing on understandings of care from feminist studies of technoscience, I argue that the Anthropocene gaze reproduces, and even deepens, Modernity's reductive, domineering approach to nature-society relations characterized by Haraway's as the "informatics of domination" (Haraway 1987). The studies in Chapters 3-5 provide examples of how this happens and point toward what is missed or excluded by the tools we currently use to understand environmental problems. Attention to the character and quality of the relationships that the design and use of information systems create between people and the environment is an act of care. Expanding on Phil Agre's work in the area of critical technical practice, I will offer an approach to operationalizing care for crisis informatics that both builds upon my dissertation work and provides a path forward researchers and practitioners.

Note:

  As described in the text, Chapters 2-5 were previously published in peer-reviewed venues. Full references for each are listed below. Though formatted to be consistent with the rest of the dissertation, Chapter 3-5 are otherwise presented in their original form. Slight adjustments have been made to the Conclusion of Chapter 2 in order to connect to the material presented in later chapters.

INFORMATING CRISIS:
EXPANDING CRITICAL PERSPECTIVES IN CRISIS INFORMATICS

This inscription, what does it cost us? What do we lose? What do we win?
- Barthes, 2009:3

Introduction

In her 1988 study of technology in the workplace, In the Age of the Smart Machine, Shoshanna Zuboff introduced the term informating to describe "the process through which digitalization translates activities, events, social exchange, and objects into information" (Zuboff 2014:1). For Zuboff, informating produced both a new form of labor automation and a new site of contestation between labor and management as work processes were increasingly quantified, described, or otherwise captured through computational means. Despite the book's status as a classic in the fields of workplace studies, information science, and computer-supported cooperative work, the term itself has not been widely adopted (Brown 2008). Yet we see echoes of its intent in Fortun's separate use of the term in research on environmental risk and emerging web technologies in the 1990's and early 2000's (Fortun 2004), the introduction of social informatics in the 1990s (Kling 2006), and the rapid adoption of similar terms by research areas that have sprung up to examine the digitization of other domains being changed by the introduction of information and communication technology (ICT). Among these is crisis informatics (Hagar & Haythornthwaite 2005, Palen et al 2009).

Crisis informatics has been described as a "multidisciplinary field combining computing and social science knowledge of disasters" (Palen & Anderson 2016:1). Concerned with the ways in which information systems are entangled with socio-

behavioral phenomena connected to disasters, crisis informatics offers a rich set of research methods and empirical opportunities for examining the consequences of the role of technology in mediating our relations with the world. Here we focus in particular on crises and disasters stemming from natural hazards, the authors' area of focus. Due to climate change, urbanization, and a range of other socio-political factors, these disaster events are occurring with increasing frequency and impact (IFRC 2016). In this paper, we reflect on what crisis informatics research might look like with an expanded and more critical agenda that is demanded of it as ICTs are increasingly enrolled into practices of crisis response and management. In doing so, we also re-examine what informating might mean to us today, and how crises, as increasingly frequent and globalized affairs, inform studies of technology.

To motivate the discussion, we first relate an unexpected encounter with an exhibition at the San Jose Institute of Contemporary Art about the Lick Observatory in California. As a research site for astronomers, Lick was the first permanently occupied mountain-top observatory in the world. It has been in continuous operation since 1888, with its high-power infrared and visible light telescopes attracting premiere scientists from around the globe. A central feature of the exhibit was a fascinating series of hand-written notebooks of the eight original Lick astronomers, containing records of their observations of the characteristics and Jupiter and Saturn in the summer of 1897. In displaying the data recorded by each scientist together, the exhibit confronts viewers with the diversity of styles in which the astronomers went about inscribing their perceptions. The inscriptions within the notebook of James Schaberle, for example, indicate someone working quickly

and passionately. His drawings are rough; his handwriting is large and looping with frequent underlines to emphasize points. Most strikingly, he does not use any numbers or coordinates. This is in contrast to the work of his colleagues whose notes were sparser, more exacting in their portrayals, or more quantitative in approach.

As the exhibit takes viewers forward in time through new technologies and information systems that enforced greater consistency in observations, we recognize how these new tools would enable a regularity to allow techno-scientific research to scale and advance along some trajectories. But, in the spirit of the Barthes quote at the beginning of this paper, we are also forced to wonder about what is lost during this process, and what shape that scientific understandings of the universe might have taken if different tools or alternative approaches to standardization had been adopted. What perspectives might have been erased along the way to the practice of contemporary research in astronomy? What have been the consequences of the particular socio-technical research practices adopted by the field? What, if anything, remains of the vigorous, idiosyncratic approach to documenting planetary phenomena employed by Schaberle? For us, this encounter seeded questions about the nature of inscriptions of scientific data—a kind of informating—and how those forms allow us to make sense of the phenomena we seek to understand and, as such, must be under question.

It is with such questions in mind that this paper addresses our own area of study: crisis informatics. We recognize that significant progress has been made over the past decade, but we also see an urgent need to include an expanded set of research methods,

theoretical perspectives, and design practices to address the pressing issues confronting the world. A 2013 report by the International Committee for the Red Cross argues that "a more technology-oriented approach to humanitarian action is essential—and inescapable—to take advantage of the opportunities to improve, for example, information gathering, analysis, coordination, action or fund-raising" (Vinck 2013:9). As the quote indicates, ICTs are increasingly central to the ways in which we collectively make sense of, and coordinate our response to, crisis. Complex computer models calculate risk of natural hazards like floods or earthquakes in ways that are used to set insurance rates and land-use plans (Soden et al 2017). RFID tags, iris recognition software, and blockchain technology are used to manage humanitarian supply-chains and track their beneficiaries (Juskalian 2018). Drone and satellite imagery supports post-disaster damage assessment (Lallemant et al 207), and emergency managers are increasingly looking to social media to support situational awareness (Latonero & Shlovski 2011, Norris 2017).

The concept of informating directs our attention to the situated practices surrounding the socio-technical accomplishment of representing the world through data. It was first developed by Zuboff in the 1980s to direct attention to the significant shifts in the ordering of the workplace underway as a result of the introduction of digital information systems (Zuboff 1985, Zuboff 1988). We argue that it serves to foreground important issues that deserve greater attention from crisis informatics researchers. It also holds the potential to assist designers of information systems not dealing directly with crises to more carefully consider the roles their designs play in a digitally-connected world. Most importantly, we argue that the concept helps to surface critical perspectives in crisis

informatics, orienting research not only toward answering empirical questions or solving particular problems in the area of practice, but also to a close examination of how such questions and problems are posed in the first place, with what consequence, and to whose benefit. In doing so, crisis informatics is positioned to draw from, and contribute to, a rich tradition of critical research and design in human computer interaction (HCI) and computer-supported cooperative work (CSCW).

The paper proceeds as follows. First, we explore relevant literature in CSCW, science and technology studies (STS), and the social sciences to set the ground for our arguments. Then we delve further into informating and related ideas to establish an analytical frame that can be deployed to make use of the concept within crisis informatics research. We then discuss four examples of contemporary practices in informating crises linked to natural hazards, relying on published literature as well as several cases with which the authors have direct knowledge or prior publications. Based upon this review of theoretical literature and empiric examples, we argue that informating is: 1) a socio-technical and cooperative practice; 2) both representational and generative; 3) a site of politics and contestation; 4) an influence on our own subjectivities; and 5) a potential target of design. We then outline a research agenda that could deepen and expand critical perspectives in crisis informatics and support wider engagement with work being conducted in HCI, CSCW, and the social sciences.

Related Work

Crisis Informatics

Since its emergence in 2007, crisis informatics has made important contributions to scholarly and practitioner understanding of information systems in mass emergencies. The field draws on computing and social science perspectives to study the ways in which ICT enables, constrains, and mediates human practices related to crisis and disaster [90]. Crises can be sparked by many different kinds of societal stressors, including natural hazards, "man-made" hazards, political strife, criminal activity and more. Crisis informatics researchers in HCI and CSCW have studied events that arise from criminal or political hazards— including the violence in the 2007 Kenyan election (Meier & Brodock 2008), the 2007 Virginia Tech Shootings (Palen et al 2010), the Iraqi War (Semaan & Mark 2010), the 2013 Boston Bombings (Starbird et al 2014), and "urban warfare" in Mexico (Monroy-Hernandez et al 2013). Though there are additional definitions of crisis that matter to the field, for the purposes of this paper we focus specifically on our area of expertise, disasters arising from hazards such as flooding, earthquakes, and hurricanes, over "crisis" in general. The distinction between natural hazards and other forms of crisis is nevertheless worth making, because the technologies and practices that informate different types of crisis diverge as do the socio-behavioral responses (Palen & Anderson 2016).

Crisis informatics researchers who study these topics share common commitments to a sociological understanding of hazard and disaster; an understanding of information systems that draws from studies of computer-supported cooperative work; and an inclusive view of who counts as users and producers of information relevant to

crisis. This perspective has proved generative, enabling crisis informatics to engage productively in research as diverse as social media, software development, big data analytics, infrastructure studies, and citizen science. Though a large number of studies have been conducted in this growing research area over the past decade, we remind readers that the field is still relatively young. To date, relatively few review papers that help research communities assess progress, articulate agendas, or delineate areas of debate, have been published (Palen et al 2010, Palen & Hughes 2018, Reuter & Kaufhold 2018). In this paper, we contribute to the further development of critical perspectives in crisis informatics research. The resulting, expanded, agenda raises questions about how particular understandings of crisis are created and sustained through information systems—with what consequences—and supports the development of alternatives that are better attuned to the challenges of the present moment.

Social Science & Disasters

Disasters have long been objects of study in the social sciences. Contemporary approaches are often traced to the 1755 Lisbon Earthquake, which is cited as both the first major disaster in which the state took responsibility for recovery and that was systematically studied through the lens of science (Coen 2012, Dynes 1999). In a letter to Voltaire, Rousseau penned the first arguments in the Western tradition that disasters were social constructions, and that vulnerability to naturally occurring hazards was unevenly distributed and the result of our economic and political systems (Dynes 1999). These themes continue to be important questions in studies of disaster in geography, sociology, anthropology, and other disciplines. Disaster and climate risk in late modernity is

associated with increased "anxiety" as risks become more globalized, harder to assess and therefore manage (Beck 1992, Lupton 1999), and as risk science itself has become more ambitious in its attempt to discipline the future through the quantitative rationalization of threat (Beck 1992, Boyd 2012, Ewold 1991). At the same time, critiques of disaster response have assessed the way in which compassion for the suffering of affected peoples, mobilized through the logic of humanitarian rationality, has reproduced undesirable power relations between affected communities and those seeking to assist them (Fassin 2011, Ticktin 2011, Tierney et al 2006). Crisis informatics has yet to fully interrogate the role that information and communication technology plays in sustaining such relations, and we hope to demonstrate that there is a rich opportunity to do so.

Critical Studies of Technology & Crisis

Critically-oriented research in human geography, media studies, and STS have brought important perspectives to the role of technology in shaping our understandings of, and responses to, crisis and disaster. They remind us that "there is no such thing as raw data," and that our technologies are always shaped by, and serve, some interests over others (Gitelman 2013). This body of work emphasizes the role that data standards, classification practices, and the design of information products in humanitarian assistance legitimate some understandings of disaster while foreclosing others (Burns 2014), shape what kind of material assistance is made available as "aid" to affected communities (Redfield 2013), or expose underlying tensions within the humanitarian community over such questions (Finn & Oreglia 2016). While scholars in this area have argued that such perspectives could bring valuable insight to the area of crisis informatics across a number

of issues, including to further challenge to the narrow temporal framing of the crisis perspective or to draw attention to the role of technologies in perpetuating structural inequities affecting who is affected by a disaster and who is able recover (Crawford & Finn 2015), this potential has yet to be fully realized within HCI and CSCW research. Through a reinterpretation of the concept of informating within this context, we seek to provide a conceptual scaffolding to support a more active engagement with these questions.

Informating

The word informate has two distinct, though complementary, usages in the CSCW and STS literatures. Zuboff first coined the term as part of her ethnographic study of the relationship between changing technologies and the political economy of the workplace in the 1980s (Zuboff 1985, Zuboff 1988). She observed a two-fold threat in the practices surrounding the informating of labor. The first, as an extension of automation, was tied to the de-skilling of work that occurs as investments in workplace technologies, which was in turn tied to the goals of management that sought to increase intensity, regularity, and predictability of worker's output. In addition, she urged caution that the unique ability of information technology to produce new streams of data about work reflexively creates a new regime of knowledge with the potential to be used by managers to exert greater discipline and control over workers. Informating thus became a new site of struggle between labor and management, a concern to important debates within early CSCW and second wave HCI (Bodker 1993, Suchman 1993, Winograd 1993).

In a more recent formulation of the concept by Fortun (2004, 2013), informating is again used to describe a societal shift in practices related to ICT. In this case, the focus is on informating environmentalism, or the cultural shift that has been underway since the late 1990s as a result of public access to an increasing amount of data about environmental conditions, risks, and harms made available through online, interactive, web technologies. Fortun is concerned with the "particular bias and blindnesses" that result from reliance on the classificatory schemes designed into information systems to apprehend worldly phenomena, and the discursive impacts that such biases have on our understanding of the environment and the kinds of subjectivities that are inculcated through practices of informating. As with Zuboff, Fortun sees informating as a site of politics and contestation. She writes that "when fields of practice are informated, previous latent signification often comes to the surface; discursive gaps—spaces where established analytic and explanatory language fail, spaces where hegemony comes to crisis—can be displaced" (Fortun 2012:21).

Importantly, both scholars reject a naïve determinism that would essentialize the current practices of informating in their research sites as the inevitable outcomes of factors inherent to technology. In the work of each, we can see the possibility of more positive practices of informating. Zuboff writes that the particular features of technology "define the horizon of our material world as it shapes the limits of what is possible and what is barely imaginable; it erodes assumptions about the nature of our reality, the 'design' in which we dwell; and it creates new choices" (Zuboff 1985:5). She holds out hope for ICT to flatten workplace hierarchies and liberate human potential, act as a support for creative

collaboration rather than an agent of de-skilling and drudgery. Fortun argues that the affordances of modern website technology could allow people to engage more deeply in science, rather than act as passive recipients of environmental information. The concept of informating thus provides an approach to consider how the design choices that shape information systems intersect with culture and politics.

Informating shares resemblance with a number of other ideas coming from social science research and critical theory. It is reminiscent of Latour and Woolgar's discussion of the role of inscription as a central element of scientific practice captures how material artifacts and social practice shape how observations of the world are converted into recorded measurements that are both mobile and durable (Latour & Woolgar 1979). Foucault's development of the concept of apparatus (dispositif) is also relevant here . He writes that an apparatus is a "heterogenous ensemble consisting of discourses, institutions, architectural forms, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral and philanthropic propositions ... The apparatus itself is the system of relations that can be established between these elements" (Foucault 1980:194-195). Apparatuses are crucial technologies of governance, shaping—and in turn being shaped by—culture, social relations, and individual conduct (Wakefield & Braun 2014). Informating, from this perspective, is central to the replication and self-maintenance of these apparatuses, co-productive of the information and communication technologies through which the world is increasingly ordered.

In putting the Zuboff and Fortun's work on informating in conversation, we highlight several key ideas for HCI and CSCW research into crisis informatics. Crucially, the concept turns our attention to the ways in which information does not emerge spontaneously, ex nihilo, but rather is enacted through collective human effort in concert with technology. Such efforts are increasingly a part of the ways in which high-tempo coordination work of humanitarian response as well as the governance of disaster risk and post-disaster recovery are accomplished. The distribution of risk, the provision of aid, and the planning of recovery all occur along uneven socio-technical landscapes shaped by various forms of expert knowledge, economic and social inequality, and politics in which ICTs are implicated. Zuboff's concerns about the delegation of authority to machines vs human agency (cf Akrich 1992) are equally relevant to the practices of informating relevant to crisis informatics. These relationships can only be understood through careful attention to the ongoing interplay of human action and technology that sustain them. The perspective of informating thus aligns with many of the concerns raised in the evolving debates around the "practice turn" in HCI (Kuutti & Bannon 2014, Randall et al 2018, Schmidt 2018), though a full discussion of this relationship is beyond the scope of this paper. Informating nonetheless affords a conceptual tool for critically evaluating the practices surrounding ICTs and crisis management.

Examples of Informating

To develop the concept of informating within the field of crisis informatics, we discuss four examples, drawn from relevant literatures and our own experience in the field. In each, we seek to describe the practices through which the crisis event is being

informated and assess their consequences. In doing so, we seek to both further elaborate

our understanding of the concept and demonstrate its value as an analytic approach. These

examples cover a range of natural hazards, geographies, and temporal dimensions but

neither exhaust the forms of informating that are conducted in the domain of crisis

response and management nor fully outline the range of issues that informating forces

researchers to contend with. However they do begin to provide a sense of what is at stake,

and how the concept of informating may help develop a more explicitly critical perspective

to the study of information systems and crises.

OpenStreetMap Haiti and the Conditions of Participation

Following the 7.0 magnitude earthquake that struck Haiti on January 12, 2010,

thousands of volunteers from around the world converged online in an effort to assist with

the humanitarian response. The Haiti earthquake was the first large-scale online disaster

where volunteers used social media and other digital platforms, in patterns that have since

grown familiar, to seek and share information, connect survivors to responders, and

otherwise assist the international relief effort (Palen et al 2015, Soden & Palen 2014). This

convergence was facilitated by developments of new technology, changing attitudes around

crowdsourcing, social media, and open data, and, importantly, a network called "Crisis

Mappers" that consisted of technologists and humanitarians who for several years prior to

the earthquake had been advocating for the role that new information and communication

technologies could play in humanitarian response. One of the more prominent platforms

was OpenStreetMap (OSM). OSM is an online, openly accessible map of the world that is

created by its user community. Participants trace features like roads or buildings from

satellite imagery, collect GPS data, or draw directly into the map, producing an open source

and open access geospatial database that, in many parts of the world, rivals official sources

in terms of accuracy and completeness (Anderson et al 2018, Haklay 2010). One of the core

motivations of OSM participants is to "democratize mapmaking," historically a domain

controlled by governments and the military (Wood 2010), through involving the public in

creating the maps that represent their communities (Budhathoki & Haythorthwaite 2013,

Haklay 2013).

As news of the earthquake spread, hundreds of OSM mappers, organized in part by

the then-nascent group of volunteers called the Humanitarian OSM Team (HOT), logged

into the platform and, using aerial imagery made available by providers like Google and the

World Bank, created the most detailed map of the quake-affected areas of Haiti in existence

[110,136]. Within a month, members of the international OSM community had traveled to

Haiti to involve residents in the use of the platform for creating maps in support of the

response efforts. Funding from the International Organization for Migration (IOM), the

World Bank, and other donors supported the training and employment of hundreds of

Haitians to map, in OSM, damaged buildings, public health infrastructure, and camps for

earthquake-displaced people that were constructed following the disaster [110]. Central to

the logics underpinning these activities was the belief by both HOT and their international

donors that involving Haitians in the mapping work that would lead to a more effective,

inclusive, and equitable response. Drawing inspiration from the field of participatory

development and mapping (Bryan 2011, Chambers 1997, Peluso 1995), HOT sought to

create a process that would provide employment opportunities for individuals affected by

the earthquake, support local skill development in the areas of mapping and computing, and, most importantly facilitate the incorporation of the knowledge and priorities of Haitians into the information products that would guide response and recovery activities (Soden & Palen 2014).

One limitation of this example of informating was that most of the important decisions over what kinds of things that the local teams would map, and the data standards that were used to describe them, were made by HOT and their funders (Soden & Palen 2014). For example, when mappers were tasked with working on collecting information about the location and characteristics of public health infrastructure to plan a response to the cholera outbreak, they were given detailed instructions and survey forms enumerating what kinds of buildings—e.g. hospitals, clinics, and temporary sites—and what information about each—e.g. GPS location, patient capacity, and contact details—to collect (Soden & Palen 2014). In processes of informating, these decisions produce a kind of closure in the "knowledge politics" (Burns 2014) surrounding the issue at hand, in this case the cholera response in Haiti. Such closures have a coordinating function: as durable abstractions they support communication and enable Latour's "action at a distance" (Latour 1987). At the same time, they foreshorten debate over contentious issues, mask uncertainty, and limit the inclusion of alternative perspectives (Burns 2014, Soden et al 2017). We do not know what the Haitian mapping teams involved in the project would have understood the cholera response infrastructure to be because, despite HOT's aspirations to support a participatory process, no one truly asked them. Though the mapping process may have supported the work of the formal disaster response agencies, they limited Haitian input

about what got counted as public health infrastructure, and ultimately affected which people received assistance and how.

Today, the Haiti earthquake response is remembered as anything but effective and inclusive. In fact many of the criticisms center around the ways in which international organizations, in their rush to respond to the disaster, crowded out Haitian communities and institutions from the planning and execution of the response and recovery work (Katz 2013, Schuller 2016). These arguments place the international humanitarian effort within a much longer arc of political conflict, foreign intervention, and economic interference that made Haiti so intensely vulnerable to the earthquake in the first place (Schuller 2016). The informating practices adopted by OpenStreetMap Haiti, though only one small part of the multi-billion dollar response effort, are instructive for evaluating the participatory potential of new disaster information systems. Practices of categorization and classification (Bowker and Star 2000) are central elements of informating; they play a major role in determining what is represented in ICTs and in what manner. The process by which Haitians could participate in the informating of the disaster was narrowly circumscribed by the information standards that dictated how their perspective was included in the maps (Arnstein 1969, Wood 2010). Thus the labor of the "participants" was aimed at producing a valuable commodity, map data, for humanitarian responders and their work had the character of employment, rather than active citizenship. Such relationships, central to Zuboff's conception of informating, are an important feature of contemporary, professional, humanitarian work, yet so far have largely gone unexamined in crisis informatics.

Social Media & Situational Awareness in Hurricane Sandy

When Hurricane Sandy slammed into the US mid-Atlantic region in October 2012, the massive storm caused billions of dollars in damage, becoming what was at the time the second most destructive storm in US history. Because of the population density of its US landfall, and at a moment when Twitter had achieved high public awareness, the amount of social media communications that were generated before, during, and after the storm was enormous. Twitter claimed there were 20M tweets that described Sandy's social media footprint (Twiter 2012), with approximately 6-7M of these geotagged with some sort of spatial reference (Wang et al 2015). The sheer volume was perceived as evidence of social media's value to disaster response, and tempted some practitioners and researchers into uncautious analysis of the raw data. Despite the apparent utility of such a large amount of information, the role of social media data in informating situational awareness during large disaster responses has yet to meet its promise.

To date, crisis informatics has been most recognized for the study of social media in disasters. This aspect of the research can be organized into three main areas (Palen & Hughes 2018). These include, first, the socio-technical innovations afforded by social media including citizen reporting and journalism, digital volunteerism, community-oriented organizing, and distributed problem-solving (Norris 2017, Norris & Voida 2017). Second, social media had been examined as a tool for emergency responders to communicate with the public, and how it affects their roles and practices, often negatively, as a result of the limited resources agencies have to address the changing information landscape (Denef et al 2013, Hughes et al 2014, Latonero & Schlovski 2011). It has been the third area of social

media work, which considers social media traces as data sources (Castillo 2016) that can be "harvested" to support real-time detection of information that has been most challenging. Attempts to develop methods to use social media in ways that can be relied upon consistently to provide situational awareness (Semaan & Mark 2011) — how emergency responders assess the status of the impact of a crisis on people and infrastructure at any one time to make decisions about deploying aid—has garnered immense attention from popular accounts while simultaneously proving extremely difficult.

A recent analysis of the Twitter data from Hurricane Sandy argued that a multitude of factors including intermittent power outages, uneven adoption or access to social media, and the polysemous relationship between geotags and physical space challenged simplistic claims about the role of social media in situational awareness of the event (Shelton et al 2014). The authors conclude that "seeing spatial concentrations of social media activity in disaster situations as being equivalent to areas in need of relief vastly oversimplifies the ways that social media is used in disaster situations, while also potentially reinforcing offline social inequalities by failing to provide relief to areas which may not be producing such content" (Shelton et al 2014:178). Another study showed that people in Far Rockaway, a both especially disaster-prone and socioeconomically vulnerable area, felt that their requests for aid from formal response organizations through Twitter went unheard (Anderson et al 2016). These findings support what crisis informatics researchers have long argued: only through careful treatment of social media traces could researchers obtain smaller datasets to interpret and properly contextualize. Despite a

mostly thoughtful body of work by crisis informatics researchers dedicated to studying socio-behavioral phenomena and with the capacity to meet the computational demands of big data (Palen & Hughes 2018; and for example, Kogan & Palen 2018, Semaan & Mark 2011), the pace of social media's growth has attracted both data scientists new to disaster research, and social scientists with limited background in computational sampling of social media data.

By the time Sandy hit, there had been 5 years of study on how to derive actionable information from social media. This research is challenged by frequently changing user interfaces, terms of service, and APIs of the technology platforms. In addition, retaining the temporal coherence of large amounts of social media data in real-time is difficult, though necessary if it is to be used for disaster response (Norris 2017). Further, the liability of trying to make decisions about what data is collected is high—any computational solution will invariably introduce new types of bias into an already difficult situation. Who gets heard? Whose perspectives on disaster or requests for assistance get amplified, and whose do not (Anderson et al 2016)? How should we interpret the silences of those who do not appear at all? How should we account for the ways that existing inequalities are replicated or reinforced through social media? The use of social media data for the informating of situational awareness holds promise, but significant challenges remain, and the impact on the practice of crisis response has been less than hoped. This provides a special challenge for a crisis informatics agenda that perhaps can be in part addressed through a turn to more critical analyses.

L'Aquila & The Dangers of Risk

In the middle of the night on April 6, 2009 an earthquake struck central Italy near L'Aquila, collapsing thousands of buildings and killing 309 people. Three and a half years later, seven seismologists and government officials were sent to prison, convicted of involuntary manslaughter, for failing to provide the public with the necessary information to protect themselves during the disaster. The incident and court case sparked a massive global controversy. At its height, over 500 scientists from around the world wrote a letter to the Italian government, stressing the impossibility of predicting earthquakes and urging that the charges be dropped (DeVasto 2016). According to many outraged reports in the popular press, the case was about an incompetent and scientifically illiterate government looking to assign blame in the aftermath of a major disaster whose high mortality rate had more to do with poor design and enforcement of building codes than scientific malfeasance (Hasian 2014). While there is some truth to this account, the controversy raises more complex questions about science communication, coping with uncertainty, and the relationship between technical expertise and public policy. For the purposes of our argument, we focus on an emerging set of challenges driven by the enrollment of ICTs in the creation, circulation, and use of information about disaster risk.

In the months leading up to the earthquake, the region had been affected by hundreds of minor earthquakes. Seismic researchers have attempted to understand the connection between seismic "swarms" of this type and the probability of a larger earthquake (DeVasto 2016). However, there is no consensus on this relationship. Meanwhile, a local amateur had begun publishing predictions of an imminent earthquake

based on a spike in readings coming from homemade radon gas detectors (DeVasto 2016, Hasian 2014). Though there is no scientific evidence to support this claim, some have speculated that radon gas, released by small fissures in the earth's crust, might foreshadow a major earthquake. The public was increasingly concerned and, following local tradition in a seismically active area, began sleeping and spending most time outside to protect themselves from falling buildings in the event of an earthquake. On March 30, the head of the Italian Department of Civil Protection convened a meeting of scientists and government officials intended to reassure the public. Some of Italy's leading seismologists were called upon to address the links between seismic swarms, radon gas, and earthquake forecasting.

At the meeting, and in press interviews that followed, the scientists reported, correctly, that science was unsettled on the link between these phenomena and there was no firm evidence to suggest that a quake was any more likely to occur in the coming days than at any other time. They also stressed the impossibility of accurately predicting earthquakes and the necessity of focusing on improving the building stock as a means of risk reduction (Donovan & Oppenheimer 2014). To make their claims, they relied on their backgrounds in probabilistic seismic risk assessment. This multi-disciplinary scientific practice has expanded rapidly in the past 40 years, in part due to the new affordances of powerful computers, sophisticated software, and new sensing technologies. Practitioners use these tools to bring into relation historic seismic observations, detailed fault, soil and geologic maps, and data on the location and structural features of built infrastructure. Unlike earlier deterministic approaches that sought to characterize the impact of a single, modeled event, probabilistic risk assessments attempt to encapsulate all possible

earthquakes in a given area, along with associated damage levels of each, into a single analytic frame. Drawing on their prior research (eg Boschi et al 1995) and expertise in this area, the scientists reported that no firm link could be made between ongoing seismic swarms and the likelihood of an earthquake in the near future. Six days later, an earthquake destroyed L'Aquila.

Risk science has been developed largely in relation to the insurance industry (Ewold 1991) but, in recent years, has moved to prominence in a wide range of governmental decisions about health, safety, and environmental hazards (Boyd 2012). In this example we see some of the challenges that arise when scientific understandings of disaster risk produced by increasingly complex and powerful technologies, software, and data standards developed within a particular domain, escape into other contexts, including public discourse, that lack the conceptual tools to properly assess its claims and limitations (Latour 2004, Soden et al 2017). Public difficulty interpreting probability is well-documented (Hacking 2001) as are the challenges in public decision-making processes around low-probability, high impact events like major earthquakes (Donovan & Oppenheimer 2014). The increasing role of complex computer models in the study of earthquake risk has served to deepen these challenges (*ibid*). Such models, while valuable to governments and insurance industries looking to distribute risk across large territories or asset portfolios, are not designed to advise individual protective behavior. In earlier periods of Italian history, popular understandings of earthquake threat would move the public to spend their time outdoors during times of earthquake swarms, as indeed they did in this case. Public confusion about the meaning of emerging, informated formulations of

seismic risk, along with government concerns about popular panic shaped the impact of this disaster. Though all the scientists were eventually acquitted, the place of informated understandings of risk in the governance of disaster is far from settled.

The Post Disaster Needs Assessment in Nepal: Figuring Loss, Prescribing Recovery

Within two weeks of the 7.8 magnitude April 2015 Nepal Earthquake, the government of Nepal, with guidance and technical support of the international community and development banks, began conducting what is called a Post-Disaster Needs Assessment, or PDNA. The PDNA, created in 2007 but drawing on earlier forms of damage assessment, is a technology of sense-making about disaster. It is one of the primary means by which governments of affected countries attempt to determine the impact of large disasters and coordinate recovery strategies with international donors. According to the official guidelines, published jointly by the World Bank, the United Nations, and the European Union, the goal of the PDNA process is to "assist governments to assess the full extent of a disaster's impact on the country and, on the basis of these findings, to produce an actionable and sustainable Recovery Strategy for mobilizing financial and technical resources" (GoN 2015a:12). These guidelines, covering two volumes and hundreds of pages, provides detailed information on the rationale and conduct of the PDNA process, along with a toolkit that prescribed how damage was to be informated, including sample forms, terms of reference, and recovery planning templates.

Over 250 people, including international experts, statisticians, engineers, and Nepal government officials, participated in the PDNA or provided guidance to various

actors involved. Many of the participants were chosen for their prior experience

conducting PDNAs (Bennike 2011), and two of the individuals responsible for creating the

PDNA methodology were present for part of the process. The work was divided into 23

thematic areas and sought to quantify, from an economic perspective, the damage and

losses caused by the earthquake, and develop recovery strategies across four sectors:

social, productive, infrastructure, and cross-cutting (GoN 2015a). Given the short time

period, it was impossible to conduct a complete, field-based survey, so the teams had to

develop the means by which they could develop rough estimates (Lallemant et al 2017).

They collected pre-event, "baseline" datasets from various sources, held phone calls with

local government officials across the 14 most-affected districts that were included in the

assessment, poured over satellite imagery for evidence of impact, and conducted site visits

to validate reports and calibrate models used to extrapolate damage totals for entire

districts based on limited information. Once gathered, the data was entered into template

spreadsheets, in both US dollars and Nepal rupees, provided by the PDNA toolkit and

shared among all of the teams for further expert review and verification through Google

Docs and Dropbox [personal communication].

The PDNA took three weeks to complete. At the end of the process, it estimated

that total recovery needs were about $6.7 billion USD, about half of which was comprised

by the housing sector (GoN 2015a). The speed and orderly manner in which the

assessment was conducted was widely commented upon in Nepal at the time. Some

speculated that the unexpectedly large amount of funding ($4.4 billion USD) promised at

the donor conference on June 25th of that year was in part reflective of the great deal of

consensus surrounding its findings. Yet for the all the consensus, it was quite clear that the results of the assessment were not completely accurate. For example, in some cases, local government officials reported that the number of houses damaged to be exactly equal to 2011 census figures on number of households in the area (Lallemant et al 2017). An official for one international development agency close to the process told us that the point is not to achieve absolute accuracy; what matters is that national government and donor agencies come to agreement over the figures in the report and the next steps those numbers suggest. Thus the level of correspondence between these numbers and the damages they purport to represent was less important than the degree of consensus about them between the government and the donor agencies. The apparent efficiency of the process was crucial to supporting this consensus, highlighting the ultimately social and political character of processes involved in the informating of official disaster statistics (Liboiron 2015).

The suite of tools, standards, and expertise that together formed the technology of the Nepal PDNA was deployed in a manner that was necessarily flexible. This is evidenced by the emphasis on consensus, driven by the recognition of inability to achieve perfect accuracy, the inclusion of expert judgment, and the collaborative review process. Flexibility was important because the consensus produced during the PDNA process in turn dictated how the funding pledged by donors for various aspects of the recovery would be allocated. However, it was not complete. Important aspects of post-disaster recovery that are harder to measure in economic value, such as mental health, addressing communal land tenure, or the planned resettlement of communities in landslide prone areas, received less attention in the PDNA (GoN 2015a, GoN2015b), and less support in the subsequent recovery process.

In addition, the process was largely closed to those who were not part of the group of assembled disaster experts, donor agency representatives, and government officials, limiting the kinds of judgment and perspective that could be brought to bear on recovery planning (Bennike 2017). As tools and methods aimed at improving the speed and accuracy of PDNA processes develop (Lallemant et al 2017), it will be important to assess whether they serve to expand this flexibility and increase the agency of affected communities, or further delegate the informating of damage, and the scripting of recovery practices (Soden & Lord 2018), to these technologies.

Informating Crisis

In this section we draw upon prior usages of the term informate by Zuboff and Fortun and the examples provided above to highlight five aspects that informating offers in support of critical study of contemporary technological changes in the domains of crisis and disaster.

First, informating is a socio-technical and cooperative practice, a means by which our information systems are designed, enacted, and maintained. The informating of crises takes place in particular contexts, particular spaces, and at particular moments in history. Research and writing on informatics can present abstracted and decontextual understandings of information systems, whereas as we seek to use informating to return our attention to the situatedness of such practices (Randall et al 2018, Suchman 1987). Informating thus aligns with earlier understandings of information as a processual activity of informing a person or situation, rather than the contemporary approach of treating

information as a discrete element that can be commoditized and measured (Day 2008). Locating disaster information in the context in which it is created, maintained, and used also suggests attention to the material properties of software, data, and information, an area of growing concern to HCI scholars (Dourish 2017). Disasters, and disaster-vulnerable places, offer rich opportunities to investigate these issues.

Second, informating is both representational and generative. It is an attempt at developing abstractions to describe complex and ultimately irreducible phenomena in the world through ICTs. Dourish and Mazmanian argue that the "ways in which information can be interpreted, negotiated, manipulated and understood to represent then carry implications for organizational processes and social practice" (Dourish & Mazmanian 2011:8). In doing so, these abstractions can come to stand in for what they represent (*ibid*). They shape our imaginations of the world, the objects within it, and how they may be acted upon (Bowker & Star 2000, Wood & Fels 2008). Informating frequently has the character of converting contested political and social issues into technical problems (Leavitt & Clark 2014) that are amenable to expert intervention and management. In Nepal, for example, the PDNA was both the means by which the impacts of the earthquake were determined by the government and the donor community, as well as the basis upon which the recovery was designed. The discursive consequences of various approaches to informating is an area that deserves more attention.

Following from this, informating is a site of politics and contestation. It shapes the form of knowledge that can be created and delimits the authority to create and access it. To

informate is to make decisions about what phenomena count and in what ways. These decisions are inescapably political acts (Kitchin & Lauriault 2014). In Haiti, the data standards that determined what was to be mapped, and how, was made by the international agencies, placing strong constraints on the ability of Haitian participants to represent their own experience and perspective, which was quite different than that of the formal disaster response. The controversy surrounding the L'Aquila tragedy demonstrates that apparently "objective" scientific research can be far more contentious than its practitioners believe, or have the training to assess, when situated in the social and political context in which it is produced, circulated and used.

Fourth, informating shapes us. These tools and practices increasingly mediate our understandings about our lives and the world around us. They help craft what we believe it means to be human, what life should consist of, and how we should act. We see this attention to the influence of informating on subjectivity in Zuboff's arguments about the different kinds of capacities that are developed in workers given routinized versus open-ended tasks. Fortun argues that interactive websites that give users the ability to explore environmental data, drill down to specific locations, or compare across different areas can more deeply engage the public in environmental issues, leading to increased curiosity, investment, and commitment. Prior research has described the "torque" that occurs when practices of classification and individual biographies intertwine, shaping people's beliefs about their own identities (Bowker & Star 2000), and that technology design choices have profound interactions with how humans explore their desires and curiosities, and express agency (Bardzell & Bardzell 2015, Woolgar 1990). What might such insights express in

relation to the ICTs that designate populations that are either victims, or at-risk, of natural hazards?

Finally, informating is a potential target of design. Neither Zuboff nor Fortun see contemporary means of informating as fixed or inevitable. On the contrary, informating is a part of larger, shifting apparatuses, of knowledge, technologies, and politics that are developed, and open to reexamination, through any of the various approaches to design in HCI and CSCW that aim to unsettle dominant practice or envision alternatives. The practices of informating crisis are continuously being remade, experimented with, and redeployed, and design plays an important role in this evolution (Redfield 2016).

Expanding Critical Perspectives in Crisis Informatics

Informating, as described above, offers a powerful analytic with which to study the social and political consequences of the information systems we use to understand crises. In doing so, we find that it offers the opportunity to expand the critical perspective within crisis informatics. Rose has written that critique has the potential "reshape and expand the terms of political debate, enabling different questions to be asked, enlarging spaces of legitimate contestation, modifying the relations of the different participants to the truths in the name of which they govern or are governed" (Rose 1999, cited in Li 2007:22). Within HCI, numerous formulations of "critical" are at work, including debates over the place of non-instrumentality in design research and practice (Bardzell et al 2012, Dantec and Disalvo 2017, DiSalvo 2012, Korn & Voida 2015, Pierce et al 2015), reflexive interrogation of the positionality of the ethnographic researchers in the field (Williams & Irani 2010),

and considerations of the possibility of technology as an emancipatory agent [Stolterman & Croon Fors 2008). Crisis informatics, by drawing upon sociological research into disaster, has raised important critical questions about who produces and consumes information related to crisis. Through the concept of informating, we see opportunities to deepen and expand critical perspectives in the field. Here we sketch an outline of a research agenda that could respond to this opportunity.

Beyond Social Media

Crisis informatics scholarship was initially developed just preceding the advent of social media. As a result, the field has tended to focus on the affordances of these new technologies as they relate to sense-making, communication, and collaboration during periods of disaster. Work in this space has been valuable, as it helped to temper the techno-centric frame that enthusiasm for social media demanded at the time (for example Palen et al 2010). However, recent studies have begun to expand the range of technologies under investigation, including the role of participatory mapping in disaster risk modeling (Soden et al 2015), the linkage between situation reports as information products and wider ideological tensions in humanitarianism (Finn & Oreglia 2016), interplay between social media and traditional communication technologies (Dailey & Starbird 2016), application development (Hughes & Shah 2015), and the information standards that guide flood mapping in the United States (Soden et al 2017). Continued efforts at widening the domain should prove generative and allow crisis informatics to in turn widen the range of theoretical and methodological contributions it is positioned to make.

Developing a Long View of Crisis

Similarly, we also need to look beyond the immediate moments of crisis to the various ways in which social life produce the very vulnerabilities that produce crisis and disaster and give shape to their impacts. Critical research into disaster has demonstrated that there is no such thing as a "natural disaster" (Quarantelli 2005, Wisnet et al 2001), instead pointing to the ways that hazards and stressors like earthquakes work to reveal, and often deepen, pre-existing, socially produced vulnerabilities. As demonstrated by the L'Aquila controversy, the technologies that describe risk and vulnerability are increasingly the means by which these phenomena are understood, and an important terrain on which competing political values and beliefs are contested. Disasters reverberate through the history of the places in which they occur. Long after the period of crisis is deemed to be over, they continue to have impact, foreclosing some possible futures, and opening others. Taking the long view of crises, and the practices of informating that surround them, is therefore a necessary step toward understanding their genesis, dynamics, and meaning. Research into the longevity, maintenance, and decline of ICTs (Cohn 2016, Jackson & Kang 2014, Ribes & Finholt 2009) provides a solid foundation upon which these questions could be raised in crisis informatics.

Foregrounding the Politics of Crisis Information

Recent literature in the area of critical data studies has sought to assess data, algorithms, and information systems as sites of power where claims over what gets measured and how data is combined and analyzed have material consequences and are important sites within wider political struggles (Dalton & Thatcher 2014, Gitelman 2013,

Kitchin & Lauriault 2014). Such concerns have been increasingly taken up in recent work within HCI and CSCW on big data and the politics of measurement (Kaziunas 2017, Pine & Liboiron 2015, Soden et al 2017, Voida et al 2017) but also featured in some of the field's earliest debates (Suchman 1993, Winograd 1993). Practices of informating determine whose perspectives about disaster are heard, who receives assistance during a crisis and how, who is considered vulnerable, and who will live with risk. Humanitarian agencies are situated differently in relation to situational awareness about disasters than affected populations. As discussed in the Haiti examples, responders have different relations to risk information than residents of vulnerable areas. These positionalities shape the approach to informating that various actors practice. The processes by which we informate disaster are thus political. Taking these politics, and their consequences, seriously should be a priority for crisis informatics.

Historical Analysis of Crisis Information Systems

Both Zuboff and Fortun focus on placing informating within particular historical moments, focusing on periods of change, and asking questions about the implications of such change. Genealogical approaches to research, such as those deployed in critical theory and STS, can support better understanding about how technologies came to be how they are, provide evidence that they could have been otherwise, and resurface under-explored approaches. Within HCI, Bødker's call for historical analysis to "focus to the question of why (technology) use is organized the way it is, how different roles of artifacts come into play, and in particular why some contradictions occur" (Bodker 1993:10), is important, but not widely responded to. One possible reason is that genealogy, as an approach to research,

is quite different from the phenomenological posture that much HCI and CSCW theory

draws from (Dourish 2001). As shown by the L'Aquilla example, tracing the lineage of

disaster risk modeling to its roots in the insurance industry help to explain the outcomes of

its application to other problem areas. More attention to historical analysis could assist in

evaluation of current approaches to informating by supporting more thorough study of the

contexts in which these practices occur, and suggest concepts for designers to explore.

Design as an Means for Engaging with Informating

Crisis informatics, as a field of research, has strong connections to HCI and CSCW.

We thus have access to well-established traditions of design research and practice that

offer the potential to reimagine and reshape contemporary modes of informating crisis.

Work in the area of participatory, critical, speculative, and values-sensitive design, to name

some of the more prominent areas, provide a strong foundation to engage with ways in

which crisis is currently being informated, and allow us study how the design of such

systems might yield outcomes that are in greater alignment with our values and political

commitments. In expanding the range of phenomena that crisis informatics studies, and

highlighting the political character of crisis, we can also look at how different modes of

informating can privilege some outcomes over others. In the case of the Nepal example,

how might design research suggest new approaches to post-disaster damage assessment

that can meaningfully account for thorny issues of trauma and land-ownership, or invite a

wider range of perspectives? The significant body of design research developed in HCI and

CSCW should be deployed in support of efforts to undermine problematic discourses of

disaster, reshape the ways these events are understood, and support new forms of sense-making, information-sharing, and collaboration in response.

Conclusion: Toward New Practices of Informating Crisis

As we have argued, informating is anything but a neutral practice of representing the world through data. In the area of disasters and natural hazards, current approaches are often defined by techno-scientific expertise in engineering and physical sciences, aligned with bureaucratic needs of the state (Liboiron 2015, Scott 1998, Stallings 1995, Tierney et al 2006) characterized in Chapter 1 as the Anthropocene gaze. This alliance, comprised of institutions, communities of practices, funding agencies, and scholarly disciplines acts as an epistemic gate-keeper, determining what counts as expertise, how problems are framed, and whose voice is heard. It is further shaped and mobilized through ongoing processes of late capitalism, in particular neoliberal reorganization of the economy, that guide the creation and distribution of risk and access to resources for post-disaster recovery (Klein 2007, Wakefield & Braun 2014, Wisner 2001). Critical disaster research has highlighted the limits of this orientation, but government policy and practice have been slow to adopt its recommendations (Knowles 2012, Knowles 2014). Informating reminds us that the hegemony of contemporary apparatuses, though formidable, is never complete (Gibson-Graham 2008, Li 2007). In efforts toward developing new practices of informating, including those described in this paper, we see attempts to reconfigure relationships between responders and affected communities, between planners and "at-risk" populations, between people and the natural environment. Crisis informatics has the

potential to expand and better define this space for designers, researchers, activists, and practitioners.

In many ways, this chapter is simply a call to bring the insights of critical social theory to bear more expansively on crisis informatics, and it is not the first effort to do so (Crawford & Finn 2014). We have argued that HCI and CSCW literature provide a collection of critical perspectives and methods to support this engagement. This research has considered the environmental impacts of computing (Silberman et al 2014), the development of technologies for use in constrained resource environments (Tomlinson et al 2014), the ongoing legacy of colonialism (Philip et el 2012), and designing for "existential crisis" (Light et al 2017). ICT will continue to play an ever-expanding role in shaping the nature/culture divide. As this divide grows increasingly troubled and prospects for sustainable futures decline, such research will become more important. Ethnographers use a variety of tactics in their research to "make the familiar strange" (Van Maanen 1988), or to establish a critical distance from everyday life to better understand the societies in which they live. Disasters, as sites of "information convergence" (Fritz 1956), demand a critical analysis that can challenge frames that are taken for granted or understandings that appear objectively observed and measured. In Chapters 3-5 of this dissertation, I offer examples of how this approach can be applied across several different geographies, hazards, and social contexts.

CHAPTER 3: THIN GREY LINES:
CONFRONTATIONS WITH RISK ON COLORADO'S FRONT RANGE

Introduction

Upon initial examination, the map that delineates the 100-year floodplain appears

straightforward and uncontroversial. Imbued with the trappings of scientific expertise that

cartographers deploy—scale bar and legend, graticules of latitude and longitude, and the

official logos of scientific and technical agencies—the map conveys a cold, administrative

rationality. Thin grey lines snake across the terrain, tracking major waterways and places

of low elevation, demarcate zones of flood risk. Between them and underneath the light

pointillism used by mapmakers to portray area, outlines of buildings, streets, and

neighborhood parks appear: they fall within a *Special Flood Hazard Area*, a designation of

the Federal Emergency Management Agency (FEMA), for places with a greater than 1%

annual chance of major flooding — this is the 100 year floodplain.

The FEMA Flood Insurance Rate Map (FIRM) (Figure 1), described above, does

work – the side of the line that one's house or neighborhood falls on has meaningful

consequences. Those seeking to construct homes or businesses within the 100-year

floodplain are required to obtain flood insurance and subject to various restrictions

regarding where and how structures can be built. But the map, for all its marks of precision

and authority, conceals the most salient aspect of flood risk. Risk is, by definition, a

probabilistic lens through which we attempt to make sense of the world. The binary

formulation of flood risk presented by the FIRM map has implications for those who rely on

them. As we will show, it conceals uncertainties and prevents important conversations that are necessary to navigate the complex task of managing floods in Colorado.

FIRM maps sit at, and are produced by, the intersection of the technical, legal and bureaucratic apparatus that is the United States National Flood Insurance Program (NFIP). Their production relies upon the collection of and use of spatial data about the natural and built environment, deployment of technical and scientific expertise from a range of disciplines, and participation, support, and funding from various scientific and bureaucratic organizations. The 100-year floodplain standard, developed from among competing standards in the late 1960s, is now stabilized and serves as a boundary object that facilitates coordination between these groups. Though intended primarily as regulatory devices, FIRM maps also have significant, if unintended, effects once they travel beyond the contexts in which they were produced.

At first glance, the lines on the flood map seem to make clear statements about flood hazard. Yet our research shows how this apparent clarity masks important uncertainties inherent to risk information. This paper begins with a close examination of the creation and uses of FEMA flood maps and a discussion of how the 100-year flood map became a standard. We then describe two design interventions we developed that require participants to engage with the complexity inherent in flood risk science. These interventions provide a means of confronting the assumptions that underpin the 100-year floodplain standard and thinking through the impacts that such standards can have on the knowledge politics surrounding uncertain and contentious issues along the nature/culture

divide. Drawing on the growing body of literature in HCI connecting design research to Deweyan conceptions of publics, we argue that engaging with uncertainty and complexity are means of supporting public formation around flood risk.
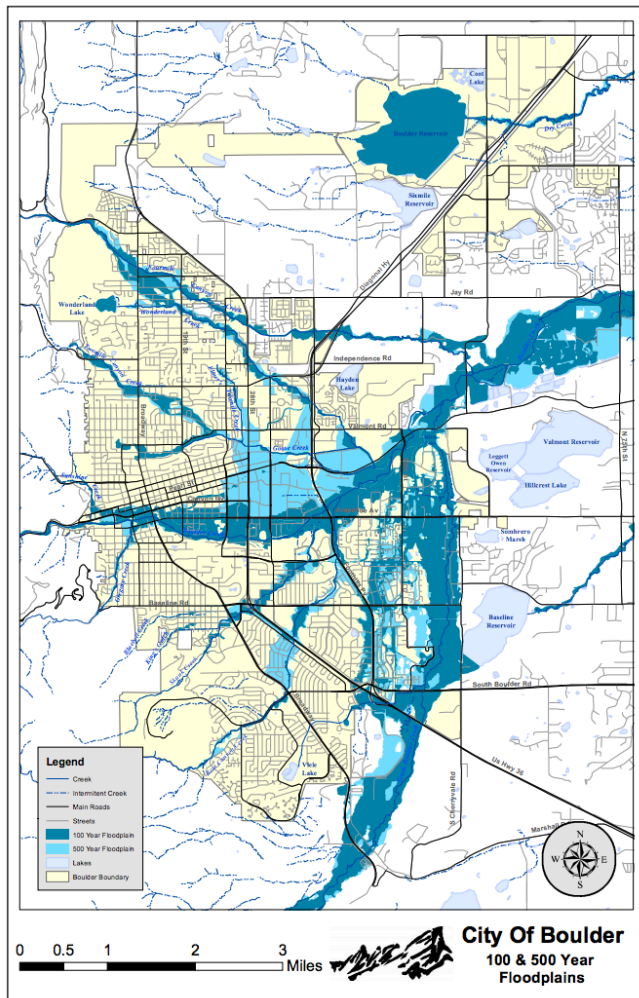

Figure 1. FIRM Map for the City of Boulder
Source: https://bouldercolorado.gov/flood/floodplain-maps

Design and Publics

This paper draws upon, and seeks to contribute, to research within the field of human centered computing (HCC) on the intersection of design and an understanding of

publics inspired by the writings of John Dewey (Dewey and Rodgers 2012). This line of

work draws upon Dewey's pragmatism and optimism about democratic politics and the

ability of individuals, under the right circumstances, to come together, as a public, around

collective problems and come up with workable solutions (DiSalvo 2009, Disalvo et al

2014, Le Dantec & DiSalvo 2013). Publics, however, do not exist ready-made but come into

existence as the result of a particular problem, an externality, or a misalignment between a

problem and the current ability of government to address it. The facilitation of deliberative

and participatory knowledge processes can be approached as a design challenge, what the

literature in HCC is increasingly taking up as part of what DiSalvo et al. have called "public

design" (DiSalvo et al 2014).

Public design is design-for-future-use, design structured to create fertile ground to

sustain a community of participants. Within public design projects, the emergence of

publics can be studied through analysis of infrastructuring and attachments (Le Dantec &

DiSalvo 2013). Here, infrastructuring is building socio-technical mechanisms for

constituting and supporting a public, such as providing scaffolding for affective bonds or

provide a group with capacities that transfer to addressing future obstacles. Attachments

are the dependencies and commitments that become resources for enacting public

involvement in controversy.

Floods and flood risk are intensely political, in ways that make apprehending the

relationship between flood knowledge and flood policy challenging. Though Porter and

Demeritt note that flood mapping "was supposed to ensure more rational, reliable, and

responsible planning approaches to managing flood risk" (Porter & Demerritt 2012:2367), such attempts at rationality are more often than not undermined by the uncertainties inherent in risk science and, just as often, the interests that are challenged or would stand to gain from alternate representations of flood potential.

Whatmore et al. note that "publics quite as much as knowledges are produced in the event of environmental knowledge controversies" (Whatmore et al 2011:595). Design that can assist people to engage with, or muddle through, knowledge controversies is especially useful for preparing citizens to navigate the complex and unchartable waters of disaster risk and climate change. Anna Tsing has written that in the Anthropocene, we need cultivate the "art of noticing" and develop new forms of scholarship that embrace this (Tsing 2015). Risk is a concept that asks us to engage with complexity in ways that modernity's emphasis on certainty makes challenging. John Law has written that we need to recover our vocabulary for dealing with complexity, and that:

> *the real chance to make differences lies elsewhere. It lies in the irreducible. In the*
>
> *oxymoronic. In the topologically discontinuous. In that which is heterogenous. It lies in*
>
> *a modest willingness to live, to know, and to practice in the complexities of tension.*
>
> - Law 1999:12

In this paper, we engage with the knowledge politics of flood risk in Colorado as a site of controversy and irreducible uncertainty. We consider how encounters by the public with expert flood knowledge might be staged in ways that create opportunities and build

capacity for understanding complexity needed for collectively engaging with disaster, climate change, and other uncertain futures.

Study Site

2013 Colorado Floods

Over a period of four days in September 2013, Colorado's Front Range area received nearly one year's worth of rainfall. The intense amount of precipitation affected multiple drainage catchments, leading to widespread flooding that killed eight people, isolated mountain communities, and caused an estimated $430 million in state-owned road damage alone (County of Boulder 2014). Within Boulder city limits, all major waterways overflowed their banks, and the storm-water system was overwhelmed. This resulted in significant damage to over 50 city-owned buildings, an estimated 14% of the housing stock, water and sanitation infrastructure, and widespread destruction of parks, trails, and recreation areas. The nearby City of Lyons and mountain communities to the north and west of Boulder, including Jamestown and Ward, were particularly hard hit with many areas cut off from outside assistance during the flood as the result of road or bridge collapse.

Redrawing of Floodplain Maps

Despite Boulder's history as a pioneering city in the area of floodplain management (Hinshaw 2006), FEMA's floodplain delineations for many of the catchment areas are several decades old and thus require significant update to reflect current conditions. The 2013 floods caused such major changes to the region's topography that

Colorado's office of FEMA petitioned for and received funding from the federal government to update the NFIP 100-year floodplain maps for many of the affected portions of the Front Range. This process is ongoing; it often takes several years between initiation of projects and the finalization of these maps. At the time of writing, the state has contracted several engineering firms who are collecting and analyzing new data for the area, producing new maps, and convening meetings that provide opportunities for the public to review the results before they go into effect.

Mapping Floods: Past and Present

The first part of this research effort draws upon qualitative research of flood hazard mapping in Colorado. We conducted participant observation of flood modeling in a Colorado-based engineering firm contracted by FEMA to update FIRM boundaries following the 2013 floods, and provide consultation on development and construction projects that take place within floodplain. We attended team meetings, assisted with data preparation and modeling tasks, and observed the work of experienced engineers. In addition, we conducted interviews with staff and consultants of Colorado's FEMA Region VIII Office, engineers and project managers employed at consulting firms hired by FEMA to conduct flood mapping work, and staff of the City of Boulder and other local governments in the region. This data collection was supplemented with analysis of government documents related to the NFIPS program and archival flood documents at the Carnegie Center for Local History in Boulder, Colorado.

The NFIP Program

The United States Congress signed the National Flood Insurance Program (NFIP) into law in 1968. The program was designed as an arrangement between municipalities and the federal government to meet a demand for flood insurance that private markets could not meet. In return for local level commitment to floodplain management and regulation of new construction within the 100-year floodplain, the NFIP program would provide affordable flood insurance to homeowners that would otherwise be unable to obtain private insurance (Lowe 2004). The move to insurance was part of a wider move in flood management strategies from structural, or physical, forms of flood control like dams and levies to non-structural measures, itself a reflection of shifts in political economy and discourses surrounding risk management (*ibid*).

To determine areas that would be eligible for involvement in the NFIP program, Flood Insurance Rate Maps (FIRMS) needed to be developed to delineate floodplains. In the 1960s there were a number of competing models for how to approach this. The US Army Corps of Engineers used the "Standard Project Flood," or the most severe incidence of flooding that could be modeled using site characteristics, in the design of their projects. The USGS was hesitant to rely on modeled floods and instead advocated for methods based on observations of past events as a design standard (Robinson 2004). At a workshop at the University of Chicago in 1969 where flood experts convened, the 1% standard—or the 100-year floodplain—emerged as a compromise between these and other approaches. When FEMA adopted the 100-year floodplain standard as the official measurement for the NFIP program in 1971, its stabilization (Lampland & Star 2009) had the effect of replacing other

standards of flood hazard assessment across other areas of flood management (Robinson 2004).

The 100-year floodplain standard facilitates uniform management at the national level at the expense of local adaptability for site-specific circumstances. In practice, the development and updating of FIRM rate maps has often been more expensive and time consuming than projected. In 1999, when FEMA launched the Map Modernization program, an effort to create digital flood maps that are believed to be more easily updated and allow for greater communication with the public, over 75% of FIRMS were over 10 years old (Patterson & Doyle 2009). Map Modernization stalled within a decade as the program ran out of funding due to poor quality of previous maps and an expensive public appeals process. In Colorado, the program was launched in 2002 and halted in 2008 with only half the counties completing the process (interview data). The lack of updated maps facilitates continuing unsafe development in flood-prone areas through reliance on out of date information and the grandfathering of new construction that would be disallowed under revised maps (Thomas & Leichenko 2011).

The Limits of Risk Science

Beyond the practical challenges of producing the FIRM maps that enable the NFIPS program, there are legitimate concerns about the impacts about the ways that floodplain delineation represents scientific knowledge about flooding. Flood mapping in the United States is a massive enterprise. Tens of million dollars a year go to engineering firms, such as the one we observed, who work to produce and maintain NFIP maps. This work is

increasingly being awarded to large companies who have the capacity to stay abreast of,

and meet, the ever more complex set of regulations governing the standards to which these

maps are produced. Attempts to further standardize the flood-mapping process in the

wake of the levy failures that caused so much damage during Hurricane Katrina have led to

increasingly complex requirements (interview data). This complexity has, in turn, reduced

the ability of smaller, local risk modeling firms to bid on FEMA contracts. According to one

FEMA employee involved with NFIPS mapping for Colorado, the increase in bureaucracy is

also slowing the process down and making it more expensive.

Some of the scientists and engineers we interviewed expressed frustration at the

situation. One engineer said he was "dealing with volumes and volumes of guidelines" and

felt "boxed into the regulatory framework." There was concern by some that regulations

were leading to decreasing quality of the maps and inability to test new or improved

approaches. A scientist said that the larger companies who are doing an increasing share

of the work "have a cookie cutter approach to modeling. They can't afford to do innovative

or interesting stuff." Attempts to standardize existing processes around the NFIP have had

the consequence of limiting the kinds of organizations who can be involved in the process

and reducing the autonomy of the scientists and engineers that FEMA contracts to explore

and develop new ways of improving the maps.

Because these maps play a direct regulatory role in regards to who is required to

purchase flood insurance and what can be built and where, the public review process has

grown intensely difficult. According to many of the engineers and scientists interviewed,

the technical production of the map to FEMA specifications is often straightforward. The

challenge comes in afterwards, when the maps go into post-processing, which allows for

public appeals through the Letter of Map Adjustment (LOMA) process. These appeals can

last for years, to the extent that sometimes the maps go out of date and need to be

recreated from the beginning. One engineer explained:

> *It's nice that people are all into resilience and risk management but what happens if*
> *the new regulatory maps come back and half of the town is in the floodplain... The*
> *biggest problem we have is if we can't get the community onboard, and then they get*
> *together with the developers and homeowners with the pitchforks... We used to be able*
> *to say: this is the best available data; this is the floodplain. Now you need consensus*
> *from the community.*

The "developers and homeowners with the pitchforks" can be understood as a

public, but one that formed through resistance to the requirements of purchasing flood

insurance as well as the development restrictions that come with being mapped in the

floodplain. This highlights the critical impact that framing of the issues has on the kinds of

publics that form in response (Le Dantec & DiSalvo 2013). The intense scrutiny that

mapping processes undergo leads to a situation in which the location of the floodplain ends

up too often as a very conservative estimate, the minimum that the firms feel they can

defend against external scrutiny. This results in a situation one engineer described as

"some people don't have flood insurance that will need it when their communities are

flooded."

Unintended Consequences of the Floodplain

The limitations of the 100-year floodplain maps are well known among the scientists and engineers working in our study site. According to one hydrologist working on floodplain mapping in Boulder County:

> *the idea of a floodplain boundary came about during a period when we had much coarser understanding of how floods worked. Now we have better information, better data, better models, yet we still use this outdated approach. You're either in the floodplain or out of it.*

The NFIP maps, based on hydrological, soil, and erosion models, do not account for many of the important issues scientists, engineers, and planners now think about when discussing flood risk, including the impacts of climate change, projected development in the region, and the interaction of flood hazard and wildfires. One engineer said "there's all kinds of things that can happen during a flood that throw these maps out the window."

Despite this awareness among those involved in FIRM Map production, many members of the public who lacked intimate engagement with flood science did not hold such nuanced views. This loss of information between the experts engaged in map production and the public understanding of flood risk had important consequences during the 2013 Floods in Boulder County. In Jamestown, for example, debris caught in one of the channels led to the river overflowing its bank and causing major damage in an area that was outside of the floodplain and not expected to flood. Within the City of Boulder, the topography of the streets and landscaping had similar effects, channeling water outside the

floodplain. Yet many of the homeowners and businesses in these areas had not prepared for flood events. Homeowners reported that they had been convinced not to purchase flood insurance because the FIRM maps located them just outside the floodplain. The understanding of flood risk conveyed by the maps thus contributed to Boulder's vulnerability during the 2013 floods.

Such problems are not confined to Boulder. After almost five decades of the NFIP program and billions of dollars in investments, flood damages in the United States continue to increase (Patterson & Doyle 2009). Estimates related to continued development in risky areas and the impacts of climate change project that this trend will continue into the future. One study of the NFIP implementation in North Carolina found that while the program reduced development in areas delineated by the floodplain, it actually increased exposure in areas just adjacent to it, which were labeled "safe" due to imprecisions in the maps or inaccurate or out of date flood models. In other cases, the practice of incorporating flood levies into the modeled floodplains has encouraged development behind them, which is then at-risk when these structures are over-topped during flood events (Pinter 2005). In other cases, the classification of particular neighborhoods or areas as "risky" is also seen to have blighted areas (Gandy 2014). Other concerns relate to the FIRM maps lack of inclusion of climate change or future development projections and their impact on flood risk. Finally, events such as the downing of trees or the accumulation of debris in riverbeds may dramatically alter the path of floodwaters in ways that even sophisticated flood models cannot forecast.

Designing New Confrontations with Flood Knowledge

The second part of this this research sought to explore ways of restoring some of the complexity of risk science that the floodplain boundaries elide. As shown above, the NFIP does not support formation of publics that engage substantively with flood risk. Instead, the NFIP is the sort of technocracy that Dewey cautioned against, run by political agents that make decisions that have indirect and extended consequences without participation form local communities or citizens. We designed and deployed two design interventions to engage residents of the Colorado Front Range with risk knowledge. The first intervention is a flood game, conducted with members of the public that explored deliberative approaches to the co-construction of risk understanding. The second is a design prototype of a municipal flood information website that provides homeowners with information about their property's floodplain status and associated insurance responsibilities.

Recent research in the social sciences has set out to explore more deliberative approaches to risk communication that alter risk communication and the practice of risk science (Donaldson et al 2013, Kousky & Schabman 2015, Porter & Demeritt 2012, Whatmore 2009, Whatmore & Landstrom 2011). Such approaches seek to involve new actors, expose uncertainties and assumptions in ways that spark deliberation and debate. Rather than masking complexities, these methods seek to expose, enhance, and dwell upon the uncertainties and controversies that arise during the production of risk knowledge. Stengers' notion of cosmopolitics looks to "not say what is, or what ought to be, but to provoke thought" (Stengers 2005:1). For Stengers, this is a question of design, or the "artful

staging of an issue" in ways that resist simplistic framings and support intimate engagement with the aporias that issues like risk present.

One example of this is a recent project in the UK in which, in the wake of flooding, a "competency group" comprised of both experts and members of the public worked together over the course of a year to reimagine possible approaches to flood mitigation that both challenged government plans and allowed for sustained exploration of the issue through collaborative technical work on complex flood models and public exhibition that allowed the work of the competency group to travel (Whatmore 2009, Whatmore & Landstrom 2011). This process facilitated a "redistribution of flood modeling expertise in ways that challenged the hardwired arrangements" (Whatmore & Landstrom 2011:595) previously in place between the scientific and government entities involved in flood science.

We discuss two design exercises that draw inspiration from these approaches to create thoughtful encounters for members of the public with flood information and the 100-year floodplain standard. The first is a tabletop game that encourages participants to collectively reflect on flood risk and options for mitigation. The second is a website that provides information to homeowners about flood insurance. Our team developed, deployed, and tested both designs.

Case 1: Flood Risk Game

The game is a communication design co-designed by the authors and interdisciplinary collaborators (Figures 2 and 3). As such, it is designed to enable communication that may be unlikely to occur on its own—more deliberative discussion about risk (Sprain et al 2014). In these game sessions, small groups of three to four players work together to make a series of choices related to flood risk. The group is given a budget of $1 million in play money to be spent on a house and various flood management actions and repairs. Led by a facilitator, they begin by buying a home, which requires considering location (e.g., inside the 100-year floodplain or outside the 500-year floodplain) and building design (e.g., basements vs. crawlspaces). Then the group must decide whether to purchase insurance, do mitigation, or take no additional action. The group rolls a die that represents flood risk during a ten-year period, determining whether a flood occurs and, if so, the damage and repair bill based on the group's choices. The game includes three rounds of rolling the dice. During play, groups work with flood maps, information handouts based on engineering models, and experts to decide whether to buy a new house, purchase

Figure 2. Flood Risk Game Materials

Figure 3. Playing the Flood Risk Game

insurance, or use mitigation strategies. The game does not aim to present a fixed

identification and assessment of flood risk. Instead, it creates the conditions for

participants to negotiate understandings of flood risk by experiencing multiple flood

scenarios, sharing player's knowledge and understanding of floods, and interacting with

information about damage. Analysis draws on full transcripts of game play of ten groups

taken from a local conference on disaster risk and an undergraduate engineering class. For

coherence, we draw on data from a single group.

During game play, participants co-constructed notions of risk. This includes both

general characterizations of themselves as risk tolerant or risk adverse, trajectory stories

of them being risk tolerant within the game, constructing the relevant criteria for

evaluating risks, and constructing particular aspects of flooding (e.g., hydrostatic pressure)

as particularly dangerous and not well-understood. Participants also questioned and

deconstructed the insight about flood risk offered by the flood map. In the excerpt below, a

group is given a map showing the 100-year floodplain and a map with the houses that

submitted FEMA individual assistance damage reports in 2013.

Grace: ... Um, okay, so this is even more interesting that you give us this because if you

overlay these, the FEMA floodplains do not correspond to the damage. Why? [Asked to the

facilitator] You don't know. (laughs)...

Kyle: Hmm. (Jon mutters something) Interesting.

Jon: The floodplain is not covering all of the flooded areas.

Grace: But this is post.

Jon: The event exceeded the hundred year flood [amount].

Grace: Yeah, where it rose above.

Grace notes that the damage reports do not match up with the floodplains—people reported damage even outside the floodplain. Jon's initial explanation is "the event exceeded the hundred year flood amount." The group circled back to this issue several times, de-constructing the flood map as a straightforward representation of flood risk and replacing that with the sense that some floods go "beyond the extent of the hundred year floodplain" and damage does not always correspond to the floodplain (implying the floodplain alone was not the best indicator of risk).

Even though the game focused on homeowner decisions, collaborative play encouraged them to think about flood risk beyond the perspective of individuals, as demonstrated in this excerpt:

Jon: If I was thinking as an individual, I probably wouldn't want the headache of a home in the floodplain.

Kyle: Yeah.

Jon: And also thinking from a community perspective, to have all these homes in that risk location is. . .

Kyle: Right.

Jon: . . .I mean, it takes a toll on the community. . .

Kyle: Absolutely.

Jon: . . .in terms of recovery efforts.

Kyle: Yeah.

Josh: And, um, it's just, uh, especially with uncertainty about the floodplain, that there's damage happening outside the hundred year, that's where the level of uncertainty right now, there could be an event that goes way beyond these boundaries earlier than the next thirty.

Kyle: Yeah.

Jon: . . .fifty years, I think, um, making proactive choices to reduce, reduce the risk, 'cause, uh, something I would feel good about, in terms of the community taking on.

Grace: From a community standpoint, I would also feel a little bit selfish getting a home in the commun- in the, in a floodplain when I know that the likelihood of it flooding is quite high. And I'm asking other people to risk their lives to potentially save me and my home.

Kyle: Absolutely.

This interaction shows evidence of attachments that serve as resources for public formation. Jon's move to think from "a community perspective" introduces a relation to flood risk that is collective in nature. This attachment bears the emotional and material costs of recovery efforts because community is committed to the public good and ensuring to public safety. Flood risk itself is uncertain, as Josh mentions, which challenges community planning. Grace notes the dependence of individuals on community emergency management to be rescued, an attachment that makes living the in the floodplain "selfish." Together these attachments articulate negative externalities and consequences of flood risk that are experienced collectively—the basis of public formation.

Case 2: Designing for Friction in Web-Based Maps

According to our interviews, one of the most common scenarios for members of the public to encounter flood science is when they, as homeowners, seek to find out whether their homes are in the 100-year floodplain and, if so, to understand options for either purchasing flood insurance or contesting that designation. Our interviews with city officials from various municipalities in Colorado indicated that interacting with members of the public around this issue was a major source of work for their staff. To ease these demands, many city and county governments in the region have launched websites that

Figure 4: Flood Risk Website

After entering a street address into the search bar, users are given indication as to whether the property is in the floodplain and, if so, what actions they are eligible to take. Also displayed on the map is the footprint of the 2013 Colorado floods.

allow users to view boundaries of the floodplain. Our team saw this as an opportunity to

explore the opportunities that everyday interactions between local government and the

public might afford for encouraging understandings of flood risk that allow for, and engage

with, complexity and uncertainty.

To help think through ways of accomplishing this, we drew upon the concept

frictional design. In HCI research on technologies for civic engagement, friction is a design

tactic that offers a critique of e-government and other strategies aimed at producing

smoother, more efficient relations between citizens and their governments. Instead,

frictional design seeks out those challenges and inefficiencies that can help raise issues that

might otherwise be invisible. Korn and Voida write that friction "can help to expose

diverging values embedded in infrastructure or values that have been left aside during its

design" (Korn & Voida 2015:2). As opposed to design that enables technologies to fade into

the background, frictional tactics resist transparence to promote new connections or more

meaningful engagement. In this case, we saw the tactics of frictional design as potential

antidotes to the problematic discursive closure presented by FEMA's designation of the

100-year floodplain.

To explore this potential, we developed a simple, functional, prototype of a

municipal website (Figure 4) that presented users with the location and boundaries of the

floodplain. The basic operations of the site allow users to enter their address into a search

form and receive immediate notification, presented visually on a map, whether their

property is located within the 100-year floodplain as determined by FEMA's FIRM map

(Figure 1). If the address entered by the user is located within the floodplain, users are presented with basic information about how to obtain insurance or file a Letter of Map Revision if they feel the map is inaccurate. According to our interviews with city officials, these were the most commonly asked questions that residents asked about flood insurance.

To explore the impact of frictional design tactics in what would otherwise be a superficially straightforward e-government tool, we conducted user testing after introducing a small change to the platform. On the map section of the interface, in addition to displaying a basic street map, the outline of the 100-year floodplain, and a red pointer reflecting the location of the address the user is querying, we also chose to display the areas affected by the 2013 floods. Though in some parts of Boulder, the extent of flooding fell within the floodplain, there were many areas outside of the floodplain affected, and some areas within the floodplain were unscathed. By adding a layer of extra information—though itself unnecessary to the central task of assessing flood insurance requirements—we introduced a bit of complexity to the process. We saw this as an opportunity to provoke users to more carefully consider the limitations of flood hazard mapping while engaged in an otherwise mundane interaction with local bureaucracy.

We recruited 19 participants from around the Front Range and described to them several situations in which they were asked to determine whether a given address was located within the 100-year floodplain, what the associated insurance requirements were for the property, and eligibility rules for filing a Letter of Map Revision—all information that the site was designed to provide. None of the participants had any background or

experience with flood modeling. Some were homeowners in Boulder, both in and out of the floodplain, and had experienced flooding in 2013. After completing these basic tasks, users were then asked about their understanding of the 100-year floodplain. In particular, we sought to assess the ways in which the addition of the 2013 flooded areas to the map impacted their view of the reliability of the 100-year floodplain. Here we discuss the main findings of this exercise.

First, as we anticipated, the presence of a map of the areas affected during the 2013 flooding on the site raised questions among participants about the 100-year floodplain. For example, when asked if they thought the floodplain was a reliable indicator of flood hazard, one participant said,

I don't know, I mean I'm wondering looking at this, looking at the footprint of the 2013 floods whether human development has affected the floodplain because you can kind of see that just, you know, there are some streets where the street itself was flooded although the shading is really kind of only on the street so it looks like it was like kind of a river or something.

Another told us that,

If you look at the shading in most places, the flood is within the floodplain although not in all places. So I'd be kind of interested to know what proportion of the entire past area that was flooded is inside versus outside the floodplain. But yeah, I mean I would still… I mean I still think that there is useful information conveyed in the one in 100-year floodplain… but it's not perfect information.

Additionally, as a result of the uncertainty introduced by the discontinuity between the flooded areas in 2013 and the floodplain, participants often expressed interest in learning more about the methods and information sources used to determine where the floodplain boundary was drawn. For example, one participant told us,

It was interesting to see the areas that were impacted according to this map that weren't in the 100-year floodplain. I'm also curious as to where their information is on the floodplain. Like I might perhaps, if I knew what their source was for their floodplain, agree with that...

When examining one part of the map where an area outside of the floodplain had flooded, a participant said,

It seemed like maybe because, I don't know, sewers were clogged or something there. So I'd probably try to find out more about when the floodplain was mapped and the last time it was updated.

In this questioning, participants frequently differentiated between statistical probability and individual flooding events, which demonstrated an unpacking of one of the concepts that is masked in the simplistic conception of flood risk that the floodplain presents.

If you look at the map, if you look north, the 100-year floodplain is much bigger north of the creek than what happened in 2013. So I guess I would imagine it's a statistical

approximation that kind of accounts different patterns of water flow as opposed to

the, you know, 2013 event was just one event, so it was one pattern of water flow.

Another said,

I wanted to know what they're basing their map on. Is it just what happened in the

past or calculations based on as you said a type of flood that we only have a 1% chance

of having every year. I would like to understand a little more how they came up with

the map.

Others looked for contextual information on the map or relied on their own

knowledge of the area in question to assess how best to deal with the information.

I mean just from looking at these two properties there seems to be a clear relationship

for example to the proximity to the creek, which is a very kind of intuitive thing, right?

So being in [Property 1] you're closer to the creek and intuitively I do have a sense that

you're probably more likely to get flooded than being on [Property 2]. I don't know

about how much. I don't know how to quantify that.

Participants with direct experience of being flooded in 2013 relied upon these

experiences in their evaluation of the floodplain boundaries. They were among the most

likely to question the NFIP floodplain boundary. We provide quotes from two different

participants here.

I think having been through a flood like the one in 2013 and everything that went

along with that in any home I would ever purchase I would do as much water

remediation or prevention as possible... Especially in Boulder because I don't believe

it's predictable that only the floodplains are going to be the areas affected.

Based on my own experience, no, because mine and my neighbor's homes were filled

with water and it was gross and it cost a lot of money and right now (according to the

map) it looks like we're dry as can be. And so no. I don't trust this website.

Some of the participants, however, adopted a pragmatic stance that both questioned the certainty that the floodplain boundary conveyed while still sensing that the underlying science was not without merit. Illustrated by the statement below, this engagement with the risk information—resisting closure without disregarding it altogether—provides the scaffolding upon which publics might emerge.

I don't know how often floodplains change... but there's a lot of variables that come

into play with flooding. I don't know how you could exactly predict where you're going

to have water and where you're not. So I would never think like, "Oh, well you have the

water's likely to stop right there," you know... So I think it would probably be close, but

I would never like rely on specific boundaries.

Loving our Monsters, Resisting Closure

Our research on the NFIP program in Colorado shows that flood risk science, as an attempt to make rational calculations about possible futures to guide public policy, limits meaningful public engagement with this controversial issue and conveys a sense of

certainty that is unwarranted on scientific terms. Boyd (2012) has documented how over the latter part of the 20th century, the analytic and technological development in risk science and environmental monitoring has led to increase in the predominance of risk thinking in environmental planning and management over the previous emphasis on the precautionary principle. Of this over-taking, he writes:

It is hard not to follow Max Weber and embrace a deep ambivalence about these developments. In the seemingly relentless march of disenchantment, in the never-ending quest for calculability, it is clear that something important was lost as the strong precautionary impulse of earlier years was subsumed by more formal approaches to risk and embedded within increasingly elaborate bureaucratic routines and expert systems.

- Boyd 2012:905

Risk, in this framing, is an attempt at collective management of threat through instrumental rationalism (Beck 1999, Patel 2006). The NFIP program seeks to distribute the financial impacts of potential harm from flooding and relies on the 100-year floodplain as a standard to determine who should participate. This standard is then enacted and struggled over by the complex web of scientists, engineers, bureaucrats, and members of the public that we have described in this paper. Yet as Callon argues in his critique of risk's attempt to tame probability, "science often proves to be incapable of establishing the list of possible worlds and of describing each of them exactly" (Callon 2009:).

In the gap between the ambitions of those who design and enact standards and the world that these standards seek to encapsulate live what Haraway has termed *monsters* (Haraway 1992). Monsters occur "when an object refuses to be naturalized" (Bowker & Star 2000:304). They provide "ways of speaking about the constraints of the classifying and (often) dichotomizing imagination." They are silences, created by the contours of our knowledge systems, which refuse to stay quiet. Standards that are tightly coupled to the phenomena they seek to organize, like the 100-year floodplain, are especially generative of monsters. Characterized by increasing entanglement and uncertainty along the nature/culture divide, the Anthropocene is full of monsters, and more are coming. Climate forecasts, hurricane "cones of uncertainty", flood risk maps—they each create monsters through their attempts to order the world in a fashion that accords with contemporary rationality.

Standards work to bracket off uncertainty or alternative interpretations. Though we have focused here on some of the negative impacts that standards, such as the 100-year floodplain, can have, standards play essential, unavoidable roles in the ordering of modern life (Jackson & Barbrow 2015, Lampland & Star 2009). Their reductive qualities are precisely why they can serve to enable Latour's "action at a distance" (Latour 1987). The task for scholars has been to cast a critical gaze upon the standards (Bowker & Star 2000, Lampland & Star 2009) at work in our research sites, demonstrating the ways in which they are deeply historical and contingent, and tracing their effects. We have shown here that the 100-year floodplain standard, developed in the 1960s at a time when multiple other standards of risk were in use, has served the bureaucratic requirements of the NFIP

program. We have also shown some of the consequences of this formulation of risk, in particular in the ways that it can interfere with public formation by turning complex political issues into "solved" technical or scientific questions.

We find that one of the central problems of flood maps is that they represent a kind of *discursive closure* (Deetz 2007) in the knowledge politics surrounding flood risk. The "thin grey lines" on the 100-year floodplain map are the product of numerous datasets, the input and assumptions of technical experts from various disciplines, and a lengthy bureaucratic process. These lines do the work of hiding these contingencies and uncertainties in favor of presenting a finished, decided-upon boundary of the floodplain. In their design, they convey a certainty and finality to which the science underlying them has no epistemic claim.

In a revisiting of Mary Shelley's *Frankenstein,* Latour argues that Dr. Frankenstein's sin was not in his creation of the monster, but in his abandonment of it (Latour 2007). As standards and classifications emerge, stabilize, and decline, monsters will continue to appear at their margins. Yet for Latour, with proper love and care, these monsters can be our allies. This attention is in accordance with Stenger's call for slowing down in the face of environmental controversies or Haraway's "staying with the trouble" (Haraway 2014, Stengers 2005). Recent work in HCI has also pointed to the ways in which, under the right circumstances, even tightly constrained standards can offer affordances for creativity and innovation rather than shackles alone (Jackson & Barbrow 2015). In a play off on CSCW's notion of articulation work, Bowker and Star (2000) describe the practices

required to manage some of the difficulties enacting standards as categorical work. Following Latour, we might also call it *loving our monsters.*

What kind of standards, relations with them, and ways of enacting them might we design as an alternative? What kind of knowledge about disasters can express uncertainty and inspire reflection rather than foreclose debate? How might we look to countermand the hegemony that the 100-year floodplain has over the public imagination of flooding? A recent review of flood decision-making processes called for more opportunities for the public to engage in deliberative thinking about risk (Koulsky & Shabman 2015). This is what we experimented with through the flood risk game. We have also shown that frictional design tactics can intervene in everyday relations between the government and the public and complicate these interactions. These kinds of interventions may be best suited for working in collaboration with standards to help keep the controversies alive in the public discourse that the standards would otherwise foreclose.

This research contributes to HCI's examination of the relationship of design to Deweyian publics through exploration of these concepts within an ongoing knowledge controversy. We find, in agreement with Whatmore (2009), that such controversies can generate publics, and that designers can intervene in ways that help encourage deliberation and collective understanding of disaster information. The publics that emerge through such controversies can help to tame our monsters. Encounters with disaster information can be staged as confrontations with the standards that our institutions require to enable publics to organize around the challenges of risk. Such encounters might

include conflicting forecasts, historical records, oral histories, and artistic expression. These possibilities for representing complex knowledge about disasters allow for nuance, contemplation, and polyvocality in ways that singular, reductive standards elide.

Our design interventions demonstrate attachments and infrastructuring that support public formation around flood risk. The game revealed attachments between the community and flood risk, attachments that serve as resources for enacting public involvement in controversies over where people should live and how the community should plan in the face of increasing uncertainty. Both the game and the web site helped participants explore uncertainty and recognize complexities otherwise masked by the thin grey lines on the flood map. These activities are an important form of infrastructuring because they provide the capacities needed to address future obstacles. This infrastructuring alone does not constitute a public. But our designs show potential for contributing to public formation through infrastructuring and developing attachments.

If the emergence of publics is a valid area of concern for design research and a site of intervention for designers, then we must ask what kind of publics are formed through our interventions and how various design tactics influence the dynamics of public formation. In other words: What do different interventions yield with respect to different kinds of publics? Who is excluded during public formation around disaster issues? Is the framing provided by risk science more likely to yield individualistic responses, or inspire expressions of collective concern much in the way one of our participants shared?:

> There's the services that are along that plain that ... would freak you out. Like there's
>
> the prison that's right there by the creek and I don't even know who gets held there,

but I would think they have evacuation plans in place because it's so ridiculously

close.... I'd be interested to know where Boulder Community Hospital falls in the

floodplain because the old one was within it.

In addition to the prison and hospital mentioned by our participant, one of the city's largest high schools is located along the creek, as is international student housing for the University of Colorado. Do vulnerable populations like prisoners, patients, students and international residents have a means to be included in public formations around flood risk? These issues of voice and framing, long considered in disaster studies and participatory design, must be considered when designing for publics.

Conclusion

The case of the flood mapping illustrates the problems that occur when uncertainties are obscured and "hardwired into government policy" (Donaldson et al 2013:510). The interventions in this paper draw from design tactics within HCI and allied fields to point us in the direction of approaches we might take to design for publics. Through problematizing the standards by which many citizens arbitrate and anticipate past and future events (often to their detriment), we can begin to test and explore how design can support public engagement with contentious or uncertain knowledge politics. How many monsters might be tamed through use of tactics that design for publics? How can the results challenge, supplement, or serve in the stead, of current standards?

This paper set out to engage with these questions by exploring how publics can be constituted around flood risk. It highlights the relational and emergent characteristics of flooding that forge new connections between flood knowledge and flood policy. We show how the discursive closure of those thin grey lines can be resisted, with productive effects. In doing so, we point to some of the ways that emerging approaches in HCI can design encounters that support publics capable of developing the necessary resources for facing disaster, climate change, and other sources of threat during difficult times.

CHAPTER 4: MAPPING SILENCES, RECONFIGURING LOSS:
PRACTICES OF DAMAGE ASSESSMENT & REPAIR IN POST-EARTHQUAKE NEPAL
INTRODUCTION

Following major disasters, the government entities and humanitarian agencies comprising the formal crisis response mechanisms of contemporary society engage in a series of practices aimed at describing the scope, severity, and distribution of the event's immediate impacts. Using techniques that range from on-site visual inspection by civil engineers to smartphone applications or crowd-sourced analysis of satellite imagery, statistics are produced such as the number of human casualties, buildings and roads damaged or destroyed, crops and livestock affected. These socio-technical processes, increasingly reliant on new technologies, convert the lived experience and condition of individuals, communities, and their infrastructures into information legible to the moral, bureaucratic, and logistic sensibilities that govern crisis response (Fassin 2011). This process, referred to as 'damage assessment' is an act of sense-making about disaster that in turn shapes response and recovery activities (Fortun 2009, Weick 1988). In the process, the statistics produced during damage assessment also come to dominate public discourse about the memory and significance of the disaster as well as imaginations of what future 'recovered' life in the affected areas might consist of (Fortun 2009, Liboiron 2015, Schafers 2016, Simpson 2013).

For all of their practical significance, the tools used in damage assessment are hardly neutral technologies that provide unbiased or objective understandings of disaster impact. On the contrary, their results are frequently exaggerated or under-reported by both governments and individuals in order to influence the amount of aid delivered or shape

public opinion about the events (Schafers 2015, Simpson 2013, Wisner 2001). On a more fundamental level, these activities produce specific understandings of disaster that reflects a combination of engineering expertise and the exigencies of bureaucratic logic. The reductive quality of this process shares characteristics with what geographer Brian Harley referred to as "cartographic silencing", in which objects and phenomena "outside the surveyor's classification of 'reality' are excluded" (Harley & Laxton 2002: 98) and thus eliminated from discourse. Harley argues that silences are "affirmative statements, and they have ideological consequences for the societies in question. Such silences help in the reproduction, the reinforcement, and the legitimation of cultural and political values" (Harley & Laxton 2002:106).

Our research inquires into the silences produced by the social practices and information systems supporting the Government of Nepal damage assessment that took place following the April 2015 earthquakes, their consequences, and their implications for the types of repair work that were conducted during disaster recovery activities. We find that the damage assessment acted as a kind of inscription device (Latour & Woolgar 1986) that constructed the infrastructures impacted by the earthquake as targets for specific approaches to repair work. In doing so, the assessment ultimately scripted (Akrich 1992) the kinds of earthquake recovery that took place in post-earthquake Nepal: enabling some, and rendering others unthinkable. Our research combines a qualitative study of the actors and institutions that planned and executed the government damage assessment and participatory mapping activities undertaken in the Langtang Valley, a remote and severely affected part of Nepal. Drawing on fieldwork in each site, we argue that the silences created

by the data collection tools and methods of the official damage assessment foreclosed opportunities to address important challenges that the people of Langtang faced in the aftermath of the earthquake.

Making Sense of Catastrophe

Crisis & Broken World Thinking

Over the past decade, the field of crisis informatics has studied technology usage and activities of cooperative behavior and sense-making during moments of crisis (Palen & Anderson 2016). The Latin roots of the word crisis meant "turning point," or "decision," or "judgment." As traditionally understood, crises function as breaks in discourse, moments of transition during which old concepts and ways of thinking and being fail and their replacements aren't yet able to bear the weight we need them to (Roitman 2013). People who live through crises are struck by the disorientation and the foreshortened view of future horizons characteristic of moments when, in Marx's phrasing, "all that is solid melts into air." Yet this view of crises—as being temporally limited and extraordinary events that are triggered by external causes—has unfortunate side-effects, directing attention away from the longer arcs of vulnerability that allow disasters to occur (Blaikie et al 2014, Liboiron 2015, Tierney 1999, Wisner 2001) or the multiple ways in which their impacts continue to reverberate through time long after the crisis has ended.

Our means of apprehending contemporary crises are increasingly mediated by information systems and infrastructures that are sometimes global in scale (Edwards 2010). The design of such systems is therefore a critical area of research. Liboiron, in a

study of post-Hurricane Sandy damage assessments, notes the predominance of "data collection and representational practices that emphasize sensational or episodic moments of destruction rather than the structural conditions that facilitate particular patterns of devastation" (Liboiron 2015:159). Recent research suggests opportunities to consider instead the more continual ways in which artifacts and infrastructures are continually emerging through creative action (Jack et al 2017), being maintained or repaired, or being broken down (Cohn 2016). Gordillo sees the material remains of prior infrastructure as an "invitation to transformation" and to offer the "possibility of building something better" (Gordillo 2014:45). Such an approach, which Jackson illustratively terms "Broken World Thinking" (Jackson 2014), enables us to consider crisis as a relational or ontological, rather than epistemic, phenomenon and offer approaches to recovery that don't take the wholeness or permanence of pre-crisis socio-material relations for granted.

Sense-Making About Repair

Studies of repair decenter HCI's traditional focus on design and use of technology in order to attend to more rarely noticed temporalities oriented around maintenance, sustainability, and breakdown (Jackson 2014). In our field site, questions of repair are foregrounded by the recent catastrophe and ongoing efforts to cope with and recover from its effects. The targets of repair in this study are the infrastructures that residents of Nepal rely on as they go about everyday life in a challenging environment. Recent work in repair studies has shown that these processes are far from straightforward. Repair, as a set of socio-technical practices, is infused with values (Houston et al 2016) and particular social and cultural logics. Understandings of what counts as "broken" or "fixed" or choices about

what gets repaired are contested and continually negotiated (Houston et al 2016, Rosner & Ames 2014). Ribes writes that unless we ask question about "the repair and maintenance of what, serving whose interests, and at the expense of what people? (Ribes 2014:75), focus on maintenance and repair, no matter how well-meaning, may ultimately end up "reproducing the existing social order" (ibid).

Repair work, enacted in the present, has complex relations to both past and future. Diagnosis, a precursor to repair, relies upon implicit assertions about a previous, stable, or ideal instantiation of infrastructure, describing a particular and frequently depoliticized past. Repair work is also anticipatory (Steinhardt & Jackson 2014) and guided by normative visions of the future, both individual and collective, even if they are frequently left un-articulated. Sense-making about repair thus plays a central role in the practice, and includes activities related to problem recognition, identification of the source or cause, assessing various options for intervention and determining a course of action, receiving feedback and adjusting course throughout repair activities, and finally, determining whether the repair work has been successful. Repair is often associated with tacit knowledge and an ethos of care (Cohn 2016, Houston et al 2016, Jackson 2014) associated with human-scale objects like cellphones or copy machines with which it is possible to establish a physical, intimate, co-presence. Here we explore some of the challenges of "caring at a distance" (de la Bellacasa 2017:111) that arise when sense-making about the repair of large infrastructures are mediated by other technologies (Cohn 2016, Jack and Jackson 2016)—an issue of central concern in disaster response and recovery.

Mapping as Situated Action

Our research in the Langtang Valley uses participatory mapping activities as a method for interrogating the tools, information standards, and data collection practices used by the government damage assessment. Building on research in human geography and critical data studies (Burns 2014, Crawford & Finn 2014, Finn & Oreglia 2016, Shelton et al 2014), we find that these activities offer a means of studying the data politics of humanitarian technologies. In participatory planning and development, maps have been used as means of supporting inclusive planning processes, incorporating local knowledge into data collection, challenging authoritative framings of spatial phenomena, or resolving disputes over territorial claims (Bryan 2011, Peluso 1995). Other research has explored the ways in which mapping can support collective remembrance and history making during periods of rapid change (Sletto 2014, Wood 2003). Sletto writes that memory is not "simply a retelling of the past but an iterative and unstable co-production of identity and landscape" (Sletto 2014:362). Mapping can thus be a means of performing alternate or emancipatory memory that undermines official or hegemonic histories. In this view, mapping can be understood as situated action, equally as important for its performative qualities as for any information artifacts it may yield (Bryan 2011). In the wake of the Nepal earthquake, where the intensity of the disaster exceeds the enumerative and descriptive capacity of technical assessments, we explore the potential that mapping offers for a generative practice of sense-making—a way to begin to account for losses that are ultimately un-measurable.

This Study

Nepal Earthquake & Recovery

On April 25, 2015, a major earthquake struck central Nepal, devastating many rural villages and triggering landslides around the country. During the earthquake and ensuing aftershocks, over 9,000 people were killed and over 1 million rendered homeless. The disaster triggered major humanitarian response from the Government of Nepal, international organizations and, importantly, local civil society groups, both established and emergent. While the country had undertaken significant preparation for a major earthquake in the capital city, Kathmandu, this was largely a rural disaster, and the difficulty of access to remote areas complicated response efforts of the government and international organizations. Following the immediate search and rescue activities, relief agencies worked to provide relief shelter, quickly re-establish schools and/or temporary learning centers, and deliver medical services to affected areas. Alongside formal efforts, informal organizations and voluntary groups played a crucial role in creating, analyzing and provisioning information to both victims as well as response and relief agencies (Lord & Murton 2017, Soden & Palen 2016).

In June of 2015 seven weeks after the earthquake, the international community pledged $US 4.1 billion dollars in reconstruction assistance to Nepal at a major donor conference held in Kathmandu. The majority of this aid was for the housing sector (GoN 2015a), and delivered in a centralized fashion through the newly created National Reconstruction Authority (NRA). The NRA, with technical assistance from international donors, devised what has been referred to as a plan for "owner-driven" reconstruction

whereby households deemed eligible through a house-by-house damage assessment would receive $2,000 in several tranches. Following the initial damage assessment, inspectors would return several times to verify that home reconstruction was being conducted following government-specified techniques that would help ensure new homes would be "built back better", in order to withstand future seismic activity. Payments would be delivered through electronic bank deposits, following certification by trained engineers that rebuilding was underway in a manner deemed earthquake resistant according to government-produced guidelines. This approach to recovery planning and monitoring, based upon techniques devised following the 2005 Pakistan earthquake, was enabled by emerging technologies including GPS-enabled tablets, cellular data networks, and open source software.

Overview of Study Sites & Methods

The Government of Nepal's ongoing housing recovery efforts are enabled and underpinned by a large-scale damage assessment completed during early 2016. To ground our observations of this process, we focused our study of these activities on two sites. The first study site was located in the offices of government and donor agencies in Kathmandu from where the housing damage assessment was planned and overseen. This research is based on participant observation during the planning stages of the NRA damage assessment conducted between May and August 2015, during which time the first author worked for the World Bank as a consultant, as well as interviews and focus groups with key participants, and review of key project documents. By most accounts the damage assessment, though delayed by political infighting within Nepal and conflicts between

Nepal and India, was imperfect, but conducted reasonably well given the circumstances.

The broader recovery program in which it was embedded was designed with guidance

from post-disaster recovery experts from international institutions (Lallemant et al 2017).

Because of this, we argue that it provides an important opportunity to engage with the

logics embedded within contemporary humanitarian information systems. The issues

raised in the following section stem largely from the assumptions and outlook that guided

the design of the damage assessment, rather than particular failures in its implementation.

The second study site was the Langtang Valley in northern Nepal, where the

second author was physically present during the earthquake. The author has since been

involved with recovery work and is conducting long-term ethnographic research on

disaster reconstruction, vulnerability, and infrastructure development in the region (Lord

& Murton 2017). Prior to the earthquake, the Langtang Valley was home to around 600

people and an important site for Tibetan Buddhism. The area is also becoming a popular

destination for trekking and is in transition from a pastoral yak-herding community to a

tourism-based economy (Jack & Jackson 2016). During the earthquake, five major

landslides and avalanches occurred in the Valley, destroying several villages and killing

more than 300 people including residents, Nepalis from other parts of the country, and

visiting tourists. Funding through the government reconstruction program, for which the

damage assessment we studied was designed, did not arrive in Langtang until over two

years after the earthquake. In the absence of formal assistance from the government during

this period, Langtang residents primarily relied on their own networks and ingenuity, as

well as the assistance of a small network of NGOs, to repair and rebuild community

infrastructures—trail networks and bridges, community and religious centers, a health post, and a small hydro-power station—that support everyday life and livelihoods in the valley. For this paper, we conducted qualitative research and participatory mapping in the Langtang Valley in order to understand the ways that the official damage assessment was enacted in this context with what effects.

Expert Discourse of Damage

To study the NRA-led damage assessment, we relied on participant observation of the planning process. The first author spent three months in 2015 working as a consultant on the project during the planning phase and interacted with central figures in the Nepal government and international agencies responsible for its execution. Following the completion of the assessment, we conducted four focus groups of engineers who carried out the assessment, with a total of 30 participants, to understand their approach and execution as well as the character of their interactions with the communities where they were working. In addition, we conducted follow-up interviews with several of the individuals who worked directly in Langtang. We also interviewed six residents of the Langtang community who were present for the damage assessment, and interacted with the engineering team, in order to understand their perspectives on the process. Lastly, we conducted a review of various project documents, so as to understand the logics at work in the design of the damage assessment and the specific practices surrounding its implementation. These methods allowed us to study the Government of Nepal-led damage assessment, the narrative of the earthquake it produced, and the vision of recovery it contained.

The Government of Nepal's housing damage assessment began in December 2015 and was completed by May 2016, just over one year after the earthquake. The government intended that the assessment "would be based on the principles of equity, inclusion and community participation through an owner-driven reconstruction (ODR) approach to build back better" (GoN 2015a:1). The assessment was carried out by a workforce of over 1700 engineers, trained in Kathmandu and sent into the rural areas with tablet devices to record detailed engineering data on the condition and level of damage faced by private houses along with comprehensive demographic data of the residents. The engineers, many of whom were in their early 20's and just out of undergraduate, were teamed up with "social mobilizers," often residents of the communities being assessed, who could help navigate the social and geographic terrain of the area and interview homeowners and photograph the current status of the house for verification purposes. The assessment teams relied heavily on these social mobilizers to navigate unfamiliar areas, locate houses to be surveyed, and identify and interact with their owners.

The assessment teams used the tablets to collect information about houses and their owners, record GPS location of the house, and photograph its condition at the time of the assessment. The results were transferred to government servers in Kathmandu over the cellular network and entered into a database where they were used to assess individuals' eligibility to receive financial assistance to rebuild their homes. The tablets utilized open-source software, based on OpenDataKit, and customized by a local technology organization (Soden & Palen 2019), to implement the damage assessment survey. The

survey captured the location of the house and basic information about its owner and

residents, its construction type and materials, and a damage classification that detailed the

buildings as being either: 1) undamaged; 2) partially damaged; or 3) completely destroyed.

In the analysis that follows, we describe how the data collection practices and information

standards mandated by the design of the government damage assessment and encoded

into the application used by the surveyors constructed a particular understanding of what

happened during the earthquake, what constituted damage, and with what consequence.

Figuring Loss

The Nepal government damage assessment, described above, identified the

number of residential houses that were partially damaged or completely destroyed during

the earthquake. While such information is fundamental to an earthquake reconstruction

program solely focused on providing funds to individuals for rebuilding their homes, its

limitations when considered in the broader context of post-disaster Nepal are readily

apparent. As a way of introducing some of these gaps as well as the conditions under which

the assessment occurred, we introduce data collected from two of our interviews

participants. The first was with an engineer, one of the members of the surveying team who

conducted the assessment in Langtang. The second was with a community member who

was present in the valley when the assessment happened and assisted the surveyors with

their work. For purposes of clarity and narrative presentation, we limit the data presented

to just these discussions. However, the themes highlighted in the narrative align with the

findings from the other interviews and focus groups conducted with damage assessment

teams and members of the Langtang community.

The survey team, relying on tools and training oriented toward inspecting the condition of individual residential houses, was unready to deal with the totality of the destruction caused by the landslides in some parts of the Langtang Valley. The engineer told us that:

I had not seen such collapse. I was there with just two days' experience. I thought there would be some damage. That's how I felt. But when I reached [Langtang]... nothing was there. Everything was a flat plain. I was very surprised to see that. It shouldn't have collapsed like that. I thought small houses could be seen. But there were no houses.

The community member registered the surprise of the surveying team as well, telling us:

They were shocked. 'Oh there are houses here?' they said... Our home is totally buried under. It's totally flat now. We were also shocked, before there were houses here, people also.

The Langtang community's refusal to stay still in the intervening period between the earthquake and the assessment also highlighted issues with the assessment design. Many residents were still living in Kathmandu with relatives or a camp for people displaced during the earthquake and thus not present for the assessment. Others had moved around in the valley, erecting temporary shelters using corrugated iron, tarps, or other materials delivered by helicopter or donkey to the valley. Still others had already begun rebuilding

their homes, making it difficult to demonstrate the levels of damage caused by the earthquake. The engineer relayed these challenges to us, saying:

> *There were temporary residents in a place called Kyangjin. They weren't permanent residents. They were there for 6 months for work. In times of tourist season, they stayed there. And rest of the time, they stayed in [other places]. Some people reconstructed their house; those with partial damage. When you don't have place to stay, you have to rebuild and cannot wait forever for the government.*

Language difficulties compounded the confusion and the ability of the assessment team to build rapport with the community. Many of the residents of Langtang speak a local dialect of Tibetan, whereas the surveying team was counting on being able to communicate in Nepali. This was compounded by the fact that the software on the tablets carried by the team was in English. The engineer told us that at one point early in the assessment he phoned his supervisor in Kathmandu, saying that:

> *The working situation is very bad here. Should the government see this from different perspective? Or should I do the data collection?' ... [his supervisor replied that] 'You have already reached there... Please coordinate with the house owners to find out about the land and what was there.'*

These difficulties led to concern amongst the residents of Langtang who were present at the time that they would be deemed ineligible to receive recovery assistance. The community member said:

Some people were afraid. Because they thought 'oh, maybe we will not get

[government assistance] if I don't give the correct answer.'

Ultimately, residents were able to produce enough pictures of the area prior to the

earthquake that the assessment team was willing to accept their version of events and

record information about the 116 houses destroyed in the valley and their residents. The

engineer was nonetheless left unsatisfied. He had been forced to deviate significantly from

the information standards and collection practices prescribed by the assessment. Yet he

still felt that the information gathered was incomplete, and in any case did not adequately

capture what had occurred in Langtang. Nor did he feel that empowered to address this

gap.

What I was feeling, I will go to government bodies and make a different separate

report on Langtang. Later, I couldn't do it. I feel very sad about Langtang. Before,

there were houses there; there were places. Now it is like a desert...

Mapping Silences in the Langtang Valley

To supplement observations of the Nepal government's damage assessment, we

organized a series of mapping workshops and map-based interviews with members of the

Lantang community. In total 42 community members participated in these workshops –

about one fifth of the surviving residents of the valley, representing a diversity of age,

gender, and livelihoods – were involved in around 25 hours of collective mapping activities.

This work took place both in the villages of the Langtang Valley and in Kathmandu, where

some of the displaced survivors were residing prior to reconstruction. These workshops

were conducted during three research trips to Nepal in May 2016, January 2017, and July 2017. Mapping activities were designed both to gather information and to guide conversations about the past, present, and future of Langtang Valley. These maps and conversations focused on historical settlement patterns, the location of cultural and religious sites, the oral record of past landslides and avalanches; perceptions of future risk, the impacts of tourism on development; challenges faced during post-earthquake recovery, and participants' hopes for the future.

Figure 5: Community members working on cultural map of Langtang

Figure 6: Mapping the history of landslides in the Langtang Valley in

Figure 7: Reconstruction process map of Langtang Village created in May

The purpose of the mapping activities was thus three-fold. First, they provided an opportunity to elicit local narratives of the disaster and its impacts that we could compare with information from the official damage assessment. Second, the mapping activities served as a sort of dialogic probe (Boehner et al 2012) to help more clearly understand the information needs of the residents of Langtang as they chart their own pathways to recovery following the devastating earthquake and landslides. Third, they facilitated the collection of historical data on social and spatial change in the Langtang Valley, including oral histories that describe past disasters and chronic vulnerabilities. Each session was recorded and transcribed, and the first and second author collaborated on a process of open coding to develop a series of thematic memos that considered the relationship between the NRA-led damage assessment and localized understandings of disaster and recovery in Langtang.

In the following sections, we consider the gaps that emerged between these different modes of reckoning loss, drawing on the findings that emerged from the mapping activities and interviews conducted with surviving residents of Langtang. Building on Harley's concept of 'cartographic silencing' (Harley and Laxton 2002) we present these gaps as silences created by misalignments between the narrative of loss produced by the technology supporting the government damage assessment and the lived experience and expressed ideas of the Langtang community. The silences related to 1) ongoing landslide danger; 2) everyday and collective practices of repair; 3) trauma suffered by the earthquake survivors, and; 4) the rapidly changing vision of 'the good life' underway in the Valley. These silences in the post-disaster damage assessment are not just blank spots on a map, but holes in the official narrative of the disaster that shape patterns of long-term reconstruction.

Silence 1: Ongoing Landslide Danger

The damage assessment conducted by the Government of Nepal, as discussed above, was designed to capture information about the status of individual houses made uninhabitable by the earthquake. The totality of the devastation caused by the avalanches in Langtang, which buried the village of Langtang and made it impossible to determine the existence of individual structures, was beyond the scope of what this assessment was able to encapsulate. While the assessment included a single box for 'landslide' as one of six potential geo-technical risks that could be assessed at each property, surveying teams received little guidance on how to judge this complex issue and as a result it was not used in practice. This inability only represents part of the conflicting understandings of safety

between residents and the Government of Nepal's assessment that surfaced in the aftermath of the event and appeared during our mapping activities. More fundamentally, the assessment understood the earthquake as a one-time event, whereas the mapping process unearthed a longer and more continuous history of hazard, risk, and adaptation about which the damage assessment was silent.

For example, according to local oral histories, the village now referred to as Langtang was relocated from a site slightly further up the valley, just below the present village of Mundu, after a large landslide occurred there roughly 200-250 years ago. This area is still marked by a series of long mani walls that mark the extent of the past avalanche – essentially a local form of damage assessment and materialized social memory that speaks to long-term risks (Emerson 2017). According to our interviews, when the last major earthquake struck Nepal in January 1934, it destroyed several houses throughout the valley and killed six people. Roughly thirty years ago, a very large avalanche occurred near Langtang village in the early winter season during the national festival of Dashain that killed 2-3 people, and blew the roofs off houses on both sides of the village, with snow reaching nearly a kilometer away. And in 2007, an avalanche near the village of Sindhum damaged all fifteen houses in that settlement and killed two people. As one resident summarized:

> *Avalanches and landslides happen every year, maybe every 2-3 years. This is normal*
> *for us.*

The history of earthquake and landslide danger in Langtang is thus one of continuous negotiation, adaptation, and uncertainty, rather than a punctuated equilibrium that an isolated focus on major events like the 1934 and 2015 earthquakes would portray. In the wake of the 2015 earthquakes, several scientific studies and independent technical assessments of the Langtang Valley were completed by Nepali agencies and international expert teams (Fujita et al 2017, Kargel et al 2016). These studies sometimes provided uneven and sometimes-conflicting guidance on the relative exposure and safety of different areas of the valley. Given the significant uncertainties inherent in landslide hazard modeling, few scientists were willing to make firm claims either way, fearing accountability or blame should their models prove to be inaccurate. These challenges reflect common patterns of communication difficulty between technical experts and communities' lived experience with risk (Wynne 1989). .Constrained by the indecision of the government and the land-use restrictions of the Langtang National Park that surrounds them, the displaced residents of the Langtang Valley faced difficult and limited choices about where to rebuild. One resident told us:

> *The government says that Langtang is still not safe on the news… If they say it is not safe, then they should give us land elsewhere where it is safe. We are left like raw meat, they haven't killed us completely nor have they cooked us*

Another participant expressed frustration with the assessment and recovery programs lack of attention to landslides and avalanches, an observation we heard multiple times:

Earthquakes did not destroy our houses; the avalanches are what destroyed our houses. We need to make a plan about how to be safe from avalanches.

The assessment was ill-equipped to consider one of the most significant questions about recovery in Langtang: landslide danger and the politics of post-earthquake land-use and resettlement in the Valley. This silence has complicated active debates in the Valley over the safety during future events, the delineation of acceptable risks, and community self-determination during the reconstruction process.

Silence 2: Everyday & Collective Acts of Repair

As with many communities across the Nepal Himalaya, the people of Langtang have been negotiating situated cycles of disruption, damage, repair, and adaptation for centuries. Such ongoing work of maintenance and repair is necessary to make life possible in a harsh environment like the high altitudes of Himalayan mountains. In response to past events like landslides and storms described in the previous section, residents of Langtang told us that they have rerouted paths and shifted the location of houses, repaired and reinforced walls, secured roofs and bridges, and reconnected local infrastructures. In November of 2014, when an avalanche occurred just below Langtang Village in the middle of the night, it took locals just a few days to repair the 5-6 buildings that were damaged and reconnect transmission lines from the local micro-hydropower project. Just one week prior to the April 25, 2015 event, locals responded quickly to another small avalanche that occurred in Sindhum, nailing the roofs back on a dozen houses. One interviewee told us:

We use the old materials for the roofs [wood and stones] instead of the tin roofs,

because they don't fly off as easily and are easier to repair.

When people pointed to places during the mapping activities and described the damage that occurred, they also described the work that was required in response. Much of what they discussed related to material practices of repair that went beyond individual homes covered by the government damage assessment. Instead they often discussed practices related to the repair of collective infrastructures such as restoring trails throughout the Valley, rebuilding important community assets such as bridges, the yak cheese factory, or the hydro-electric plant, repairing and rerouting trails, and rebuilding the monastery and mani walls throughout the valley. Such work was typically carried out collectively, coordinated through formal committees or informal work parties organized along lines of kinship or shared habitation—an extension of traditional practices of mutual aid referred to as parmo used to deal with past damages and scarcities, reanimated in the wake of the disaster.

Despite the scale and intensity of the April 25th event in Langtang, much of the material repair work required in Langtang after the 2015 earthquake was in many ways familiar. This kind of practical and place-based knowledge of adaptation and repair, both emerging from a specific local history and similar to other patterns of 'living and dying with glaciers' in the Andean region (Carey 2005) is integral to the post-earthquake recovery work that is ongoing in Langtang. And yet, critically, there was no way to input data about past damage, past knowledge, or information about prior means of recovery into the tablet

devices and information systems used by the NRA assessment teams. As such, the assessment was effectively silent on these collective methods of recovery and everyday practices of repair, obscuring and devaluing these processes.

Silence 3: Trauma & Care

Given the intensity of the tragedy in Langtang, people in the Valley face ongoing struggles with mental health, as experienced by many disaster-affected communities worldwide (Blaikie et al 2014). However, the government damage assessment conducted in Nepal makes no attempt to account for mental health issues or their social effects. Unfortunately, this kind of damage is often overlooked or subordinated to other concerns in the wake of disaster. This silence also diminishes the importance of the practices of post-traumatic care that allow communities to begin other kinds of repair work. This was true across Nepal, but particularly so in Langtang, where the intensity of the disaster and the loss of life was extreme. In Langtang, the community seeks to address these issues using the ceremonies and funerary rites of the Tibetan Buddhist tradition as a means of coping, providing individual and collective forms of care.

For the Langtang people, these funerary rites are perhaps the most significant and immediate form of repair work, used to help orient the community during the process of death and dying. Over a period of forty-nine days, the community undertakes a recursive and recombinative series of social and ritual actions that provides a narrative for the social process of 'a good death' and a way of guiding the souls of the deceased forward toward reincarnation. These practices, referred to as ghewa and common in this region of Nepal,

facilitate a "transmutation of life" (Desjarlais:160) that is also a form of community reproduction and societal repair. By engaging the entire community in collective cycles of remembering and forgetting, these rites provide a way of metabolizing grief and trauma— they serve as technologies of repair that shape and define spiritual or psychological aspects of post-disaster recovery. While these ceremonies typically follow individual deaths, their cyclicality and rhythm has helped provide continuity and balance in the wake of the tragedy.

According to several participants in our mapping activities, further rituals will also be necessary to repair ruptures in the social fabric and to restore strained relations with local deities that protect the community from harm. In the Langtang Valley, moral and social relations must also be carefully and ritually maintained to prevent misfortune within a precarious environment. In the aftermath of the earthquake, many people cited these ritual practices of repair as essential to long-term of recovery and the future health of the community. One individual told us:

> *If we do these ceremonies, then the village will prosper.... only one or two people will get sick and die. If we continue doing like this, nothing like last year [referring to the avalanches] will happen again to us.*

Amid the extreme disorientation following the earthquake, these funerary ceremonies and everyday rituals were again used to help make sense of the damage and destruction that had occurred. These acts helped the Langtang people to process their own incomprehensible loss, to reassert the social bonds that shape their collective cultural

identity, and to reorient themselves and their community in relation to a possible future. While attempting to rebuild their material lives, they also seek to repair and restore social damage caused by individual and collective trauma. These are practices of care that "underpin the ongoing survival of things as objects in the world" (Jackson 2014:230), yet they were silenced by official practices of damage assessment that followed the earthquake.

Silence 4: Changing Visions of the 'Good Life'

The Nepal government damage assessment was fixed at a single point in time, designed to restore the stability of a particular temporal frame: the order of things at the time of the earthquake, as understood from the perspective of the government. This kind of sense-making, oriented around the restoration of a vision of the pre-existing state of affairs, which is itself not necessarily a neutral or equitable outcome, assumed a stasis that did not exist in Langtang. The valley, as both a landscape and a community, is changing. While some of the residents would seek to recover the past order of things, or to restore trajectories plotted before the earthquake, others' aspirations track alternative valences. Ways of 'imagining the good life' (Lim 2008) were changing rapidly, leading to conflicting ideas of what 'building back better' meant in Langtang.

Conducting research on post-disaster recovery in the wake of the similarly devastating co-seismic avalanche that occurred in Yungay, Peru in 1970, Oliver-Smith used the term 'negotiated traditionalism' to describe the ways in which the community collectively sought to achieve a 'continuity of meaning' that could connect the damaged

past with the imagined future. His analysis highlighted the way that the past is a "necessary element in the present, necessary for our efforts to impose a structure of logic on altered circumstances. It is crucial for creating and coping with change. The people of Yungay, then, must be seen as involved in a struggle to link their destroyed past to their present misery and insecure future (Oliver-Smith 1986:17)."

During our participatory mapping exercises in Langtang, we also elicited local perceptions of what the 'post-recovery' future might look like. These exercises prompted frequent discussion about the varied shapes of differently imagined futures. These conversations often centered around the ways that tourism has become increasingly central in their social and economic lives, accompanied by a decline in yakherding (Spoon 2013). Meanwhile, the majority of young people now go to schools in Kathmandu, prompting anxieties about their future interest in traditional livelihoods and cultural practices: in coming home. Tellingly, there are no schools operating in the valley now. Speaking to these transitions, one yakherder explained:

> *There are only a few of us ghotalo [herders] left now. Future generations wont do this work because they are clean and they think this is dirty.*

Conversely, a wealthy hotel-owner who was in the midst of reconstruction reflected:

> *Before I wanted to make big money and send my children to Europe or USA, but not now... now I want them to come back here. The earthquake taught me something.*

Desires for material comfort, development, and greater connectivity still color imaginations of the future, just as they did before the earthquake (Lim 2008). Debates over the scale and scope of infrastructure development continue, mixing with hopes for internet connectivity, proposed hydropower projects (Lord 2017) and a potential access road aimed at increasing tourism. In Mundu, the one village in the entire valley where traditional houses still remain, people are divided as to whether they should repair their homes (now symbols of a 'traditional' or lost past) or deconstruct them and build new based on the modern government-endorsed designs. Caught between longing for that which is lost and desires for a new post-earthquake future, they are engaged in their own kind of 'negotiated traditionalism.'

Amid rapid social change and the disruptions of disaster, the past is frequently used as a resource to imagine stability or to articulate new kinds of future-making projects (Oliver-Smith 1986, Simpson 2013). In this way, memory and the work of recall becomes a method of reorientation amid uncertainty, a way of reckoning loss while being forced to reimagine possible futures. In constructing their own narratives of damage and loss, Langtang community members are also reconfiguring their relationship to the past. Many people in the community, particularly the older generations and those who lost their entire families, hope to recover a future that resembles the past. And yet, it is also true that the ruptures of the disaster, the influx of resources and attention that accompanied the humanitarian response, and policies designed to encourage Nepalis to 'build back better' after the earthquake have also created new possibilities for realizing differently imagined

futures. The damage assessment, designed to facilitate a national process of 'building back better,' is silent regarding these contested processes of social change.

Discussion

In Langtang, as in many places across Nepal, the work of repair began immediately in the wake of the April 2015 disaster, even if it was often illegible within the frame of official processes of damage assessment. In this section of the paper, we draw upon research within STS, anthropology, and HCI to reflect on the broader discursive and material impacts of the Nepal government's damage assessment. We explore the gaps generated by misalignments between the formal damage assessment and local repair practices, that we have described here as silences, in order to investigate the relations between sense-making, repair, and the informatics of damage. We argue in the section that follows that, as a result of these silences, the government damage assessment has: 1) had outsized influence on public memory of the disaster; 2) scripted particular kinds of repair work that crowded out local recovery practices; and 3) constrained opportunities for hopeful reconfigurations of social life that crises can afford.

Narrating Loss

Critical studies of disaster have shown how, over time, official statistics come to dominate public memory of disaster (Libiorin 2015, Simpson 2013). These statistics are used to narrate the impact, and compare the relative magnitude of the event against other disasters in the historical record, creating the illusion of commensurability across diverse and fundamentally singular phenomena. The impacts that are not measured, or are less

indexical, such as the experiences of the Langtang Valley described above, in turn fade from historical memory. The persistence of the official data, produced through processes like the government damage assessment, provides an important example of how disaster statistics, designed and created for use in one context can live on and shape thought, practice, and imagination in other contexts for which they may be less appropriate (Soden et al 2017). The production and circulation of such statistics constitute important forms of memory work.

Memory work is a central component of diagnosis, a critical act of sense-making that guides repair. Through the development of a common understanding of what a target of repair was in the past, memory shapes the criteria for what constitutes successful repair practice. It can also help develop the cultural resources necessary to navigate the uncertainty-laden environments of crisis and breakdown by providing rich examples from other contexts. Orr highlights the importance of anecdotes describing past repair jobs, traded among technicians as "war stories," as providing important narrative context and grounding that more abstract technical manuals could not (Orr 1986). A recent study of humanitarian logistics also pointed to the importance of narrative to supporting work in that context (Jack & Jackson 2017). The reductive quality of official disaster statistics produced by the Nepal housing damage assessment, and the kind of memory work these statistics in turn support, has serious consequences, as described in this paper.

Scripting Repair

The damage assessment, by narrating loss in the particular fashion described in the preceding sections, shaped and constrained the kinds of recovery practices that could

be considered. As a result of the assessment's focus on the status of individual dwellings, owned by "heads of household," post-disaster recovery work in Nepal was largely oriented towards aiding with the restoration of these homes, while rendering other communal possibilities for reconstruction illegible or illegitimate. Recovery work is thus circumscribed to be relatively short-term: determined complete once individual homes were rebuilt. Its success or failure will ultimately be judged based on the perceived efficiency and fairness with which individual, atomized homeowners are able to rebuild their houses. This script for repair aligns well with the Nepal government's bureaucratic incentives towards uniform management of recovery at a national scale and the reassertion of state authority in a period of crisis (Fassin 2011). However, it failed to account for the range of needs, aspirations, and ongoing practices occurring in Langtang.

Sociologists of technology have long argued that the design technological objects inscript, or encode, arguments about the users of the technology and the context in which such usage would occur (Akrich 1992, Bijker et al 1987, Latour 1986, Verbeek 2005, Woolgar 1990). Akrich writes that "many choices made by designers can be seen as decisions about what should be delegated to a machine and what should be left to the initiative of human actors" (Akrich 1992:216). The extent to which technologies resist such delegation might help to account for what scholars describe as the fluidity of such objects, or their ability to be re-shaped to fit multiple, sometimes unpredictable purposes in local contexts (Law 2004, Redfield 2016). Redfield, echoing HCI research in the area of design for appropriation (Dourish 2003), argues that ambivalence and doubt are well-suited to humanitarian design because (Redfield 2016:19) they facilitate local adoption in complex

and uncertain circumstances. However, these characteristics are exactly what the bureaucratic logics underpinning the Nepal government damage assessment were intended to avoid. The assessment's deployment of a uniform standard that could be applied efficiently across the hundreds of earthquake-affected communities in the country meant that it was incapable of meaningfully describing local site conditions in any one of them.

The work of diagnosis was thus delegated to the script embedded within the design of the damage assessment, rather than the agency of affected people in Langtang. Such delegation suited the needs of the centralized NRA housing reconstruction program, but it also delegitimized local initiative and crowded out other recovery processes. Local NGOs and humanitarian agencies, many of which were active during the immediate response phase and closer to "the ground" than the national government, were not involved in the damage assessment and were largely excluded from the formal reconstruction activities. The considerable delay between the April 2015 earthquake and the time when assistance through the government program finally reached affected families – over two years in Langtang – also left many communities in a liminal state, where they feared that pursuing immediate actions needed for local recovery would risk disqualifying them from program eligibility. Many residents of Langtang did eventually begin to rebuild prior to receiving government assistance, but not without significant anxiety, delay, and effort spent trying to understand the complex details of the recovery program.

Cracks & Careful Reconfigurations

Damage, in both material and information form, reveals cracks in the existing

order, denying the essential wholeness or inevitability of prior social relations (Gordillo

2014, Schafers 2016)—a recognition that may be difficult to recognize during more stable

periods. These cracks can prove generative, amenable to reassembly in creative ways

through careful practices of repair (Jackson 2014). Angell has argued that over the long

history of Istanbul, earthquakes have been recurring forces that have helped to shape and

reshape the city (Angell 2014), acting as instigators of both destruction and renewal. From

this perspective, post-disaster recovery work can be about more than just the restoration

of pre-existing structures and relations—it instead provides an opportunity to reconfigure

them. Cracks create new surfaces, with attendant possibilities for new kinds of attachments

and patterns of relations. Crises, or infrastructural breakdowns, by revealing these cracks,

offer opportunities to reconfigure prior constellations (Gordillo 2014) of social and

material relationships. The notion of crisis as opportunity is not a new one, however, much

of the recent attention this idea has received (Klein 2007, Masco 2017, Roitman 2013) has

focused on less hopeful manifestations.

As demonstrated here, damage assessments, such as the one practiced by the

Government of Nepal, can work to seal these cracks before they can be deployed as

resources in support of reconfiguration of socio-material arrangements. This may be

especially true when certain forms of informatics intervene in sense-making about repair.

In Langtang, for example, the assessment focused attention solely on reconstructing homes,

ignoring the vulnerabilities created by regulations prohibiting people from relocating their

homes outside of already-settled areas of Langtang National Park, many of which were felt to be unsafe or clearly uninhabitable. The opportunity to create a holistic plan for reconstruction that could address long-standing tensions with the Park was subordinated to the demands of the larger state-driven reconstruction process.

The narrative created by the damage assessment aims to produce a bifurcation (Stengers 2011) between that which can be measured in objective terms and more affective relations associated with an ethos of care. Returning to Redfields's concern with ambivalence raised above, ambivalence, uncertainty, and doubt might seem somewhat dubious goals for design to aspire to. This is especially true in the realm of informatics where such characteristics are typically considered as flaws to be erased. However, Redfield makes the argument that design that incorporates uncertainty can invite questioning, further engagement, and the concern that characterize care (Redfield 2016). Similarly, Gaver et al. write that ambiguity in design supports "deep appropriation" of technologies "by impelling people to interpret situations for themselves, it encourages them to start grappling conceptually with systems and their contexts, and thus to establish deeper and more personal relations with the meanings offered by those systems" (Gaver et al 2003). A damage assessment that accomplished this would then allow for narrative, affect, multiplicity, and uncertainty. It would support the agency of affected peoples in sense-making and diagnosis, rather than delegate these tasks to tightly scripted classificatory schemes. It would seek to expose and engage with, rather than elide, the cracks.

If practices of care are, as scholars argue, ontological work of shepherding, maintenance, and sustainability that necessitate thick, situated connectivity, and densely woven networks (de la Bellacasa 2011, Mol et al 2010, Murphy 2015), then this raises questions about the opportunities for care at scale (de la Bellacasa 2017, Jack & Jackson 2016). Our experiences of, and connections with, large-scale infrastructures are often mediated by informatics that describe the condition and activity of these infrastructure. Yet the consequences of such mediation are so far under-examined in our field. What sorts of sense-making are facilitated by such relations? How do formal standards for assessing artifacts and infrastructures interact with alternate ways of knowing? Is care truly "other to technology" as some have suggested (Mol et al 2010)? Or can we envision the design of new practices that offer the hope of re-centering affect in a supposedly objectified world (Tsing 2016)? The reshaping of possible worlds in the aftermath of crisis and disaster is care work, though it is often not undertaken as carefully as we might imagine.

Rebecca Solnit, in her book, A Paradise Built in Hell, discusses the "beautiful communities" that come together in solidarity during disaster to perform the needed care work to address disruption (Solnit 2010). Drawing on decades of research in disaster sociology, she shows that in contrast to popular discourses of affected populations acting either as helpless victims or dangerous mobs, during periods of crisis people instead more frequently act altruistically and with common purpose. Such behavior, Solnit argues, provides a glimpse of what social life could look like, were it configured otherwise. Contemporary practices of damage assessment, as demonstrated by this study, support a kind of disaster recovery that is oriented toward restoring pre-quake conditions. Aligned

with engineering expertise and the bureaucratic logics of the state, it fails to support locally

driven recovery processes, or provide the opportunity to reimagine dominant modes of

sociality. HCI has the potential to support the development if a new, more care-ful,

informatics that enable alternate practices of sense-making about crisis, and design

technologies that support, rather than usurp, the agency of local communities attempting

to navigate and reconfigure post-disaster recovery landscapes.

Conclusion

The government-led housing damage assessment portrayed the Nepal earthquake

as a temporary disruption, to be resolved through engineering expertise and bureaucratic

procedure, in an otherwise steady trajectory toward the future. In the process it has

silenced the lived experiences of the survivors, masked social and political contributions to

disaster vulnerability, and limited the extent to which communities can shape their own

recovery. By directing the narrative of what could be counted as lost during the disaster,

the data collection tools and methods deployed by the damage assessment also scripted a

series of implicit arguments about what kind of society should be rebuilt. Our participatory

mapping activities helped to identify issues that had been silenced by the official mode of

assessing damage, but were nonetheless critical in shaping the nature of the social and

material repair work undertaken in post-earthquake Langtang. Such silences are an

inescapable feature of any attempt to represent our complex and messy world through

socio-technical practice (Wood 2010). To borrow from Korzybski's famous phrase, the map

is not, and never can be, the territory. HCI and CSCW research has previously taken up the

complex politics of technology's role in producing in/visibility (Star & Strauss 1999). As the

role of ICTs in disaster management continues to grow, improving our collective ability to

recognize and engage with such politics is essential.

CHAPTER 5: INFRASTRUCTURING THE IMAGINARY
HOW SEA-LEVEL RISE COMES TO MATTER IN THE SAN FRANCISCO BAY AREA

Introduction

In 2012 a local artist and technologist released a series of short blog posts

describing everyday life and politics of San Francisco in the year 2072, after the occurrence

of 200 feet of sea-level rise. The series, entitled "San Francisco Archipelago", includes

fictional future news stories discussing rapid population growth of the city, legal battles

over tech industry's unwillingness to pay local taxes, unreliable public transportation, and

a proposed bond measure to build an expensive floating sports stadium just off the island

of Alcatraz. The anchor of the work is a set of realistic maps of San Francisco, much of

which is depicted as underwater or as a constellation of small islands–an archipelago–as

the result of sea-level rise. Through an intensification of select contemporary political

issues and the portrayal of a balkanized landscape upon which these struggles play out, San

Francisco Archipelago delivers a compelling portrayal of one possible future of the region.

It doing so, it acts as a critique of present-day life and politics in the region and an

attendant call for change.

Other depictions of the future of the Bay Area have been less self-consciously

dystopian, though no less political. In 1949 John Reber, in a fit of post-World War II

industrial optimism, proposed a radical reshaping of the region's ecological and

infrastructural landscapes. His plan included damming the major rivers that flow into the

Bay, constructing massive causeways that would separate the north and south reaches of

the Bay from the Pacific Ocean, the infill of over 80 square kilometers of the bay's shallow

marshes and mudflats, and a major expansion of development and industrial and military installments focused on the central Bay. To assess the impacts of "the Reber Plan", the US Army Corps of Engineers constructed an enormous 320 by 400 foot working hydrologic model of 1600 square miles of the San Francisco Bay and surrounding deltas. The model draws 135,000 gallons of water per day through its channels, canals, and rivers, simulating the interplay between hydrology, the physical landscape, and the built environment of the region. It helped show that Reber's ideas were unfeasible, and although the Plan was scrapped by the early 1960's, the Bay Model is still functional and open to tourists and school trips. A small exhibit on geographic information systems (GIS) reminds visitors that engineers and scientists now develop these kinds of models every day on laptop computers with far greater ease and precision.
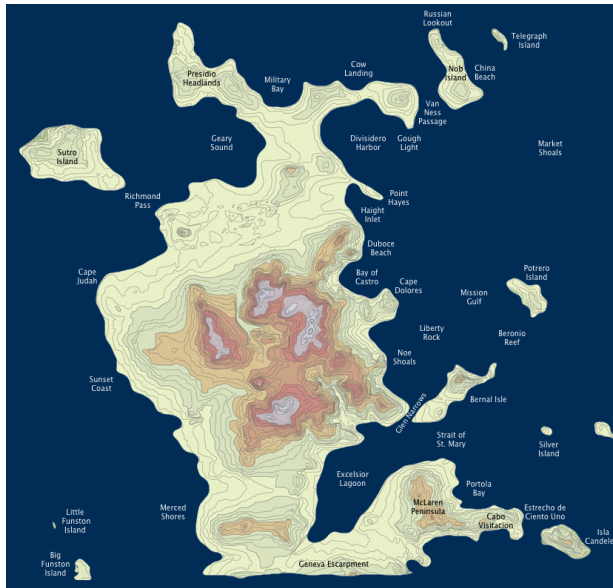
Figure 8: The San Francisco Archipelago - Burrito Justice, 2012

Figure 9: The Bay Model (photo by authors)

Human settlements have long been entangled with the wetlands ringing the shallow estuary that is the San Francisco Bay. Over the past two centuries, this relationship has included the effort to create more land to accommodate increasing population and high demand. In the 100 years leading up the Reber plan, over 400 square miles of land was produced through infill and drainage, reducing the size of the Bay by one third of its total area. Today, as a result of sea-level rise driven by anthropogenic climate change, the Bay is expanding again. There are great uncertainties involved in forecasting the rate at which this could happen, but some models anticipate as much as 24" before 2050 and 60" before 2100, which could put at least 270,000 people at risk of flooding during storm events and threated billions of dollars of property and infrastructure (BCDC 2011). There are a number of efforts underway involving local and regional government, universities, engineering and architecture firms, and civil society organizations to plan for and develop responses to protect low-lying areas against rising waters. Such efforts, and the technologies that inform them, are bound up with the region's complex history and ongoing struggles over it's future.

The maps, models, software, and databases that experts use to understand and represent the environment are formidable salvos in struggles over what human geographers have called "the environmental imaginary". In post-structural terms, environmental imaginaries are discourses – specific configurations of knowledge, ideology, and practice – that shape the ways in which human societies interact with the environment (Peet & Watts 2004). In a similar fashion, science and technology studies (STS) scholars have developed the concept of "socio-technical imaginaries" to describe the contentious

processes by which technology and technical practice continually reshape the landscape of possible action and delimit potential futures (Jasanoff & Kim 2015). The concept of imaginary is thus a powerful tool for describing the interconnections between socio-technical systems, values and politics, and the environment. In this paper we examine the relationship between competing imaginaries of sea-level rise and the information infrastructures that experts, policy-makers, and the public depend upon to respond to this challenge in the San Francisco Bay Area.

Our research identified three distinct imaginaries that are competing to influence sea-level rise planning in the region. First, practices of coastal management have historically centered largely on construction of so-called grey infrastructure, including man-made levees and sea walls for flood protection. In contrast, the second imaginary, green infrastructure, prioritizes stewardship of coastal ecosystems such as wetlands to mitigate flood impacts. The third, environmental justice, foregrounds the social and political contexts in which debates over questions of coastal risk and protection take place. Based on 18 months of qualitative research, this paper argues that these competing imaginaries are intimately connected to the information infrastructures they use to understand sea-level rise as a problem and evaluate various solutions. Second, existing information infrastructure in the Bay exhibits an infrastructural bias. That is, it privileges some imaginaries at the expense of others. Finally, community-based organizations have a complex relationship with the data and information produced by engineers and other technical experts, seeking both to appropriate it to their own ends, and to resist the de-politicization that frequently accompanies expert framing of contentious issues.

Related Work

Climate change, disasters, and other environmental issues, like sea-level rise, are political, and these politics are intertwined with the technologies used to understand, prepare for, and respond to them (Fortun 2004, Soden & Palen 2018). Decisions about what data to collect, the methods and standards used to collect it, and the algorithms, models, and techniques used to render it each meaningful inescapably encodes particular values and worldviews. In an oft-repeated phrase that captures this idea, "there is no such thing as raw data" (Crawford et al 2014, Gitelman 2013). This paper draws together research from human-computer interaction (HCI) and science and technology studies (STS) to consider the relationship between the politics of societal responses to environmental challenges and the technologies that are increasingly important to how we come to understand them. The protracted, slow-onset nature of sea-level rise provides an opportunity to examine this in detail, and especially yields insight into how different kinds of imaginaries and the information infrastructures that support them can emerge around ostensibly the same "issue".

Infrastructuring Politics

Scholars in HCI and STS have worked for several decades to articulate the relationships between information infrastructures, knowledge practices, technical work, and, to a lesser degree, politics. This line of research, crucially, collapses the fixed distinctions between social and technical components of such infrastructures, highlighting instead the various ways in which human capacities, social networks, organizations and

institutions are as constitutive of infrastructure as the networks of cables and wires we might traditionally associate with the term. Other key insights from this work are the relational and processual nature of information infrastructure. Infrastructures may appear very differently to its different users, and, in important ways, are continuously in a state of becoming through interactions between their human and technical elements. The concept of infrastructuring thus describes how users of information infrastructure, such as the sea-level rise modelers and community activists in this study, appropriate available resources to their own ends in sometimes unexpected or surprising ways (Jack et al 2017, Pipek & Wulf 2009, Soden & Palen 2016).

HCI research in civic technology has explored the relationship between knowledge politics and the work of infrastructuring public life. This work has largely drawn on philosopher John Dewey's notion of publics (DiSalvo et al 2014). For Dewey, publics emerge in the event of externalities, or issues for which the current political system is not well equipped to address. Such externalities are overflow (Donaldson et al 2013, Whatmore 2009) which for various reasons go beyond the capacity of everyday governance institutions to manage and therefore emerge as problems, controversies, or contradictions that demand closer attention and broader participation from interested groups. Publics are thus groups of citizens with shared concern, or attachments, for these issues and, in Dewey's optimistic liberalism, are able to come together in a deliberative fashion to develop solutions. Civic technology has thus taken up questions of how technology design intersects with public formation and activity (Le Dantec & DiSalvo 2013). In this context, information infrastructures have a central role in constructing sea-

level rise as a problem around which various publics can form, and as a result are vital components of the politics of sea-level rise planning in the Bay Area.

Here we seek to emphasize that the ways in which issues are articulated by information infrastructures shapes the sorts of associations that may arise, and the opportunities that are available to mobilize political action around them (Marres 2007, Soden et al 2017). The intense uncertainties involved in sea-level rise create many surfaces upon which different sorts of attachments might be formed, and different kinds of publics may emerge. In addition, HCI research in participatory design and civic technology has considered the fraught and sometimes contentious relationship between communities and well-meaning technical experts from the outside. Relevant here is a recent argument by Le Dantec et al that "we need to interrogate how data-driven public processes may overshadow alternate narratives of how we engage in democratic society and collective action" (Le Dantec et al 2015). As we will show, different visions of the relationship between environmental data and policy-making is central to debates over sea-level rise planning between community activists and civil engineering or coastal management experts in the Bay Area.

Imagining Water

Humanity's relationship to water is complex: water comprises a significant percentage of our bodies; we need to drink clean water frequently and regularly in order to survive; it is a necessary component of agricultural systems, and a key input to many industrial processes (Gandy 2014). Water's role in supporting sanitation is also a core

element in the promotion of public health in the modern era. This complexity unsettles fixed understandings of the relationships and boundaries between nature, society and technology that are associated with Modernity (Haraway 1985, Latour 2012). Though we cannot exist without it, too much water in the wrong places is called "flooding", and societies everywhere take measures to protect lives and property in flood events. Coastal communities have created defenses from simple barricades and walls, to complex locks, levies, and pumping systems for thousands of years. These infrastructures were shaped by, and in turn co-produced, local mechanisms of governance and politics (Edwads 2010). For most of modern pre-industrial human history, these approaches were aided by the fact that sea levels have remained relatively constant (Griggs 2017), creating the illusion that coastlines were stable, even permanent, geographic features. Globally, sea levels began rising in the last century due largely to the effects of anthropogenic climate change. This shift will raise new challenges, and necessitate new kinds of politics.

The politics of sea-level rise will be shaped by the "imaginaries" that animate our understanding of it as a problem, in turn delimiting the kinds of solutions that may be considered. Imaginaries matter because they help to structure politics; they create some possible futures while foreclosing others. Jasanoff and Kim define socio-technical imaginaries as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of advances in science and technology" (Jasanoff & Kim 2015). Imaginaries are always uneven, partial, and contested. They each have issues on which they go into great details and other concerns on which they are silent. Further,

they are dynamic, changing over time in response to socio-material conditions or other, competing, imaginaries. Far from being intangible, or existing solely in the heads of individuals, imaginaries, as Jasanoff and Kim discuss, are situated and collectively enacted, reinforced by custom, law, and as we discuss here, the information infrastructures that we use to understand the world and our place within it.

Sea-level Rise in the Bay Area

Site Description

Sea-level rise will be one of the most significant environmental challenges of the 21st century. Hundreds of millions of people around the world live within a few feet of the coast (Griggs 2017), and are thus vulnerable to rising seas. In the Bay Area, as in so many other places, sea-level rise will intersect with numerous other factors shaping the region. Earthquake, wildfire, and flooding are also major concerns. As rising waters are shrinking the amount of land in the San Francisco Bay Area available to human activity, the region is facing the nation's most severe housing crisis, driven by the tech boom, land speculation, population rise and other factors. The region plays host to some of the most ethnically diverse cities in the nation, has served as a critical industrial and shipping hub for the US West Coast since World War II, been home to radical political organizations such as the Black Panther Party and the Free Speech Movement, and germinated an explosive nexus of technological expertise and finance capital in Silicon Valley. Debates over shoreline conservation and development are thus interwoven with a host of other concerns and bound up in the region's complex history.

The Bay Area, perhaps more than many parts of the United States, has significant

technical expertise to respond to climate change, in addition to a public and political

culture that acknowledges the role of climate change in driving the risks associated with

sea-level rise. The region is home to multiple world-class universities, architecture and

design firms, and non-profit organizations that seek to address the topic. This expertise is

being cultivated and called upon by several high profile public initiatives aimed at

achieving "resilience" to natural hazards and the impacts of climate change in the region.

For example, the Rockefeller Foundation provided funding for several Bay Area cities to

develop citywide resilience strategies. In 2017 and 2018, the region launched a

competition, called Resilient by Design, which assembled teams of architects, urban

planners, and engineers to develop infrastructural approaches to coping with sea-level rise.

These regional efforts exist alongside multiple local projects in the over 60 cities, counties,

and other jurisdictions along the Bay to model the potential impacts of sea-level rise and

design responses.

To model the impacts of sea-level rise, practitioners use statistical and

cartographic software to represent hydrological flows, the physical landscape of the Bay

and low-lying coastal areas, and information about the communities exposed to rising

waters. By bringing together diverse datasets including landcover, geology, physical

infrastructure, economic activity, human population, wave, tidal and global climate

projections, modelers attempt to estimate the consequences of sea-level rise under various

climate futures and weigh the impacts of various approaches to coastal protection. Their

work is dependent upon complex information infrastructures to which they themselves

contribute but also includes physical sensors mounted on satellites or tide gauges, internet

sites that catalog and make relevant data available, information standards that guide how

data is collected and distributed, and professional associations and communities of practice

that develop and share new methods and circulate best practices. The characteristics of

these infrastructures shape our understanding of the impacts of sea-level rise, with

important consequences for what parts of the San Francisco Bay shoreline will be

protected and in what fashion.

Despite the many institutional advantages the region possesses, efforts to prepare

for sea-level rise are beset by significant uncertainties. First, when considered on the long

time scales of this slow-onset crisis, uncertainties stemming from various greenhouse gas

emissions scenarios, rates of polar ice melt, and variations in local landscape all make it

very difficult to predict how much water to expect and where it will go. A recently released

report on land subsidence showed that many parts of the region will have to prepare for

rising waters while also taking into account gradual sinking of the region's shoreline

developments built on soils characterized by soft bay mud (Shirzael & Burgmann 2018), a

factor not accounted for in most projections. Second, there are considerable interaction

effects at play in efforts to mitigate sea-level rise. For example, if one municipality chooses

to build a hardened shoreline barrier, flood effects may be exacerbated in adjacent areas.

The lack of a central authority amongst the over one hundred city, county, and regional

government entities in the Bay Area will complicate attempts to evaluate such interactions

or respond to them in a coordinated manner (Lubell 2017). These uncertainties create

significant space for alternative and competing imaginaries of the issue to emerge.

Research Methods

This paper is based on 18 months of qualitative research in the Bay Area and had two phases. The first 12-month phase consisted of observation of numerous public and invitation-only meetings, events, and workshops where sea-level rise and climate change adaptation were being discussed. These included presentations by experts, community meetings in at-risk areas, and workshops that brought experts together around various relevant topics. In total, we estimate that we conducted about 60 hours of observation during this period. Our field notes from these events related primarily to how different actors relied upon information products such as maps, impact forecasts, and other data in the discussions. During this period we also focused on the differences between expert discourse on sea-level rise and the ways in which community activists and environmental justice groups framed the problem. Our observations were complemented by numerous informal conversations and review of technical reports, scientific studies, and software packages related to predicting the impacts of sea-level rise in the region and weighing various policy and planning responses.

In the second phase of the research, the authors conducted 19 semi-structured interviews with individuals working on different aspects of sea-level rise information or planning. Interview participants were identified based on personal and professional networks developed during the first phase of the study and selected to represent a diversity of perspectives, areas of expertise, and organizational affiliations. We developed two different interview schedules based upon the results of the first research phase. The

first was for use with technical experts – scientists, engineers, spatial data analysts – and focused on the details of their work practices. With this group, we sought to understand how they produced their models, what information sources they relied on, and the challenges they encountered. We used the second interview schedule during interviews with staff of community-based organizations. These interviews focused on how these organizations engaged with data and information about sea-level rise, how they deployed it in their planning and advocacy efforts, and their views of its contributions and limitations. All interviews were recorded and transcribed.

To analyze interview and field-note data, the first and second author collaborated on developing an axial coding schema based on our observations and research questions. This schema was designed to assess how each of the three imaginaries at work in our field site constructed the problem of sea-level rise differently, how they related to one another, and the role of information infrastructures in these construction. After collaboratively coding our data, we produced a series of thematic memos that would become the major elements of the arguments presented in the following sections of this paper. While these findings are drawn directly from our observations of the San Francisco Bay Area, we expect that they will be relevant to sea-level rise and disaster planning in other areas as well as to HCI research on the relationship between data, communities, and the environment more broadly.

Competing Imaginaries

Our research into the various approaches to understanding sea-level rise in the Bay Area identified, broadly speaking, three distinct imaginaries. These perspectives aren't internally homogenous nor entirely exclusive. They exist both in tension and dialogue with one another. So while we are careful to avoid attributing a wholeness or coherence to these perspectives that they do not possess, there are enough regularities (Murphy 2006) across them to provide evidence of a strong discourse, or imaginary, that publics mobilize around in their efforts to shape the future of the region. To begin, we discuss two historically disparate technical disciplines, civil engineering and coastal resource management, that the issue of sea-level rise is has brought into conversation in region. We then explore how advocates of a third imaginary, environmental justice, contest the terms of this discussion by reassertion of the essentially political character of sea-level rise planning. For each of the three imaginaries we describe its scope and major features, and show the ways in which they, despite in some cases having roots that go back centuries, are today intimately intertwined with and dependent upon the characteristics of the information infrastructures used to understand and plan for sea-level rise.

Grey Infrastructure: Command and Control

Coastal engineering approaches evolved prominently in the Mediterranean Sea during the Bronze Age for the protection of harbors and ports to facilitate maritime trade (Hill 2015). Practices reliant upon hard structures like sea walls, jetties and breakwaters (often constructed by deploying large stones in linear arrangements) emerged as regionally-specific applications for rocky coastlines and deep water. While initially

conceived as tactics for protecting discrete and spatially-constrained trade operations, these approaches have been deployed extensively to protect developed global shorelines, in particular made famous by the efforts of Dutch engineers to protect the low lying Netherlands from coastal inundation. In the modern era, concrete structures have often replaced stone as the common building material. Strategies reliant upon these structures are thus often characterized as "grey" infrastructure. Because of their durability, relative ease of construction and use of inexpensive materials; and the large body of knowledge about their design and performance under various circumstances as a function of their widespread use over long time periods, grey approaches for coastal engineering are widely evident in developed shorelines.

At present, less than 20% of the original coastline of the San Francisco Bay remains either undisturbed wetland or otherwise in a natural condition such as beach or bluffs (Doehring et al 2016). Grey infrastructure projects are an important element of coastal management in the region, the most prominent example of which is undoubtedly the San Francisco seawall. Constructed between 1890 and 1917, the seawall establishes San Francisco's iconic bayshore, stretches for four miles and serves to stabilize the artificial fill and poor soils underlying the city and protect against coastal flooding. Behind it are ten's of billions of dollars in property, the SF downtown and financial district, and some of the most expensive commercial and residential real estate in the Western Hemisphere. Due to sea-level rise, the wall is regularly overtopped during high-tides, leading to minor, flooding in the area. The Port of San Francisco is currently planning to retrofit and update the now 100-year old sea wall. The retrofit is intended both to improve the seismic stability

of the wall as well as increase its height to protect against sea-level rise, making it one of the most prominent coastal defense projects in the US.

From an information infrastructure perspective, one of the most important questions that engineers working on the seawall retrofit are trying to define is what level of protection – the height of the seawall – that the city should invest in. To do this, they rely primarily on cost-benefit analysis (CBA). CBA has been a central component of national flood management strategy in the United States since the Flood Control Act of 1936, which gave the federal government significant responsibility to invest in flood control measures, provided that the economic benefits of such measures exceeded the costs of their construction (Pearce 1998). 100's of miles of levees, walls, and other defenses have been built under its auspices. Central to the application of CBA in the case of the sea-wall are the data used for estimating the value of assets that will be protected - the benefit side of the equation. As is common for CBA approaches, "value" is considered in economic terms, and in the case of the sea wall, studies we examined considered only the real estate value of the land being protected, relying on publicly available government data.

The sea-wall modeling project is characteristic of other grey infrastructure studies conducted in the region. The spatial scale typically considered is that of the proposed intervention, and interaction effects with other parts of the Bay are often ignored. These models also take a long view of coastal management, typically using 50 or 100-year periods as the relevant planning horizon, estimating both the rate of SLR and the benefits of protection over that time period. Despite the complex phenomena under consideration,

these models, at root, are seeking to answer a relatively straightforward set of questions around the likely impact of various sea-level rise scenarios and the efficacy of various protective measures. The structure of the models, and the form of their results have been shaped by decades of interaction with the legal and bureaucratic structures governing coastal management. To accomplish their work, the practitioners who develop these models are able to draw upon a wide range of resources, including existing data, well-established and documented methodologies, and an extensive community of practice spanning the civil engineering and planning disciplines.

As an imaginary, grey infrastructure approaches are often rooted in what has been described as a "command and control" ethos (McPhee 2011). Water is treated as a threat: something to be kept at bay or disciplined through channels or pumping systems. For a variety of reasons, this orientation is being reexamined by planners and policy-makers. Extensive literature has documented the ecological shortfalls of these approaches, which often accelerate erosion and other detrimental geophysical processes; disrupt or degrade habitat for native species and negatively impact biodiversity in general. Grey approaches, through their tendency to increase erosion and shunt floodwaters, may "telegraph" flooding to adjacent reaches of a given shoreline, raising important ethical and equity questions. And because grey approaches are generally static in nature, they may behave as brittle components on a coastal engineering scheme, occasionally failing catastrophically. As such, they are costly to repair or replace, and, because of their static nature, are often cumbersome, expensive and limited in terms of adapting their design for changing

environmental conditions or performance required by the uncertain future sea level conditions.

Green Infrastructure: Living With Water

As an alternative to grey infrastructure, modern coastal planners are increasingly beginning to experiment with a set of practices known collectively as green infrastructure. Planning and resource management practitioners have relied upon natural processes to promote environmental sustainability and quality of life in coastal cities for centuries. Prominent examples of embracing natural features (like topography or hydrology) ecosystem services (such as air and water quality improvements), and approaches that stressed development schemes intended to "build with nature" are evident in many coastal metropolitan areas. In the SF Bay Area, the green approach to shoreline protection has manifested in connection with decades-long, large-scale ecological restoration efforts of thousands of acres of tidal marsh plains that were filled as part of development schemes over the past century and half. As a result, green approaches are emerging as a novel challenge to the dominant grey imaginary, which is often framed by critics as being both imported and out of date. In the words of one practitioner, "We're not the Netherlands, and this isn't the 19th century".

The South Bay Salt Ponds (SBSP) in the southern SF Bay is the focus of the largest tidal wetland restoration project on the West Coast of the United States and a representative example of the green imaginary as it is enacted in the Bay Area. The project was launched in the late 1990's, when thousands of acres of previously diked and

disconnected salt evaporation ponds run by Cargill corporation were acquired by state government Today, they are being reconnected to the tidal rhythms of the Bay as part of efforts to restore ecological functionality and create a large flood protection infrastructure for adjacent communities. The SBSPs is an ambitious example of the green imaginary's approach, as it relies on ecological processes to deliver multiple benefits including shoreline protection also providing open space for public recreation and . The project is designed and implemented according to principles of adaptive management, whereby planning cycles are short – often in the range of three to five years – and new data about local conditions is continuously gathered in order to judge the results of prior interventions and experiment with alternative approaches as needed.

Though in principle the data, models, and performance standards used for designing and evaluating green infrastructure projects are meant to answer similar questions as the grey models – the location, frequency, and impacts of coastal flooding due to sea-level rise, in practice they are quite distinct. SBSP serves as a large-scale, continuously evolving experiment that generates data for analysis and adaptive management and planning: the iterative process of evaluation and decision-making that governs that project. As discussed above, this means more frequent data collection and shorter future horizons are considered by green models. In addition, practitioners of the green imaginary, in an attempt to fit into the planning discourse established by the grey imaginary, have adopted the logics of cost-benefit analysis. Yet, unlike they grey imaginary that understands "benefit" to mean the economic value of protected real estate, green approaches pursue multi-benefit valuation strategies that include protection of other goods

including recreational use by neighboring communities or the provision of habitat for endangered species. This means that engaging a much wider suite of domain expertise, data inputs and modeling techniques is required for understanding how rising seas will interact with planning processes drawing upon the green imaginary.

If the grey imaginary can be described as a command and control orientation to coastal management, then the green imaginary is about "living with water". Instead of treating water as a threat to be excluded from human settlements, advocates understand it as a resource, and design systems that include and accommodate its processes in spatial terms. This allowance seems to respond to many of the weaknesses of the command and control imaginary, but raises its own challenges. Apart from the different modeling and information requirements of these techniques, 'green' shoreline schemes often hinge upon the utilization of large areas to accomplish flood mitigation goals, since wetlands act as floodplain buffers — gradually sapping energy from storm-driven waters. In practice, this may mean that some coastal neighborhoods would not be protected under green approaches. Additionally, adaptive management implicitly entails flexible phasing/master-planning efforts, and regularly responds to updating projections and data regarding sea-level rise and the SBSP performance over time, and taking into account as-yet unknown economic and political changes in the region that could lead to alternate planning priorities.

Environmental Justice

In addition to the futures envisioned by proponents of grey and green imaginaries, a heterogeneous collection of activists, community organizers, and non-profit organizations in the Bay Area have been working to articulate the threat posed by sea-level rise from the perspective of environmental justice. In the United States, the environmental justice movement arose in the early 1980s in response to activist concerns over unequal impacts of pollution on minority communities (Dawson 2010). In the Bay Area, environmental justice advocacy has historically focused on the disproportionate burden faced by predominantly minority neighborhoods of air pollution, soil contamination, and unsafe drinking water (Dillon 2018). Only in recent years have questions of "climate justice", including sea-level rise, been taken up as a serious concern. However in many parts of the region, it is these same neighborhoods where environmental justice advocates have focused that are most exposed to sea-level rise impacts. Many neighborhoods in the Bay Area, were destinations for Africa Americans during the "Great Migration" out of Southern States in the mid-20th century (Johnson 1994). For example, due to proximity to job opportunities and discriminatory housing policies, many new arrivals attracted by the shipping boom at the Port of Oakland during and after World War II moved to the very low-lying areas that are now vulnerable to sea-level rise (Bagwell 1982).

Environmental justice advocates interacted with information infrastructures related to sea-level rise quite differently than the other imaginaries we studied. Public presentations given by staff or volunteers from environmental justice organizations often didn't include any of the usual statistics of forecasted impacts, maps of inundated areas, or

graphs projecting the rate of sea-level rise that dominated presentations of the issue

developed by either the grey or the green approaches. In addition, their public materials

often included topics such as gentrification and deplacement, community relations with

law enforcement, or funding for public schools that were, on the surface, unrelated to sea-

level rise. Yet, as some HCI research has argued, the inclusion of the wide range concerns

faced by disadvantaged communities is in fact central to approaches that center justice as a

core value (Dombrowksi et al 2016). As one advocate we interviewed explained, "We talk

about adaptation and resilience from a very holistic perspective. We are being hit with so

many things right now." This broadened and more contextualized perspective on the

impact of sea-level rise led community groups to engage with information about the topic

in different ways than participants in either the grey or green imaginaries.

A key fault-line in the debate between environmental justice advocates and

proponents of other imaginaries is the role of technical expertise in public decision-making.

Indeed, almost all the groups we interviewed raised the difficulty of challenging the

recommendations of scientists and engineers, and described feeling disempowered by

public discussion oriented around the complex, technical models deployed by civil

engineers or coastal resource managers. They related, in many cases, being unable to

participate on an equal footing with technical experts (see also Bopp et al 2017). However,

at the same time, where strategic, they used the data produced by experts as a means to

inform and mobilize their communities. HCI research in participatory design and civic

technology has sought to transcend this difference, arguing that partnerships between

technical experts and community organizers can be productive and mutually beneficial if

significant investments in relationship building and developing shared understanding are made (Le Dantec & Fox 2015). In the Bay Area, we found that while several attempts at this work are underway, a significant divide remains between environmental justice organizations and sea-level rise experts. These dynamics are described further below.

Imaginaries, as with all discourses about the future, always take flight from a particular location. They are situated in a particular context and relationship to the present. One way to understand the logics and political valence of various imaginaries, then, is to examine what they hold constant, as compared to what they envision is malleable or open to change in the future. The grey and green imaginaries, guided by scientific and technical expertise, reinforce contemporary social and political arrangements by essentially leaving them unchanged while envisioning different ways of living with water in the region. By comparison, environmental justice advocates challenge the status quo on a much wider range of issues. By not addressing questions of gentrification or unequal distribution of the harmful effects of climate change in their imaginaries, both grey and green approaches in effect serve to naturalize these issues, treating them as either unproblematic or immutable. By raising questions of inequality and racism into policy debates dominated by a more narrow technical discourse, environmental justice organizations are raising the possibility of an alternative imaginary, prioritizing values of justice and equity over narrowly focused technical expertise.

Discussion

Imaginaries aren't static. Nor are they complete, as they are continually being enacted and re-articulated by their proponents. In the course of ongoing debates over politics and policy, they can interact in surprising and unexpected ways. Indeed, most of the technical experts that we encountered accepted that some mix of "green" and "grey" infrastructure was desirable for coastline protection, and conceded that the perspective of environmental justice drew important attention to important blind spots or silences in the models and maps they put forward. To help articulate some of the ways in which these imaginaries compete and interact and the role of information infrastructures in these processes, we offer two arguments in the closing section of this paper. The first is that the information infrastructure that enables understanding of sea-level rise, as currently constituted in the Bay Area has a bias toward the grey imaginary, supporting a command-and-control relationship with the coastline. Second, we identify four tactics used by environmental justice advocates use to resist the technical framing of the green and grey imaginaries and reassert the fundamentally political character of sea-level rise information.

Infrastructural Bias

The networks of human, social, and technological resources that are used by experts, policy-makers, and the public to understand and plan for sea-level rise currently provide greater support to the development of models and analyses that align with the grey imaginary. This allows proponents of this imaginary to more easily and effectively present their vision for coping with the challenge of sea-level rise. These advantages are not surprising. The suite of tools and approaches that comprise the grey infrastructure

approach to coastal protection have a long history in research and practice and are closely linked to the bureaucratic and legal mechanisms that have developed around the governance of coastal protection. In contrast, many of the practitioners and experts we interviewed characterized the green approach as being "in the information wilderness" as one practitioner illustratively described, or least emergent and untested. Here we consider the role of information infrastructures in sustaining this situation.

From a technical perspective, the information infrastructure that the grey imaginary utilizes is robust and well-developed. The civil engineers we interviewed that work in this area were able to rely for the most part on existing data and software to carry out their analysis, allowing them to work faster, at less expense, and with greater confidence in their results. Conversely, practitioners working within the green imaginary are frequently forced to collect their own data or devise new means of gathering information. One example of this challenge relates to temporality of the data required to inform sea-level rise models. Models produced in the context of the grey imaginary require data about the condition of the coast and the property value exposed to coastal flooding once, at the start of the project, in order to determine the level of protection to design for timespans of 50 to 100 years. The adaptive management techniques deployed as part of the green imaginary, on the other hand, requires the periodic monitoring of results. New data is collected frequently in order to evaluate the results of previous interventions and iterate accordingly. In discussing this difficulty, one of our interviewees told us that they were investigating the use of drones, partnerships with community groups to conduct citizen

science monitoring of the coast, and automated classification of satellite imagery in order to try to keep up with the rapidly changing coastline. They said,

> It takes a lot of work to produce and maintain these maps and datasets. We need to find new ways to keep up, to incorporate these interventions, new green infrastructures. Right not we don't have a way account for all this stuff.

Further, the green imaginary's expansive definition of "value" means that, unlike grey models which typically rely data on property values from public records or other existing sources, green imaginaries seek to account for non-market values like habitat for endangered species or public use and recreation. The challenges of bringing such values into commensurability with the exchange value of commodity, like property, is well documented within the environmental economics literatures (eg Daily et al 2009) and was highlighted by many of our interviewees. One team working on the design of a green infrastructure project in the southern part of the Bay was forced to develop and maintain a new database on fish population in order to understand the impact of their work in the area on biodiversity and track change over time. Another relied on complex calculations in an attempt to assign monetary figures to the value of public parks to residents for recreation purposes.

In addition to its technical components, most formulations of information infrastructure now also take into account the social elements of its construction (Lee et al 2006, Soden and Palen 2016). This includes individuals and their relationships as well as communities of practice, technical standards, and legal and economic institutions of

various types. In the Bay Area we found that these aspects also exhibit bias in favor of the grey imaginary. For example, the lack of social and professional consensus surrounding the modeling approaches being developed by coastal restoration experts within the wider community that engages with coast planning translates into lack of professional support for practitioners and heightened uncertainty about how to interpret or evaluate the results of their models. One coastal ecologist told us, that in compared to proponents of the grey imaginary:

> *We're weaker on turning data and models into decisions. There's not an agreed upon methodology for incorporating social values, historic preservation, and the other kinds of things that don't fit neatly into the models used by engineers and planners.*

The resulting uncertainty around the information and modeling practices deployed in green imaginary projects is also reflected in the risk tolerances and performance standards developed by engineers and encoded into policy and regulation. The ecologist quoted above went onto complain that the standards of evidence required for permitting protective interventions were outmoded, privileging the construction of permanent barriers, grey infrastructure, over more permeable or adaptive solutions. They said, "we're bound by regulations developed in the 1970's. Our institutions aren't very nimble." Another project manager related the difficulty of partnering with a federal agency whose regulations mandated an altogether different set of data and models on coastal protections than that which would be used to design and evaluate adaptive management processes.

In the SF Bay, advocates of the green imaginary struggle to access and utilize the resources offered by information infrastructure in ways that their colleagues working on grey approaches often take for granted. This negatively impacts their ability to advocate for responses to sea-level rise that align with their values and beliefs. Research on the role of data in public life has raised questions of algorithmic bias, focusing on how these technologies can reproduce structural inequalities along lines of class, race, gender, and sexuality in settings as diverse as law enforcement and hiring practices (Crawford et al 2014, Gitelman 2013). Here we find the roots of such biases running both deeper and wider, into the socio-technical information infrastructure underpinning algorithms, and extending to the imaginaries that shape our politics and visions of the world around us.

Rendering Technical and Resistance

A common feature of both the grey and green imaginaries is that they are both shaped, to a large extent, by scientific and technical expertise. As discussed, the design of grey infrastructures is informed by a long tradition of research and practice in civil engineering. Green infrastructure inevitably relies upon a range of disciplines, but draws from ecology and coastal restoration practice in particular. Tanya Li, in her anthropology of the relations between governance and expert technical knowledge, argues, "questions that are rendered technical are simultaneously rendered nonpolitical" (Li 2007). Technical expertise here relies on a sort of discursive closure (Soden et al 2017) that brackets away contentious social or political questions in order to reduce the matter at hand to something amenable to expert, presumptively "neutral" intervention. However, this practice of rendering technical, to use Li's phrasing, is never neutral, complete, or uncontested.

Community groups, resisting the framing of both green and grey imaginaries and instead

advocating for imaginaries rooted in justice, deploy a range of tactics to resist the closures

produced by expert knowledge and reassert the political character of sea-level rise

planning.

The first tactic used by environmental justice organizations to resist the de-

politicization of the question of sea-level rise is *differentiating* its effects on different

communities. With some notable exceptions , maps, models, and projections of sea-level

rise in the Bay Area typically don't account for the ways low-resource communities are

often both more exposed to coastal flooding and less able to cope with its impacts. The

statistical aggregates that are generally used to discuss the potential impacts of sea-level

rise effectively work to mask significant variability in who will be affected by coastal

flooding, and their ability to mitigate its impacts and recover in the aftermath. One

community organizer told us that, "one of the biggest problems of disadvantaged

communities is that they are segregated and there's like an information shield so people

don't know what's happening there… or they don't want to know". As a public, the

environmental justice movement emerged in order to highlight and address these

disparities. By continually raising awareness about them in public discussion of sea-level

rise, activists call into the question the supposedly neutral character of the models

produced by experts.

The second is by *complicating* the matter. In contrast to the reductive character of

expert discourses of sea-level rise, environmental justice groups continuously raised issues

such as gentrification, racism, or police violence against communities of color to paint a richer picture of the challenges faced by their constituents. This served to re-situate the threat of sea-level rise within the complex and dynamic milieus in which it is occurring. One advocate complained that the dominant discussion about SLR in the Bay Area was only leading to superficial solutions, in part because they were not involving at-risk communities. They said, "as an environmental justice organization we have to be grounded in what our communities are prioritized and what they are facing." This organization did use data and models selectively, as useful, to mobilize and inform their constituents, but they decentered it, and put the drivers and impacts of the problem in a wider context. By introducing a range of questions that fall outside of the domain of technical experts to the discussion, environmental justice groups seek to resist the technical prescriptions offered by experts and mobilize alternate sorts of publics around the issue.

In a related fashion, activists worked at *localizing* the discussion over sea-level rise, and in turn establishing their own valid form of knowledge based on their relationship to place – the communities where they live and work. These groups, as a result of their connection to a particular neighborhood or community, were able to claim knowledge of these places that technical experts did not possess. They used what participation research has termed local knowledge (Abdelnour-Nocera et al 2013) to contest the accounts of experts, who were often painted as transient outsiders. In one case, residents used their past experience of flooding in their community to argue, successfully, that the authoritative, regional-scale, model of sea-level rise mischaracterized which areas of their community would be vulnerable to sea-level rise. The model was eventually altered as a result. In

another example, during a public meeting about sea-level rise a well-known environmental

justice advocate stated that if experts wanted to partner with community organizations on

the issue that "they had better come correct," meaning that they needed to acknowledge

and respect the priorities and knowledge of the local community over pushing their own

outside agenda.

Finally, *narrative* was an important tactic used by the environmental justice

groups we interviewed. In discussing their vision for the future, advocates would often

stress the rich history of activism in the Bay Area, and seek to contribute to communities'

sense of pride by telling stories about, in the words of one, "thriving in the face of

adversity." One advocate argued that a plausible "story" of how a community would

manage to successfully adapt to climate change and the other factors influencing the future

of the region as being of equal if not greater importance to the necessary scientific

modeling, data, or even project funding. HCI research has examined the role of

environmental data in creating and shaping narratives (Baket et al 2002). In our research

we found that activists and community organizations draw upon their own narratives in

order to place their agenda in conversation with, and sometimes in opposition to, the data

used in support of the imaginaries articulated by technical experts.

Conflicts over data between experts and community activists are not uncommon.

In some cases, environmental justice groups have used low-cost sensors to collect their

own data to challenge official statistics e.g. (Aoki et al 2013). These sorts of projects, often

called participatory mapping or citizen science, seek to translate local knowledge into

authoritative data through adherence to recognizable data collection methodologies (Wilson 2011). In this case however, activists sought to reframe the discussion of what kind of information mattered to discussion of sea-level rise in the first place and how it should be evaluated. Here we see them using the tactics we identified to reassert control over the imaginary of their communities by influencing about how sea-level rise data "comes to matter" (Taylor et al 2015).   These findings are important to HCI research and practice in civic technology and public design in two ways. First, they provide researchers and designers dynamics that they might encounter, and thus need to be aware of, in their own field sites. Second, designers and participatory researchers could design tools and processes that would augment and support the tactics deployed by justice organizations to articulate their imaginaries.

Conclusion

As part of a discussion on prospects for sea-level rise planning in the region, an engineer told us, "from a technical standpoint, we have this issue solved. The problem is politics." Over the course of our careers, we've heard similar sentiments from experts working across a wide range of technical domains and geographies. In some ways, these arguments are representative of a classic "inside/outside" problem in philosophy of science and STS. In our field-site we witnessed experts working inside their discipline to update their models and forecasts and community organizations working on the outside to reassess how model results and projections should be situated within wider political debates. At the same time, the concept of the imaginary helps us to see the ways in which this technical/political binary isn't quite as solid as the engineer we spoke with would

seem to suggest. Imaginaries, as we have shown here, draw our attention to the ways in which the technical and political co-produce one another. This paper is, in part, about how that works, and the role of information infrastructures in shaping these dynamics.

We have argued that, first, important HCI concerns with the role of data and software in public life should also be addressed to research on information infrastructure. Infrastructural bias, as we have termed it, is an issue that runs both broader and deeper than much of the work in this area currently accounts for. The concept of the socio-technical imaginary, drawn from science and technology studies, helps to illustrate this connection and assess the relationship between technology and politics. In the Bay Area, the privileging of the grey, or command and control, response to rising sea-levels is founded in the ways in which sea-level rise is articulated by the technical and social components of the information infrastructure used to understand the problem. In addition, we have articulated some of the tactics used by community organizations to reassert the fundamentally political character of sea-level rise and advocate for their own approach to responding to the issue.

Taken together, these findings point toward what we might think of as a turn to discourse in infrastructure studies. Bowker has written that "(w)e all too rarely think about the ways in which our social, cultural and political values are braided into the wires, coded into the applications, and built into the databases which are so much a part of our daily lives" (Bowker 2014). We agree that the development of a richer conceptual apparatus for describing the ways in which information infrastructures shape our socio-technical

imaginations, and vice versa, is necessary. As a species, humanity is still grappling with the implications of the incredible changes in understanding of the world around us that advances in technology over recent decades have granted us. This task, though extraordinarily complex, is underway in much of the literature in critical data studies, STS, and HCI that we have engaged with throughout this paper. We add our findings to this body of work and hope that other HCI scholars will be encouraged to take up these questions in their own research.

CHAPTER 6: TOWARD DISASTERS AS MATTERS OF CARE

Critique and Crisis in the Anthropocene

To critique is to call into crisis - Barthes

To ensure that environmental information systems serve the goals of safety, justice, and sustainability, crisis informatics research and practice needs to attend more closely to the ways their work shapes society's relationship to disaster. In this concluding chapter of the dissertation I present an approach to designing and evaluating these systems to help accomplish this. This dissertation has examined the socio-technical practices shaped by the Anthropocene gaze, their effects, and the forms of social and material resistance they encountered. In each of my research sites, I showed that ICTs were constitutive elements in wider socio-technical apparatuses that systematically produce socially undesirable outcomes through the reproduction of discourses previously identified as problematic in social theory and humanities research on crisis and disaster. Yet, as shown in the previous chapters, such reproduction is never complete or uncontested (Li 2007). My fieldwork has explored some of the ways that critical design tactics, participatory research methods, and community mobilization can intervene in these assemblages to highlight the weaknesses of the Anthropocene gaze, sharpen its inherent contradictions, and limit its reach. In doing so, I have shown that there are alternatives to current practices of informating disaster and climate change.

The Anthropocene is, above all, a story about crisis. Following Isabelle Stengers, the "intrusion of Gaia (Stengers 2015)" is a reassertion of the material limits of the planet

and, as a result, a fairly compelling critique of Modernity, the aspirations of which relies on

a strict division between nature and culture. The unraveling of this binary, which STS

scholars argue has never really been tenable anyway (Haraway 1984, Latour 1991), in turn

undermines fundamental Modern concepts of human exceptionalism, freedom, ethics, and

politics. Even as disasters act as pointed critiques of contemporary society's myths about

human liberation from nature's bondage and the political economy of late-capitalism

(Nixon 2011), the Anthropocene calls into question the narrative of Modernity itself. In

doing so, it provokes a crisis in much of mainstream contemporary social, political, and

ethical thought. The Anthropocene gaze responds to the resulting crisis by doubling down

on Modernist epistemology, seeking to rescue Modernist notions of certainty and

universality of knowledge through use of emerging surveillance technologies including big

data, real-time sensing, biotmetrics, drone and satellite imagery, and artificial intelligence.

But this is not the only way through the Anthropocene.

Information systems are bound up with the politics of both in naming event as

crises as well as identifying the ways in which they have come about, their effects, and how

they should be responded to. For some critical theorists, crises are an epistemological

question. Roitman writes that for scholars like Butler and Foucault, crisis is a productive

revelation of limitations or contradictions in discourse and offers opportunities for the

development of new subjects and new politics (Roitman 2014:34-35). As captured by the

Barthes quote at the start of this chapter, to provoke crisis is thus the role of critique. In

contrast, from the vantage point of STS, in particular work that draws from on the

materialist turn, these questions take on a more ontological character, and emphasis is

placed less on the negating elements of critique (Latour 2004, Barad 2007). Crises can instead be understood as a breakdown in relations and as affording opportunities for reconfiguration (Gordillo 2014, Jackson 2014, Soden and Lord 2018). As will be discussed further, this line of work has intersected in helpful ways with longer running discussions in feminist theory on care (de la Bellacasa 2011, 2017).

With that introduction, we should return to the overarching research questions that drove this dissertation:

1 - What understanding of crisis do contemporary information systems related to disasters and climate change support?

2 – How are collaborative efforts to mitigate, prepare for, or respond to disasters and the impacts of climate change shaped by the tools we use to understand them?

3 – What alternative design practices can be drawn from HCI's traditions of critical and participatory research? What can be learned through application of these practices in difficult environments?

I have argued that current tools and practices used in understand and responding to disaster support an approach to these phenomena that I characterize the "Anthropocene gaze." The anthropocene gaze reinforces and extends Modernity's hierarchical, reductive, and supposedly objective characteristics through reliance on larger datasets, high resolution and frequency sensing and surveillance, and complex algorithms to filter

through the massive amounts of information that these systems now produce. Each of the three studies in this dissertation – flood mapping in Colorado, post-earthquake damage assessment in Nepal, and sea-level rise modeling in California – exhibit these some or all of these characteristics.To use Latour's characterization, the systems I have studied treat disasters as matters of fact, rather than matters of concern. In this final chapter I will give greater consideration to the role that some traditions of HCI research can play in supporting alternative approaches to crisis informatics. Following de la Bellacasa (2011,2017), I provide a means for crisis informatics to treat disasters as matters of care.

I begin by first drawing from research in science and technology studies to go into further detail about the distinction between matters of fact and matters of care to provide an alternative to the ontological and epistemic approach offered by the Anthropocene gaze. Second, I offer a modified version of Phil Agre's concept of critical technical practice to develop a method for incorporating an ethos of care into crisis informatics. Finally, I return to some of the findings from the field studies that comprise the dissertation in order to present a novel set of anti-patterns in the design of environmental information technologies. These anti-patterns will influence the design of future systems as well as provide an example of how critical technical practice can yield tools that allow crisis informatics researchers and practitioners to engage with disasters with the ethos of care. Taken together, the arguments presented in this chapter constitute a vision for how crisis informatics researchers and practitioners may begin to treat disasters as matters of care.

From Matters of Fact to Matters of Care

One of the core characteristics of the Anthropocene gaze is its reductive quality. In a 2004 article on the contribution of critique to contemporary debates about the role of science and technology in public life, Latour draws on Heidegger's distinction between objects and things to differentiate between what he calls "matters of fact", and "matters of concern". In this framing, facts are atomic entities, un-situated and alienated from their social, historical, and affective context. In the three studies that comprise this dissertation, my research found that this was both present, as an animating presumption of the Anthropocene gaze, and in many ways problematic. Latour writes that a reimagined, generative, critique would engage with matters of concern and "would require that all entities, including computers, cease to be objects defined simply by their inputs and outputs and become again things, mediating, assembling, gathering many more folds" (Latour 2004:248). In contrast to many criticisms of naïve social constructivism, this move, from matters of fact to matters of concern, doesn't seek to deny the existence of facts. Instead treating facts as matters of concern creates more intimate relationships with them by understanding of how they come to be, and the consequences of their construction.

Latour reintroduces an attention to the relational characteristics knowledge politics that naïve realist positions lack, but this may not go far enough. Such is the argument of Maria Puig de la Bellacasa, who has suggested that Latour's notion of concern is apolitical and has suggested "matters of care" as a more helpful alternative to matters of fact (de la Bellacasa 2011). The ethos of care draws from longer traditions in feminist philosophy and calls attention to "everything we do to maintain continue and repair our

world so that we can live in it as well as possible" (Tronto & Fisher, cited in de la Bellacasa 2012). Care is therefore an active practice of ontology, one that focuses attention on the labors necessary to maintain the networks of relations through which objects become things. Because care work, while vital, so often goes unnoticed, this attention also foregrounds political questions regarding who is doing this situated labor, under what conditions, and with what consequences. Though it is tempting to attach a moralizing undertone to the concept and assume all care work is positive, research in this area has also highlighted the ways in which relations of care can also be manipulative, controlling, or even debilitating (Mol 2010, Murphy 2015).

Human-computer interaction research has taken up the question of care in two ways that are relevant to this dissertation. The first is in the area of repair studies, which has much to say on questions relevant to disasters. HCI and STS research in this area emphasizes moments of technology repair, maintenance, and breakdown as opposed to historically privileged moments of design and use (Jackson 2011). As a form of care, repair work has a markedly different temporal signature than these more studied practices. It is a slow-twitch, ongoing form of labor that engages with the means of shaping and sustaining the social and material life of technology after its initial creation (Jackson 2015). The chapter on post-earthquake reconstruction in Nepal engages with practices of sense-making about repair work, focusing on the ways in which information systems supporting damage assessment mediate in repair work and prescribe forms of repair by producing stories about harm. It shows that moments of breakdown, or crises, can act as

opportunities for reconfigurations of systems that either reinforce pre-crisis social

relations (and vulnerabilities) or lead to new, more hopeful outcomes.

HCI has also incorporated care into a body of work that attends to the relationship

between technology and a Deweyan understanding of publics (DiSalvo et al 2014). Dewey

distrusted technocratic solutions to political problems, remaining optimistic about the

ability of engaged citizens to come together, as publics, to address the problems that arose

in modern society. This area of research, called "public design", has addressed how the

features of socio-technical systems support the scaffolding to support collective action

around complex societal challenges. In the Boulder study, my research shows how

standards that guide the measurement and communication of risk work to undermine

public formation around the contentious and uncertain issue of flood hazard. In the San

Francisco Bay area, I argue that socio-technical imaginaries play a central role in

infrastructuring the formation of publics, and delve more deeply into examining how

alternate configurations of information infrastructure give publics their shape. Together

these studies help to improve our understanding of how ICTs shape collective action

around disasters and other environmental challenges.

By putting feminist studies of technoscience into conversation with research on

public design, this dissertation approaches the knowledge politics surrounding disasters

from the perspective suggested by Isabelle Stengers' call for attention to the "artful staging"

of knowledge controversies. Doing so addresses related shortcomings in both literatures.

"Matters of care" at this point still reads as a bit of a blunt instrument. The thick

interspecies entanglements conjured by Haraway and Barad are powerful but the

mechanisms which structure the ways such assemblage emerge, are sustained, and over

time dissemble – all through practices of care work – are in many ways under-addressed. In

a similar way, I find the political theory underlying public design to be unsatisfying.

Situated in pragmatist philosophy, itself an important influence on both science studies and

the ethnomethodolgical tradition within HCI, Dewey's optimistic liberalism pays scant

attention to the consequences of 1) how issues are framed or decided to be problematic, or

2) the politics of public formation, sustainment, and action. In this chapter I will offer a

reading of critical technical practice as a way of addressing these shortcomings and the

idea of anti-patterns as one of the potential outcomes of this approach.

Developing a Critical Technical Practice for Crisis Informatics

In this section, I build on Phil Agre's development of what he called "critical

technical practice" (Agre 1997) to provide a method for crisis informatics to adopt an ethos

of care. Designers of technology, often unwittingly, embed particular worldviews into their

tools through their practice (Sengers et al 2005). As part of this, the values and

assumptions of these worldviews have a way of coming to appear natural or inevitable.

They become part of the infrastructure of everyday life. This is part of the reason that it can

be so hard to surface and critique the political ramifications of technology choices. It is also

why, for many technical workers, the insights of social theory and the humanities can seem

so distant from the practical concerns of their profession. In our contemporary imagination

of what technical work is supposed to consist of, the sorts of skills and knowledges used to

identify and counter strong discourses, like the Anthropocene gaze, are thought to be quite

different than more instrumental expertise drawn upon by technical practitioners. In important ways, this distinction is baked into the notion of expertise itself, which is deepened through cumulative and progressive closure. This is what Tanya Li described with her phrase "rendering technical" (Li 2007). But as I argue in Chapter 5, this process is never complete, nor are the particular shapes that technicality takes inevitable.

For Agre, critical technical practice is a way for experts to resolve technical impasses in their discipline. To do so he sought to deploy insights from critical theory and the humanities to surface some of the unexamined assumptions of technological work. He argues that technical practices operate as discourses, and are thus subject to the sorts of critique deployed by Michel Foucault, Judith Butler, and other critical theorists. He maintained that critique is best performed and expressed through a double-move of technical engagement and then critical reflection on that engagement. This view is broadly compatible with Latour's argument for a form of critique that is generative, discussed above. The work that Agre did through his critical technical practice involved identifying operative metaphors in the field, inverting or decentering them, and then reflecting on the results in order to identify and experiment with alternative approaches. Agre's research was in the area of artificial intelligence, and it is through these processes that he claims he was able to make contributions to emerging work in the area of situated cognition. He stressed that the process of trying to continuously identify and subvert the dominant metaphors in his field was necessarily uncomfortable, and that his engagement with humanities literature often led him to make arguments that his more traditional colleagues criticized for being "imprecise, wooly, or vague" (Agre, 1997).

Importantly, adopting a critical technical practice challenges dominant

conceptions of what it means to be a technical practitioner. Agre writes that "a critical

technical path will... require a split identity -- one foot planted in the craft work of design

and the other foot planted in the reflexive work of critique." This dual mode of working

runs against standard practice in technical disciplines and adopting it would run against

the grain of the ways in which technical roles within organizations are delimited and the

kinds of training they receive. He says that this "will require a praxis of daily work: forms of

language, career strategies, and social networks that support the exploration of alternative

work practices that will inevitably seem strange to insiders and outsiders alike." Studies of

technical work have consistently emphasized the importance of judgment, intuition, and

skill in this kind of labor, demonstrating that workers mandate already goes far beyond

what can be captured in the formalisms offered by manuals or textbooks (e.g. Kidd 1994,

Orr 2016). Here, Agre's vision of a critical technical practitioner seeks to extend this

mandate even further, into questioning the beliefs, values, and metaphors that underlie the

technical formalisms that shape a discipline.

For all of Agre's insights into the approach, benefits, and risks of critical technical

practice, his description is light on what, specifically, the practices involved in this mode of

work might consist of. In his story of how he developed the approach Agre notes his own

practices of intense self-observation of daily activities and mental processes, including

particular attention to what he called "hassles". Through written documentation and

analysis of hassles, or routine difficulties that surfaced during everyday activities, Agre

over time built up a critique of how the formalisms that drove AI research at the time modeled human activity. The only other real practice Agre relates is his wide reading of philosophy and critical theory, finding inspiration in particular from continental philosophers Heidegger and Foucault. HCI scholars that have attempted to adopt Agre's ideas have often been forced to turn elsewhere for more practical details on how they might be implemented, focusing in particular on traditions of critical design (broadly construed) and Donald Schon's writings on reflective practice (Sengers et al 2005, Schon 2017). Future work of this sort will be required to support efforts by flood modelers, earthquake engineers, emergency responders, and other technical experts to adopt critical technical practice in the work in crisis informatics.

Critical technical practice offers a starting place for reimagining the contributions that technical workers who are informing disaster and climate change can make towards addressing these challenges. Yet, as originally envisioned by Agre, it is incomplete. In addition to further development of the practical activities that support a critical technical practice, at least two other major issues will need to be addressed. First, as noted by a recent paper, the practice is oriented towards the ways that critical reflection can help to resolve technical impasses (Khovanskaya et al 2018). In its original description, the social outcomes of technical practice are given little, if any, consideration. However, the socio-technical perspective adopted by HCI research offers the possibility of extending CTPs analysis of technical systems to the social context in which they are imbricated and help to shape. Indeed, as evidenced by some of the methods and approaches utilized in this dissertation, HCI research has a range of tools including critical design practice,

participatory research, and infrastructural inversion that are well suited to this task, should critical technical practitioners choose to expand their vision of their work.

Second, and perhaps more challenging, critical technical practice largely places the impetus for changing technical work on individuals. This, I would argue, is also a weakness of much of the broader debate over technology ethics, where ethical technology outcomes are often seen to be the result of individual, heroic, decision-making. A narrow focus on individual decision-making, crucially, masks the structural factors that shape and constrain such decisions. Here I would want to again extend Agre's formulation to also include new, or altered, forms of labor-management relations, company ownership, and understandings of the role and responsibilities of technical workers as being necessary for critical technical practice to meet its potential. There are some signs that this shift is underway, albeit in a very nascent fashion. For example in the last several years tech workers at Google, Amazon, and other companies have begun organizing around various issues and won several fights with management (eg). In addition, the number of worker-owned cooperatives in the technology sector is growing, and many organizers cite the desire for greater social responsibility as being a factor in the decision to incorporate in this way (Schneider 2018).

A critical technical practice in crisis informatics, expanded to include both a socio-technical perspective and attention to structural factors that shape technical work, can serve to identify the role that technologies play in sustaining problematic understandings of disaster and suggesting alternatives. My own process for writing this dissertation has been in many ways similar. In both Boulder and Nepal, I participated in the technical work

of flood modeling and damage assessment. In the Bay Area I was able to rely on my prior experience creating the kinds of models that are being used to forecast sea-level rise to understand their details. In all three sites I used careful observations and analysis of the tools and approaches developed, and drew widely on social science and humanities literatures to understand the ways in which effects of the information and communication technologies we use to make sense of and respond to disasters and crisis shape our relationships with these phenomena. Where relevant, I also suggested alternative approaches, or ways forward that could inform the design of new systems. In the next section I revisit these studies and read their findings through the concept of pattern languages as it has emerged through architecture, software design, and user experience. Doing so allows me to make broader arguments about the relationship between care, disaster, and environmental information systems and show how critical technical practice can provide important insights into these issues.

Anti-Patterns in the Design and Deployment of Crisis Information Technologies

Since the 1960s, architect and UC Berkeley professor Christopher Alexander has been attempting to develop a systematic view of architecture as a discipline, one that would uncover deep truths about the relationship between humans and the environment we construct for ourselves. Deploying a rhetorical style that often more closely resembled classic Taoist texts than architecture guidelines, Alexander argued that there were certain fundamental characteristics of this relationship, ultimately rooted in human nature but as well shaped by culture, that when properly expressed through architectural form, would allow buildings and cities to "come to life". He called this resonance between the social and

the material quality, and argued that it was instantly recognizable to anyone, regardless of whether they had any background in architecture. Alexander argued that over time humanity had come to rely too heavily on formal training and expertise in architecture and planning, in turn forgetting the language for describing quality, and endeavored through his research and writing to recover this lost birthright. To accomplish this, he and his collaborators developed the concept of patterns.

Alexander wrote that patterns "describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice (Alexander 1977:X)." For example, one pattern is "window place." For Alexander, windows were vital points of connection between the interior of a building and the world, and should be designed carefully with seating, partial enclosure, and natural light. Rooms without window places "may keep you in a state of perpetual unresolved conflict and tension (Alexander 1977:834)." Patterns were not isolated, but all related in a network structure that together, once uncovered and described, functioned as a language that harmonizes the relationships people share with the built environment they create for themselves. His books on the topic, *A Timeless Way of Building* and *A Pattern Language* are some of the best selling architecture books of all time .

Though architects for the most part have not taken up Alexander's call to further develop his pattern language, his idea have nonetheless been influential both in the field and beyond. Computer programmers in particular have taken up these ideas, and his work

was often featured in Whole Earth Catalog, an important publication and community that helped to connect Bay Area hippie culture with Silicon Valley techies in the 60's and 70's (Turner 2010). Since then, numerous academic publications, conferences , and textbooks have been organized or published on the topic of developing pattern languages for software development. As part of this translation, computer scientists have shed most of Alexander's moral and holistic concerns, and instead concentrated mostly on patterns as vehicles for communication of important concepts in software design. Alexander argued as much in a keynote at the 1996 ACM Conference on Object-Oriented Programs, Systems, Languages and Applications (OOPSLA), where he also urged computer programmers to take into account the ethical and social dimensions of their work, cautioning against them behaving as "technicians" or thoughtlessly building whatever their employers instructed .

Efforts to develop pattern language in the field of human-computer interaction (HCI) go back at least as far as the 1990s (Casaday 1997). Researchers have proposed pattern languages a wide range of relevant areas including interaction design (Tidwell 2010), ubiquitous computing (Landay and Borriello 2003), human-robot interaction (Sauppé and Mutlu 2014), and participatory technologies (Schuler 2008). Others have developed tools for deploying patterns in user interface development (Diaz et al 2010). Across this body of work, we see diverse, and even conflicting (Pan & Stolterman 2013), motivations for patterns research and claims regarding the benefits of pattern languages to HCI. One common argument in favor of patterns is their ability to act as boundary objects, or a "lingua franca (Erickson 2000)", across the many diverse disciplines and subfields that make up design research and practice. Importantly, this perspective also emphasizes the

benefits that consistent design across various interfaces would provide to users. Other research has focused on the use of patterns in educating technology designers (Borchers 2002). Some scholars have looked to patterns as a useful form for the presentation of the results of ethnographic research to technical audiences (Martin et al 2001), an approach that I draw on here.

One area of patterns research in HCI that is gaining attention recently is in the area of what have been called "anti-patterns". In software development, anti-patterns are widespread, solutions to common problems or challenges that lead to negative or sub-optimal results. HCI work has extended this concept to interaction design, identifying anti-patterns as solutions to recurring design challenges that are either ineffective or even harmful. One common example from software development is "spaghetti code" where efforts to manage increasing size and complexity of a project result in a disorganized codebase that is increasingly difficult to maintain or update over time. Other anti-patterns have been identified where designers rely on principles of human psychology in order to purposefully deceive users. A common is example is ecommerce websites' use of recommendation engines to encourage users to make impulsive purchasing decisions. The use of patterns in HCI research into the negative effects of technology design choices can be a useful way of discussing the specific ways in which design of technologies systematically produce negative social outcomes. Anti-patterns, once identified and communicated, can improve the design of disaster information systems by providing approaches to avoid and spurring design research into their alternatives.

Building on this review, I will use anti-patterns as a means of articulating some of the persistent socio-technical configurations of people, information and communication technology, and nature that I encountered in my field research, but that I believe to be widely present across contemporary discourses around disasters and climate change. Following Martin et al 2001, patterns are well suited to organizing ethnographic accounts of techno-scientific culture because of their attention to how technology and social life are mutually constituitive. Because I am focusing on patterns that are demonstrated to be problematic, I will use the term anti-patterns. Unlike Alexander, I don't believe there to be anything fundamental about patterns. The value in their uncovering doesn't stem from reversal of some mystical fall from grace, but rather because they are themselves mystified, or made to seem natural or inviolable through their participation in dominant discourse of the anthropocene. Like infrastructure, they are for the most part invisible, just beneath the surface yet actively contributing to the shape of contemporary life. They are not timeless, but they are durable.

Anti-Patterns in the Design of Crisis Informatics Systems

In A Pattern Language, Alexander utilizes a consistent presentation format for each of the 253 patterns the book contains. This consistency, along with the variety of elements of the format help to communicate Alexander's ideas to the range of backgrounds and areas of expertise that are present in the architecture and planning discipline. Here, in recognition of this tradition and the similar diversity of technical domains that find themselves working in the area of crisis informatics, I take a similar approach and present a simplified version of Alexander's format. For each anti-pattern, I include a title, a short

description of the pattern, a theoretical grounding, and empirical evidence derived from the research presented in Chapters 3-5. Finally, I offer a list of design tactics from the HCI literature that may redress, countermand, or avoid the anti-pattern. While these anti-patterns are drawn from my research on information systems related to disasters, they are purposefully presented in a way that would support their adoption by other domains if this was found valuable through future research.

Closure

Complex or contested phenomena are rendered simplistically or in ways that make them appear unproblematic. The uncertainties, assumptions, and difficulties in representing them through data are hidden by design choices in the data models, visualizations, or other mediums.

Theoretical Grounding

Closure is a concept in science and technology studies that refers to a situation in which complex debates are seen to be settled, unproblematic. As a result they fade into the infrastructure of everyday life. Pinch and Bijker write that "[c]losure in technology involves the stabilization of an artifact and the 'disappearance' of problems. To close a technological 'controversy', one need not solve the problems in the common sense of the word. The key point is whether the relevant social groups see the problem as being solved" (Pinch and Bijker 1992:44). As a result, opportunities for design and interpretive flexibility are lost. Closure can be productive. It creates the possibility for people to collaborate, technology to be interoperable, amongst other things. However, closure can also be problematic in some

of the ways we have shown here. Information systems can mislead users and the public

when they construct or communicate issues in ways that mask important uncertainties,

controversies, or gaps in knowledge.

Empirical Evidence

In the case of floodplain mapping, the 100-year standard essentially produces a

binary understanding of what is an inherently probabilistic phenomenon—flood risk. In

addition, there are significant uncertainties and assumptions introduced throughout the

process. A wide range of datasets, including those describing past rainfall, elevation,

landcover, and the built environment, are used in flood modeling. Each of these dataset

were produced at different times with different sensors at varying degrees of precision and

reliability. When joining these datasets together in common databases and analyzing them

using spatial modeling software, model parameters, software default settings, and expert

judgment of the technician producing the maps all intervene to shape the final form of the

floodplain maps. Yet once the map is completed, the simplified presentation of the

floodplain boundary hides all of these uncertainties and assumptions from readers of the

map, who are presented with a certainty and a firmness that the underlying science does

not warrant.

Tactics

Friction, Visualizing Uncertainty, Deliberation, Serious Games

Silence

Important aspects of the phenomena being informed are hidden because they go unaccounted for in the data models or data collection practices used to understand them. They are therefore naturalized and as a result, efforts to address the issue are insufficient or incomplete.

Theoretical Grounding

All information systems and classification practices produce silences. Necessarily reductive, these tools capture a limited perspective on the world. This shares characteristics with what geographer Brian Harley referred to as "cartographic silencing", in which objects and phenomena "outside the surveyor's classification of 'reality' are excluded" [Harley 2002:98] and thus eliminated from discourse. Harley argues that silences are "affirmative statements, and they have ideological consequences for the societies in question. Silences can be the result of willful and malfeasance obscuring of important facts as well as technological limitations, but just as often result from ideological blind spots or gaps in knowledge systems. Silences help in the reproduction, the reinforcement, and the legitimation of cultural and political values" [Harley:106]. Rather than consider what is contained in the data we use to understand the world, Harley would encourage us to ask what it doesn't contain, why not, and with what effect?

Empirical Evidence

In Nepal, the housing damage assessment essentially produced an understanding of the disaster that was limited to its effects on individual homes. While these effects were

significant and important, there were many other ways in which people, communities, and infrastructures were impacted by the earthquake. There were also many sources of vulnerability to disaster, some of which were the result of longstanding inequalities in the country that the assessment did not account for. The silences in the damage assessment in turn led to gaps in the reconstruction program that the assessment process informed. These gaps were missed opportunities to redress communities' vulnerability to disasters or meet important needs during the post-earthquake recovery process.

Tactics

Ethnography, participatory design, speculation

Prescription

Agency and decision-making power are vested into machines, infrastructures, and systems that are designed to value regularity and predictability over human autonomy, creativity, and skill.

Theoretical Grounding

Prescription is an anti-pattern that is endemic to modern information technologies and common across many domains. Akrich writes that "many choices made by designers can be seen as decisions about what should be delegated to a machine and what should be left to the initiative of human actors". Prescriptive technologies, as articulated by Franklin (1999), locate agency in machine, data, or process rather than human capacity. Jasanoff writes that technologies of hubris, a similar concept, fail because they 1) can't

account for uncertainty (closure); 2) pre-empt political discussion (instrumentalize); and 3) leave vital issues outside of their frame (silences) (Jasanoff 2007). Prescriptive technologies are thus brittle technologies, and they lend themselves to concentration of power in hierarchical structures and surveillance. Zuboff's discussion of informating, raised in Chapter 1, was a warning against the rising adoption of prescriptive designs in workplace settings.

Empirical Evidence

In Nepal, the damage assessment process was tightly coupled with the overall recovery program. Heads of households of homes designated as damaged according to the standards and practices of the assessment were automatically enrolled into a beneficiary database and thereby eligible to receive reconstruction assistance. A grievance mechanism, through which individuals left out of the beneficiary database could contest their status, was implemented but in ways that made it inaccessible to many Nepalis and thus ineffective (Lord 2018). As a result, there was little opportunity for human judgement to intervene in the process or accommodate for the incredibly diverse set of circumstances under which survivors of the earthquake found themselves. The prescriptive qualities of the damage assessment reduced the adaptability of the overall reconstruction process and limited the extent to which affected communities could take the lead in their own recovery.

Tactics

Ambiguity, Human in the loop data systems, Human augmentation, Design for appropriation, Technologies of Humility

Slippage

Information produced within one context travels to another without necessary articulation work to adjust for the ways in which the new context may alter the meaning or significance of that information. This leads to misinterpretation, confusion, or inability to properly utilize the work.

Theoretical Grounding

Technologies travel. Invented, designed, produced, or utilized in one setting, they often wind up in very different ones. This is part of their power, one of the ways in which they scale, one of the ways they connect. The strategies by which they travel and the consequences of these strategies are a subject of interest and debate in science and technology studies, and have particular relevance for efforts to understand the politics of international development, humanitarian response, and postcolonial computing. How are tools, knowledges, practices developed in one context, taken up in others? How does this travel work to reshape both the technology and the context in which it arrives? Early work by Akrich and others focused on the role of standards and how "immutability" seemed to facilitate uptake (Akrich 1992, Latour 1986). Tsing's notion of friction describes the energy that is released when technologies with universalizing aspirations arrive in particular, situated contexts (Tsing 2015). Other work has focused on how opposite design strategies emphasizing ambiguity, configurability, or "fluidity" might encourage an entirely different sort of travel (de Laet & Mol 2000, Redfield 2016). Slippage occurs when the articulation

work needed for the technology and the new context to meet is either unperformed or unsuccessful. The resulting misalignments lead to confusion, maladaption, and misuse.

Empirical Evidence

An example of slippage in this dissertation is the 100-year floodplain maps. These maps are produced within a context shaped by engineering expertise and the bureaucratic requirements of the United States National Flood Insurance Program (NFIP). Within that context, the 1% annual chance of flooding was chosen, from amongst competing standards, to delineate areas where homeowners should be mandated to purchase flood insurance. Extensive, and increasing, guidelines mandate how the engineers and hydrologists that produce floodplain maps conduct their work. This is in part an effort to accomplish fairness and transparency across a heterogeneous landscape of US flood hazard, where the root causes and effects of flooding vary significantly. Yet, as we have shown, once these maps are created, they are put to use in a variety of other contexts for which they were not initially designed. In particular the public, who typically are not aware of the particular circumstances of a floodplain map's production will as a result not have the necessary tools or knowledge to carefully evaluate the meaning that the maps convey. As shown in the Boulder example, this can result in increased flood danger.

Tactics

Fluid design, metadata, provenance, infrastructural inversion, close reading

Instrumentalization

Scientific or engineering expertise intervenes in public debates in ways that remove their political character and make them amenable to technical interventions. The opportunity to foreground other societal values, such as justice and equity, are in turn lost.

Theoretical Grounding

Technology is never neutral, and the information technologies that shape our understanding of the world are perhaps least neutral of all. Instrumentalization occurs when the technical aspects of socio-technical systems are given priority over the social. This phenomenon is well known and studies of technology and politics. Tanya Li described the ways that experts rendered complex social and political questions as technical issues amenable to interventions through their own particular skills and resources (Li 2006). It is also linked to much longer-running critique of rationalism and "instrumental reason" in critical theory (Horkheimer 2013). In practice, the process of instrumentalization is never complete or uncontested, but it risks limiting public debate over contentious issues, marginalizing the voice and perspective of communities, and reinforcing existing inequalities.

Empirical Evidence

In the study on sea-level rise modeling in California, the engineers and ecologists that sought to design coastal protection schemes relied on cost-benefit analysis approaches that required expert knowledge to develop and utilize. Their models weighed the costs of building and maintaining protective infrastructures against estimated benefits of such

protection. On the surface, these models seemed to yield robust, neutral recommendations for sea-level rise mitigation. Their complex construction and technical language served to intimidate non-experts and limit public participation in debates over sea-level rise planning. The very serious ways in which questions about which communities would be protected intersected with long-standing concerns in the Bay Area over housing equity, racial justice, and the distribution of environmental harms and benefits were frequently left out of the discussion or seen as political problems that were orthogonal to technical questions of sea-level modeling. They were thus normalized by the planning process and likely to be reinforced through future coastal protection schemes.

Tactics

Participatory design, action research, activist design, ethnography

Other Potential Anti-Patterns:

In addition to the patterns discussed above, several other anti-patterns in the design of crisis information systems were surfaced through this research or relevant literature. In addition other anti-patterns from the broader HCI research in this space such as vendor lock-in, stovepipe systems, or issues related to privacy have definite relevance to crisis information systems. They merit further investigation in future work on this topic.

1. *Bias* - Existing information infrastructure and resources may privilege some worldviews and values over others due to past investment, closer ties to power and authority, or other

reasons. This may bias decision-making or public understanding of complex issues in unfortunate ways.

2. *Temporal scale error* - The temporal framing of the issue results in important aspects going unobserved.

3. *Spatial scale error* - The spatial scale (neighborhood, city, province, etc) to which data and models are designed to assess is inadequate to the problem, disempowering local communities, ignoring transboundary issues, or other.

4. *Atomization* - Social phenomena are measured at the level of the individual, leading to silences around collective issues.

5. *Treats dynamic settings as static* - Information systems capture snapshots of rapidly evolving situations, rendering them as unchanging and quickly becoming out of date.

These anti-patterns, uncovered through in-depth qualititative and design research across my field sites and calibrated in reference to STS and humanities research on disasters and information systems, represent only a small subset of the ways in which technology serves to inscript and circulate harmful discourse about crises. Nonetheless, they are contributions to research and design of ICTs used in crisis informatics. Given the intense diversity of disasters, the social contexts in which they arise, and the range and rapid change of technologies that intervene in these settings, a full catalog of anti-patterns

is both unrealistic, and more important undesirable. Instead, these patterns, and others

that are uncovered over time through techniques including critical technical practice,

should serve as resources in support of a broader effort towards inclusion of reflection on

the social consequences of technology into everyday technical work.

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