Thin Grey Lines: Confrontations With Risk on Colorado's Front Range

Robert Soden
Department of Computer Science
University of Colorado Boulder
robert.soden@colorado.edu

Leah Sprain
Department of Communication
University of Colorado Boulder
leah.sprain@colorado.edu

Leysia Palen
Department of Information Science
University of Colorado Boulder
leysia.palen@colorado.edu

ABSTRACT
This paper reports on two years of ethnographic observation of the science and politics of flood risk in Colorado, as well as design research that examines citizen interaction with expert knowledge about flooding in the region. We argue that the 100-year floodplain standard that inform maps produced by the United States Federal Emergency Management Agency (FEMA)'s National Floodplain Insurance Program (NFIP) represent a problematic form of discursive closure of scientific understanding of flood hazard. We show that in order to meet the requirements of the NFIP, this standard acts as a closure that conveys a certainty that the underlying science does not warrant and foreshortens dialogue on disaster risk and public understanding of flood hazard. Engaging with literature in science and technology studies and human-centered computing, we investigate design opportunities for resisting closure and supporting public formation through encounters with the uncertainty and complexities of risk information.

Author Keywords
Flood risk; Design; Human-centered computing; Public engagement; Science and technology studies.

ACM Classification Keywords
H.5.3. Groups & Organization Interfaces—collaborative computing, computer-supported cooperative work; K.4.2. Social Issues

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

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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.

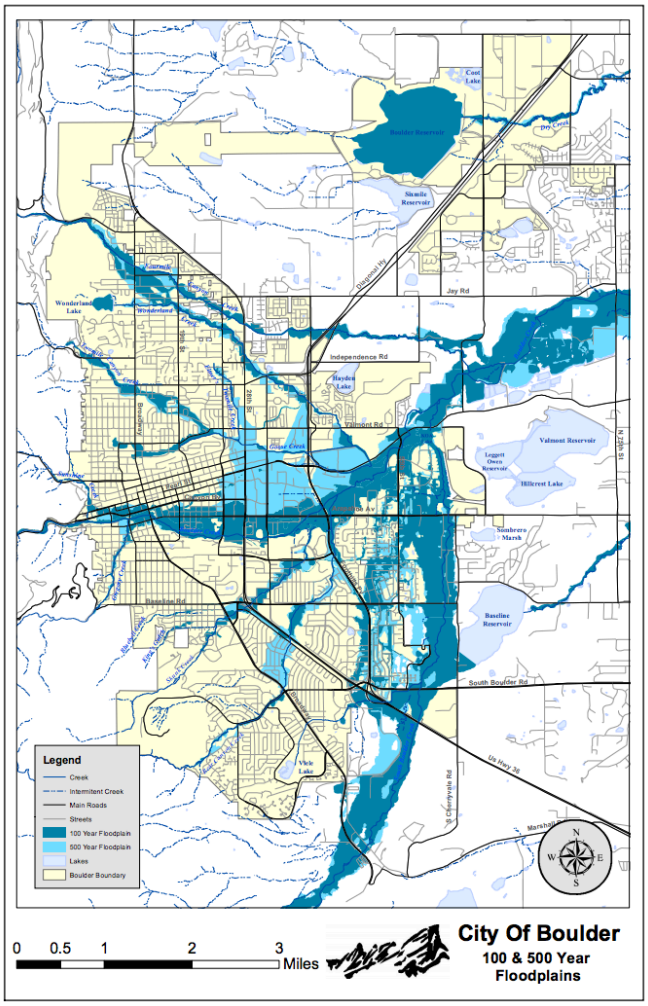

Figure 1. FIRM Map for the City of Boulder
Source: https://bouldercolorado.gov/flood/floodplain-maps

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 [7]. 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 [9,10,25]. 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" [10].

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 [25]. 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" [30:2367], 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" [38:595]. 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 [35]. 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." [24:12].

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 [6]. 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 [6].

Redrawing of Floodplain Maps

Despite Boulder's history as a pioneering city in the area of floodplain management [16], 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 [26]. 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 [26].

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 [31]. 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 [20] had the effect of replacing other standards of flood hazard assessment across other areas of flood management [31].

The 100-year floodplain standard facilitates uniform management at the national level at the expense of local adaptability for site-specific circumstances [30]. 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 [28]. 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 [34].

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 [25]. 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 claimed that "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 [28]. 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 [28]. 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 [29]. In other cases, the classification of particular neighborhoods or areas as "risky" is also seen to have blighted areas [13]. 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 [11,13,19,30,37,38]. 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" [33:1]. 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 [37,38]. This process facilitated a "redistribution of flood modeling expertise in ways that challenged the hardwired arrangements" [38:595] 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 [1] 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 [32]. 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 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

Figure 2. Flood Risk Game Materials

Figure 3. Playing the Flood Risk Game

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 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" [18:2]. 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

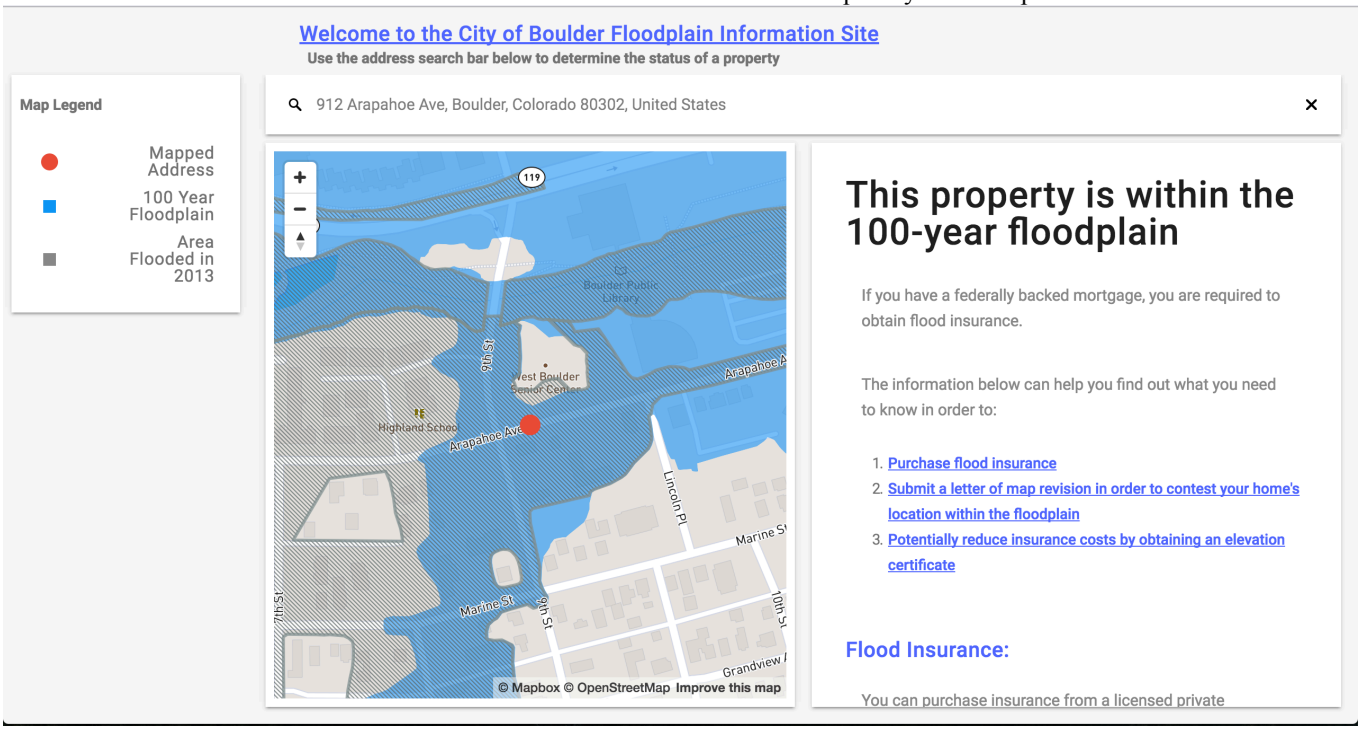

Figure 4: Flood Risk Website

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.

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 [4] 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 [4:905].*

Risk, in this framing, is an attempt at collective management of threat through instrumental rationalism [2,27]. 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" [521].

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* [14]. Monsters occur "when an object refuses to be naturalized" [3:304]. 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 [17,20]. Their reductive qualities are precisely why they can serve to enable Latour's "action at a distance" [21]. The task for scholars has been to cast a critical gaze upon the standards [3,20] 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* [7] 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 [23]. 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" [15,33]. 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 [17]. In a play off on CSCW's notion of articulation work, Bowker and Star [3] 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 on flood decision-making called for more opportunities for the public to engage in deliberative thinking about risk [19]. 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 [37], 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" [11:510]. 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.

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