Flood Planning and Climate Forecasts at the Local Level

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Abstract

We examine the use of El Niño-Southern Oscillation (ENSO) forecasts for flood planning in the Pacific Northwest. Using theories of resource mobilization as a conceptual foundation, the paper relies on: 1) case studies of three communities vulnerable to flooding that have had access to long-term forecasts of ENSO conditions; and 2) analysis of data collected from a survey of nearly 60 local emergency managers, planners, and public works staff. We find that understanding the regulatory machinery and other institutions involved in using climate forecasts is critical to more effective use of these forecasts. Forecast use could be promoted by: 1) an extension service to broker climate information; 2) the identification or creation of federal authorities to fund activities to mitigate ENSO impacts; and 3) the proactive use of ENSO signals to identify areas most likely to be influenced by climate anomalies.

Key Words: flooding, ENSO, La Niña, climate variability, climate forecast, natural hazards, water policy

JEL Classification Numbers: Q2

Contents

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1. Introduction

The influence of scientific information in public decisionmaking can be notoriously difficult to establish. Such decisions often are the result of numerous adjustments that involve many parties and take place over what can be long periods due to demands for policymakers and politicians to accommodate a diverse set of interests while focusing on immediate impacts. This problem is especially acute in the context of science-based predictions of future climate events, which typically lie beyond immediate policy horizons and, by definition, can be highly uncertain. Moreover, a number of institution-specific pressures and structural disincentives may impede the use of climate forecasts in policy formulation and implementation.

This paper presents the findings of our research on the use of seasonal and interannual climate forecasts in one specific decisionmaking context, namely flood planning and management at the local level. Our work borrows from the risk communication literature and rests on several case studies of forecast use, as well as a survey of local officials in some 30-plus counties in western Oregon and Washington. In particular, we focus on the conditions that support the use of climate forecasts in flood planning and management, and those that inhibit it in the study counties.

We start the main body of the paper in section 2 by summarizing the relationship between streamflow variation in our study region and intermediate-term climate events. We also outline possibilities for using this information in river system management. In section 3, we briefly review literature relevant to the use of forecast information in decisionmaking, focusing on the difficulties of making climate forecasts more prominent in flood planning. We also introduce in this section the "social arena" conceptual model that we use to examine forecast use. We then present in section 4 three examples where

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climate forecasts have been considered and explore the utilization of forecasts in the context of the social arena. In section 5 we discuss the survey design and provide highlights of the survey results. We follow this in section 6 with a statistical analysis that examines the conditions that shape the use of climate forecasts in flood planning. We conclude the paper in section 7 with observations on the role of climate forecasts in flood planning, and provide several recommendations for enhancing this role.

2. Background

Since at least the late 1980s, researchers have studied the relationship between continental- and larger-scale atmospheric disturbances and a range of impacts at the regional or local levels. Work in the Pacific Northwest, for example, has shown the seasonal El Niño-Southern Oscillation (ENSO) cycle, in conjunction with the slower-cycled Pacific Decadal Oscillation (PDO), appears well correlated with regional precipitation and temperature deviations, as well as a host of indirect impacts arising from such weather anomalies (Cayan and Peterson 1989; Cayan and Redmond 1994; Cayan and Webb 1992; Greenland 1994; Kahya and Dracup 1993; Miles et al. 2000; Redmond and Koch 1991). In general, the warm phases of the ENSO (El Niño) and PDO cycles are associated with warmer and drier winters and springs in the region, while the cooler phases of ENSO (La Niña) and PDO cycles tend to bring cooler and wetter winters and springs (Gershunov and Barnett 1998; Mantua et al. 1997; Redmond and Koch 1991). As these climate events occur, they can influence wintertime snowpack conditions in the Cascade mountains and the magnitude and timing of spring snowmelt; the supply of irrigation and municipal water; flood control and hydropower generation; electricity demand; and even the survival of anadromous Pacific salmon populations (Clark, Serreze, and McCabe 2001; Miles et al. 2000; Pulwarty and Redmond 1997; Vaccaro 2000).

Although the association between the large-scale climate fluctuations and local weather anomalies is far from perfect, and uncertainties about the strength and specific location of the anomalies and their possible interactions with other events abound (Wernstedt and Hersh 2001), it is possible to use ENSO forecasts to improve water resource management throughout the Pacific Northwest (Hamlet, Huppert, and Lettenmaier 2002; Hamlet and Lettenmaier 1999; Miles et al. 2000). The system of dams in the Columbia Basin allow reservoir managers to shape natural river flows—to vary the amount stored at certain times of year to better meet the multiple objectives of the river system—and climate forecasts of precipitation and temperature can be helpful inputs in reservoir operations decisions. ENSO signals can improve the early season forecasts of runoff volumes, reducing errors of the forecasts substantially. This is useful for power planning as well as fish management, since endangered and threatened salmon stocks in the region may require that reservoir operators commit to minimum flows to meet salmon survival objectives. At higher elevation subbasins, where snowpack is a substantial contributor to runoff—such as the catchment above Dworshak dam in Idaho—these early signals can be particularly important. This site provides substantial upstream storage and is one of the principal control points for outflow from the Snake River into the Columbia River mainstem.[1]

Despite the appeal of forecasts, taking advantage of ENSO signals is not straightforward. To the extent that the agencies have clear responsibilities for certain water resource objectives—the Corps of Engineers and Bonneville Power Administration's responsibilities for flood control and hydropower generation being the two clearest examples—it is easier to utilize forecast information. However, even in these situations, the multiplicity of interests affected by reservoir operations, as well as institutional rigidities in reservoir management, impede forecast use. This is even more problematic when the influence of federal agencies is weak, and where the institutional arrangements linking federal intent to state and local implementation have been strained, as is the case with flood planning and management.

3. Relevant Literature

The extensive literature on the use of technical information in decisionmaking in areas such as flood management suggests that the dissemination and reception of ENSO forecasts is not merely a transmission of technical ideas but also a process of melding political, social, and institutional interests (Changnon 1996; Comfort 1994; Innes 1998; Kasperson 1992; Parker and Handmer 1996). Clearly, the form of an ENSO forecast, the probabilities associated with different threshold events, and the packaging of the forecast will affect the way in which the information is understood and used by different policy actors involved in flood protection, and how widely it is disseminated (Glantz 1996; Pielke 1997). But the value of ENSO forecasts also will depend on what one can loosely call the politics of flood management; that is, the extent to which groups such as

[1] The Bonneville Power Administration—the federal authority responsible for marketing power generated by the system of federally-owned dams in the Columbia River basin—also has explored using ENSO signals to better plan power purchases so that it is not forced to buy power on the spot market in an emergency situation when prices can be very high.

hydrosystem operators, emergency response authorities, and local governments have clarified issues related to a more regional approach to flood planning, as well as intergovernmental coordination of emergency services, recovery assistance, logistics support, and floodplain insurance.

To better gauge the role ENSO forecasts can play in flood planning we need to consider the potential benefits different groups anticipate from long-range forecasts, as well as the consequences these groups could face if they fail to successfully implement ENSO forecasts. Before this, however, we must grapple with two powerful structural forces that militate against the ability to use improved climate forecasts effectively: the lack of concern and support for flood planning and policy, except when disaster strikes; and the "shared governance" of flood planning and management among multiple levels of government.

Limited Salience and Shared Governance in Flood Planning and Management

May and Williams (1986) and Petak (1985) noted more than 15 years ago that an atmosphere of "apathetic politics" permeates flood and other disaster policymaking, management, and planning. On the policy side, legislators typically must turn their attention toward the most pressing matters and, in normal times, when water is not lapping at the feet of their constituents, flood concerns lie in a policy backwater. In addition, many of the potential advocates and constituents for better flood information and planning—lower-income residents that reside in floodplains, for example—often lack the necessary political or financial capital to effect policy changes. Similarly, most agencies with operational responsibilities for flooding typically have a host of other functions and responsibilities they must carry out; their limited resources do not allow them to focus on flood preparations, except when confronted with pressing real-time decisions. Moreover, longer-range planning for floods often attracts limited interest because flood events are inherently probabilistic. Agencies often perceive that the political and economic costs of proactive flood management planning are disproportionate to its benefits (Berke 1998; Wiener 1996). The latter are often heavily discounted because they are not realized until the future, if at all. As a result of this situation, May and Williams (1986) suggest, flood planning suffers from a ratchet effect. Its contours are shaped by the most recent extreme event, and disaster assistance, rather than better planning and management, becomes the recurrent "solution" to flooding. In such a mixed world, it is difficult to encourage the effective and systematic incorporation of improved climate forecasts into flood management.

This difficulty is compounded by a second structural problem, namely that multiple levels of government share the responsibilities for flood policy, management, and planning. Observers have long noted a dissonance between the federal interest in promoting flood hazard mitigation and preparedness and the inability of the federal government to control the implementation and effectiveness of such efforts (Burby et al. 1988; Holway and Burby 1993). Money and technical assistance frequently come from the federal level, but programs typically are operated and impacts felt by local agencies. These latter entities often give low priority to mitigation and preparedness. In a 1982 study that reported on interviews with more than 2,000 governors, mayors, planners, realtors, developers, and bankers with interests and/or responsibilities in disaster policy, the state and local interviewees clearly preferred post-disaster relief and structural mitigation as a cornerstone of disaster policy; nonstructural mitigation and compulsory insurance were the least favored policies (Rossi, Wright, and Weber-Burdin 1982).

The often divergent objectives among the tiers of government raise questions about the adequacy of current flood protection measures, since, by all accounts, structural and nonstructural approaches to averting flood losses are, by themselves, insufficient. The differences suggest that a coherent flood policy must rely on coercion, cooperation, or some mixture of these two approaches before it can be implemented on the ground (May and Burby 1996; May et al. 1996). Moreover, even when cooperation and commonalties emerge, and all parties fully support preparedness rather than aversion, the technical, financial, and administrative capacities of local governments may constrain the effectiveness of even the best-coordinated and well-intentioned management efforts. The implications of these two structural dilemmas for the effective incorporation of improved climate forecasts should be clear. Not only must flood stakeholders successfully absorb and act upon improved forecasts in a decision arena where flood planning and management are, in normal times, typically of low political salience, but once they absorb and decide on actions, the stakeholders need to coordinate their efforts across institutions that may have quite disparate missions, incentives, and cultures. Understanding the institutions and the motivations of stakeholders is thus essential for promoting the effective incorporation of improved climate forecasts.

The Social Arena of Flood Planning and Management

The conceptual framework for our study builds upon the scholarly literature that examines the role of information in policy planning (Habermas 1984; Innes 1998; Schon and Argyris 1978; Williams and Matheny 1995), theories of organizational learning in the context of natural and technical disasters (Carley and Harrald 1997; Comfort 1988; Comfort 1990; Comfort 1994; Lagadec 1997; Quantarelli 1985; Wynne 1992), and, most centrally, the work of Ortwin Renn (1992) and others (Hilgartner and Bosk 1988; McCarthy and Zald 1973) pertaining to social arena theory.

The basic claim of the social arena concept is that the availability of resources for any group determines its degree of influence on shaping policies in a specific political arena. Renn's work on the social arena evokes the image of a venue where stakeholders mobilize resources in political debates about risk, the structural conditions (such as regulatory, institutional, and historical factors) that shape interactions among groups, and the ability of institutions to influence the policy process (such as flood planning and response). An "arena" for Renn is a metaphor, the "symbolic location of political actions that influence collective decisions" (Renn 1992, p. 181). It consists of both formal rules—laws, regulations, mandates—as well as informal rules, including regulatory styles, managerial approaches to discretion and flexibility, role expectations, and, more broadly, the political climate of group interactions.

For our purposes, the flood "arena" is structured by federal flood policies—those authorized either by Congress or the executive branch and carried out primarily by the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (Corps)—state hazard planning requirements and local floodplain ordinances. In addition to this patchwork of formal rules, government agencies and other stakeholders in the arena operate under the constraints of informal rules. These include the low political salience for flood planning; shared governance; expectations of disaster subsidies to compensate local victims of severe flooding; local resistance to nonstructural mitigation strategies that are seen to affect property rights; and the belief of many in the local community that their right to undertake small-scale flood control projects (such as debris removal from streams) to safeguard their property has been circumscribed by state and federal regulations to protect the natural environment.

To be successful in Renn's arena—to influence decisionmaking on topics such as the application of new forecast information, for example—it is necessary for groups to have access to five social resources. We collapse them here into three aggregate categories. The five resources include, not unexpectedly, *power* to produce conformity or to demand compliance to rules, and *money* to provide less coercive incentives. Often these two resources operate in tandem in the context of floodplain management: the federal government, for example, offers floodplain insurance premiums at reduced rates to residents in communities that have met certain criteria for flood prevention. For this reason, we will present *power and money* together in the subsequent discussion.

Other resources are, perhaps, more arcane. *Value commitment* pertains to the ability of a group to persuade other actors that their objectives and goals have a commonality, a sense of shared purpose. *Social influence* relates to a group's ability to convince others it is credible; this credibility may stem from deploying recognized "experts" or advocates who are considered to be sincere and competent. This influence depends on the final resource defined by Renn: *evidence*, the technical and scientific claims about what the problem is and how it might be fixed. Because this evidence is largely useless if its proponents or presenters lack social influence, we combine social influence and evidence into what we will call *legitimacy*.

3. ENSO Forecasts and Flood Planning: Three Examples

Given the historical resistance to integrated floodplain management in this country and the shared governance problem noted earlier, it is, perhaps, not surprising that local officials may find it difficult to use a climate forecast to change flood planning or management practices. Yet, in at least two situations we know of, emergency managers have taken advantage of an ENSO forecast to improve flood management. The social arena theory is useful for examining how these successful applications came about. The theory also can help us to understand why other counties similarly exposed to ENSO climate events have not used ENSO forecasts.

Tillamook County, Oregon

Tillamook County, OR, one of the wettest areas in the continental United States,[2] has a long history of wintertime flooding. This reflects both its exposure to Pacific storms and the shallowness of Tillamook Bay, which, particularly during high tides, limits the rate at which several major rivers along a flat coastal margin on the north side of Tillamook City can discharge to open water. In 1996, 1998, and 1999, the county experienced a series of particularly damaging floods, with the February 1996 flood alone causing more than $30 million of damage to public infrastructure, more than $5 million in property and inventory damage, and a loss of $10 million in the agriculture sector (Tillamook County Emergency Management 1999).

[2] Average annual precipitation exceeds 2 meters in Tillamook City, the county seat, with more than three fourths of the precipitation typically falling between November and March. Daily rainfalls commonly exceed 10 centimeters during storms and some single storms deposit more than 50 centimeters of precipitation. Average annual precipitation in higher elevations of the county exceed 3 meters per year.

In 1999, the local emergency manager and other stakeholders in the Tillamook flood arena used a La Niña forecast issued by the National Weather Service to help secure federal funding for flood mitigation from the Corps of Engineers' Advance Measures program.[3] These funds supported the construction of several structures to reduce the backup of river flows during high river discharges that many thought would accompany the forecasted wintertime La Niña conditions. Tillamook officials credit the structures—whose implementation was completed two days before a major Thanksgiving flood hit Tillamook in November 1999—with reducing flood damages by more than an order of magnitude from the similar-sized February 1996 flood (Manning personal communication, 2000).

Without question, the resources commonly viewed as the most important for securing favorable action—power and money—were instrumental in Tillamook's use of the La Niña forecast. In addition to the obvious importance of funds from the Corps' Advance Measure program, the federal money received from FEMA's Project Impact—which was used to help keep a full-time, experienced emergency manager on the Tillamook payroll—was pivotal. The emergency manager had the time to attend meetings with meteorologists from the National Weather Service and the state of Oregon who discussed the implications of looming La Niña conditions, as well as staff resources to bring flooding to the attention of important stakeholders and work the political trap lines at the local and state level. Perhaps most critically, this individual had direct access to the county commissioners, rather than one-off contact through the sheriff or public works department (an alternative arrangement found in many other counties). This access facilitated action—particularly in the later stages of project approval, as the flood season neared—when the Corps' headquarters in Washington, D.C., initially balked at approving funding. The emergency manager contacted the county commissioners, who in turn lobbied their Washington contacts, pressing the case with the Corps' headquarters staff and the vice president, and receiving approval for the project within 24 hours of the lobbying blitz. The Oregon governor's office also weighed in, along with the area's Congressional delegation. In addition, local business interests on the north side of Tillamook City constituted a powerful group that was instrumental in pushing for federal money for action.

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3 The Advance Measures program funds emergency activities to protect against loss of life or damages when there is an imminent threat of unusual flooding. The activities are designed to meet a specific threat and in principle are only temporary in nature.

The second resource category—value commitment—was also critical for ENSO forecast utilization in Tillamook, in several ways. First, the commitment of the local emergency manager to the goals and objectives of local businesses, residents, and officials—a commitment that had stood out in prior demanding emergency situations in which 24-hour plus workdays had been required—provided the credibility and standing for the emergency manager to press other county officials and the Corps to take advantage of the opportunity that the La Niña forecast provided. Second, a shared commitment between the Corps and the emergency manager to quick action provided an important conduit for the latter to press the case for forecast use. In fact, rather than work through the offices of the Corps that were carrying out the long-term feasibility study of Tillamook flooding—offices that had been at loggerheads with the county on several issues in the study—the county's emergency manager targeted the emergency management side of the Corps for support. Third, the emergency management side of the Corps itself drew on sympathetic construction, design, and hydraulic engineers within the agency who supported the project, to convince their colleagues who were dubious of the forecast or proposed engineering solution.

Finally, the effective use of the forecast information depended on the legitimacy of the evidence and the credibility of those who argued that measures to reduce flood risks could be built quickly. With respect to the former, for the La Niña signals to be acted upon, forecast promoters first needed to gain the support of key groups who would likely see some value of the information and an opportunity to act. Previous years' floods and local and media coverage of the possible link between La Niña and wintertime flooding had sensitized local residents to the possible link—the local emergency manager opined that 90% of adult Tillamook residents likely have heard of La Niña. In fact, local receptivity to La Niña events warnings has facilitated longer-term efforts by the planning department to shape development to reduce the area's vulnerability to flooding.

Most critically, the La Niña forecast issued by the National Weather Service office in Portland that anticipated an "elevated risk" of heavy precipitation in Tillamook under expected wintertime La Niña conditions (Keeton, 1999) loosened federal purse strings. This forecast was in the form of a letter sent by a meteorologist at the National Weather Service to the local emergency manager. It did not arrive unsolicited, but rather was encouraged at the initiative of the local emergency manager and Corps engineer and developed jointly by the emergency manager and the meteorologist.

Snohomish County, Washington

The second example of forecast utilization—in Snohomish County, WA—took place the same year and also centered on the use of a La Niña forecast to secure Corps funding to construct an emergency measure. In this case, a weak dike that protected a sewage treatment plant along one of the county's principal rivers was thought to be at risk from potentially high river flows. Local stakeholders successfully used a forecast of a La Niña winter and the "imminent" threat of the damage that would result if unusually high, wintertime flows inundated the treatment plant to press the Corps to repair the dike.

Snohomish, like Tillamook, is one of the wettest counties in the continental United States, with annual precipitation exceeding 2 meters in the eastern, higher elevation parts of the county. Unlike Tillamook, however, the area's population is rapidly growing, increasing by 30% between 1990 and 2000 and is now more than 20 times the population of Tillamook. Average income and education levels are notably higher in Snohomish, and annual county expenditures are 10 times the amount in Tillamook. Even with these advantages and a greater breadth of technical expertise within the local government, however, the utilization of the ENSO forecast still depended on the mobilization of the social arena resources by local and regional stakeholders. This took several forms.

First, power and money resources were as important to the successful use of the La Niña forecast in Snohomish as they were in Tillamook, through many of the same mechanisms. Neither the sewer district that ran the treatment plant nor the local diking district had the resources to repair the dike, but the Advance Measures authority of the Corps provided the key funds for the $700,000 project. Although local matches of funds are viewed as desirable in Advance Measures, unlike the arrangement with many of the Corps' other authorities for flood protection and mitigation, the requirement is flexible and dependent on local ability to pay. In the case of Snohomish, local participants only needed to provide a modest $50,000 local share contribution, plus in-kind aid supplied by the sewer authority's geotechnical expert. In addition, the Snohomish emergency management office did not have the Project Impact designation that Tillamook benefited from, but tax revenues from the county and 13 incorporated jurisdictions (including Everett, the county seat with a population of nearly 100,000) allow the operation of a five-person county department of emergency management. This has supported the hiring of several specialists, including an individual with an extensive meteorological/ climatological background who is attuned to ENSO signals.

Second, local emergency management staff in Snohomish have been effective in educating local stakeholders about the possible impacts of climate anomalies in the region, and thus were able to build value commitment within the community. The staff regularly discuss La Niña and other climate forecasts in meetings with representatives from diking districts, the public utilities district, the county engineering office, and the public works and transportation departments at the state and county level to encourage more aggressive maintenance of flood protection structures and the refinement of snow and ice removal plans (McAllister personal communication, 2001). To this end, the local emergency coordinator draws on his meteorological background in the county's preseason flood meeting in early October to share his climatological predictions and, together with the attendees, identify problem areas that may be vulnerable to increasing flood probabilities.

The application of the La Niña forecast in Snohomish also benefited from an apparent shared commitment of public officials outside the local emergency management agency with local residents. The Corps' Advance Measures authority can accelerate the typical process of consultation with environmental and other review agencies, allowing paperwork under the National Environmental Protection Act to be filled out ex-post and, typically, waiving the public hearing requirement. In the case of Snohomish, the reconstruction of the dike protecting the treatment plant resulted in the creation of more floodplain habitat, a feature of the project that won support of the local environmental community and the National Marine Fisheries Service.

These value commitment resources may have been particularly important, since the legitimacy resources were mixed. The use of the La Niña forecast to support the dike reconstruction was ill-timed in one respect, insofar as it followed a prediction in the previous year of La Niña conditions that could bring the worst winter weather since the beginning of the century. Residents, hearing dire warnings of threatening floods and snowdrifts that would pile up to the first floor of buildings, bought emergency generators and extra snow removal equipment. Heavy snows in fact had ensued the previous year, but only at elevations above 500 meters rather than the lower elevations where the bulk of the population resides.[4] This likely devalued the legitimacy of the La Niña prediction the following winter.

Legitimacy resource were successfully mobilized in other ways, however. The staff in the Corps' office in Seattle was familiar with the impacts of El Niño conditions in California several years earlier, so they were sensitized to the possible benefits of anticipating conditions under La Niña conditions. Perhaps more importantly, the risk

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[4] 1,140 inches of snow fell in the 1998-1999 season at Mount Baker, north of Snohomish County, the most snowfall ever recorded in the United States in a single season.

posed by a breach in the dike was too great to ignore. The poor conditions of the dike suggested that the treatment plant was safe from flows with a recurrence interval of four years (meaning a flow that would exceed the dikes ability to protect the plant would have a one-in-four chance of occurring in any given year). This would be reason enough to repair the dike, but the higher probabilities of problem flows under the anticipated La Niña conditions added even more legitimacy to the proposed project, since the environmental costs of effluent from a flooded treatment plant reaching the Skykomish River were high.

Lincoln County, Oregon

Lincoln County borders Tillamook on the latter's southern boundary and, like Tillamook, runs north-south along the Pacific shoreline and stretches east into the Coastal Range. It also has a similar wintertime pattern of flooding and suffered the same 1996, 1998, and 1999 floods. Unlike Tillamook, however, the flood planning community in Lincoln County appear to have only limited interest in using La Niña forecasts to plan and manage floods. Several factors likely contribute to this disinterest, and these are instructive for learning more about the utilization of ENSO forecasts.

First, and most importantly, the county experiences less regularly damaging floods than Tillamook. Although two of the floods in the late 1990s resulted in significant impacts—one receiving a gubernatorial and the other a presidential declaration of disaster—the frequency of flooding is lower and actual floods are less devastating to built-up areas. Each of the two rivers that pose a flood threat, the Siletz and Alsea, traverses primarily rural areas; the county's major settlements (Newport and Lincoln City) either sit at higher elevations or do not lie along major rivers. Moreover, there are only a few small community water systems at risk—much of the rural area relies on homeowner septic systems—and, in general, there is little significant public infrastructure vulnerable to flooding. In addition, unlike the problems that the shallow Tillamook Bay presents to the northern portions of Tillamook City, developed areas in Lincoln County generally are not as vulnerable to tidal influences that decrease the rate at which coastal rivers can discharge high flows to open water.

Second, and related to this, the availability of power and money resources in Lincoln County is different than Tillamook. Although emergency managers in both counties have ready access to top city and county decisionmakers, financial support for county-wide activities in the aggregate is more constrained in Lincoln; per capita county expenditures are about half those of Tillamook, in part because a higher proportion of county residents live in incorporated areas that provide local services outside of the county budget. In addition, Lincoln County has not been a FEMA Project Impact community and thus has lacked the visibility and heightened ability to leverage flood mitigation and prevention resources that this designation brings. Lincoln also lacks both the pressures from the business community in Tillamook and the environmental and sewer/diking district constituencies in Snohomish that would demand solutions to flood problems, partly because much of the flooding affects second homes rather than primary residences or businesses.

Third, although value commitment resources appear abundant enough in Lincoln to marshal enthusiasm for using seasonal climate forecasts if desired, these resources have been applied in other ways. For instance, the local point persons on the flooding front are the local emergency manager and the county planner. Both use the credibility they have established to work with residents. The emergency manager relies on extensive forecast information from the National Weather Service's River Forecast Center and Doppler radar and satellite technologies; the latter, shorter-term weather forecasts are particularly important since only a few offshore, marine reporting stations exist to the west of the county, where most of the prevailing weather comes from. He uses these river and weather forecasts to communicate warnings of imminent threats to residents, relying on the personal contacts and trust that he has built through a quarter-century of experience fighting floods in the county. The county planner also has deep roots in the community, and the planning department has effectively prevented new development in flood-prone areas unless proposed structures meet flood requirements. In addition, the department has used federal funds from the Flood Mitigation Assistance program and Oregon's Hazard Mitigation Grant Program to elevate or floodproof a number of vulnerable residences.

Finally, most residents do not pay attention to La Niña forecasts. Unlike both Tillamook and Snohomish, there has been little push to broadcast these forecasts and, indeed, little push from local residents and businesses to use longer term forecasts given the limited impact that flooding generally has on the bulk of the population. Consequently, there is little record to establish the legitimacy of these forecasts. Rather, the supply of legitimacy, as it were, comes from the shorter-term river and precipitation forecasts that the emergency management community disseminates well and the local community tunes into and relies on.

4. Survey of Emergency Managers, Planners, and Public Works Staff

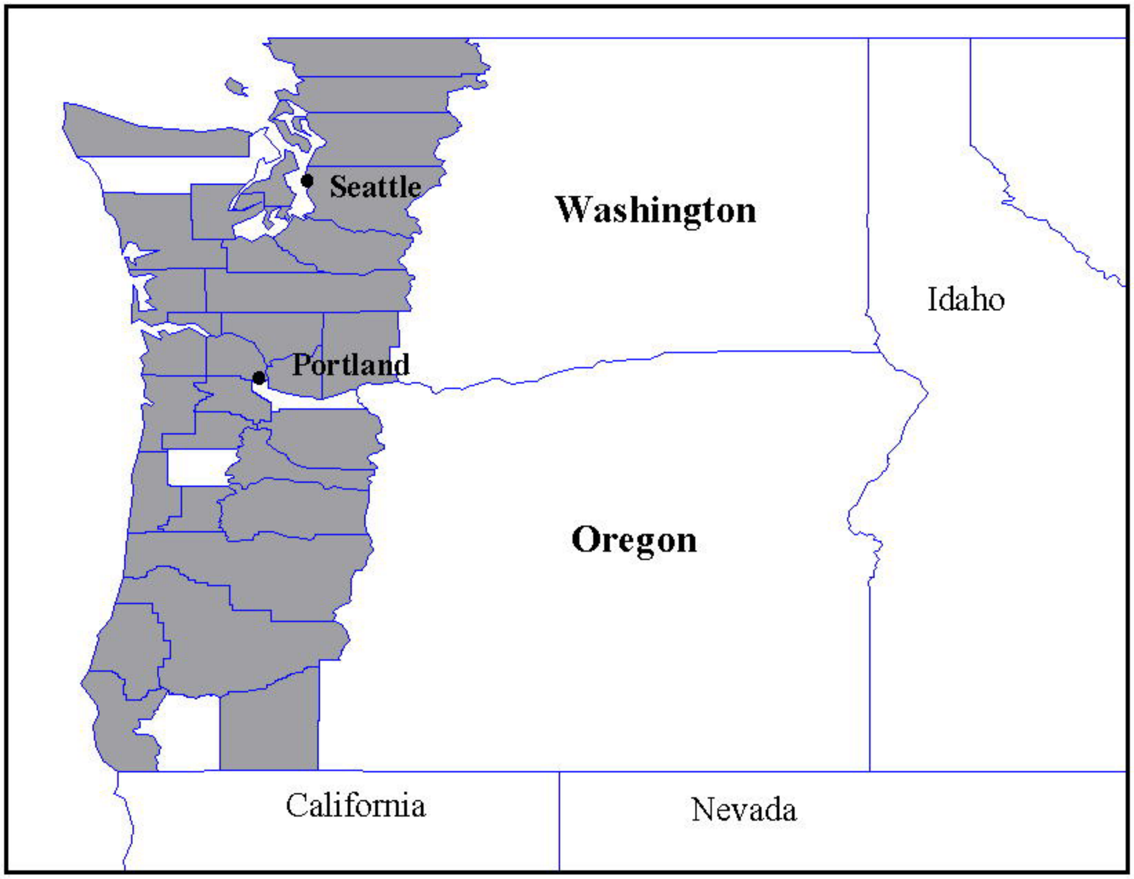
Central to our understanding of the social arena of flooding and forecast use is an appreciation of the context of flood planning beyond the particulars of the individual Tillamook, Snohomish, and Lincoln cases. How important is flooding to local communities and what are the perceived causes of damaging floods? What measures are in place to combat flooding? How commonly do local officials utilize climate forecasts, and what are the opportunities and constraints that these officials face when using climate forecasts to improve flood planning and response? What resources do local officials and other stakeholders believe they can draw on in the social arena of flood planning and management, and what do they think are the important resource limitations?

To address these questions, we conducted a telephone survey of county-level emergency managers, planners, and public works staff in the 37 counties in western Oregon and Washington that lie west of the Cascade Mountains (see Figure 1). Our population consists of 111 potential respondents (37 times 3). Completed surveys represent administration of the questionnaire to 57 individuals (in each of two counties, two individuals responded jointly to a single survey questionnaire) in 33 counties, a 51% response rate (see Figure 1). In addition, we include results from four city officials (emergency managers in Seattle and the Oregon cities of Eugene, Salem, and Medford), for a total of 59 observations. Thirty of the principal respondents are emergency managers, while 15 are public works staff and 14 are planners. It is important to emphasize three features of the survey at the outset.

First, most of the questions in the survey target the perceptions that stakeholders have of forecast use and flooding; these drive the behavior of respondents. Thus, even though a number of our questions could yield factual responses (such as the annual flood damage in the respondent's jurisdiction), we are interested in the more subjective understanding of the flood environment and attitudes of the respondents. Because of this, we surveyed multiple individuals in each county, and thus may find different responses to the same "factual" question. We return to this issue later.

Second, the bulk of our survey does not target ENSO experiences per se. Previous work and conversations with state-level emergency management officials had suggested that few counties have utilized ENSO forecasts directly, the Tillamook and Snohomish cases being notable exceptions. This complicated our instrument design, since we recognized from the outset that a line of detailed questions on La Niña forecasts likely would yield very limited results. Therefore, we have attempted to glean the potential for such forecast use by concentrating on the major perceived opportunities and constraints to flood planning, framing these with the value commitment, money and power, and legitimacy resources of our social arena model.

Figure 1: Study Region



Third, although our dataset of 59 observations is large enough to permit the formal statistical tests we present below, the large number of missing responses for individual questions limits the range of statistical analysis. In addition, our sample is a convenience sample in part. We have a good representation of the emergency managers in the region—typically the director of emergency management in each county or the person most responsible for flood planning—but our respondents from the planning and public works departments are likely less representative. Not only are they fewer in number than the emergency managers, but we also had difficulty identifying and in some cases garnering the cooperation of the single person in each of the departments who was most knowledgeable about flooding and forecast use. In addition, the experience of emergency managers, planners, and staff from public works departments can be substantially different, implying that any one county can have very different levels of familiarity with flooding and forecast use.[5] All of these issues complicate comparisons across all observations, and limit the number of variables we can work with in a statistical model, as we discuss later.

In the following subsections, we first present responses related to the flood planning and management arena itself. We then present the results vis-à-vis the three arena resources, discussing value commitment first, followed by money and power, and concluding with legitimacy. Table 1 highlights the principal points of the discussion.

The Flood Planning and Management Arena

Flooding is an important problem for many of the county and city officials who responded to our survey. All of the 59 respondents report that the jurisdiction in which they work has experienced flooding within the last 10 years, with about 20% of these indicating that the floods have led to a loss of life. The summary results in Table 2 highlight the respondents' experiences with flooding. Although the figures show that the number of individual floods that have caused $50,000 or more in damage in the last decade is relatively low in most of the counties—the median number of such floods is four—the cumulative damage over the course of different floods over several years can be quite high. Median annual flood damage over the last 10 years for those able to estimate damages are $500,000 to public property and $500,000 to private property. Consistent with this, slightly less than half of the respondents that ranked the major types of structural damages from flooding indicated the principal damage is to county or local public infrastructure, while an equal number indicated that it is to residential and personal property. Mean damages in both categories are significantly higher than median values due to outliers (such as the estimated $5 million annual public damage in Tillamook county). Public agencies and programs based outside of the county (for example, the National Flood Insurance Program, federal disaster assistance, and federal or state road repair) reimburse much of this damage (the median reimbursement proportion is 75%).

[5] For example, we have 11 counties in our dataset in which both an emergency manager and a planner responded to our question on the proportion of the work year spent on flood issues. Looking at just these counties so we can directly compare percentages between emergency managers and planners county-by-county, the median absolute difference (that is, ignoring the sign of the difference) in the proportion of the work year spent on flood issues between the two types of respondents is 15 percentage points. This is a large difference relative to the percentage of time that emergency managers and planners in the 11 counties spend on flood issues (the median across both groups is 9% of the work year).

TABLE 1: Flood Policy and Social Arena Resources: Survey Results

Element	Description
Flood Policy Arena	
Local Stakeholders	county offices (emergency management, planning, public works, sheriff, fire & police), county executive & commissioners, Red Cross, flood control districts, schools
Non-Local Stakeholders	Federal Emergency Management Agency, Corps of Engineers, National Weather Service, Federal Highway Administration, Oregon and Washington agencies (offices of emergency management, environmental agencies, Oregon Department of Land Conservation and Development)
Backdrop of Flooding	every county has experienced flooding in last 10 years; chief causes of flooding include heavy, long lasting rainfall; median annual flood damage is $½ million/year to public structures and $½ million/year to private structures); many respondents believe damages will increase in next 10 years; wide range of flood measures utilized with most cost-effective ones being building code requirements and zoning
Value Commitment	
Local Preferences	local residents and businesses don't always strongly support the flood measures (building codes, zoning) that officials view as cost effective; local support for structural measures and debris removal has decreased over last 10 years
Compliance and Regulatory Style	mixed views on how effective county is in obtaining compliance with building code provisions for flood protection; 51% of respondents characterize regulatory approach as a mix of incentives and coercion and 39% as mostly coercion
Power and Money	
Available Funding	only 1% of county budgets devoted to flooding; 40% of respondents indicate money is critical constraint to forecast use
Access to Power	legal prohibitions to taking action (such as prohibitions against dredging) in response to climate forecast is an important constraint; lack of additional actions to take cited as constraint to forecast use by all respondents; reluctance of local businesses and residents to take action cited as constraint to forecast use by all respondents
Legitimacy	
Forecast Information	uncertainty of forecast cited by majority as constraint to taking action based on forecast; likelihood of forecast needs to be high before action would be taken; uncertainty of the location of forecasted event is important constraint
Forecast Use	concern with issuing forecast of high flows and not having them occur and not issuing forecast and having high flows occur, with the latter more problematic

Table 2: Respondents' Experiences with Floods, Summary Results

	min	max	mean	median	*n*
# of floods causing >/= \$50,000 damage in last 10 years	0	50	3	4	48
annual damage to public property	\$0	\$5,000,000	\$1,020,000	\$500,000	24
annual damage to private property	\$100,000	\$20,000,000	\$2,690,000	\$500,000	11
% of damage reimbursed by sources outside county	0%	90%	59%	75%	28
% of damage that is repetitive	0%	100%	29%	15%	38
% of all residential damage accounted for by residences located in 100-year floodplain	0%	100%	71%	75%	39
% of all residential damage accounted for by seasonal or recreational homes	0%	60%	10%	20%	39

The proportion of overall damage that is repetitive (that is, repeat damage to the same structure in two or more years) is relatively low for most jurisdictions—a median value of 15%—but is very high in some jurisdictions. More than one third of respondents indicate that at least half of the flood damage in their jurisdiction is repetitive, and this proportion reaches 100% in one county. Even in those areas with relatively little repetitive damage, much of the flood-related damage occurs in predictable locations. For example, structures that lie within the 100-year floodplain account for about 75% (median) of all residential damages. Damage to seasonal or recreational homes typically is a relatively minor contributor to residential damage, accounting for a median value of 20% of damage in the jurisdictions of the respondents who made estimates.

Nearly 40% of respondents ranked heavy, long-lasting rainfall as the most frequent cause of flooding, while 35% ranked the combination of rain and snowmelt as a very frequent cause (Table 3). Both of these often are associated with La Niña events, although they also readily occur in non- La Niña years. These causes also generate the most damages (Table 4). Intense precipitation and floods from ocean storm surges are both relatively infrequent causes of flooding and not responsible for much damage (high tides combined with high precipitation is a more frequent and damaging cause than these latter two). Respondents most often noted 1996 as a particularly bad year for damages, but 1997 also was frequently cited.

Table 3: Cause of Flooding, Frequency of Cause

Cause of Flooding	*1*	*2*	*3*	*4*	*5*	*NA*	*n*
intense, short-lasting precipitation (flash floods)	5%	11%	9%	21%	46%	7%	56
heavy, long-lasting precipitation (accumulated floods)	39%	41%	14%	5%	--	--	56
snowmelt, triggered by temperature increase	7%	13%	18%	25%	33%	4%	55
snowmelt, triggered by temperature increase & rainfall	35%	25%	18%	13%	7%	2%	55
storm surges from ocean	6%	12%	8%	8%	15%	52%	52
high tides combined with high precipitation	13%	17%	11%	8%	11%	40%	53

1= very frequent cause, 5=very infrequent cause, NA=not applicable (not a cause)
Row totals may not add to 100% due to rounding

Table 4: Damages from Flooding, Frequency of Damage

Cause of Flooding	*1*	*2*	*3*	*4*	*5*	*NA*	*n*
intense, short-last precipitation (flash floods)	4%	8%	11%	23%	42%	13%	53
heavy, long-lasting precipitation (accumulated floods)	44%	32%	15%	7%	2%	--	54
snowmelt, triggered by temperature increase	8%	11%	19%	19%	34%	9%	53
snowmelt, triggered by temperature increase & rainfall	32%	21%	19%	11%	17%	--	53
storm surges from ocean	8%	10%	8%	8%	10%	55%	49
high tides combined with high precipitation	13%	17%	11%	8%	11%	40%	53

1= very damaging cause, 5=slightly damaging cause, NA=not applicable (not a cause)
Row totals may not add to 100% due to rounding

The responses to our survey question on trends in flooding in Table 5 suggest no strong sense that the frequency of damaging floods has increased over the last 10 years. Well over half of respondents believe that the frequency has stayed the same or even decreased. However, more than half of respondents also indicate that the intensity or magnitude of damaging floods has increased over the last 10 years, implying that changes in the built and natural environment have contributed to the increased flood damages. Moreover, more than one third of respondents believe it likely that flood damages will increase in the next 10 years (as ranked by a response of 1, 2, or 3 on a 10-point scale, as displayed in Table 5). Increased development in flood-prone areas, land use changes that increase runoff, and the sedimentation and collection of debris in riverbeds are the factors most often identified as likely causes of more flood damages in the future. In this context, La Niña forecasts could be effective prods for sensitizing residents to the likelihood of flooding and for mobilizing community support for actions that address factors contributing to flood damages (as has been done in Tillamook).

Table 5: Trends in Flooding

% responses indicating changed frequency of damaging floods in last 10 years	**increased**	**constant**	**decreased**	***n***
	43%	46%	11%	54
% responses indicating changed intensity of damaging floods in last 10 years	**increased**	**constant**	**decreased**	**n**
	54%	41%	5%	56
% responses indicating likelihood of higher flood damages in next 10 years	**1, 2, 3**	**4, 5, 6, 7**	**8, 9, 10**	**n**
	38%	50%	12%	56

(1=certain damages will increase, 10=certain damages will NOT increase)
Row totals may not add to 100% due to rounding.

Not surprisingly, a wide range of entities inside and outside the surveyed counties have flood planning, fighting, response, or recovery responsibilities. In addition to the emergency management, planning, and public works offices that we polled, local entities most frequently include fire and police departments, Red Cross, flood control districts, health departments, and schools. For the emergency managers in the sample—the position with the most direct responsibilities for flood planning and management—about half of the respondents are subordinate, at least in part, to the sheriff's office, while most of the others report to the county executive or legislative body. The most often identified federal programs and offices that the counties cooperate with include the Corps, National Weather Service, Federal Highway Administration, and, most frequently, the Federal Emergency Management Agency and its National Flood Insurance Program. State-level entities include each state's Office of Emergency Management and environmental agencies, and, in the case of Oregon, the Department of Land Conservation and Development.

Finally, all of the respondents indicated that their jurisdictions provide flood protection and mitigation measures. Table 6 shows that the most-mentioned approaches are building codes, structural measures (dams, spillgates, and levees), zoning, and insurance. 75% or more of the respondents indicate that their jurisdiction uses these measures. Conversely, repetitive loss ordinances and tax incentives and easements that encourage landowners to moderate development in flood-prone areas are used by 25% or less of respondents.

Table 6: Prevalence of Flood Protection Measures

Flood Protection & Mitigation Measure	***Yes, Used in County***
structural measure (e.g., dams, spillgates, levees, etc.)	80%
dredging & debris removal	49%
building code requirements	88%
zoning (overlay, conservation, etc.)	80%
repetitive loss ordinance	12%
cost-sharing for relocation (buy-outs) or retrofitting	32%
purchase of easements	25%
tax incentives (e.g., tax breaks for undeveloped land)	14%
insurance	75%
hazard mitigation plan	54%

n=59 for all listed measures

With the exception of the structural alternatives, the flood protection and mitigation measures generally require some degree of ongoing cooperation among local businesses and residents to work. This is certainly the case with building codes and zoning, where effective enforcement of regulations may be far from assured. For example, a recent national-level survey reported by Burby and co-authors (1998) on compliance with building codes by contractors, developers, and builders suggests that attaining widespread adherence to the codes is not a simple matter of detecting violations and punishing offenders. Rather, improving compliance often also involves increasing the commitment of local stakeholders to comply through incentives, education, flexibility, and technical assistance.

Borrowing from the study by Burby and co-authors, we can examine how agencies achieve compliance with policies aimed at flood protection and mitigation. Different jurisdictions may promote this through more coercive sticks such as inspections, penalties, and stop-work orders, an approach that may be more common in those environments in which a shared commitment is low. Alternatively, other jurisdictions may rely more on incentives or carrots such as negotiation, technical assistance, and willingness to relax rigid requirements in certain situations. The latter appears well suited—or at least is the approach most likely to succeed—in situations where shared commitment is high. When asked what mix of carrots and sticks are used in each county, about half of the respondents characterized their county's approach to encouraging compliance with zoning and building codes aimed at flood protection and mitigation as a mix of sticks and carrots (a value of 4, 5, 6, or 7 on a scale of 1 to 10, with 1 indicating an approach relying completely on sticks and 10 an approach relying completely on carrots). Almost four times as many of the remaining respondents indicated that their jurisdiction relies more on sticks than carrots (see top part of Table 7).

Table 7: County Approaches to and Experiences with Regulatory Compliance

County Approach	**mostly sticks** (1, 2, 3)	**mixed** (4, 5, 6, 7)	**mostly carrots** (8, 9, 10)	***n***
What approach does your county use to promote compliance with zoning and code provisions?	39%	51%	10%	49
County Experience	**effective** (1, 2, 3)	**mixed** (4, 5, 6, 7)	**ineffective** (8, 9, 10)	***n***
What is your county's overall effectiveness in obtaining compliance with code provisions?	56%	36%	8%	50

Value Commitment

In the county-level settings of flood policy, management, and planning that our survey reveals, a wide variety of stakeholders typically influence flood-related actions (such as the innovative use of climate forecasts) taken by the public agencies represented by our survey respondents. This influence can be in support of agency objectives or in opposition, depending in large part on the degree to which the agencies are perceived to share the objectives, interests, and values of local private residents and business stakeholders. What value commitment resources do the agencies have available to persuade local stakeholders that their goals and objectives have a commonality, a sense of shared purpose? To get at this in our survey, we asked questions pertaining to the respondents' attitudes toward flood control measures and their perceptions of local support for these.

Perhaps the most appealing way to get at value commitment is by directly asking respondents the degree to which local stakeholders comply with the regulatory programs of flood institutions. One of our questions asked respondents to assess, on a 10-point scale, their jurisdiction's overall effectiveness in obtaining compliance with building code provisions that provide flood protection and mitigation, with 1 indicating that the respondent believes the jurisdiction is very effective at attaining compliance and 10 indicating it is very ineffective. As we see in the bottom part of Table 7, more than 50% of respondents report that their jurisdiction is largely effective in obtaining compliance (a response of 1, 2, or 3). Less than 10% report that their jurisdiction is largely ineffective (a response of 8, 9, or 10). The compliance story appears even rosier from the perspectives of those generally most familiar with the actual implementation of building code requirements, namely the 14 planners in our sample. More than 75% of these respondents indicate that their jurisdiction is largely effective in attaining compliance.

This strong sense of compliance, coupled with evidence suggesting increased support for building code requirements in the last 10 years, might imply that local stakeholders share the objectives and goals of agencies. The perception of compliance may be far from its reality, however. Clearly, local residents and businesses may comply with codes so that they can secure public financial support for measures to protect private property, for example, or as part of a larger strategy to engender cooperation on other measures that they believe are important. In addition, an agency simply may be effective at forcing local residents and businesses to comply with codes but not necessarily to share the agency's values or agenda.

Unfortunately, our sample does not allow us to directly capture the attitudes of local residents and businesses on compliance, since we survey only agency representatives. We can, however, compare the degree of local support for flood protection and mitigation measures (as perceived by our respondents) with the agencies' preferences for these measures. From the standpoint of the respondents, the most advantageous (meaning the most cost-effective) of the measures is building code requirements (Table 8). About two-thirds of respondents view these as very cost effective. Zoning is the only other measure that at least half of the respondents indicate is very cost-effective, although repetitive loss ordinances and hazard mitigation plans both have more than 60% of respondents indicating relatively high cost-effectiveness (a value of 1 or 2 on the 5-point scale). At least 15% of the respondents view debris removal, repetitive loss ordinances, buy-outs, tax incentives, or insurance as having low to very low cost-effectiveness (a value of 4 or 5 on a 5-point scale). Tax incentives, dredging and debris removal, and buyouts are the only three of the 10 listed measures in our survey that more than one respondent indicate have very low cost-effectiveness.

Table 8: Cost-Effectiveness of Flood Protection and Mitigation Measures

Flood Protection & Mitigation Measure	*1*	*2*	*3*	*4*	*5*	*n*
structural measure (e.g., dams, spillgates, levees, etc.)	23%	37%	29%	9%	3%	35
dredging & debris removal	15%	46%	23%	8%	8%	26
building code requirements	66%	28%	7%	--	--	44
zoning (overlay, conservation, etc.)	54%	28%	13%	5%	--	39
repetitive loss ordinance	39%	22%	17%	17%	6%	18
cost-sharing for relocation (buy-outs) or retrofitting	35%	22%	26%	9%	9%	23
purchase of easements	19%	38%	33%	5%	5%	21
tax incentives (e.g., tax breaks for undeveloped land)	17%	33%	22%	11%	17%	18
insurance	24%	27%	35%	12%	3%	34
hazard mitigation plan	34%	43%	20%	3%	--	35

1= very high cost-effectiveness, 5=very low cost-effectiveness
Row totals may not add to 100% due to rounding

Summary figures for the degree of support from the local public for the flood protection and mitigation measures (assessed by asking the respondents their perceptions of the support for the measures) appear in Table 9. Overall, there is little strong local opposition to any of the measures, with the least popular option—structural measures—having only 16% of respondents indicating that there is very strong local opposition. Zoning is the only other measure with 10% or more in strong local opposition. On the positive side, insurance is the only measure that more than 30% of the respondents indicate has very strong local support. A hazard mitigation plan and structural measures have the next two highest proportions of respondents indicating very strong local support.

The respondents' attitudes toward the measures' cost-effectiveness match up somewhat unevenly with local support for the measures. On the one hand, there are few extreme cases in which highly cost-effective measures attract very strong local opposition or in which measures that aren't very cost effective attract very strong local support. The two leftmost columns in Table 10 highlight for each measure the comparison between the proportion of respondents indicating "very high" cost-effectiveness (from the "1" column in Table 8) and the proportion indicating "very strong" local opposition (from the "5" column in Table 9). Of the four measures with the highest proportion of respondents indicating "very strong" cost-effectiveness (underlined in Table 10), only zoning has more than 10% in "very strong" local opposition. Similarly, the two rightmost columns in Table 10 facilitate comparing options with "very low" cost-effectiveness (from the "5" column in Table 8) and "very strong" local support (from the "1" column in Table 9). Of the measures with the three highest proportions of respondents indicating "very low" cost-effectiveness (underlined in the right half of Table 10), none have notably high proportions in "very strong" local support.

Table 9: Local Support for Flood Protection and Mitigation Measures

Flood Protection & Mitigation Measure	*1*	*2*	*3*	*4*	*5*	*n*
structural measure (e.g., dams, spillgates, levees, etc.)	14%	18%	30%	22%	16%	50
dredging & debris removal	12%	10%	13%	5%	3%	43
building code requirements	12%	37%	27%	18%	6%	51
zoning (overlay, conservation, etc.)	11%	28%	30%	17%	13%	46
repetitive loss ordinance	7%	20%	33%	33%	7%	30
cost-sharing for relocation (buy-outs) or retrofitting	11%	24%	39%	21%	5%	38
purchase of easements	5%	28%	38%	21%	8%	39
tax incentives (e.g., tax breaks for undeveloped land)	10%	45%	39%	3%	3%	31
insurance	34%	29%	32%	5%	0%	41
hazard mitigation plan	18%	45%	32%	3%	3%	38

1= very strong local support, 5=very strong local opposition
Row totals may not add to 100% due to rounding

On the other hand, there is less agreement between the perceived cost-effectiveness and degree of local support when we examine overall negative positions rather than just the extreme cases. For example, the two measures that have the highest proportion of respondents indicating opposition among the local population (the sum of the "4" and "5" columns in Table 9) are structural measures and repetitive loss ordinances. Table 11 shows that nearly 40% of the respondents indicate that one or both of these two measures have "strong" or "very strong" local opposition. At the same time, roughly 60% of the respondents view the measures as having "high" or "very high" cost effectiveness. Alternatively, the two measures that have the highest proportion of respondents with relatively negative feelings about cost-effectiveness are the repetitive loss ordinance and tax incentives. Roughly 25% of the respondents evaluate these measures as having "low" or "very low" cost-effectiveness. One quarter of respondents also indicate that the repetitive loss ordinance has "strong" or "very strong" local support, while more than half of the respondents indicate that tax incentives have "strong" or "very strong" local support. Thus, there appears to be some divergence between public officials' opinions on flood protection and mitigation measures (as measured by their attitudes toward the measures' cost-effectiveness) and the degree of local public support for these measures (as measured by the respondent's perception of local support). Greater divergence would tend to reduce the level of value commitment resources available to the public agencies.

Table 10: Comparison of Cost Effectiveness and Local Support, Extreme Cases

Flood Protection & Mitigation Measure	Very High Cost Effective	Very Strong Local Oppose	Very Low Cost Effective	Very Strong Local Support
structural measure (e.g., dams, spillgates, levees, etc.)	23%	16%	3%	14%
dredging & debris removal	15%	3%	8%	12%
building code requirements	66%	6%	0%	12%
zoning (overlay, conservation, etc.)	54%	13%	0%	11%
repetitive loss ordinance	39%	7%	6%	7%
cost-sharing for relocation (buy-outs) or retrofitting	35%	5%	9%	11%
purchase of easements	19%	8%	5%	5%
tax incentives (e.g., tax breaks for undeveloped land)	17%	3%	17%	10%
insurance	24%	0%	3%	34%
hazard mitigation plan	34%	3%	0%	18%

Table 11: Comparison of Cost Effectiveness and Local Support, Moderate Cases

Flood Protection & Mitigation Measure	**High Cost Effective**	**Strong Local Oppose**	**Low Cost Effective**	**Strong Local Support**
structural measure (e.g., dams, spillgates, levees, etc.)	60%	38%	12%	32%
dredging & debris removal	61%	8%	16%	22%
building code requirements	94%	24%	0%	49%
zoning (overlay, conservation, etc.)	82%	30%	5%	39%
repetitive loss ordinance	61%	40%	23%	27%
cost-sharing for relocation (buy-outs) or retrofitting	57%	26%	18%	35%
purchase of easements	57%	29%	10%	33%
tax incentives (e.g., tax breaks for undeveloped land)	50%	6%	28%	55%
insurance	51%	5%	15%	63%
hazard mitigation plan	77%	6%	3%	63%

Our final attempt to capture an overall sense of the congruence between perceptions of measures from the agency and local residents' perspective was by looking at the average level of local support for those measures that have the highest cost-effectiveness in the view of agency representatives (building codes, zoning, repetitive loss ordinance, and cost-sharing for relocation). In both Table 9 and Table 10, we can see that at least 35% of the respondents indicate that one or more of these four measures has "very high" cost effectiveness. The mean local support for these four measures (as perceived by the respondents to our survey) is about 3, which is "moderate."[6] However, there is considerable variation across the data, with mean local support for the four measures by respondent ranging across the range from 1 to 5.

[6] Technically, arithmetic means should not summarize Likert responses. This implicitly assumes equal weighting among the four measures, as well as a consistent, interval-like difference between adjacent Likert responses. A median summary statistic would be better. However, for the purposes of this section and later use in modeling, we use arithmetic means, which in fact are very close in each jurisdiction to the median response. In addition, we find no appreciable differences when we use median responses in the analysis.

Of course, this provides only a static picture. Attitudes can change over time, either as public officials move to embrace options favored by the local public or the local public moves toward measures favored by public officials. Indeed, about one quarter of the respondents indicate that support for structural measures or debris removal in their jurisdiction has decreased over the last 10 years, while roughly half indicate that support for building code requirements, insurance, and a hazard mitigation plan has increased in that time span.

In the modeling section below, we use the degree of local support for the four most cost-effective measures discussed above.

Power and Money

Although shared commitment to a course of action may be critical for mobilizing support to use climate forecasts in flood planning, application of money and power resources may exert an important influence, too, and help close gaps between different values by making stakeholders' interests more coincident. With respect to money, a useful—albeit problematic—indicator of the availability of financial resources is per capita expenditures by each jurisdiction on overall government services. For 1996-1997, the latest year for which full data are available, these expenditures range from $380 per person (Clallam County, Washington) to $3,100 per person (Seattle). Mean expenditures for the 33 counties and four municipalities are $850 per person. The budget for flood fighting, preparation, training, recovery, and planning typically consumes little of most jurisdictions' budgets. The mean proportion of each jurisdiction's budget devoted to these efforts, for example, is less than 3% and the median proportion only 1%. However, these figures are potentially misleading because they are based on limited responses (less than 60% of respondents addressed flood protection budgets). In addition, flood protection and mitigation support may appear in other accounts or be appropriated only in emergencies.[7]

Nonetheless, flood planning typically is of little political interest and flood planners thus may lack ready access to additional resources to take advantage of forecasts. Indeed, 38% of our respondents identify lack of money and resources as a critical constraint to

[7] In addition, there are nuances in the financial picture for flood protection and management. For example, our questions on the availability of funds for flood protection and mitigation actions reveal that more than 20% of the respondents believe funds are easily or somewhat available from county sources for actions such as maintenance of structures and debris removal. When we include funding sources from outside the county, at least 20% of the respondents indicate there is general availability of such external funds for relocation and buyouts and purchase of easements.

taking actions in response to a long-term climate forecast (see bottom half of Table 12). An additional 15% cite it as an important constraint to long-term forecast use. Only one respondent noted that it was not a constraint at all. In addition, 46% identify availability of staff as a critical or important constraint to taking actions in response to long-range forecast information. Both the money and staff limitations appear to impose more important barriers to using long-term forecasts than to using short-term forecasts. Table 12 shows that at least half-again the percentage of respondents consider the factors to be critical constraints to using long-term forecast information than consider them to be critical for using short-term forecasts. The higher uncertainty of the longer-term forecasts seems to be the primary reason for this difference, a point we return to below.

Table 12: Constraints to Short- and Long-Term Forecast Use (Power and Money)

Constraints to Using Forecasts	*1*	*2*	*3*	*4*	*5*	*NA*	*n*
Short-Term Forecasts							
no additional feasible action	4%	18%	24%	22%	24%	7%	*45*
lack of money	23%	16%	25%	5%	27%	5%	*44*
lack of staff time	16%	20%	23%	9%	30%	2%	*44*
legal prohibitions	12%	10%	13%	5%	55%	5%	*40*
reluctance of locals to take action	12%	12%	16%	21%	33%	7%	*43*
Long-Term Forecasts							
no additional feasible actions	15%	13%	21%	23%	26%	2%	*47*
lack of money	38%	15%	17%	13%	15%	2%	*47*
lack of staff time	24%	22%	13%	17%	20%	4%	*46*
legal prohibitions	19%	14%	12%	2%	40%	14%	*43*
reluctance of locals to take action	27%	16%	14%	16%	23%	5%	*44*

1= critical constraint, 5=slight constraint, NA=not applicable (not a constraint)
Row totals may not add to 100% due to rounding

A second question on power relates to whether there are additional actions that a jurisdiction could take in response to long-term climate forecast information. Nearly all of our respondents who answered our question about the constraints to long-term forecast use indicate that the lack of response options is a constraint to using forecast information.

Twenty-seven percent of the sample characterize the lack of actions as a critical or important constraint, and all but one of the remaining 34 remaining respondents characterize it as a slight to moderate constraint.

Unfortunately, there may be little one can do to respond to forecasts when there is either a lack of options and/or federal and state legal restrictions to taking action. For example, state or federal authorities may not allow local agencies or private individuals to disturb riparian habitats of endangered species or prohibit access to streams that may be filled with debris. Moreover, even when anticipatory actions might be feasible (such as stockpiling sandbags, emergency flood proofing, emergency preparedness testing, updating of contact lists, cleaning culverts, inspecting levees) or regulatory requirements flexible, agency representatives may not be able to compel local residents and businesses to take these actions. Ninety-five percent of the respondents cite the reluctance of local businesses and residents to take additional actions as a constraint to using longer-term climate forecasts. A high percentage of respondents indicate that this reluctance also is a constraint in the context of short-run forecasts, but it is much more frequently an important or critical constraint in the long run; 24% of respondents indicate it is an "important" or "critical" constraint in short-run forecasts, while 43% indicate this in the context of longer-run forecasts. This is the widest gap of the five constraints identified in Table 12. The 27% who identify it as a "critical" constraint in the longer-run context make up the second largest group of the five.

Based on this, money and local reluctance appear to be the most significant barriers to long-run forecast use. We use these two measures in the modeling section below.

Legitimacy

In addition to power and money and the value commitment of local agencies, a central concern in forecast use hinges on the reliability of the forecast. The probabilistic nature of flood forecasts based on climate signals can make taking additional actions problematic. This may be because of event uncertainty (whether a forecasted event will occur) or location uncertainty (where a forecasted event will occur). The bottom part of Table 13 shows that more than 60% of respondents indicate that one or both of these uncertainties are critical or important constraints (the sum of the "1" and "2" columns) to using long-term forecasts for flood planning, dwarfing the less than 15% that indicate these uncertainties are slight constraints or not at all restrictive (the sum of the "5" and "NA" columns). Roughly an additional 20% identify these to be moderate constraints.

Table 13: Constraints to Short- and Long-Term Forecast Use (Legitimacy)

Constraints to Using Forecasts	*1*	*2*	*3*	*4*	*5*	*NA*	*n*
Short-Term Forecasts							
uncertain if forecast event will occur	7%	11%	37%	24%	20%	2%	*46*
uncertain if forecast event will occur at location of interest	7%	7%	39%	28%	17%	2%	*46*
not aware of forecast or lack access to forecast	11%	6%	4%	6%	68%	4%	*47*
Long-Term Forecasts							
uncertain if forecast event will occur	37%	29%	22%	6%	4%	2%	*49*
uncertain if forecast event will occur at location of interest	39%	22%	18%	6%	12%	2%	*49*
not aware of forecast or lack access to forecast	15%	15%	11%	15%	38%	6%	*47*

1= critical constraint, 5=slight constraint, NA=not applicable (not a constraint)
Row totals may not add to 100% due to rounding

These uncertainties appear to be much more significant barriers in using long-term forecasts than in using short-term forecasts. The top part of Table 13 shows that less than 20% of respondents view event uncertainty or location uncertainty as a critical or important constraint to using a short-term forecast. Comparing the responses between the short- and long-term forecasts for each individual in our sample, the median difference in scores is 1 for both event uncertainty and location uncertainty; that is, on our 5-point scale, the median respondent places the uncertainties in the longer-term forecast context one unit closer to the critical end of the scale compared to where the respondent places the uncertainties in the shorter-term context. Roughly 70% of the respondents characterize event uncertainty as being a relatively more critical impediment to using long-run forecasts and roughly 60% characterize location uncertainty as being a relatively more critical barrier to using long-run forecasts, when the importance of each uncertainty is compared to its analog in the short-run context.

The differences in perceived barriers between long- and short-term forecasts undoubtedly reflect the larger uncertainties associated with longer-term forecasts. They also may reflect the limited familiarity of the respondents with longer-term forecasts. While more than 90% of respondents indicate that they or other officials in their county use short-term forecasts from the National Weather Service or its Northwest River Forecast Center in their work, only 31% of the respondents indicate that they use longer-term ENSO forecasts. This limited utilization may represent a conscious decision to not use longer-term forecasts because they are perceived to have little to offer or because there is a lack of access to or awareness of longer-term forecasts. With respect to the latter, Table 13 shows that more than 40% of respondents identified lack of awareness of or limited access to longer-term forecasts as a slight constraint to using longer-term forecasts, or as no constraint at all, and 30% identified it as a critical or important constraint. More than 70% of respondents identify awareness and access as slight constraints or not constraints at all to using short-term forecasts, and only 17% said they are critical or important constraints.

The differences in responses to our access and unawareness question between longer-term and shorter-term forecasts are substantial, but they probably do not fully account for the limited utilization of longer-term forecasts among the respondents. Some portion of the 70% of respondents who don't use longer-term forecasts probably could access such forecasts but do not find it advantageous to do so. They may face other obstacles to using the forecasts or find the relationship between ENSO and flooding implausible.

The previous section and Table 12 highlight some of the other constraints, but additional features related to uncertainty and legitimacy with the public are at play. In particular, there are risks with using a forecast and not having the forecasted event happen, as well as with not using a forecast and having the forecasted event happen. Table 14 shows respondents' concerns with situations where a decision about whether to circulate a forecast to the public—a decision made in the presence of continuing uncertainty about future river flows—does not match the true state of river flows that is ultimately revealed. If, for example, a high flow is forecast and the forecast information is passed to the public in the hope that it may help galvanize support for actions, there is a danger of losing an already dubious audience if high flows do not occur. Most of the respondents note that this is a concern, with 71% characterizing it as at least a moderate concern (9% characterize it as no concern at all). Those who indicate it is a concern almost invariably cite the loss of credibility associated with such false alarms.

On the other hand, if a high flow is forecast and the forecast information is not passed to the public, there is an even greater danger if high flows in fact occur. All respondents using long-term forecasts note this would be at least a moderate concern, with 79% of respondents indicating that it would be a very high concern. Most respondents also cite a loss of credibility with this error, but many also note that litigation, diminishment in agency viability, and loss of respondent's job are distinct possibilities.

Table 14: Concerns with Forecast Use Related to Forecast Outcomes (Legitimacy)

Concerns with Using Forecasts	*1*	*2*	*3*	*4*	*5*	*n*
a *high* flow is forecast, forecast is passed to public, high flow does *not* occur	8%	25%	38%	21%	9%	*53*
a *high* flow is forecast, forecast is *not* passed to public, high flow *does* occur	79%	19%	2%	--	--	*52*
an *average* flow is forecast, forecast *is* passed to public, high flow *does* occur	23%	31%	27%	13%	6%	*52*

1= very high concern, 5=no concern
Row totals may not add to 100% due to rounding

Even average forecast conditions do not appear immune to complications. In particular, if an average flow is forecast and this forecast is passed to the public, public expectations may solidify. If a high flow then occurs, the resulting damage may not match expectations, causing potential problems for agency staff. This eventuality is not as serious as the previous scenario, but more than 80% of respondents still identify it as at least a moderate concern.

Finally, the credence given to the relationship between longer-term climate events such as ENSO and the Pacific Decadal Oscillation and flooding is a key feature of the legitimacy of forecasts. This relates both to the attitudes of the agency representatives and of the general public. When we asked officials whether they believe any floods in their jurisdiction in the last 10 years have been related to climate disturbances such as ENSO, global warming, and the PDO, nearly 90% of respondents answered "yes." This was largely consistent across all of the respondent categories, with the highest proportion (100%) answering "yes" being planners. Almost all of those who noted specific climate disturbances specified ENSO events.

The strong belief in an ENSO-flood connection does not appear to fully carry over to the general public, however. Two-thirds of our respondents indicate that 40% or fewer of the adult residents in their jurisdiction associate La Niña forecasts with an increased probability of flooding; that is, when we asked respondents to choose the percentage of adult residents they believe associate La Niña forecasts with flooding and provided them with 20-percentage-point increments (0%-20%, 21-40%, 41%-60%, 61%-80%, and 81%-100%), two thirds of the respondents choose one of the two lowest categories. Eighteen percent chose the 41%-60% category and the remaining 18% the 61%-80% category.[8]

[8] This relatively limited public awareness of the relationship between La Nina events and flooding potential is consistent with an apparent limited use of climate forecasts by the public. When we asked whether local residents used forecasts of El Nino or La Nina events, only 8% of our respondents responded affirmatively.

Many of the variables related to legitimacy appear to correlate relatively well with each other and capture different aspects of the legitimacy concept. Event uncertainty and location uncertainty capture the most evident aspects of the legitimacy that the agency representatives themselves place on longer-term forecasts. The concern that these representatives have with using a forecast and not having the forecasted event occur also represents a threat to the credibility of the agency representatives or, perhaps, the agency itself. Finally, the degree to which local residents associate La Niña events and flooding is suggestive of the validity that the residents place on the association between La Niña and flooding.

5. Explaining Forecast Use

We can better understand how the three types of social arena resources—power and money, legitimacy, and value commitment—have shaped the utilization of longer-term climate forecasts by looking at the relationship between forecast use and some of the measures of the resources discussed above.

Table 15 shows several indicators of forecast use developed from our survey results. The first of these, *PRODUCT*, relates to the use of specific seasonal forecast products, such as the regular weekly or monthly forecasts from the National Weather Service's Climate Prediction Center or forecasts issued by state climatologists. As we have already noted, only 31% of the respondents indicate that they or other officials in their jurisdictions use specific products that provide forecasts of La Niña, El Niño, or PDO conditions.[9] Even when we look only at emergency managers, who are the most likely respondents to use longer-term forecasts, fewer than half of the members of this subset use these products (47%). The figures are significantly lower for public works staff (20%) and planners (7%).

When we examine the broader use of term climate forecast information—both those contained in formal forecast products and those that may be transmitted by less formal means, such as the face-to-face contact and outreach by state climatologists and others that we see in the Tillamook case—a broader pattern of forecast information use emerges. Looking at the *INFO* variable in Table 15, 67% of respondents indicate that they or other officials in their jurisdiction use climate forecasts in their work. About 75% of these

[9] Nearly 90% of respondents say they use general forecast products from the state climatologist and more than half indicate that they use products from state emergency management offices. These may include ENSO information. However, respondents may not include them in their characterization of ENSO product use. In principal, such use should show up in the Info variable we discuss below.

(50% overall) note that they personally use longer-term forecasts, while the other 25% note that they rarely use such information but that others in the jurisdiction do.

Table 15: Measures of Forecast Utilization

Measures of Forecast Use						
Use of Forecast Products (PRODUCT)	***yes***	***no***	***n***			
Do you or other officials use products that provide forecasts of La Nina, El Nino, or PDO conditions?	31%	69%	*59*			
Use of Forecast Information (INFO)*	***1***	***2***	***3***	***4***	***n***	
Compared to other officials, how would you characterize your use of climate forecasts?	33%	17%	7%	43%	*58*	
Forecast Probability for Action (ACTION)**	***0-20***	***21-40***	***41-60***	***61-80***	***81-100***	***n***
How likely would a long-term forecast of flooding have to be before you would take additional steps to reduce potential flood damages?	4%	7%	16%	51%	22%	*45*

Scale for* ***INFO* *Variable*

1=Rarely uses climate forecasts and does not know of any other county officials who use it.

2=Rarely uses climate forecasts but knows others in the county who rely on them to some degree.

3=Uses climate forecasts to some degree but others in the county rarely use them.

4=Uses climate forecasts to some degree and others in the county also use them to some degree

Intervals for* ***ACTION *variable refer to percentages (e.g., 0-20 indicates forecast probability would need to be between 0% & 20%)*

Finally, the *ACTION* variable in Table 15 highlights the relationship between the likelihood of flooding (based on a long-term seasonal climate forecast) and the willingness to undertake actions based on a forecast. Over half of the respondents note that a long-term forecast of flooding would have to be 61% to 80% certain before the respondent would take additional actions to reduce potential flood damages; an additional 22% indicate that the probabilities would have to lie between 81% and 100%.[10] The remaining 27% indicate that the likelihood could be 60% or less, with almost all of these indicating that it would have to be at least 21%. The responses are roughly similar across the three types of respondents, although staff from public works departments appear somewhat more conservative in their application of forecasts (for example, 43% indicate that the probability would have to be between 81% and 100% before they would take additional steps).

These three measures appear to capture different aspects of forecast use. The value of Cronbach's alpha—an aggregate measure of inter-item correlation that indicates how well multiple variables capture a single latent construct—for the three variables is less

[10] Pulwarty and Redmond (1997) report that 80% of the respondents in their survey of individuals involved in salmon management indicated that a climate forecast should be "right" 75% of the time to be useful.

than 0.4, for example. Even the correlation coefficient between the *PRODUCT* and *INFO* variables—both of which measure some aspect of forecast utilization—is less than 0.4 (the coefficient of determination is 0.15, meaning that only 15% of the variance in *PRODUCT* is accounted for by *INFO*, and vice versa).

Model Variables in the Statistical Analysis

In the following regressions, we analyze both *INFO* (taking on a value of 1, 2, 3, or 4) and *ACTION* (taking on a value of 1, 2, 3, 4, or 5) as independent variables, using $INFO_b$, a binary version of the *INFO* variable as a control variable in the regressions on *ACTION*. We ultimately wish to represent the social arena resources in a model that relates forecast use to the presence of the resources. However, our overall small sample size means that using many right-hand side, independent variables to represent the full range of the constituents of each social arena resource is not realistic. Many of these variables are also highly collinear, of course. At the same time, too parsimonious a specification may not allow us to capture much of the variation in forecast use. While, in principle, we can address both of these problems by combining variables representing the same underlying construct into various index measures, missing values throughout our dataset means we cannot calculate scores for all observations. In addition, including all of the 59 respondents in the sample is problematic because the observations are not truly independent, since a number of counties have more than one observation. A model including all observations would have autocorrelated disturbances, likely biasing the estimated variances of the coefficients and leaving the tests of significance unreliable. We could address this by basing the model on estimates of the means of each, but because many of the variables used in the regression are not continuous, taking the mean in each county is not wholly acceptable. Moreover, mean values would depress the variability in responses. Hence, we will estimate the models only on the subset of observations that represent responses from emergency managers (n=30). We still need to address the appropriate balance between parsimony and sample size, and do so by choosing a very limited set of regressors that are based largely on mean measures or principal components of variable combinations.[11]

Power and Money

Starting with the power and money variables, we use the first principal component of the linear combination of variables representing per capita expenditures and the reluctance of local residents and business to take action. This component accounts for 60% of the variance of the two power and money indicators. This admittedly is relatively small for a two-variable principal component, but is nonetheless appealing because the two variables conceptually capture the underlying latent construct. We designate this variable the *POWMON* regressor.

The construction of the principal component that represent the power and money resources does not lend itself to straightforward interpretation of the regression coefficients. However, the sign of the coefficients can be anticipated. Given the way the variable representing the barrier imposed by the reluctance of locals to take action is scaled, a less significant barrier will have a higher value of *POWMON*. Higher values of *POWMON* also indicate higher per capita expenditures. Based on this, we would expect a positive relationship between POWMON and INFO, the ordinal variable (1 to 4) that represents the degree to which long-term climate predictions are used with higher values indicating more prevalent use. We would expect a negative relationship between POWMON and ACTION, the ordinal variable (1 to 5) that represents the forecast probability necessary before taking action (with 1 indicating low probability and 5 indicating high probability).

Legitimacy

Event uncertainty and location uncertainty constitute the core of the legitimacy resource but we also want to include information related to concerns about local familiarity with the link between La Niña events and flooding. The four variables are somewhat correlated—Cronbach's alpha is 0.51—but the first principal component captures only 41% of the variance of the four variables. We can characterize the resource

[11] Principal component analysis can be applied in a rigorous sense only to variables that are measured on an interval or ratio scale. However, it is commonly applied to a host of ordinal and in some cases even nominally measured variables, although both metrics can distort the correlation estimates that underlie the principal components model. We make the assumption here that the numerical representation of our ordinal categories—essentially Likert scales—for measuring variables that appear in Table 13 and Table 14 accurately capture "true" (that is, close to interval-scale) between-category distances and do not distort the correlation matrices. We do not use principal components to represent nominal categories, however.

more efficiently by using a combination of the two core uncertainties and one or the other of the other two variables. In particular, we alternatively use the mean of event uncertainty and location uncertainty, the first principal component of these two uncertainties and the concern with using forecasts, or the first principal component of the two uncertainties and local familiarity with the link between La Niña events and flooding. Each of the principal components measures captures roughly half of the variance of the respective three variables. We designate the entire set of the three measures as the LEGIT regressors, although we use only one of the LEGIT regressors in each model.

The interpretation of the legitimacy variable is complicated because of these three different constructs. The simplest measure, LEGIT1, is the mean of event uncertainty and location uncertainty. When the significance of event uncertainty or location uncertainty as a barrier to long-term forecast use decreases, the value of LEGIT1 increases. Based on this, we would expect a positive relationship between LEGIT1 and INFO and a negative relationship between LEGIT1 and ACTION. The second measure of the legitimacy resources, LEGIT2, is the first principal component of the linear combination of the three variables representing event uncertainty, location uncertainty, and concern with using a forecast and not having the forecasted event occur. Each variable in this linear combination has a positive sign. Therefore, higher values of the LEGIT2 measure indicate less significant barriers and less concern with not having the forecasted event occur, so again we would expect a positive relationship between LEGIT2 and INFO and a negative relationship between LEGIT2 and ACTION. The third legitimacy measure, LEGIT3, is the first principal component of the linear combination of the three variables representing event uncertainty, location uncertainty, and the degree to which local residents associate La Niña events and flooding. This linear combination includes positive signs for the two uncertainty variables and a negative sign for the familiarity of local residents with the La Niña association and flooding (this familiarity is the proportion of local residents that make the association). Based on this, we would expect a positive relationship between LEGIT3 and INFO and a negative relationship between LEGIT3 and ACTION.

Value Commitment

Finally, we characterize our value commitment resource with the mean ranking of the variables indicating local support for the four measures deemed to have the highest cost-effectiveness (building codes, zoning, repetitive loss ordinance, and cost-sharing for relocation). This variable is scaled so higher values represent less local support for the measures. We designate it the COMMIT regressor. We also use the COMPLIANCE variable to represent the effectiveness in each jurisdiction of obtaining compliance with code provisions that provide flood protection and mitigation (from Table 7).

The commitment resource regressor, COMMIT, represents the mean local support for local flood control and protection measures. Because higher values of COMMIT indicate less local support for the measures, we would expect a negative relationship between COMMIT and INFO and a positive relationship between COMMIT and ACTION. Similarly, because high values of COMPLIANCE represent less effectiveness in obtaining compliance with code provisions, we would expect a negative relationship between COMPLIANCE and INFO and a positive relationship between COMPLIANCE and ACTION.

Results

Table 16 and Table 17 show the results of regressing the two forecast utilization variables—forecast INFO and forecast ACTION—against the social arena regressors in a series of different models that span the tables' columns. We use an ordered probit model for both sets of regressions.[12] Given the exploratory nature of our work, we are looking for relationships that are suggestive and hence report even moderate levels of significance. The symbols in the bottom part of the tables indicate these levels: entries marked * indicate significance at the .20 level, ** indicates significance at the 0.15 level, *** indicates significance at the 0.10 level, and **** indicates significance at the 0.05 level or better. Nonsignificant coefficients (at the 0.20 level or better) are represented by "0" entries, while "—" indicate that that particular model did not include that variable. Negative coefficients are represented by parentheses. The pseudo- R^2 values in the bottom row are McFadden's R^2 for models based on maximum likelihood estimation.[13]

Regression of Climate Information Use (*INFO*) and Social Arena Resources

COMMIT is significant in all four of the models presented in Table 16 and has the expected negative sign in each model (the alternative value commitment variable, COMPLIANCE, is not significant in any runs and is dropped). LEGIT1 and LEGIT2 are not significant, while LEGIT3—the legitimacy variable that includes event and location

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[12] The ACTION regressions arguably could be run with a linear estimator since the ordinal categories (1 through 5) represent an underlying state of nature that ranges from 0 to 100. However, only categorical ranges are available to the respondents and these likely have some starting point bias and thus are not truly linear. OLS regressions treating ACTION as continuous yield similar results as the ordered probit regressions, generally with slightly higher r^2 values and slightly larger p-values (less significance) for individual regressors.

[13] McFadden's R^2 equals 1 minus the ratio of the log likelihood of the model with regressors to the log likelihood of the model without regressors.

uncertainty and an indicator of the proportion of local residents who associated La Niña and flooding—is weakly significant at the 0.20 level. Its sign is positive, as expected. Finally, the power and money variable, POWMON, has the expected negative signs and is moderately to weakly significant in each specification. In the fourth model, the inclusion of LOCAL, an independent variable that represents the proportion of local residents who associate La Niña and flooding, does not appreciably improve the model fit over the indirect inclusion of this in the legitimacy principal component. As a whole, the regressors collectively appear only marginally significant in the models. We can reject a null hypothesis that the slope of all coefficients equals zero in only two of the models and there only with weak significance; that is, we can only weakly reject a null hypothesis that there is no relationship between the dependent and independent variables collectively in two of the models. The proportion of variation in INFO that the model explains is also quite low, as the small pseudo-R^2 values highlight (see footnote 12).

Table 16: Regression Results of *INFO* on Social Arena Resources

Model #	1	2	3	4
Power & $	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)
Legitimacy	LEGIT1 (event uncertainty, location uncertainty)	***LEGIT2*** (event uncertainty, location uncertainty, forecast concern)	***LEGIT3*** (event uncertainty, location uncertainty, local La Nina association)	LEGIT1 (event uncertainty, location uncertainty)
Commitment	COMMIT (mean local support of cost effective measures)	COMMIT (mean local support of cost effective measures)	COMMIT (mean local support of cost effective measures)	COMMIT (mean local support of cost effective measures)
Other	--	--	--	LOCAL
Power/$	(**)	0	(***)	(***)
Legit.	0	0	*	0
Commit	(***)	(***)	(*)	(*)
Other				0
F-sig	*	0	*	0
pseudo-R^2	0.10	0.10	0.12	0.13

Regression of Forecast Probabilities Needed Before Responding (*ACTION*) and Social Arena Resources

The results of the ACTION regressions in Table 17 appear stronger than the INFO regressions, both in terms of the R^2 values and significance of the coefficients. Starting with the leftmost model (#5), POWMON and LEGIT1 are significant at the 0.05 level or better with expected negative signs on the coefficients and an R^2 value that exceeds 0.3. The commitment variable, COMMIT, is not significant, nor is COMPLIANCE, the alternative commitment variable that represents the level of compliance in the jurisdiction (model # 6). The significance of the model holds when we characterize the legitimacy resource as the principal component of event and location uncertainties and the level of concern with using a forecast of an event that does not materialize in the LEGIT2 principle component regressor in model #7. The model's explanatory power and the significance of the coefficients drops, however, when we include the proportion of local residents who associate La Niña events and flooding in the LEGIT3 principle component regressor in model #8. However, if we include this proportion of residents as the separate LOCAL variable in model #9, it becomes significant at the 0.1 level and is negative. This implies that lower probabilities of forecast certainty are necessary as the proportion of residents who associate La Niña signals and flooding increases.

Finally, if we include the binary $INFO_b$ variable—thereby incorporating information about whether any officials in a jurisdiction use long-term climate predictions in their work—the model fit improves (model #10). McFadden's R^2 approaches 0.5,[14] and $INFO_b$, COMMIT, and LEGIT1 all are significant at the 0.05 level. Our anticipated negative signs on the coefficients of POWMON and LEGIT are realized, while we had no priors on the binary variable $INFO_b$. The interpretation of this latter variable's coefficient is that if a respondent has used long-term climate predictions or works in a jurisdiction that uses such predictions ($INFO_b$=1), the likelihood of a forecasted event needs to be higher before taking action in response to the forecast.

[14] There is no best goodness-of-fit measure, although McFadden's R^2 is one of the most popular. Other pseudo R^2 values for model #9 include an adjusted McFadden's R^2 (0.22), McKelvey's and Zavoina's R^2 (0.82), and Maddala's transformed likelihood ratio R^2 (0.69). Long (1997, pp. 102-113) reviews these and other pseudo R^2 and goodness-of-fit measures.

Table 17: Regression Results of *ACTION* on Social Arena Resources

Model #	5	6	7	8	9	10
Power & $	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)	***POWMON*** (local reluctance, per capita expenditures)
Legitimacy	LEGIT1 (event uncertainty, location uncertainty)	LEGIT1 (event uncertainty, location uncertainty)	***LEGIT2*** (event uncertainty, location uncertainty, forecast concern)	***LEGIT3*** (event uncertainty, location uncertainty, local La Nina association)	LEGIT1 (event uncertainty, location uncertainty)	LEGIT1 (event uncertainty, location uncertainty)
Commitment	COMMIT (mean local support of cost effective measures)	COMPLIANCE	COMMIT (mean local support of cost effective measures)	COMMIT (mean local support of cost Effective measures)	COMMIT (mean local support of cost effective measures)	COMMIT (mean local support of cost effective measures)
Other	--	--	--	--	LOCAL	$INFO_B$
Power/$	(****)	(****)	(****)	(****)	(****)	(****)
Legitimacy	(****)	(****)	(****)	0	(****)	(****)
Commit	0	0	0	0	0	0
Other					(***)	****
F-sig	****	****	****	****	****	****
pseudo-R^2	0.34	0.33	0.33	0.27	0.40	0.48

Caveats

The significance of the coefficients in the 10 models indicates that the utilization of forecasts is related to the power and money, value legitimacy, and commitment resources. The nature and strength of the relationships depend on the characterization of these resources, but they largely follow the directions suggested by the social arena model. Moreover, the relationship appears for two different characterizations of forecast utilization. The first relates the degree to which officials in a jurisdiction use climate forecasts. The second captures the degree of certainty necessary in a longer-term forecast before an emergency manager would take additional steps to reduce flooding in anticipation of the forecasted event occurring.

It is important to emphasize that the results are only suggestive, however. The significance levels are weak in some cases and much of the data used in the regressions are based on emergency managers' perceptions of the concerns and preferences of local residents. More critically, the sample used in the analysis is small. We have only 30 respondents in our emergency manager subsample and because of missing data, some variables have fewer than 30 observations.

The maximum-likelihood estimators used in the ordered probit regressions can be particularly sensitive to the small sample size and influential observations, yet the theoretical small-sample properties of the ordered probit estimator are unknown. We can empirically estimate a distribution of estimated standard errors and test statistics by constructing numerous samples or replicates of the original observations through bootstrapping and re-estimating the ordered probit model on each of these samples. The confidence intervals widen considerably with this approach. In several models, depending on the assumptions used to construct the distributions, 90% confidence intervals for even highly significant coefficients (0.05 level or better in the originally estimated model) contain zero. Only model 10, the full model estimated for the action that contains the INFO_b variable, reliably maintains its significance across a number of specifications, although the other models are robust under an 85% confidence interval.

6. Summary and Conclusions

In principle, climate forecasts could help emergency managers and flood planners reduce local vulnerability to flooding. The connection between ENSO signals and higher-than-normal streamflows has been recognized at least since the early 1990s, but has been chiefly applied to other water resource planning problems involving reservoir management for irrigation allocation and hydropower, as well as on-farm management decisions. These other sectors are particularly well suited to probabilistic climate forecasts insofar as the inherent uncertainty of such forecasts can be accommodated by maximizing the expected value of decisions based on the forecast probabilities. Over the long run, such a rule should yield higher benefits even if, in a given year, it results in lower-than expected benefits. This contrasts sharply with the decision environment that flood planners face. Flooding should be seen as an event, a binary process that either occurs or not, and where the costs of making a "wrong" decision in any given year can be devastating. When coupled with the low political salience and shared governance problem of flooding, forecast utilization in this sector is likely to be much more problematic. In addition, although a surprisingly high two thirds of respondents say that they or others in their jurisdiction use some type of climate forecast information in their work—including informal information on upcoming climate conditions provided in meetings or by personal contacts—less than one third indicate that they or others in their jurisdiction use specific El Niño or La Niña forecast products provided by the National Weather Service or state climatologists.

Still, the Tillamook and Snohomish cases suggest that flood managers and planners can take advantage of climate forecasts to decrease flood damages. Climate forecasts have functioned in these counties not simply as information, but as a powerful resource for the local communities to garner state and federal support. In addition, the Tillamook case shows that recurrent La Niña conditions can make local residents more aware of the recurrent nature of floods, thereby making them more willing partners in floodplain management. Accurate forecasts of these conditions have value beyond their immediate utility for helping to reduce flood damage in an upcoming flood season, as they can facilitate local political efforts to improve flood mitigation through longer-term measures such as zoning, building codes, repetitive loss ordinances, and hazard mitigation planning.

Fortunately, the old model of "if we produce it, the users will use it" is being challenged by the recognition that scientific and technical experts need to work with users to design forecast products that fit users' needs and skills. This does not simply require demonstrating to users the state-of-the-art forecast capabilities—although that is an important element—but it also demands longer-term collaboration between forecast producers and forecast users on the elements of a forecast that are particularly important for specific tasks such as flood planning. In addition, improved dissemination of both short- and longer-term forecasts has been greatly aided by the ability to access forecasts on the Web, and it is likely that users will be increasingly sophisticated about using such resources. Our survey results also imply that other counties may be able to use climate forecasts more effectively if certain conditions apply. Most fundamentally, widespread application and use of forecasts in flood planning depend more subtly on the interplay between the perceived legitimacy of the forecast evidence and the sense of shared purpose among public and private stakeholders.

Uncertainty about whether a forecasted La Niña or El Niño event will occur and where it will occur can be an obvious barrier to forecast use, and we find that flood managers who use climate forecasts in their work require higher levels of certainty before they would take action in response to the forecast. This reflects the concern many have with using a forecast and not having the forecasted event occur. Higher levels of forecast certainty before taking action also are required when local businesses and residents are unwilling to take additional flood control actions even when confronted with climate forecasts suggesting higher than normal river flows, a problem compounded by the inability of public officials to compel the private sector to take responsibility for action. To the extent that local residents associate La Niña events and flooding, this diminishes the level of certainty needed before taking action.

More generally, flood planners and emergency managers are likely to use climate information in their mitigation efforts if four conditions are met: the forecast is relevant to the circumstances and needs of end users; practical mitigation measures can be implemented once a forecast is seen to have some predictive value; the economic and political costs of a "wrong" decision are limited; and there exists among the many agencies and groups involved in flood management a commitment to act.

Next Steps?

The case studies and survey together suggest a number of avenues for improving ENSO forecast utilization in flood planning and management.

First, we need to develop and fund extension mechanisms to translate climate information into more usable knowledge for the diverse set of end users involved in flood planning and mitigation. These end users include emergency managers, planners, water utility operators, public health officials, and public works officials, among others. Additional funding could help establish an ongoing dialogue with state emergency management organizations and groups such as the Association of State Floodplain Managers. Given the coarse spatial resolution of many climate forecast products—and the problems that plague local hazards policy—state officials may have better-defined programmatic opportunities that allow them to take advantage of ENSO signals and other climate indicators such as PDO. These can be used in not only in flood planning, but also for other climate-driven hazards such as droughts, hurricanes, and winter storms.

Second, forecast application could benefit from the identification or creation of more appropriate federal authorities for funding ENSO-related mitigation activities. The current regulatory framework to reduce flood risks cannot easily exploit the potential benefits of ENSO forecasts, with most assistance restricted to flood flights during flood events. The Corps' Advance Measure program that funded mitigation in Tillamook and Snohomish counties set very high thresholds for receiving funding—an "imminent threat of "unusual flooding," which the Corps typically has interpreted as the flood of record or a 100-year-flood—and few jurisdictions can strictly meet this threshold with a climate forecast. Other statutory authorities to fund advance mitigation in years when forecasts suggest heightened flood probabilities could be developed with strict but not impossibly high thresholds.

Third, and related to this, federal or regional entities could proactively use ENSO forecast information by developing programs to identify basins where the ENSO signal in the past has been associated with a higher incidence of peak flows and flooding. Such a scheme, together with an appropriate funding authority, could help target support for local jurisdictions to take advance mitigation steps during years with strong ENSO events.

None of these changes would ensure the application of climate forecasts to flood planning. The successful use of climate forecasts rests as much on local entrepreneurs being ready to advocate forecast use—individuals who are well aware of the community of interests—as it does on funding and technical expertise. In addition, although our interviewees note some problem of "success attenuation"—an attitude of "what have you done for me lately?" in communities where forecasts have improved natural hazards management—the best advertisement for more forecast utilization may be its effectiveness in cities such as Tillamook. The documentation and dissemination of politically effective stories and reflection on how an ENSO forecast has acquired the necessary force to reshape hazard mitigation in communities such as Tillamook may push other communities to use climate forecasts proactively.

A perfect climate forecast may be useless for flood planning if there are no opportunities to apply the forecast. As Jones, Fischoff, and Lach (1999) note in the context of climate forecasts in general, for such information to be transferred and incorporated into policies and operational decisions, the information needs to be relevant to the decision or policy under consideration, and in accord with the spatial and temporal scale at which decisions are being made. It also needs to be compatible with current decision procedures and accessible to the decisionmakers, and these decisionmakers need to be receptive to it. This confluence of events is unlikely to happen spontaneously. Rather, it will follow from activity in the social arena of flooding, where stakeholders use the social resources at their disposal to achieve desired outcomes.

Furthering this activity is both an opportunity and challenge for scientists, emergency managers, planners, public works staff, and others in the academic and practitioner communities. Not only will it require greater cross-disciplinary integration among the natural and social sciences—and greater interaction between researchers and practitioners among these communities—but such an effort will be set in a political framework where too often local, state, and federal flood policies pull in different directions. Efforts to integrate ENSO forecasts in flood planning will require a better understanding of these institutional links.

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