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THE ROLE OF INFORMATION IN THE JUDGMENT OF RISKS FROM NATURAL HAZARDS: TECHNICAL DESCRIPTION OF PROJECT AND RESULTS

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16. Abstract (Limit: 200 words)

The first section of this report describes the hazard sites and criteria used in their selection. The hazard of primary interest is the earthquake hazard in Whatcom County, Washington, a hazard likely to have low salience for most residents of the area. The comparison hazard is the water supply contamination hazard at Lake Samish, Washington, a hazard likely to have high salience for most residents of the area. The second section desribes the study design which is based on the collection of three waves of field data over a five month period. This longitudinal design enables estimation of the impact of hazard information on risk judgment and hazard mitigation variables. The third section describes the basic results, mostly descriptive, of the telephone interviews with two panels of respondents, an earthquake panel and a water supply contamination panel.

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INTRODUCTION

This report describes the work completed in the project titled "The Role of Information in the Judgment of Risks from Natural Hazards, Stage II: Field Study" (National Science Foundation Grant Number ECE-8505957). There are three major sections in the report. The first section describes the hazard sites and the criteria used in their selection. The hazard of primary interest is the Earthquake hazard in Whatcom County, Washington. This is a hazard likely to have low salience for most residents of the area. The comparison hazard is the Water Supply Contamination hazard at Lake Samish, Washington, also in Whatcom County. This is a hazard likely to have high salience for most residents of the area. A key aspect of our research strategy, then, lies in deriving lessons for improving the management of the low salience Earthquake hazard by studying the management of the high salience Water Supply Contamination hazard. The second section describes our study design which is based on the collection of three waves of field data over a five month period. This longitudinal design will enable us to estimate the impact of hazard information on risk judgment and hazard mitigation variables. The third section describes the basic results of our telephone interviews with two panels of respondents, an Earthquake panel and a Water Supply Contamination panel. Most of the results presented in this report are descriptive. The results of complex multivariate analyses will be presented in subsequent reports. Brief concluding sections describe reports in progress and offer preliminary suggestions concerning the implications of our study for improved management of the Earthquake hazard in particular and other hazards as well.

THE HAZARD SITES

Since the primary objective of this study was to assess the effects of hazard information on the development of risk judgments over time, our site selection requirements did not include the actual manifestation of a hazard (e.g. earthquake, flood, volcanic eruption, etc.), only the threat of its occurrence. Since disaster threats (as indicated by predictions, warnings or other information) vastly outnumber disaster events, the number of candidate sites from which we could select was relatively large. The criteria we used included:

a) The hazard must be predictable in time and place. That is, scientific information about the potential occurrence of the hazard event must be available.

b) The expected life span of the hazard threat should extend over several weeks. If the life span is too short (a couple of days), our planned longitudinal study would not be effective; if the life span is too long (several years), there would be little variation in hazard-related behavior during our study period.

c) The affected community should be of small to moderate size (50,000 or less).

d) The hazard should be one over which local officials have some management jurisdiction.

e) The affected communities should have at least one local newspaper that is widely circulated and covers local issues.

f) The hazard should be significant to at least some residents of the community.

These criteria normally would rule out the study of an earthquake hazard due to its relative unpredictability. Fortunately, however, the Department of Energy Services in Whatcom County, Washington planned a routine earthquake information campaign during our study period. Since the Whatcom County site met most of the remaining criteria, we elected to take advantage of this opportunity. To provide a comparison for the earthquake hazard and to meet our final site selection criterion that the hazard be significant to some community residents (which the earthquake hazard might not be), we selected a second hazard site, the water supply contamination hazard at Lake Samish, Washington. Lake Samish is located within Whatcom County, and the respondents at that site were studied for both the earthquake and water supply contamination hazards. A second set of respondents drawn from the residents of Bellingham, the largest city in Whatcom County, were included only in the earthquake study. The characteristics of the two hazard sites are briefly outlined below.

Earthquake, Whatcom County

The earthquake hazard in the Pacific Northwest is well described in the work of Atwater (1987) and Heaton and Hartzell (1987). In Figure 1, adapted from these latter authors, the populous areas of Whatcom County are located east and north of the Strait of Juan de Fuca and west of Mount Baker. Whatcom County thus is affected by the behavior of oceanic and continental plates within the Cascadia subduction zone. Heaton and Hartzell present evidence that there is:

> ...active convergence at about 4 cm/yr on the 1200-km Cascadia subduction zone. Furthermore, the physical characteristics of the Cascadia subduction zone resemble those of other subduction zones that have experienced large shallow earthquakes. Even though there

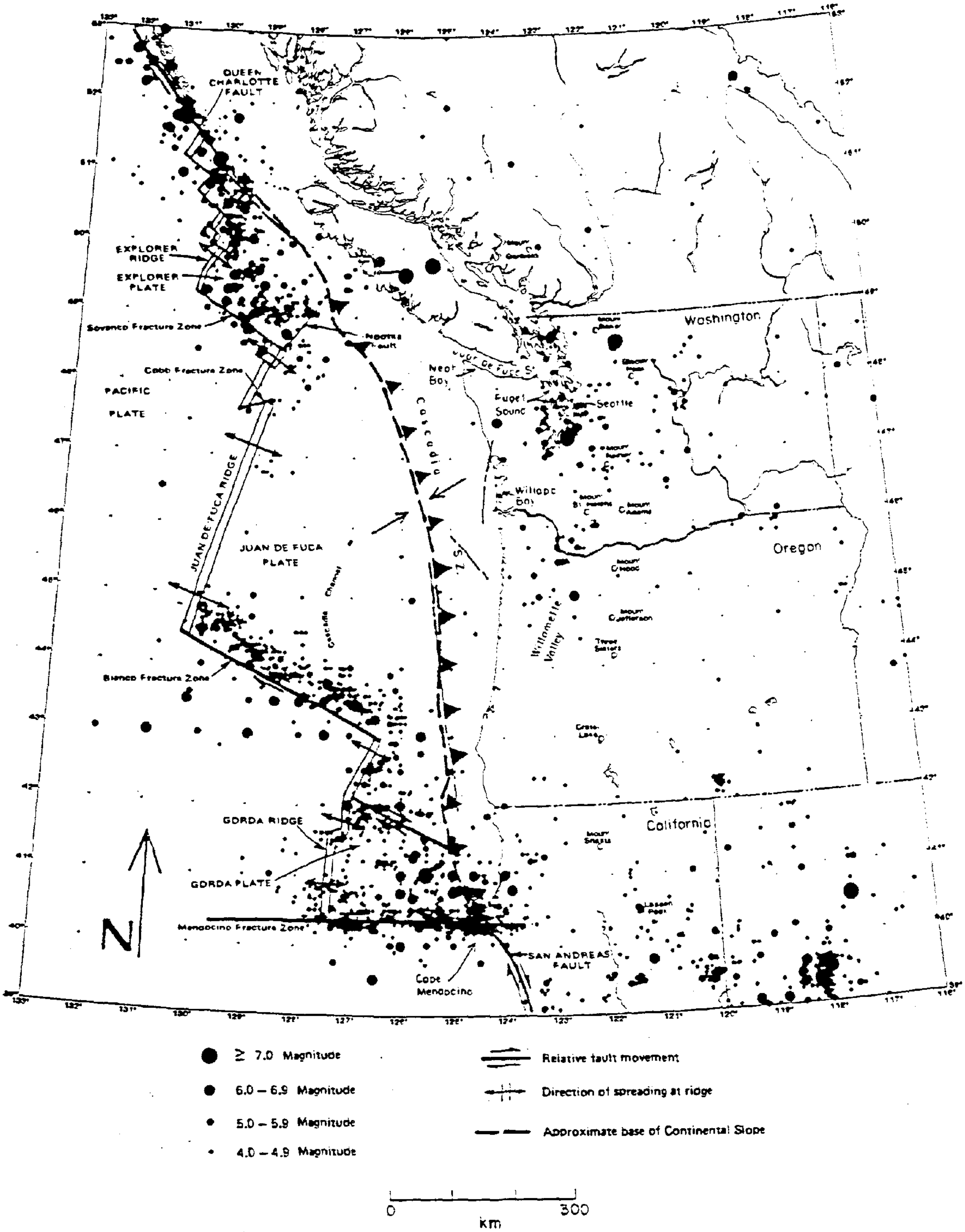

Figure 1. Seismicity and plate tectonics of the Pacific Northwest.

> have not been large historic subduction earthquakes in the Pacific Northwest for at least 150 years, the Cascadia subduction zone may be storing strain energy to be released in future great earthquakes. If the Cascadia subduction zone is locked, a sequence of several great earthquakes (M_W8) or a giant earthquake (M_W9) would be necessary to fill this gap. If great subduction earthquakes occur, then relatively strong shaking can be expected over a large area of the Pacific Northwest, including the Puget Sound and Willamette Valley regions. Large and potentially destructive tsunamis would be expected if large subduction events do occur. Great earthquakes, such as those in southwestern Japan or southern Chile, have caused great damage over very large regions. The suggestion of similar events in the Pacific Northwest is disturbing (Heaton and Hartzell, 1987, p. 236).

Whatcom County, then, is the potential site of a great earthquake. The level of earthquake seismicity is historic times has been low, however, and the experience of the local population with small earthquakes is limited.

Bellingham is the major city in Whatcom County with a population of approximately 45,000. The entire county has a population of approximately 100,000. Earthquake hazard mitigation planning in Bellingham was the subject of a case study by Heikkala and Green (1984). These authors concluded that the major national hazards in the Bellingham area were:

a) Land sliding/steep slopes.

b) Subsidence - e.g. over old coal mines.

c) Flooding - the biggest single natural hazard.

d) Debris flows - floods of debris caused by some combination of heavy rainfall, land sliding or steep slopes and poor logging practices; a combination of several hazards.

e) Possible earthquake - induced failure of the front of the delta or failure of the filled portions of downtown.

f) Failure of chlorine storage tanks in the event of an earthquake.

g) Failure of un-reinforced masonry buildings in the Fairhaven historic area.

Although several of these hazards can and do occur in the absence of an earthquake, a large earthquake could clearly trigger a number of hazards with very serious consequences.

In our study, data on earthquake hazard judgments were collected from a sample of Whatcom County residents from March through July of 1986. Just prior to and during that time period, several earthquake-related events were reported to the local daily newspaper, The Bellingham Herald:

a) "Three minor quakes shake Skagit County" (February 11, 1986). Skagit County is adjacent to Whatcom County on the south, and the earthquakes ranged from 3.1 to 3.6 on the Richter scale. They were described as "minor" by the State Seismologist, "among about 25 recorded each year that can be felt by state residents."

b) "Third quake shakes Bay Area buildings" (March 31, 1986). This and earlier reports described earthquakes in the mid-fives on the Richter scale occurring in the San Francisco Bay Area of California. Some minor property damage and injuries were described.

c) "Quake felt Sunday in central county area" (April 21, 1986. A small earthquake of undisclosed magnitude was felt by some county residents, about a dozen of whom phoned the Director of the Whatcom County Department of Emergency Services. No damage or injuries were reported.

d) "Authorities aware of earthquake danger" (May 6, 1986). Representatives from the Whatcom County Department of Emergency Services, the Geology Department of Western Washington University, the Washington State Department of Emergency Management and the American Red Cross discuss the nature of the earthquake hazard in Whatcom County. Although the availability of self-help information from the Red Cross is mentioned, few details on what individuals or government agencies can do to mitigate the effects of an earthquake are mentioned.

In sum, the earthquake hazard in Whatcom County is moderately severe, with the potential for large subduction earthquakes. Public experience with earthquakes is limited, however, probably resulting in a low level of public awareness and concern. One goal of our study is to measure public judgments of the risks generated by this hazard and to assess any changes in those judgments resulting from information about the hazard.

Water Supply Contamination, Lake Samish

Lake Samish is approximately 5 miles south and east of Bellingham in Whatcom County. The lake has a surface area of 814 acres and a shoreline length of 8.1 miles. The primary Westcoast interstate freeway, I-5, lies adjacent to Lake Samish on the east side. Local roads follow the entire lake shore except for a northwest sector which is steeply forested. Five perennial streams flowing down the steep surrounding slopes feed Lake Samish, while the only outlet is Friday Creek at the southern end of the lake. The steepness of the basin combined with clear cut logging and the impervious surface of I-5 result in heavy precipitation runoff into the lake. In the winter rainy season, the limited capacity of Friday Creek often results in rapid rises in water level (Whatcom County Planning Department, 1984). Due to evaporation and domestic water use, the summer dry season can produce very low water levels, resulting occasionally in the drying of Friday Creek (Burnfield, et al., 1985).

There were 1378 residents in the Lake Samish tract at the time of the 1980 Census. Recent population growth in the area has been at a 2% rate, resulting in a 1986 population of approximately 1550. In 1980 there were 557 year-round housing units in the Lake Samish area, including 111 mobile homes or trailers. Housing construction is at a rate of less than one per month. These low rates of population and housing growth can be directly related to water supply problems.

Although Water District 12 supplies sanitary sewer service to the Lake Samish area, it does not supply water. No local ground water sources have been located, and water pumped from neighboring areas would be expensive. Without a public water supply system or other approved water source, the County Health Department will not approve increased development of housing in the area. The water supply issue can thus be seen as a growth vs. no growth issue.

Water supply is also a health issue. The water in Lake Samish is judged by the Health Department to be unsafe for human consumption, and available groundwater is limited in quality and quantity. As shown in Figure 2, several private water purveyors supply water to groups of Lake Samish residents. One of these purveyors uses well water, the others draw directly from the lake. Residents not supplied by one of these purveyors must supply their own water, either from wells or the lake. A survey reported in Burnfield, et al. (1985) found that 72% of Lake Samish residents get their water from the lake, 14% from wells and 14% from bottles. About the same number of residents who used lake water believe that lake water is safe to drink. Although installation of

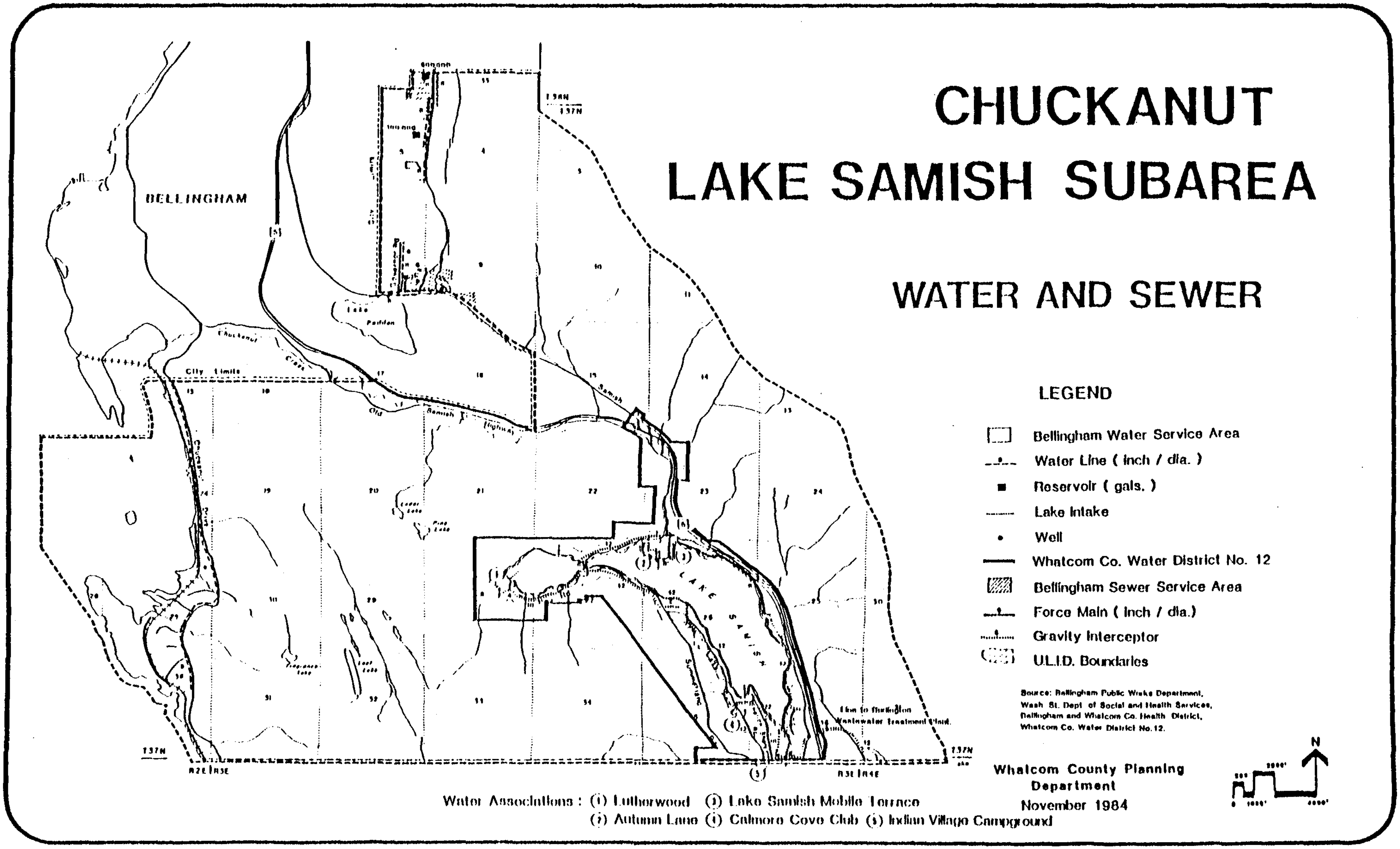

FIGURE 2. Existing private water supply systems on Lake Samish.

the sewer system in the mid 1970s reduced fecal coliform counts in the lake, several pathogens remain. Chief among these is Giardia lamblia. During 1983, for example, the Health Department reported two confirmed and several suspected cases of Giardiasis (Whatcom County Planning Department, 1984).

Giardiasis is the most common parasitic cause of water-borne outbreaks of disease in the United States, and it is a public health problem worldwide (Wolfe, 1978; 1979). Campers and hikers, using untreated water from streams and lakes, are particularly susceptible to infection, and beavers have been identified as a primary animal host. The symptoms of acute giardiasis consist of severe diarrhea, abdominal distention, gas and belching, nausea, anorexia, vomiting, fatigue and abdominal cramps. The epidemiological, pathological, clinical, diagnostic and treatment aspects of giardiasis are detailed by Wolfe in the reports cited above. Wolfe also concludes that a well-operated water treatment facility (employing coagulation - flocculation, settling and filtration) is necessary to prevent public outbreaks of giardiasis, while individuals should boil water for 10 minutes or use iodine compounds for purification. Communities with inadequate water treatment facilities may therefore be subject to possible giardiasis outbreaks. Epidemiologic studies of recent outbreaks in Rome, New York (Shaw, et al., 1977), Camas, Washington (Dykes, et al, 1980) and Aspen, Colorado (Istre, et al., 1984) are available. In addition to epidemic giardiasis, recent studies have also described cases of endemic or sporadic giardiasis. Chute, et al, (1987) studied the risk factors associated with endemic giardiasis in New Hampshire and Vermont. Chief among these risk factors was households with shallow well or surface water sources. Lake Samish residents rely on both small scale community water sources and private wells. The potential for both epidemic and endemic giardiasis is therefore present in Lake Samish.

In our study, data on water supply contamination were collected from a sample of Lake Samish area residents at the same time as data on earthquake hazard judgments, from March through July of 1986. Just prior to and during that time period, the water supply issue and other aspects of Lake Samish land use planning were the subjects of a number of articles in The Bellingham Herald:

a) "Concern over Lake Samish: Push underway to build public water system" (December 9, 1985). A long review article describes the history and current status of the water supply problem. State officials are quoted as saying, "The practice of drinking from the lake without treating the water is totally unacceptable and totally unsafe." A group of local residents is said to be circulating a petition calling for a study of a local improvement district for a public water supply system. A mobile home park on the lake is being sued by a former resident who claims to have contracted giardiasis from the park's substandard water supply system. The pros and cons of a public water supply system are discussed, the opposition being based on fears of rapid population growth and high assessments. A Whatcom County planner is quoted as saying that revisions in the county's comprehensive land use plan assume the adoption of a public water supply system at Lake Samish. Several residents of the area express their concerns about contaminated drinking water.

b) "Residents defend lake water" (December 20, 1985). A lengthy report of the opinions expressed at a forum on the water supply issue sponsored by Whatcom County Water District #12. The majority opinion, including that of one resident presenting a petition with 42 signatures, was that the present water supply situation was safe and that a public system was not wanted. The district commissioners did not argue for a public system but indicated instead that they would follow the lead of the majority of residents.

c) "Bed-and-breakfasts may close over proposed health department rules" (January 19, 1986). A bed-and-breakfast operator on Lake Samish was told that she would not be able to operate because she draws her drinking water from the lake and treats it in a substandard private chlorination and filtration system in her home.

d) "Rezoning critics voice fears of Lake Samish pollution" (March 28, 1986). Plans formulated by the Whatcom County Planning Commission for increased commercial development adjacent to Lake Samish are attacked primarily on environmental grounds by area residents. Pollution of the lake water, used as drinking water by many residents, is the main concern.

e) "Lake Samish area to remain residential" (May 2, 1986). The Whatcom County Council eliminates the Planning Commission's recommended commercial development areas from the Lake Samish subarea land use plan. Opposition of local residents is cited as the reason behind the action.

The water supply contamination hazard at Lake Samish is, in sum, a potentially severe public health hazard for local residents. Management of this hazard is complicated, however, by the effects on improved water supply system would have on population growth and taxes. In our study of public risk judgments, this hazard, which is familiar to residents, will serve as in instructive comparison case to the less well known earthquake hazard.

STUDY DESIGN

Our research strategy was based on a three-wave panel design (Baltes and Nesselroade, 1979) in which the data were collected by telephone (Tyebjee, 1979). The panel design was selected because of our interest in studying the development of risk judgments over time and the effects of hazard information on that development. Telephone interviews were used because the major alternative, personal interviews, was too costly to use in a multi-wave panel design.

Sampling

Our selection of sample frames was driven primarily by our selection of hazard sites. In the case of the Lake Samish water supply contamination hazard, we required respondents who lived on the shoreline of Lake Samish and as a consequence were faced with the opportunity of obtaining drinking water from the lake. The decision of how to supply drinking water to oneself and one's family was strictly open only to individuals who owned their own homes as opposed, for example, to residents of mobile home parks in which water is supplied by the park management. We included all shoreline residents, however, based on our belief that all water consumers would be concerned about the safe management of what they drank. Since we intended to conduct our interviews by telephone, our Lake Samish sample frame consisted of all shoreline residents listed in the local (Bellingham) telephone directory. This produced a list of approximately 260 individuals. Our goal was to finish the three waves of data gathering with 50 respondents, representing about one in every five households with listed telephone numbers. Based on our knowledge that a sizeable percentage of Lake Samish residents also have homes elsewhere and may therefore be difficult to contact, we started with a conservative systematic sample of every second individual from our initial list, a total of 131 potential respondents.

For the Whatcom County earthquake hazard site, we were faced with several choices regarding sample frame. We could have simply used our Lake Samish sample since they are also residents of Whatcom County. Whatcom County, however, consists of one moderate-sized city (Bellingham), several small communities and rural areas. By using only our Lake Samish sample, we would be ignoring the urban half of Whatcom County's population. We decided, therefore, to balance the Lake Samish sample with one drawn from Bellingham residents. Again, the local telephone directory provided our sample frame, and we systematically selected a total of 126 potential Bellingham respondents. As with Lake Samish, our goal in Bellingham was to finish the three waves with 50 respondents. Since both the Lake Samish and the Bellingham samples responded to the earthquake questionnaire, we began our study with a pool of 131 + 126 = 257 potential respondents and a goal of 100 respondents at the end of three waves.

When one of our interviewers contacted a potential respondent by telephone, she/he first enumerated the residents of the household and then used a simple sampling rule to select the respondent for that household. The essential elements of the rule were: a) the respondent must be an adult living in the household; b) if the previous respondent lived in a two-adult household and was either the male or the older person (if same sex), select the female or younger person; c) if the previous respondent lived in a two-adult household and was either the female or the younger person, select the male or older person; and d) if there are three or more adults in the household, select the oldest. The purpose of this procedure was to produce a balance of male and female respondents.

The Respondent Panels

The sampling procedure described above resulted in the creation of two respondent panels, an Earthquake panel, consisting of both Bellingham and Lake Samish respondents, and a Water Contamination panel made up of only persons living around the lake. The composition of these panels across the three waves of data collection was as follows:

Wave	Panel			
	Earthquake		Water Contamination	
	N	% Retained	N	% Retained
0	257	-	131	-
I (March, 1986)	138	53.7	65	49.6
II (May, 1986)	111	80.4	50	76.9
III (July, 1986)	97	90.2	42	84.0

These results show that the initial response rate was around 50% for both panels. The attrition rates were consistently greater for the Water Contamination panel. This was to be expected because this group, as noted above, was more likely than the Bellingham sample to have multiple residences, and they were also asked to do roughly twice the work (Earthquake and Water Contamination questionnaires vs. just the Earthquake questionnaire). In the end we closely approximated our goals for Wave III of 50 in the Water Contamination panel and 100 in the Earthquake panel. For the Earthquake panel, 70.3% of the Wave I respondents completed Wave III; the comparable figure for the Water Contamination panel is 66.3%. When the Bellingham portion of the Earthquake panel is considered alone, 75.3% of the Wave I respondents completed Wave III.

Data Collection

Telephone interview data were collected in three waves over a five month period, from March through July, 1986. The time between succeeding waves was approximately one month though this varied for individual respondents due to differences in the ease with which our interviewers could contact them. Seven interviewers, six women and one man, were trained to collect data over the telephone. All interviewers were either graduate students or employees at Western Washington University. The respondent samples were initially divided evenly among the interviewers. Each respondent was contacted by only one interviewer over the course of the three waves. Exceptions to this rule occurred only when an interviewer was unable to complete her/his assigned interviews. In those cases, the remaining wave(s) were completed by an alternate interviewer. Interviewers were paid on a piece work basis for completed interviews.

The Questionnaire

The questionnaire used by the interviewers consisted of six basic parts:

1) Cover sheet. On this sheet, the interviewer recorded information identifying the respondent, her/his address, telephone number, code number,

and call outcome data such as interview/refusal/no answer, date, day and time of interview, etc.

2) Introduction and respondent selection. (Wave I only) A standard introduction to the study was read by interviewers, and a procedure for selecting a respondent from among household residents was followed (described above in the section on sampling).

3) Hazard experience items. (Wave I only) This section was designed to provide data on respondents' personal experience with a variety of hazards. Five aspects of experience were tapped: the number of times experienced; the level of fear produced; the amount of discussion devoted to the topic; the effectiveness of government hazard management activities; and the effectiveness of individual hazard management activities. The results produced by these items for flood, earthquake and water supply contamination hazards are presented in the Results section below.

4) Earthquake items. These items, along with those dealing with water supply contamination in the case of the Lake Samish panel, constituted the heart of the questionnaire. Twenty of the 24 items devoted to the Whatcom County earthquake hazard required the respondent to make judgments about selected attributes of the hazard. The attributes and the structure of the items were based on the earlier work of Slovic and his colleagues (1980) and Fischhoff, et al. (1984). The conceptual framework that guided the construction of these items is presented in Earle and Cvetkovich (1985), and the use of these items in pilot work is described in Earle and Cvetkovich (1986). Ten attributes were covered by the questionnaire: mortality, morbidity, knowledge, concern, economic benefits, non-economic benefits, property damage, loss of income, past hazard management actions and future

hazard management actions. Two items are denoted to each attribute, one referring to the respondent and one to other persons. The four remaining earthquake items dealt with aspects of risk communication. Three of the items referred to forms of communication: conversations, mass media (newspaper, radio, television) and specialized media (magazines, public meetings, books, technical reports). For each of these forms of communication the respondent was asked whether she/he used it during a given time period, who or which media were involved, the number of occasions and the level of concern generated by the information received. The final earthquake item asked for an overall judgment of information seeking effort. Summary results on these and other questionnaire items are given in the Results section below.

5. Water supply contamination items. With one exception, the water supply contamination items parallel the structure of the earthquake items. The only difference between the two sets of items was that the water supply contamination set did not contain items referring to property damage. The questionnaire therefore contained 22 water supply contamination items, and these of course were responded to only by the Lake Samish panel.

6. Demographic and background items. (Wave I only) The final set of items on Wave I consisted of items referring to age, sex, duration of residence, education, etc. These items were designed primarily to measure the strength of respondents' ties to the local community and their level of scientific sophistication. Respondents in addition were given four items dealing with attitudes toward science and government in the management of hazards.

The interviews on Waves I and II ended with a question regarding willingness to participate further at some later date. Wave III ended the data collection and we expressed our gratitude.

RESULTS

The survey results presented in this report are primarily univariate descriptive results. Appropriate comparisons are made between the Earthquake and Water Supply Contamination hazards and between the respondent and others as the object of risk judgments. Also, the application of confirmatory factor analysis and structural modeling techniques is illustrated. More detailed analyses of subsets of the survey data will be provided in supplementary reports. The survey results are presented in the following order: a) Background information; b) Attitudes on science and government; c) Past experience with hazards; d) Risk decision factors, Earthquake; e) Risk decision factors, Water Supply Contamination; f) Communication of Earthquake information; g) Communication of Water Supply information; h) Comparisons between Earthquake and Water Supply Contamination; and i) Multi-variate analyses.

Background Information

Results for the survey items referring to respondents' demographic and background factors are given in Table 1. For both the Earthquake panel and the Water panel, the average age for respondents was about 45 years, and about 55% of the respondents were female. The Earthquake panel has lived in the local area longer than the Water panel, was less likely to move and had a lower percentage of home ownership (67% vs. 79%). On the remaining

Table 1.
Background Information

Variable		Earthquake Sample	Water Contamination Sample
Age		45.900	44.619
Sex	Male	44	19
	Female	53	23
Maximum years self or spouse has lived in local area		21.240	14.195
Likelihood of moving within next 5 years (Definitely will not move = 1; Definitely will move = 5)		2.674	3.050
Home ownership	Yes	65	33
	No	32	9
Maximum grade in school completed by self or spouse		14.181	14.286
Maximum degree earned by self or spouse (bachelor's = 2.000)		2.000	1.929
Total science courses completed by self or spouse in high school and college		3.443	3.214
Total family income		$21-30 thousand	$21-30 thousand
Number of children in local schools		.443	.405
Memberships in clubs or organizations by self or spouse		1.825	1.738

background variables the two panels were essentially the same. As would be expected in our fairly demanding three-wave panel study, the respondents who completed the full procedure were a relatively stable, well educated group.

Attitudes on Science and Government

As shown in Table 2, both respondent panels showed rather weak agreement with the proposition that "Scientists generally work for the public well being" and were neutral in their judgments that "controversies over natural and industrial hazards are best resolved by technical experts. "Respondents were neutral also regarding whether government officials had done a good job " in dealing with preparations for natural and industrial hazards." Both panels disagreed strongly, however, with the statement that "Government officials always make available to local residents all the information they have concerning natural and industrial hazards." In sum, respondents indicated that scientists and technical experts can serve the public well in the management of hazards; government officials have not done a good job, however, and one of their failings is in information dissemination to the public.

Past Experience with Hazards

Five items were used to assess respondents' past experience with three hazards, flood, earthquake and water supply contamination (Table 3). Respondents were first asked to give the number of times they had experienced each hazard. Earthquake was the most frequently experienced hazard, followed by water supply contamination and flood. As expected, the Water panel had more experience with water supply contamination than did the Earthquake panel; there were no differences between panels on the other hazards. Respondents

Table 2.
Attitudes on Science and Government

Item	Earthquake Sample	Water Contamination Sample
Scientists generally work for the public well being.	2.392	2.463
Controversies over natural and industrial hazards are best resolved by technical experts.	2.753	2.714
Government officials always make available to local residents all the information they have concerning natural and industrial hazards.	4.175	4.190
In dealing with preparations for natural and industrial hazards, government officials have done a good job.	3.371	3.310

NOTE: Strongly agree = 1.0
Strongly disagree = 5.0

Table 3.
Past Experience with Hazards

Experience	Flood	Earthquake	Water Contamination
Number of times experienced			
Earthquake sample	0.417	1.660	0.536
Water sample	0.366	1.619	0.810
Level of fear (Not at all frightened = 1.000; Very frightened and upset = 4.000)			
Earthquake sample	1.196	2.103	1.330
Water sample	1.381	2.143	1.643
Amount of discussion (Never = 1.000; Often = 4.000)			
Earthquake sample	1.722	1.948	2.677
Water sample	1.833	2.095	3.310
Effectiveness of government actions (Ineffective = 1.000, Highly effective = 5.000)			
Earthquake sample	2.825	2.670	3.863
Water sample	2.643	2.476	3.762
Effectiveness of individual actions (Ineffective = 1.000; Highly effective = 5.000)			
Earthquake sample	3.320	2.711	3.242
Water sample	3.571	2.643	3.381

were asked to judge the level of fear generated by their experiences with each hazard. Earthquake generated the most fear, followed by water supply contamination and flood. The Water panel feared water supply contamination more than the Earthquake panel. Respondents then reported the amount of discussion they had devoted to the three hazards. Water supply contamination caused the most discussion, with lesser attention given to earthquake and flood. Consistent with their previous responses, the Water panel talked much more about water supply contamination then the Earthquake panel. Two items were devoted to respondents' judgments of hazard management effectiveness. The first of these items referred to "government actions." The water supply contamination hazard was seen to be most effectively managed in this way, followed by flood and then earthquake. The second item referred to "individual actions". Both the flood and water supply contamination hazards were judged to be moderately manageable in this way, with the earthquake hazard less so. These results are particularly interesting with regard to the earthquake hazard. Of the hazards studied, the earthquake was the most experienced and the most feared when it occurred. The earthquake hazard was much less talked about than the water supply contamination hazard, however. This may be related to respondents' judging the earthquake to be the least manageable of the three hazards, either by the government or by individuals. Respondents' views of the Earthquake and Water Supply Contamination hazards are explored in more detail in the following sets of results.

Risk Decision Factors, Earthquake

In the column on the left side of Table 4 are listed the risk decision factors for the Earthquake hazard. These risk decision factors are aspects of

Table 4.
Risk Decision Factors and Questionnaire Items for the Earthquake Hazard (page 1 of 3)

Risk Decision Factor	Questionnaire Item
Mortality	
Self	How likely is it that <u>you</u> will die as a result of an earthquake in Whatcom County?
Others	How likely is it that <u>someone</u> will die as a result of an earthquake in Whatcom County?
Morbidity	
Self	How likely is it that you will be injured or become ill as a result of an earthquake in Whatcom County?
Others	How likely is it that <u>someone</u> will be injured or become ill as a result of an earthquake in Whatcom County within the next ten years?
Knowledge	
Self	To what extent are the hazards of a Whatcom County earthquake known to <u>you</u>?
Science and Government	To what extent are the hazards of a Whatcom County earthquake precisely known to <u>science and the government</u>?
Dread	
Self	Is a Whatcom County earthquake a hazard <u>you</u> have accepted with little or no concern, or is it one that you have dread for - on the level of a gut reaction?

Table 4. (page 2 of 3)

Risk Decision Factor	Questionnaire Item
Others	Is a Whatcom County earthquake a hazard that the people of Whatcom County have accepted with little or no concern, or is it one that they have dread for - on the level of a gut reaction?
Benefits	
Economic	
Self	To what extent do you gain economically by living in an area exposed to a Whatcom County earthquake?
Others	To what extent do the people of Whatcom County gain economically by living in an area exposed to a Whatcom County earthquake?
Non-economic	
Self	To what extent do you gain in non-economic benefits by living in an area exposed to a Whatcom County earthquake?
Others	To what extent do the people of Whatcom County gain in non-economic benefits by living in an area exposed to a Whatcom County earthquake?
Costs	
Property Damage	
Self	How likely is it that your house will sustain significant damage as a result of an earthquake?
Others	How likely is it that the houses of some individuals living in Whatcom County will sustain significant damage as a result of an earthquake within the next ten years?

Table 4. (page 3 of 3)

Risk Decision Factor	Questionnaire Item
Income Loss	
Self	How likely is it that you will lose income or experience increased costs as a result of an earthquake in Whatcom County - or pay for increased protection from such a hazard?
Others	How likely is it that some individuals living in Whatcom County will lose income or experience increased costs as a result of an earthquake within the next ten years - or pay for increased protection from such a hazard.
Mitigation	
Past Actions	
Self	What steps have you taken to prepare for an earthquake in Whatcom County?
Government	What preparations for an earthquake have been taken by local Whatcom County government officials?
Potential Future Actions	
Self	What steps can you take to prepare for an earthquake?
Government	What preparations for an earthquake should be taken by local Whatcom County government officials?

the earthquake hazard that respondents might use in producing overall judgments of risk and decisions regarding risk mitigation activities. The questionnaire items corresponding to each of the risk decision factors are listed in the column on the right side of Table 4.

Respondents made judgments on each of the risk decision factors on three occasions, Waves 1, 2 and 3. The means for these judgments are given in Table 5. The mortality judgments were significantly affected by Waves for both Self ($F_{2,190} = 7.12$; $p = 0.001$) and Others ($F_{2,190} = 5.01$; $p = 0.008$). Both of these effects were due to negative linear trends ($F_{1,95} = 12.18$; $p = 0.001$ for Self; $F_{1,95} = 9.40$; $p = 0.003$ for Others). These consistent decreases in mortality judgments across Waves may be due to a response effect in which the repetition of a questionnaire item over a relatively brief period of time elicits judgments that are affected by prior responses to the same item. The possibility of these affects will be investigated in subsequent analyses. Mortality judgments for Self were consistently lower than those for Others ($F_{1,95} = 67.87$; $p = 0.000$). This result would seem to follow from the simple statistical fact that it is less likely that an identified individual will be injured or die in an earthquake than it is that some unidentified individual will suffer the same fate. In an earthquake of a given magnitude, for example, the likelihood that at least one person will die can be calculated on the basis of past experience and/or models. Say this probability is 0.50. The likelihood that a particular individual living in the affected city is included in the victims is obviously very much smaller. Respondents' judgments therefore can be interpreted as reflecting a tendency toward statistical thinking as opposed to a tendency toward thoughts of

Table 5.
Mean Judgments on the Risk Decision Factors
Across Waves for the Earthquake Hazard
(Page 1 of 2)

Risk Decision Factor	Wave 1	Wave 2	Wave 3
Mortality (Very unlikely = 1.00; Very likely = 5.00)			
Self	1.536	1.299	1.237
Others	2.240	2.042	1.802
Morbidity (Very unlikely = 1.00; Very likely = 5.00)			
Self	1.742	1.784	1.464
Others	2.381	2.392	2.062
Knowledge (Risks known precisely = 1.00; Risks not known = 5.00)			
Self	3.474	3.464	3.237
Science and Government	2.833	2.500	2.667
Dread (No concern = 1.00; Dread = 5.00)			
Self	1.649	1.773	1.649
Others	1.701	1.794	1.742
Benefits (None = 1.00; Great gains = 5.00)			
Economic			
Self	2.140	2.172	2.172
Others	2.351	2.511	2.414

Table 5.
Mean Judgments on the Risk Decision Factors
Across Waves for the Earthquake Hazard
(Page 2 of 2)

Risk Decision Factor	Wave 1	Wave 2	Wave 3
Non-economic			
Self	2.872	3.574	3.404
Others	2.912	3.407	3.264
Costs (Very unlikely = 1.00; Very likely = 5.00)			
Property Damage			
Self	2.660	2.588	2.309
Others	3.093	2.866	2.753
Income Loss			
Self	2.309	2.196	2.175
Others	2.938	2.711	2.660
Mitigation (Number of actions)			
Past Actions			
Self	0.155	0.227	0.433
Government	0.237	0.639	0.887
Potential Future Actions			
Self	0.887	1.381	1.897
Government	1.000	1.845	2.258

personal invulnerability. The two modes of thinking are clearly intertwined, and disentanglement is not possible here.

The morbidity judgments were less strongly affected by Waves than the mortality judgments. The judgments for Self indicate a Wave effect ($F_{2,192}$ = 5.09; p = 0.007) and a linear trend ($F_{1,96}$ = 6.04; p = 0.016). The results were similar for Others ($F_{2,192}$ = 3.97; p = 0.21 and $F_{1,96}$ = 5.69; p = 0.019). In both cases, however, the decrease in judgments occurred only from Wave 2 to Wave 3 rather than across all three Waves. Consistent with the mortality judgments, the morbidity judgments for Self were significantly lower than those for Others on all three waves ($F_{1,96}$ = 67.66; p = 0.004).

For the two sets of knowledge judgments, there were no Wave effects, indicating that respondents believed that no changes in knowledge about the Earthquake hazard occurred during the study period. There was a consistent difference in judged levels of knowledge across waves, however, with respondents attributing greater knowledge to Science and Government than to themselves ($F_{1,95}$ = 37.72; p = 0.000).

Respondents' judgments of dread indicate consistent low levels of concern across all three Waves, with no differences between Self and Others.

Judgments of economic benefits were unaffected by Waves for both Self and Others. Respondents indicated that Others received greater economic benefits by living in Whatcom County than they did ($F_{1,92}$ = 15.35; p = 0.00). Waves did affect judgments of non-economic benefits for Self ($F_{2,180}$ = 5.44; p = 0.005) but not for Others. A significant linear trend ($F_{1,90}$ = 3.98; p = 0.049) was caused by the increase of judged non-economic benefits for self from Wave 1 to Wave 2. In contrast with economic benefits, respondents judged non-economic benefits to be evenly distributed between themselves and Others.

Respondents judged the likelihood of two types of costs, property damage and income loss, for Self and Others. Waves had a moderate effect on property damage judgments, producing significant negative linear trends for both Self ($F_{1,96} = 4.69$; $p = 0.033$) and Others ($F_{1,96} = 4.18$; $p = 0.044$). In contrast, Waves had no effect on income loss judgments. For both types of cost judgments, respondents saw Others more likely to be affected than themselves ($F_{1,96} = 12.76$; $p = 0.001$ for property damage, and $F_{1,90} = 35.98$; $p = 0.000$ for income loss).

For all four mitigation variables, the measure on each Wave consists of the number of actions identified by respondents on that wave plus the number of different actions identified on previous waves. The mitigation measures are cumulative, therefore, and the Wave effects indicate the respondents' ability to identify new mitigation actions on succeeding waves. There were highly significant positive linear trends for all four variables: past actions, self ($F_{1,96} = 14.01$; $p = 0.000$); past actions, government ($F_{1,96} = 43.60$; $p = 0.000$); potential future actions, self ($F_{1,96} = 59.78$; $p = 0.000$); and potential future actions, government ($F_{1,96} = 94.09$; $p = 0.000$). Four comparisons were made among the mitigation variables: 1) The Government was judged to have engaged in more earthquake mitigation activities in the past than the respondents themselves ($F_{1,96} = 7.18$; $p = 0.009$); 2) Similarly, more potential future actions were attributed to the Government than to the respondents ($F_{1,96} = 4.64$; $p =0.034$); 3) Respondents identified more potential future actions they could take than past activities completed ($F_{1,96} = 65.17$; $p = 0.000$); and 4) A similar strong superiority of future over past was produced also for the Government ($F_{1,96} = 42.75$; $p = 0.000$).

Risk Decision Factors, Water Supply Contamination

The risk decision factors and corresponding questionnaire items for the Water Supply Contamination hazard are presented in Table 6. The mean responses on these items for three waves of judgments are given in Table 7. The effect of Waves on mortality judgments was significant for Others ($F_{2,82} = 4.86$; $p = 0.010$) but not for Self. The Waves effect for Others was due to a negative linear trend ($F_{1,41} = 6.90$; $p = 0.012$). As with the Earthquake results, these decreases in mortality judgments may be due to a response effect that will be investigated in subsequent analyses. Also as in the Earthquake results, mortality judgments for Self were consistently lower than those for Others ($F_{1.41} = 21.03$; $p = 0.000$). The mean morbidity judgments averaged almost a full point higher on our response scales than the mortality judgments. Otherwise, however, the pattern of the morbidity means matched that of the mortality means. The effect of Waves was significant only for Others ($F_{2,82} = 5.02$; $p = 0.0009$), and that was due to a negative linear trend ($F_{1,41} = 7.14$; $p = 0.011$). The morbidity judgments for Others were consistently higher than those for Self ($F_{1,40} = 21.92$; $p = 0.000$).

Results on the two sets of knowledge judgments differed markedly from their Earthquake counterparts. Whereas in the Earthquake results there were no Wave effects, the Water Supply Contamination results showed Wave effects for both Self ($F_{2,82} = 3.34$; $p = 0.040$) and Science and Government ($F_{2,82} = 11.26$; $p = 0.000$). There was a positive linear trend across all three waves for Self ($F_{1,41} = 5.23$; $p = 0.027$). For Science and Government the positive linear trend traversed only the first two waves ($F_{1,41} = 14.73$; $p = 0.000$) before falling slightly on the third wave to create a quadratic trend

Table 6.
Risk Decision Factors and Questionnaire Items
For The Water Supply Hazard (Page 1 of 3)

Risk Decision Factor	Questionnaire Item
Mortality	
Self	How likely is it that you will die as a result of water supply contamination in the Lake Samish area?
Others	How likely is it that someone will die as a result of water supply contamination in the Lake Samish area during the next 10 years?
Morbidity	
Self	How likely is it that you will become ill as a result of water supply contamination in the Lake Samish area?
Others	How likely is it that someone will become ill as a result of water supply contamination in the Lake Samish area during the next 10 years?
Knowledge	
Self	To what extent are the hazards of water supply contamination in the Lake Samish area known to you?
Science and Government	To what extent are the hazards of water supply contamination in the Lake Samish area known to science and government?
Dread	
Self	Is water supply contamination in Lake Samish a hazard you have accepted with little or no concern, or is it one that you have dread for - on the level of a gut reaction?

Table 6.
Risk Decision Factors and Questionnaire Items
For The Water Supply Hazard (Page 2 of 3)

Risk Decision Factor	Questionnaire Item
Others	Is water supply contamination in Lake Samish a hazard that the people of the Lake Samish area have accepted with little or no concern, or is it one that they have dread for - on the level of a gut reaction?
Benefits	
Economic	
Self	To what extent do you gain economically by living in an area exposed to Lake Samish water supply contamination?
Others	To what extent do the people of the Lake Samish area gain economically by living in an area exposed to Lake Samish water supply contamination?
Non-economic	
Self	To what extent do you gain in non-economic benefits by living in an area exposed to Lake Samish water contamination?
Others	To what extent do the people of the Lake Samish area gain in non-economic benefits by living in an area exposed to Lake Samish water supply contamination?
Costs	
Income Loss	
Self	How likely is it that you will lose income or experience increased costs as a result of Lake Samish water supply contamination?

Table 6.
Risk Decision Factors and Questionnaire Items
For The Water Supply Hazard (Page 3 of 3)

Risk Decision Factor	Questionnaire Item
Others	How likely is it that some individuals in the Lake Samish area will lose income or experience increased costs as a result of Lake Samish water supply contamination?
Mitigation	
Past Actions	
Self	What steps have you taken to protect yourself from and/or reduce the effects of Lake Samish water supply contamination?
Government	What steps have been taken by Whatcom County and other government officials to reduce the effects of Lake Samish water supply contamination?
Potential Future Actions	
Self	What steps can you take to protect yourself from and/or reduce the effects of Lake Samish water supply contamination?
Government	What steps should be taken by Whatcom County and other government officials to reduce the effects of Lake Samish water supply contamination?

Table 7.
Mean Judgments on the Risk Decision Factors
Across Waves for the Water Supply Hazard
(Page 1 of 2)

Risk Decision Factor	Wave 1	Wave 2	Wave 3
Mortality (Very unlikely = 1.00; Very likely = 5.00)			
Self	1.667	1.405	1.452
Others	2.524	1.952	1.833
Morbidity (Very unlikely = 1.00; Very likely = 5.00)			
Self	2.610	2.341	2.268
Others	3.429	2.881	2.786
Knowledge (Risks known precisely = 1.00; Risks not known = 5.00)			
Self	2.524	3.095	3.310
Science and Government	2.524	3.690	3.643
Dread (No concern = 1.00; Dread = 5.00)			
Self	3.119	2.667	2.833
Others	3.310	2.786	2.786
Benefits (None = 1.00; Great gains = 5.00)			
Economic			
Self	2.119	1.524	1.690
Others	2.167	1.857	1.881

Table 7.
Mean Judgments on the Risk Decision Factors
Across Waves for the Water Supply Hazard
(Page 2 of 2)

Risk Decision Factor	Wave 1	Wave 2	Wave 3
Non-economic			
Self	3.619	3.929	4.190
Others	3.725	3.800	4.150
Costs (Very unlikely = 1.00; Very likely = 5.00)			
Income Loss			
Self	2.333	2.595	2.524
Others	3.262	2.929	2.881
Mitigation (Number of Actions)			
Past actions			
Self	1.143	1.476	1.595
Government	0.571	0.952	1.214
Potential Future Actions			
Self	1.262	1.690	2.095
Government	0.881	1.643	1.976

($F_{1,41} = 7.03$; $p = 0.011$). The general pattern of these for both Self and Science and Government is a judged decrease in knowledge across waves.

Respondents' judgments of dread indicate that levels of concern decreased from wave one to wave two for both Self ($F_{2,82} = 3.49$; $p = 0.035$ for Waves and $F_{1,41} = 3.64$; $p = 0.063$ for negative linear trend) and Others ($F_{2,82} = 3.59$; $p = 0.032$ for Waves and $F_{1,41} = 5.00$; $p = 0.031$ for negative linear trend). Respondents saw no difference between their level of concern and that of Others.

As with the Earthquake hazard; judgments of economic benefits were unaffected by Waves for both Self and Others. Similarly, respondents indicated that Others received greater economic benefits from living on Lake Samish than they did ($F_{1,41} = 6.83$; $p = 0.012$). Non-economic benefits were unaffected by Waves for both Self and Others, and, as in the Earthquake hazard, respondents judged these benefits to be evenly distributed between themselves and Others.

In the Water Supply Contamination hazard, only one type of costs, income loss, was assessed. There were no Wave effects on income loss judgments for either Self or Others. Respondents consistently judged income loss to be more likely for Others than for themselves ($F_{1,41} = 36.43$; $p = 0.000$).

For the four mitigation variables, there were highly significant positive linear trends, as in the Earthquake results: past actions, self ($F_{1,41} = 25.74$; $p = 0.000$); potential future actions, self ($F_{1,41} = 25.00$; $p = 0.000$); and potential future actions, government ($F_{1,41} = 52.14$; $p = 0.000$). The same four comparisons were made among these mitigation variables as were made for the Earthquake hazard: 1) The respondents themselves were judged to have engaged in more water supply contamination mitigation activities in the past than the Government ($F_{1,41} = 7.62$; $p = 0.009$). The Government was superior on this measure for the Earthquake hazard. 2) Respondents saw no difference in potential future actions between themselves and the Government. Again, the Government was superior for the Earthquake hazard. 3) There was no difference between the number of past actions completed by respondents and the number of potential future actions they could take. For the Earthquake hazard, respondents identified more potential future actions they could take than past activities completed. 4) Finally, respondents saw more future opportunities for action for the Government than actions taken by the Government in the past ($F_{1,41} = 8.64$; $p = 0.005$). This result was similar for the Earthquake hazard.

Communication of Earthquake Information

The communications variables for the Earthquake hazard and the mean responses for the three waves are given in Table 8. For the variables referring to number of communications events, the length of time involved was different for the first wave than the others. On Wave 1 the time period was "the past 12 months" whereas on Waves 2 and 3 the time period was that which elapsed since the previous wave (approximately one month). Because of this, Wave effects and trend analyses will not be discussed for variables counting events. Our primary interest in these variables is comparisons between hazards, and those will be presented later in a separate section.

The variable measuring concern generated by conversations was affected by Waves ($F_{2,192} = 5.07$; $p = 0.007$), with the major effect being a negative linear trend ($F_{1,96} = 10,29$; $p = 0.000$). Similar effects were formed also for concern generated by the mass media ($F_{2,192} = 35.04$; $p = 0.000$ for Waves

Table 8.
Communication of Earthquake Information

Variable	Wave 1	Wave 2	Wave 3
Number of conversations with other persons	1.969	1.928	.928
Concern generated by conversations (Not concerned at all = 1,000; Very concerned = 5.000)	1.753	1.536	1.330
Number of times used the mass media	6.629	3.268	1.660
Concern generated by the mass media (Not concerned at all = 1.000; Very concerned = 5.000)	3.144	1.959	1.753
Numbers of times used the specialized media	.515	.062	.113
Concern generated by the specialized media (Not concerned at all = 1.000; Very concerned = 5.000)	1.515	1.031	1.165
Information seeking effort (No effort = 1.000; A great deal of effort = 5.000)	1.464	1.433	1.309

and $F_{1,96} = 57.57$; $p = 0.000$ for negative linear trend) and concern generated by the specialized media ($F_{2,192} = 10.01$; $p = 0.000$ for Waves and $F_{1,96} = 6.73$; $p = 0.011$ for negative linear trend). There were no changes in information seeking effort across waves.

A comparison was made among the three modes of communication, conversations, mass media and specialized media. Regarding the number of communication events, the mass media produced the most, followed by conversations and then the specialized media ($F_{2,192} = 88.63$; $p = 0.000$). The results were similar for the level of concern generated, with the mass media followed by conversations and the specialized media ($F_{2,192} = 75.91$; $p = 0.000$).

Communication of Water Supply Contamination Information

The communications variables for the Water Supply Contamination hazard were the same as those used for the Earthquake hazard. Mean responses for the three waves are given in Table 9.

The effects of Waves on level of concern were similar for conversations ($F_{2,82} = 17.25$; $p = 0.000$ for Waves and $F_{1,41} = 24.81$; $p = 0.000$ for negative linear trend) and the mass media ($F_{2,82} = 24.15$; $p = 0.000$ for Waves and $F_{1,41} = 37.27$; $p = 0.000$ for negative linear trend). There were no differences among levels of concern generated by the specialized media across waves. Information seeking effort, however, was affected by Waves ($F_{2,82} = 19.86$; $p = 0,000$), with the primary effect being a negative linear trend ($F_{1,41} = 31.61$; $p = 0.000$).

A comparison among the three modes of communication showed that conversations were the most frequent, followed by the mass media and the

Table 9.
Communication of Water Contamination Information

Variable	Wave 1	Wave 2	Wave 3
Number of conversations with other persons	8.167	2.619	1.619
Concern generated by conversations (Not concerned at all = 1,000; Very concerned = 5.000)	3.238	2.048	1.786
Number of times used the mass media	1.714	.476	.095
Concern generated by the mass media (Not concerned at all = 1.000; Very concerned = 5.000)	2.476	1.357	1.048
Numbers of times used the specialized media	.786	.357	.095
Concern generated by the specialized media (Not concerned at all = 1.000; Very concerned = 5.000)	1.429	1.524	1.095
Information seeking effort (No effort = 1.000; A great deal of effort = 5.000)	2.762	1.976	1.619

specialized media ($F_{2,82}$ = 51.85; p = 0.000). Similarly, conversations generated the most concern, followed by the mass media and the specialized media ($F_{2,82}$ = 24.82; p = 0.000). These results show that interpersonal conversation was the most important mode of communication for the Water Supply Contamination hazard whereas use of the mass media was the most important for the Earthquake hazard.

Comparisons Between Earthquake and Water Supply Contamination

The results presented thus far have been descriptive of respondents' judgments and behavior regarding two hazards, Earthquake and Water Supply Contamination. The results for the two hazards have been presented separately for the most part, with no direct, within subject comparisons. In this section we describe results on both hazards for the Lake Samish panel, the subset of respondents that provided data on Water Supply Contamination as well as Earthquake. We will thus be able to describe direct comparisons between the two hazards on all of our risk judgment and behavioral self-report measures. Results on these measures are presented in the order followed for the individual hazards.

Mortality, self.	Means (by Wave)		
	1	2	3
Earthquake	1.57	1.40	1.29
Water Supply	1.67	1.40	1.45

The two hazards did not differ on this measure.

Mortality, other.

	Means (by Wave)		
	1	2	3
Earthquake	2.15	2.27	1.85
Water Supply	2.52	1.95	1.83

Again, there were no differences between hazards. For both Earthquake and Water Supply Contamination, respondents judged the likelihood of death for themselves to be low and for Others to be somewhat higher.

Morbidity, self.

	Means (by Wave)		
	1	2	3
Earthquake	1.76	1.88	1.46
Water Supply	2.61	2.34	2.27

Respondents judged the likelihood of injury/illness to themselves to be significantly higher for Water Supply Contamination ($F_{1,40} = 30.776$; $p = 0.000$).

Morbidity, others.

	Means (by Wave)		
	1	2	3
Earthquake	2.38	2.50	2.10
Water Supply	3.43	2.88	2.79

The judged likelihood of injury/illness to Others was also higher for Water Supply Contamination ($F_{1,41} = 31.43$; $p = 0.002$).

Knowledge, self.

	Means (by Wave)		
	1	2	3
Earthquake	3.52	3.50	3.33
Water Supply	2.52	3.10	3.31

Respondents indicated that the Water Supply Contamination hazard is better known to them than the Earthquake hazard ($F_{1,41} = 7.35$; $p = 0.010$). (Note that higher scores mean less knowledge.) There was a significant hazard by Wave interaction ($F_{2,82}$ = 3.45; p = 0.036) and interaction of linear trends ($F_{1,41}$ = 5.97; p = 0.019). These results show that respondents' judgments oftheir own hazard knowledge increased for Earthquake over Waves and decreased for Water Supply Contamination.

Knowledge, science & government.

	Means (by Wave)		
	1	2	3
Earthquake	2.95	2.36	2.81
Water Supply	2.52	3.69	3.64

The Earthquake hazard is better known to Science and Government, according to our respondents ($F_{1,41}$ = 6.88; p = 0.012). A significant hazard by wave interaction ($F_{2.82}$ = 10.24; p = 0.000) and linear trend interaction ($F_{1,41}$ 10.00; p = 0.003) indicates that judged Earthquake knowledge increased slightly while Water Supply Contamination knowledge decreased.

Dread, self.

	Means (by Wave)		
	1	2	3
Earthquake	1.76	1.98	1.86
Water Supply	3.12	2.67	2.83

Respondents were more concerned about Water Supply Contamination than Earthquake ($F_{1,41}$ = 28.47; p = 0.000). There was a hazard by Wave interaction ($F_{2,82}$ = 4.86; p = 0.010) and a liner trend interaction ($F_{1,41}$ 4.81; p = 0.034) indicating that Earthquake concern increased slightly overtime, while Water Supply Contamination concern decreased.

Dread, others.

	Means (by Wave)		
	1	2	3
Earthquake	1.67	1.93	1.83
Water Supply	3.31	2.79	2.79

Respondents' judgments about the concerns of Others followed the same pattern as those about their own. Water Supply Contamination was judged to generate more concern than Earthquake ($F_{1,41} = 50.26$; $p = 0.000$); a hazard by Wave interaction ($F_{2,82} = 5.17$; $p = 0.008$) and a linear trend interaction ($F_{1,41} = 8.82$; $p = 0.005$) show that judged Earthquake concern increased slightly over time, while Water Supply Contamination decreased.

Economic benefits, self.

	Means (by Wave)		
	1	2	3
Earthquake	2.24	2.46	2.37
Water Supply	2.12	1.52	1.69

The economic benefits of living with the Earthquake hazard were seen to be greater than those associated with the Water Supply Contamination hazard ($F_{1,40} = 19.52$; $p = 0.000$).

Economic benefits, others.

	Means (by Wave)		
	1	2	3
Earthquake	2.50	2.86	2.57
Water Supply	2.17	1.86	1.88

As with the judgments for themselves, respondents viewed the economic benefits to Others to be greater for Earthquake than for Water Supply Contamination.

Noneconomic benefits, self.

	Means (by Wave)		
	1	2	3
Earthquake	2.88	3.88	3.69

Water Supply	3.62	3.93	4.19

The noneconomic benefits of living with the Water Supply Contamination hazard were seen to be greater than those associated with the Earthquake hazard ($F_{1,41} = 8.51$; $p = 0.006$).

<u>Noneconomic benefits, others</u>.

	Means (by Wave)		
	1	2	3
Earthquake	2.87	3.64	3.49
Water Supply	3.72	3.80	4.15

The noneconomic benefits to Others were judged to be greater for Water Supply Contamination ($F_{1,38}$ 11.95; $p = 0.001$). In general, then, economic benefits were seen to be greater for Earthquake, while the noneconomic benefits were greater for Water Supply Contamination.

<u>Income loss, self</u>.

	Means (by Wave)		
	1	2	3
Earthquake	2.95	2.64	2.60
Water Supply	2.33	2.60	2.52

The two hazards did not differ on this measure.

<u>Income loss, others</u>.

	Means (by Wave)		
	1	2	3
Earthquake	3.26	2.81	2.69
Water Supply	3.26	2.93	2.88

Again, there were no differences between hazards. Respondents judged moderate levels of income loss for both themselves and Others.

<u>Mitigation, past actions/self</u>.

	Means (by Wave)		
	1	2	3
Earthquake	0.24	0.33	0.64

Water Supply	1.14	1.48	1.60

Respondents reported that they had taken significantly more actions to protect themselves from the Water Supply Contamination hazard than from the Earthquake hazard ($F_{1,41} = 23.18$; $p = 0.000$).

<u>Mitigation, past actions/government</u>.	<u>Means (by Wave)</u>		
	1	2	3
Earthquake	0.26	0.79	1.12
Water Supply	0.57	0.95	1.21

There were no differences between the number of past mitigation actions attributed to the Government for the two hazards.

<u>Mitigation, future actions/self</u>.	<u>Means (by Wave)</u>		
	1	2	3
Earthquake	0.74	1.24	1.67
Water Supply	1.26	1.69	2.10

Respondents identified more potential future actions to protect themselves from Water Supply Contamination than from Earthquake ($F_{1,41} = 4.23$; $p = 0.046$).

<u>Mitigation, future actions/government</u>	<u>Means (by Wave)</u>		
	1	2	3
Earthquake	1.02	1.88	2.14
Water Supply	0.88	1.64	1.98

As with past actions, there were no differences between the number of potential future actions attributed to the Government for the two hazards. In sum, the Water Supply Contamination hazard was superior on the two Self mitigation measures, while the two hazards were equal on the Government measures.

Conversations, number.

	Means (by Wave)		
	1	2	3
Earthquake	2.38	2.40	0.74
Water Supply	8.17	2.62	1.62

The number of conversations reported for Water Supply Contamination was greater than for Earthquake ($F_{1,41}$ = 20,81; p = 0.000). Since the questionnaire items refer to varying lengths of time for the three Waves, the Wave effects are not meaningful and will not be reported here.

Conversations, concern generated.

	Means (by Wave)		
	1	2	3
Earthquake	1.90	1.60	1.31
Water Supply	3.24	2.05	1.79

Conversations concerning the Water Supply Contamination hazard generated more concern than conversations concerning the Earthquake hazard ($F_{1,41}$ = 16.56; p = 0.000). The decline in concern across waves was greater for the former ($F_{1,41}$ = 5.47; p = 0.024).

Mass media, number.

	Means (by Wave)		
	1	2	3
Earthquake	5.98	3.95	1.93
Water Supply	1.71	0.48	0.10

The mass media were used more frequently for the Earthquake hazard ($F_{1,41}$ = 59.08; p = 0,000).

Mass media, concern generated.

	Means (by Wave)		
	1	2	3
Earthquake	3.57	2.31	1.93
Water Supply	2.48	1.36	1.05

The mass media generated more concern for the Earthquake hazard ($F_{1,41} = 43.85$; $p = 0.000$).

<u>Specialized media, number</u>.

	Means (by Wave)		
	1	2	3
Earthquake	0.48	0.07	0.12
Water Supply	0.79	0.36	0.10

The specialized media were used more frequently for the Water Supply Contamination hazard ($F_{1,41} = 4.13$; $p = 0.049$).

<u>Specialized media, concern generated</u>.

	Means (by Wave)		
	1	2	3
Earthquake	1.45	1.02	1.24
Water Supply	1.43	1.52	1.10

The two hazards did not differ on this measure.

<u>Information seeking effort</u>.

	Means (by Wave)		
	1	2	3
Earthquake	1.68	1.48	1.32
Water Supply	2.76	1.98	1.62

Respondents reported greater information seeking effort for Water Supply Contamination ($F_{1,39} = 20.13$; $p = 0.000$), and there was a steeper decline in effort across waves for this hazard ($F_{1,39} = 19.78$; $p = 0.000$).

<u>Summary</u>. Our comparisons between respondents' judgments of the Earthquake hazard and their judgments of the Water Supply Contamination hazard produced a number of interesting and useful findings. One set of items generated strongly contrasting results for the two hazards: While the Earthquake hazard was high on judgments of knowledge by Science and

Government, Water Supply Contamination was high on judgments of knowledge by Self; Earthquake was high on economic benefits to Self and Other, and Water Supply Contamination was high on noneconomic benefits to Self and Other; Earthquake was high on mass media use and effects, while Water Supply Contamination was high on the number and effects of conversations, the number of specialized media experiences and the level of information seeking effort. The Earthquake hazard thus was seen in less personal terms: It is better understood by others; it is associated with impersonal economic benefits; and information about it is communicated passively through the mass media. The Water Supply Contamination hazard, in contrast, was seen in more personal times: It is better understood by the respondents; it is associated with personal noneconomic benefits; and information about it is communicated actively through personal conversations, attendance at public meetings and other activities requiring personal effort.

A second set of items produced results in which the Water Supply Contamination hazard was consistently higher in respondents' judgments than the Earthquake hazard. These items dealt with morbidity for Self and Others, dread for Self and Others, and personal mitigation activities for Past and Future. Respondents judgments on these items clearly show that the Water Supply Contamination hazard was a more serious hazard than the Earthquake on three general psychological dimensions: cognitive (judgments of the likelihood of injury (illness), affective (level of concern experienced) and behavioral (personal activities to reduce the risk). The consistency of these results in also evidence for the validity of the items used to measure the risk decision factors.

A third and final set of items generated results that did not distinguish between the two hazards. Both Earthquake and Water Supply Contamination were given low judgments on mortality for Self and Others, moderate judgments on income loss for Self and Others, low judgments on government mitigation for Past and Future and low estimates of concern produced by specialized media. The primary contribution of these results is to contribute further evidence for the validity of our survey instrument. The low likelihood of death, low level of government activity and small effect of specialized media are consistent with other results and with our knowledge of the hazards. The same can be said for the moderate judgments of income loss for both hazards.

Multivariate Analyses

This technical report has as its primary objective the description of how our project was conducted and the basic results. Reports presenting theoretical developments and findings based on complex multivariate and analyses will be published separately. In this section we demonstrate the general approach we are taking in examining the relationships among the risk decision factors, communication variables and mitigation behavior variables. Our analyses follow a two-step procedure consisting of confirmatory factor analysis (Hertig, 1985) followed by structural equation modeling (Joreskog and Sorbom, 1982). The descriptions of these analyses given here do not include all of the statistical details that would be included in a presentation devoted solely to them.

Confirmatory factor analysis. For purposes of this demonstration, we have selected for examination the second wave of the Earthquake hazard data. These data were selected because they contain interesting relationships that provide insight into issues central to the management of the Earthquake hazard. The variables we selected for analysis were those of basic theoretical interest: the hazard information variables, the risk judgment variables and the mitigation behavior variables. Preliminary analyses indicated that, of the hazard information variables, only those dealing with the mass media and conversations could be included in complex analyses since the specialized media simply were not used by respondents. There were, therefore, four hazard information variables, the number of times used and the level of concern generated for both the mass media and conversations. There were also four risk judgment variables, mortality likelihood for Self and Others and morbidity likelihood for Self and Others. Although there were four mitigation behavior variables included in he study, preliminary analyses indicated: a) that there were no consistent relationships among the four variables (i.e. each measured a different aspect of mitigation behavior); and b) that only potential future actions by Self was related to either the hazard information variables or the risk judgment variables. Thus, only one mitigation behavior variable was included in the subsequent analyses.

The basic purpose of confirmatory factor analysis is to test a set of data for the validity of an hypothesized set of relationships. In such an analysis, our eight hazard information and risk judgment variables are indicators of specified underlying latent variables (the mitigation behavior variable can be excluded during this stage because it is taken to be the sole indicator of a perfectly measured variable). As shown in Figure 3, our hypothesized "measurement model" consists of four latent variables, each with two indicators: 1) Mass Media is measure by the number of times used and the level of concern generated by the mass media; 2) Conversations is measured by the number of times used and the level of concern generated by conversations; 3) Risk, Self is measured by judgments of mortality likelihood for Self and judgments of morbidity likelihood for Self; and 4) Risk, Other is measured by judgments of mortality likelihood for Others and judgments of morbidity likelihood for Others. It is important to note that this model is one of several possibilities, and that it was selected on theoretical grounds. Our model, for example, says that individuals distinguish their risk judgments for themselves for those for Others regardless of whether mortality or morbidity is in question. An alternative model might distinguish between mortality and morbidity judgments for both Self and Others.

Our measurement model was tested using the LISREL maximum likelihood procedures developed by Joreskog and Sorbom (1984). This confirmatory factor analysis showed that our model was consistent with our data ($\text{Chi}^2_{12} = 13.36$; $p = 0.343$). This result does not mean that our model is the only one that would fit our data. Alternative models may fit the data, but our model is consistent with both theory and data.

A central advantage to the use of confirmatory factor analysis is the capability to incorporate and correct for the effects of measurement error. Included in this procedure is the ability to specify correlated errors among the measured variables. Again, the estimation of these parameters must be consistent with both theory and data. In our present model, two correlated errors were specified: 1) between morbidity, Self and morbidity, Others ($t = 3.830$); and 2) between mortality, Self and mass media concern ($t = 2.562$). With these specifications of measurement error, our measurement model is consistent with the data and ready for use in the testing of a structural equation model.

Structural equation model. Whereas the confirmatory factor analysis examined the relations among the measured variables or indicators, the structural equation model explores the relations among the unmeasured or latent variables (except in cases when variables are perfectly measured). As Figure 3 shows, we have four latent variables and one perfectly measured variable. Although all of the variables are considered to be endogenous, only certain paths are justified on theoretical grounds. The hazard information variables refer to a time period prior to the risk judgment variables and the risk judgment variables are prior to the mitigation behavior variable. Hazard information can therefore affect risk judgment and mitigation behavior. Similarly, risk judgment can affect mitigation behavior. No other paths are justified theoretically. The total number of possible paths is six, but, as indicated in Figure 3, only two were consistent with the data: 1) Mass Media affected Risk, Others ($t = 2.130$); and 2) Risk, Self affected Mitigation, Self ($t = 3.010$).

The significant path connecting Mass Media and Risk, Others can be interpreted as evidence supporting a causal relation between the two variables. That is, the data indicate that increased use of the mass media led to increased judgment of risk to others. This result for the Earthquake hazard is consistent with previous work in other contexts. Tyler and Cook (1984), for example, studied "personal level judgments" and "societal level judgments" (with definitions similar to ours) for several hazards including firearms, fires, drunk driving, tornadoes and floods. In general, results supported what the authors call the "impersonal impact" hypothesis. The hypothesis states that personal and societal level judgments are independent

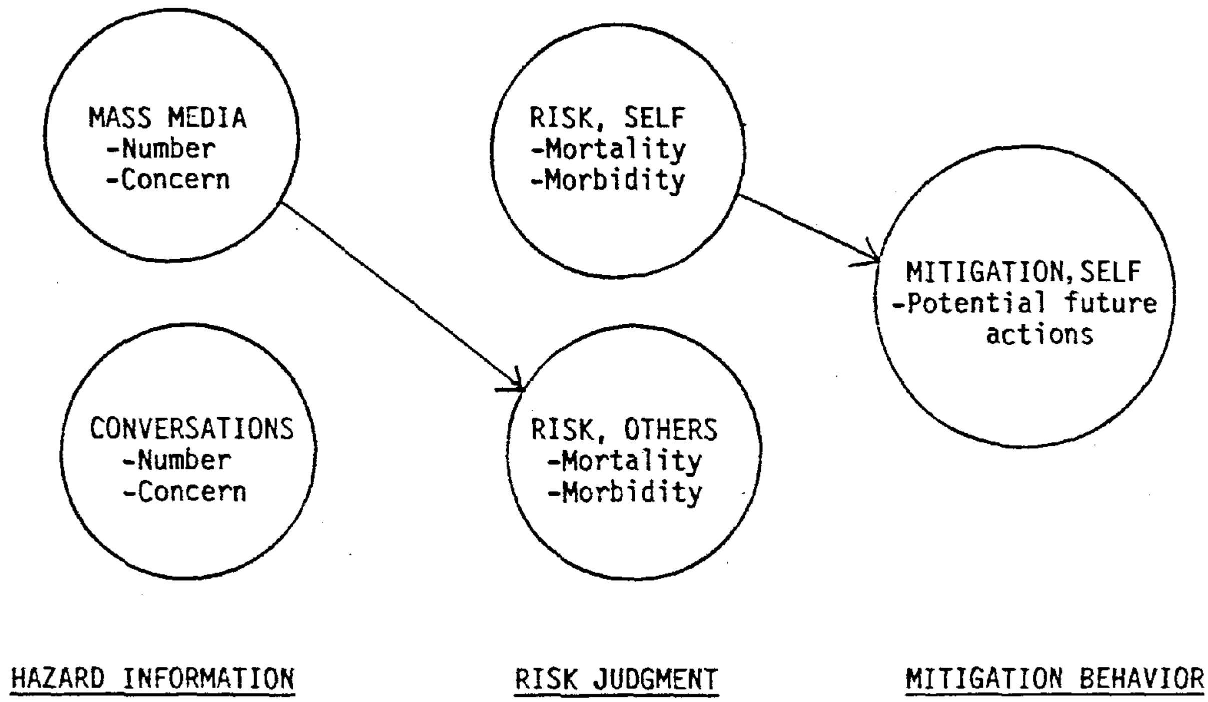

Figure 3. Earthquake Structural Model, Wave II

and that the mass media affect primarily the latter. Our finding that the impersonal impact hypothesis applies to the Earthquake hazard is particularly significant because, unlike some other hazards such as our Water Supply Contamination case, conversations do not play an important hazard information role. One implication of this is that judgments of risk to oneself are very difficult to modify solely by an impersonal Earthquake hazard information campaign.

The significant path connecting Risk, Self and Mitigation, Self indicates that increased judgments of risk to themselves led to the identification of higher numbers of potential actions that respondents could take to protect themselves from the Earthquake hazard. This result is important in that it shows that if Risk, Self can be increased, then Mitigation, Self is likely to follow. It must be kept in mind, however, that the levels of Risk, Self are very low, and the model offers no clue as to how they can be raised.

The structural equation model we have briefly presented here is just one of many models that we have developed and will develop in the future. We believe that these procedures for exploring the multiple relations among risk decision factors, hazard information variables and mitigation behavior variables are powerful tools both for theory development and for deriving useful hazard management lessons.

REPORTS IN PROGRESS

The present technical report has focused primarily on a description of how our study was conducted and a presentation of the basic results. Work is in progress on subsequent reports that will further examine the measurement properties of our variables and explore theoretically significant relations among variables across waves. Of particular interest, for example, will be the effects of information variables at Wave 1 on risk judgment variables at Wave 2 and the effects of the latter on mitigation behavior at Wave 3. We will also focus in subsequent reports on the effects of our background variables on information, risk judgment and mitigation behavior variables.

SUMMARY

In this report we have described the method and basic results of a longitudinal field study. The study consisted of three waves of telephone interview data collected over a period of five months in 1986. There were two respondent panels, one consisting of residents along the shores of Lake Samish, Washington and one consisting of residents of Bellingham, Washington. Both communities are in Whatcom County. The focus of the study was respondents' beliefs, feelings and behavior regarding two hazards, Water Supply Contamination (involving only the Lake Samish panel) and Earthquake (involving both panels). These hazards allowed us to compare a locally significant threat to the health of affected individuals (Water Supply Contamination) with a regionally significant threat to the lines and property of large numbers of (unidentified) people. In the former hazard, the link between cause and effect would appear to be short, direct, clear to non-scientists and personally-specific; in the latter hazard, the link would seem to be long, indirect, clear for the most part only to scientists and non-specific in its potential effects on people.

Survey results on general hazard management issues indicated that respondents believed that scientists and technical experts can serve the public well, but that government officials have not done a good job, particularly in the area of the dissemination of hazard information to the public. Inquiries into respondents' personal experience with selected hazards (flood, earthquake, water supply contamination) showed that the earthquake hazard was the most frequently experienced and the most feared when it occurred. The earthquake hazard was the focus of conversations to a lesser degree than the other hazards however, and this may be related to the respondents' view of this hazard as being less subject to management than the others, either by government or individuals.

A large segment of the results reported here were descriptive of the individual hazards. These results will be further explicated in multivariate analyses to be presented in subsequent reports. Direct comparisons between the Earthquake and Water Supply Contamination hazards were possible, however, for the Lake Samish panel. Those results showed that the Earthquake hazard was seen in less personal terms: It was considered better understood by Science and Government as opposed to oneself for Water Supply Contamination; it was associated with economic benefits as opposed to noneconomic benefits; and information about it was communicated through the mass media as opposed to interpersonal conversations. Respondents judged the Water Supply Contamination hazard to be more serious than the Earthquake on three general psychological dimensions: cognitive (judgments of the likelihood of injury /illness); affective (level of concern experienced) and behavioral (personal activities to reduce the risk). In sum, our results suggest that the Earthquake hazard is not seen as a personally salient hazard, one that people think, worry, talk and do something about. The implications of these and other results for the management of the Earthquake hazard will be developed in a subsequent report, but as a preliminary conclusion we can suggest that salience of the hazard. And the communications should not be limited to the risks involved. Of equal or greater importance may be information on what individuals can do to protect themselves from the hazard. This recommendation is consistent with those offered by Turner, et al. (1981) in their exhaustive study of community response to the earthquake threat in Southern California. One major difference between the Whatcom County and Southern California hazards is the level of public awareness and concern. The implications for hazard management of these and other differences between the two sites will be explored as part of our ongoing research effort.

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