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I. PROBLEM DEFINITION AND STUDY PURPOSES

Even as technological advances improve social welfare, more people are exposed to disastrous technological failures. The standard of living in the United States is higher than ever before, but our country also stands in significant danger of disaster events of far greater scope than any previously experienced. The flooding that would be caused by the failure of a major dam is one example.

Assessment of these low-probability/high-consequence events requires quantification of both probabilities and consequences. Considerable work has been done on the former (Rowe 1977, Waller and Covello 1984), but relatively little attention has been given to estimating the consequences of disasters that impact thousands of people. Society has increasing cause to plan against a really large disaster event where losses of life may approach millions and economic damage may be in billions of dollars. This study may be viewed as an exploratory venture in moving from the occupant or building to the community and (to a lesser degree) on to the regional scale in damage estimation.

When a few properties are damaged by flood, fire, or strong wind, the repair requirements can be tabulated and used to estimate the loss (whether economic or expanded to a more broadly based utility function) to the occupant or owner. The risk expectations of individuals and communities, and consequently most risk reduction and risk avoidance programs, are based on losses at this scale.

When thousands of properties are damaged, the same tabulation and estimating relationships would severely understate the loss to the community. The loss from the simultaneous destruction of 1000s of homes exceeds 1000 times that from the destruction of just one. The ability of an economy to "self insure" by moving resources from individuals who are not impacted to those who are is limited by repair capacity and mobility constraints. The impact has been scaled upwards from the occupant to the community level.

Exactly what causes this magnification? How large is it? How might one estimate the amount to expect from a given catastrophe? What magnification magnitude might one expect from a major dam break? The purpose of this exploratory study is to review historical records on catastrophes and their impacts, identify the major impacting processes, and examine the literature on these processes in order to:

1. Conceptualize the principal processes that could magnify disaster losses resulting from a dam-break flood,

2. Identify indicators to watch in determining which processes will be activated and estimate how much magnification will occur,

3. Approximate the order of magnitude of magnification likely to be caused by the worst conceivable dam break scenario in the United States,

4. Suggest scaling studies for quantifying catastrophic loss for water resources planning.

The approach is to probe the specifics of what losses are and how they occur during a catastrophe. Past efforts to define catastrophe have largely overlooked the dynamics of the interacting processes over the duration of a disaster and the changes in these interaction associated with larger scale disasters. The goal is to expand from past conceptualizations featuring societal recognition (Rowe 1977) to a reconnaissance assessment to stimulate critical thinking on the processes causing upwards scaling of losses from low probability/high-consequence events. Ideas are offered for future study rather than refined for scientific scrutiny.

II. A FRAMEWORK FOR ASSESSMENT

A. Time frames. Our starting assumption is that the magnification largely results from dynamic synergistic interaction of disaster impact processes. According to our characterization, losses (active impacts) and recovery (reactive impacts) occur over time. The event begins with a massive negative impact during a relatively short period. Its aftermath is extended by positively reinforcing feedback mechanisms (Forrester 1970) over a much longer period of continuing deterioration. Recovery begins during the event and reduces and eventually eliminates the losses through positively reinforcing feedback mechanisms. At the end, the restoration may even improve the community.

The damage occurs as physical, environmental, and social system fail to function in their accustomed manner. Losses are summed over a disaster period from the beginning of the event until the completion of the recovery. The individual losses stem from lost income or lost utility with respect to environmental or social values within this disaster period. Where justified, they can be ameliorated by repair or restoration (should the property be beyond repair) investments. The negative dynamic interactions add to the losses or constrain the recovery during the disaster period. The positive interactions work in the opposite direction.

B. Scaling. Impact magnification is analogous to scale effects in physics, meteorology, and hydrology in that the same principles can be applied for a better understanding of the upward scaling of socio-economic impacts. In physics, for example, subatomic, atomic, pore, basin, continental, and planetary studies address different processes. Socio-economically, the processes to consider in estimating the losses from not being able to use and the costs for repairing a damaged building are inappropriate for estimating the cost of restoring a devastated city. Whether one is dealing with physical or socio-economic systems,

1. The operational forces and interactions vary with scale. Atmospheric circulation occurs at molecular, storm, and frontal scales. People experience events as individuals and as members of communities, regions, and nations. Economic interactions concentrate in defined trade areas.

2. Activity at smaller and at larger scales have consequences at the scale of primary interest. For example in estimating catastrophic loss to a community, one must consider building repair costs at the property scale and the state of the economy at the regional scale.

While the term "magnification" is introduced as a multiplier, the full concept is for it to be a generic term that describes the increase in unit losses as one goes from a disaster to a catastrophe without implying that the losses are uniformly larger. Some types of losses may decrease or disappear. Others become larger. Processes that did not even exist at a smaller scale emerge and then begin to dominate at a larger scale.

Experience in the physical world suggests that larger scale processes are slower and continue over a longer time period. For example, physics tells us that processes occurring at large spatial scales take long periods atom movements are in units shorter than microseconds and stars hardly change their positions in millennia. In fact, the time dimension is useful in classifying factors contributing to catastrophic or super catastrophic losses. Also, at these larger scales, the longer time frames cause the dynamic feedback mechanisms to extend further into the future, become associated with greater uncertainties, and have a greater spread in the probability distribution of the potential impacts.

During larger scale events, losses and repairs move into different frameworks. Business and government communities are "damaged" in different sorts of ways than are buildings; their failure to function properly inflicts different sorts of losses, and they require different repair "measures." Additional interactions must be considered in assessing the effects on regional, state, and national economies and politics.

C. Definitions. In order to examine loss "magnification," one must establish some basic terms of reference. The following terminology is offered:

1. Disaster. The dictionary definition of a disaster is "any sudden unfortunate event." This study focuses on dam-break events. However, because dam-break catastrophes are rare (only 12 life-taking events in the United States since 1870), other "natural" disasters were also examined to add to the data base. For this purpose, a natural disaster is defined as one originating in natural sources as opposed to one caused by people, accidentally or purposefully.

2. Dam-break. An event in which the failure or overtopping of a dam passes a large volume of water downstream and produces a severe flood. This study focuses on dam breaks associated with major hydrologic events. The large areas impacted by heavy rains are likely to give hydrologic dam-breaks larger magnification than structural dam breaks.

3. Damage. The dictionary definition of damage is "injury or harm that impairs value or usefulness." As now generally accepted in water resources planning (Water Resources Council 1980), value will be examined in three dimensions:

a. Economic (measurable in monetary units),
b. Social (measurable in changes in the social well-being and particularly in the physical and mental health of people in ways that cannot be fully expressed in monetary units).
c. Environmental (measurable in changes to natural [chiefly biologic or geologic] systems in ways that cannot be fully expressed in monetary units).

4. Catastrophe. The dictionary definition of catastrophe is "widespread disaster." This study makes that definition quantitatively specific by interpreting "widespread" as an event large enough for damages to magnify beyond linear addition because additional processes occur at the community scale.

5. Super catastrophe. An event large enough for catastrophic damages to magnify beyond linear addition because still additional processes occur at a still larger regional scale.

6. Normal damage. The damage a disaster causes from a property-scale perspective can be estimated from the losses associated with impaired use and the costs of implemented repair or replacement to better meet occupant needs. One can use unit costs to estimate the damages to each property and sum the results to obtain a total "normal damage."

7. Magnified damage. Once an event crosses the threshold from a disaster to a catastrophe, the actual total damage exceeds the sum of the normal damages and can be called a "magnified damage." The community-scale perspective would add losses associated with:

a. Impaired community functions and the costs of reducing the impairment and restoring the functions.
b. Magnification of "normal" losses and repair costs because of the impaired community functions.

8. Property Scale. Assessment of the impacts of a disaster from the first order perspective of an individual, a property under single ownership, or some other unit of equivalent size in the environmental and social dimensions.

9. Community Scale. Assessment of the impacts of a catastrophe from the second order perspective of a larger community.

10. Regional Scale. Assessment of the impacts of a super catastrophe from a third order regional perspective.

10. Scaling Threshold. The disaster size at which magnification begins. This size varies with the type of damage and is much larger in going from the community to the regional scale than in going from the property to the community scale. Threshold magnitudes must be determined empirically.

11. Magnification. The transform used to convert an estimate of normal or property-scale damage to magnified or community-scale damage.

Simplistically, one could define "magnified damage" divided by "normal damage" as the magnification factor. Realistically, the transform is more complex.

12. Super Magnification. The transform used to convert an estimate of community-scale damage to regional-scale damage.

13. Severity. The dictionary definition of severity is "harshness." As applied in this study, severity is a scaler measure of dam-break flooding harshness that can be used in estimating normal damage (loss at the property scale).

14. Severity factors. Factors used to estimate severity. The factors commonly used for estimating flood damages are the depth and area of flooding, the value and kinds of property at risk, the suddenness of the event, and flood velocity, sediment content, and duration.

15. Property-scale occupancy. Normal flood damage is estimated by integrating spatially-distributed information on severity factors over spatially-distributed information on flood-plain occupancy. At the property scale, this information would be descriptions and values of properties by flood-plain location.

16. Synergism. The dictionary definition of synergism is "working together cooperatively." As applied in this study, synergism encompasses interactions among property-scale and community-scale processes.

17. Synergistic factors (Scaling indices). Factors used to index whether larger scale impacts will occur and the amount of magnification. Specific factors may be physical, economic, social, or environmental. They are found in properties of the event averaged over community-scale areas.

18. Community-scale occupancy. Magnified flood damage would be estimated by integrating information on synergistic factors over descriptive information on community juxtaposition with respect to the hazard. At the community scale, occupancy information includes descriptions of community land use, the distribution of community service hubs with respect to the hazard, and the spatial distribution of the communication and transportation systems.

19. Regional synergism. At the higher scaling boundary, regional synergism encompasses interactions among community-scale and regional-scale processes.

20. Regional synergistic factors (Regional scaling indices). Factors used to index whether regional-scale impacts occur and the amount of consequent magnification. Specific factors are found in properties of the event averaged over regional-scale areas.

21. Regional-scale occupancy. Super magnified flood damage would be estimated by integrating information on regional synergistic factors over descriptive information on the juxtaposition of the hazard within

the region. This information would cover regional size, the distribution of regional functions, and regional communication and transportation systems.

D. Damage Classification. Damages defined as impairments in achieving goals are appropriately classified by goal. The Principles and Standards (Water Resources Council 1980) provide the goal classification most widely recognized for water resources planning and which contains the following ten economic, environmental, and social goals:

Economic Domain.

G1: Economic Value. Beneficial and adverse impacts that can be fairly measured in monetary units.

Environmental Domain.

G2: Ecologic Value. Impacts on populations of species that can be predicted from biological interrelationships and whose worth depends on the role of those species in the total environment.

G3: Aesthetic Value. Impacts on views, sounds, and scents perceived by humans that can be predicted from physical, chemical, and biological relationships and whose worth depends on the preferences of the people affected.

G4: Historic Value. Impacts on historical, cultural, or religious sites that can be predicted from juxtapositions between impacts and sites and whose worth depends on the values people, now and in the future, place on the sites.

G5: Scientific Value. Impacts on areas that are being or can be used for scientific studies because of their special features or long record of collected data that can be predicted from juxtapositions between impacts and sites and whose worth depends on the values science, now and in the future, places on the sites.

G6: Pristine value. Impacts on opportunities for people to experience settings that are essentially unaltered by human activity and that can be predicted from juxtapositions between impacts and sites and whose worth depends on the values people, now and in the future, place on the sites.

Social Domain.

G7: Real Incomes. Adjustments to account for exchanges of goods and services that do not involve money and for differences in the utility of money among peoples of different income or different life styles.

G8: Health. Impacts on mental and physical health and safety and measured in numbers of people motivated to greater achievement or harmed, classified by degrees.

G9: Educational Opportunities. Impacts on the educational, cultural, and recreational opportunities for the population of a region and measured in numbers of people helped or deprived, classified by degrees.

G10: Emergency Preparedness. Impacts on military and police operations and on evacuations in civil emergencies and measured in types of interference, classified by degrees.

E. Indirect Impacts. Many interactive and long-term impacts cannot be neatly classified among these goals defined for property-scale analysis. An alternative approach to their examination would be to consider how a major dam failure would impact the engineering, financial, environmental, social, political, and legal feasibility of subsequent water resources projects and related public works. For example, a major failure could cause:

1. Technically unnecessary engineering design standards that make all dams more costly.

2. Greater difficulty in funding, whether by taxes or through financial markets, perceived "hazardous" facilities. At a time when Federal agencies are moving toward joint financing, the difficulties in establishing innovative funding consortia will increase. Water project services will deteriorate.

3. Politicians to become less likely to support dam projects, as has happened to nuclear power, and perhaps, at the super catastrophe scale, efforts to abolish water resources construction agencies altogether. This would force essential water resources development and management activity back to a more expensive local responsibility.

4. Laws that restrain dam building, directly or by excessive bureaucratic regulation, or that assign so much liability that few are willing to take the risk.

III. HISTORICAL DESCRIPTIONS AND TOPIC REVIEWS

Empirical observations of historical natural catastrophes were used as a starting source of information for identifying magnification effects. Contemporary records and later descriptions of natural catastrophes and assessments of what went on from a scientific perspective were searched for indications of the nature and magnitude of scale effects.

A. Criteria for event review.

1. Emphasis was placed on catastrophes that have occurred in recent years in order to have a reasonable match with present technological and socioeconomic conditions.

2. Emphasis was placed on catastrophes in the United States. Catastrophes abroad were considered in locations expected to have

similar socioeconomic impacts because of similar cultural, economic, and transportation settings.

3. The reviews of dam-failure events looked at both the physical impacts and the consequences growing out of those impacts. Other kinds of disasters were examined for information useful in understanding.

B. Selected historical events. Following the above criteria, data were collected describing the following events:

1. Historical disasters in the United States not associated with dambreaks:

a. Galveston, Texas, hurricane, September 8, 1900.

b. The San Francisco, California, earthquake and fire, April 18, 1906.

c. Hurricane Camille, Mississippi Coast, Aug. 17-18, 1969.

d. Hurricane Agnes, June 19-29, 1972.

e. Regional floods and debris flows, San Francisco Bay area, California, January, 1982.

2. The historical dambreak floods since 1870 in the United States that were severe enough to cause loss of life were:

a. May 16, 1874; Mill River, MA, 143 deaths.

b. May 31, 1889; Johnstown, PA, 2209 deaths.

c. Feb 22, 1890; Walnut Grove, AZ, 150 deaths.

d. Sep 30, 1911; Austin, PA, 80 deaths.

e. Jan 27, 1916; Lower Otay, CA, 30 deaths.

f. Mar 12, 1928; St. Francis, CA, 450 deaths.

g. Dec 14, 1963; Baldwin Hills, CA, 5 deaths.

h. Feb 26, 1972; Buffalo Creek, WV, 125 deaths.

i. Jun 9, 1972; Rapid City, SD, 237 deaths.

j. Feb 22, 1976; Bearwallow, NC, 5 deaths.

k. Jun 5, 1976; Teton, ID, 14 deaths.

l. Nov 6, 1977; Taccoa Falls, GA, 39 deaths.

Altogether, about 3500 lives were lost in these 12 events (Baldewicz 1984, p. 83). The dambreaks at Johnstown, St. Francis, Buffalo Creek, and Rapid City are described in Appendix I.

3. The historical events overseas covered were:

a. Flash river flood, Lynmouth, England, August 15, 1952.
b. Floods in Bristol, England, July 11, 1970.
c. Australian floods (Lismore NSW and Brisbane) of 1974.

These events were selected because descriptions by social scientists or historians provided useful insights to understanding "community-scale" flood damage.

Information from the historical records on the 12 selected events is summarized in Appendix I in chronological order of event occurrence. The journalistic accounts suggest what the people in the impacted communities considered important. The accounts of congressional efforts on behalf of constituents and in debating disaster relief policy suggest what politicians and government officials consider important. Author comments (impressions) are added within the Appendix and developed within the text to follow.

C. Criteria for topic review. Many of the concepts developed in the body of this report and observation from the historical records in Appendix I suggested literature searches for work that others have done on noted or related topics. These were pursued in accordance with their relevance and centrality to the magnification processes seen originally or introduced by considerations that came to light during the review of the historical events.

D. Selected review topics. Appendix II abstracts information gleaned from scholarly articles, trade journals, and other literature. The topics searched were:

1. Dam safety.
2. Rebuilding and relocation.
3. Repair cost escalation.
4. Health impacts.
5. Psychological impacts.
6. Preventative response.
7. Disaster planning by businesses.
8. Areal extent of probable maximum precipitation.

IV. PROCESS-RELEVANT INFORMATION

The disaster period was defined above as having three stages. For a dam failure example, the initial impact results as a wall of water roars down the floodplain to bring sudden destruction. An aftermath of economic, environmental, and social interactions add losses in amounts that diminish over time. Recovery processes heal the wounds, gradually at first but picking up momentum over time. Impact, aftermath and recovery processes interact in magnifying disaster loss to catastrophic dimensions.

The synergism seems to be largely a scale effect associated with discrete boundaries as events cross thresholds that change process contexts and interactive dynamics on a time scale. Starting from this hypothesis, the following structure was used to list processes occurring at the property scale, note how those processes are affected by larger scale impacts, and describe the new processes that emerge.

Processes Operating at the Property Scale

1. Health. Disasters take lives, cause injuries, and spread disease. Injuries are concentrated during the event and continue in lesser numbers (as the result of induced accidents or losses of safety) through the aftermath and recovery periods. Disease may be spread by cold and exposure, the spreading of hazardous materials and vectors, or drinking water contamination. Deaths may be caused by either injury or disease; immediately or gradually. Recovery involves rescue of the trapped or isolated, conveyance to places of warmth and safety, and treatment to prevent death and speed recovery to good health.

The physical and psychological shock effect of a quick and unexpected experience on the body's central nervous system reduces human ability to function. The lasting effect of this trauma adds to the losses as victims fail to care for themselves during the aftermath and are less effective in their recovery efforts. The accounts of the Lynmouth flood (Appendix I) describe numerous trauma situations and illustrate some of their impacts.

All of the historical accounts used deaths as the lead statistic in describing catastrophes. Health concerns, associated with contamination of the drinking water and the spread of toxic or disease-laden materials, were also publicized. Study is needed to determine how the publicity works to inspire desirable public caution or to feed fear and add to irrational behavior.

Reported interviews during the aftermath period showed the most severe lingering health problem to be the long term impacts of catastrophe experiences and their consequences on mental health. The losses were intensified by breakdowns in rescue and health services and the depressing effects of losing social support and a familiar physical environment.

Positive health effects occur during the recovery period. A period of major change opens many opportunities that feed optimism and good health. For example, widespread devastation inspired creative reconstruction in San Francisco in 1906 and Lynmouth in 1952.

2. Economic. Disasters damage property and disrupt income from land and capital investments. Cleanup delays add to the deterioration. Individuals with damaged property may do the best they can in the circumstances, restore the property to its original condition, or replace the property in a way better suited to changing needs or more commensurate with the revealed hazard.

Journalistic accounts generally estimated losses as a cost to restore or substitute for lost physical facilities and expressed them in either dollars or as a percentage of building value destroyed, absolute and relative measures respectively. Looting, charlatan help, and reneging insurance companies were noted as adding to the economic loss.

3. Personal. The sudden destruction of a disaster deprives people of many items of personal value that cannot be replaced through the market place. Other items have known or market approximated values but are not replaceable. Still others may be replaceable but beyond the means of the loser. Examples listed in journalistic accounts included table china, diaries, and ledgers of uncollected bills. These losses are less publicized than the first two in contemporary accounts, but they are probably greater than many people indicate publicly. Second to human beings, item of particular personal value generally become the focus of evacuation and rescue activity.

Magnification of Property-Scale Losses by Community-Scale Processes

1. Health. Health losses are increased by interferences with rescue and the efficient delivery of preventative and recuperative health services. Communication and transport interruptions (or disruptions by converging spectators) may delay bringing trained people and special equipment to the disaster scene. Victims are forced to rely on poorly equipped or poorly trained people. Rescue shifts from targeted searches for known people to massive scouting over large areas for cries for help or nameless bodies. The delivery of massive health services is more impersonal and further from the supporting roles of family and friends and thus more depressing to victims who are left less able to make the mental adjustments required for speedy recovery.

2. Economic loss. Aftermath events add to the cost of repair response to catastrophe by interference and delay and thus force people into a longer period of coping that also adds to their losses. Retrospective studies estimate numbers of lost jobs, a loss that is seldom reported in the news accounts because of the difficulty in compiling statistics quickly.

3. Personal loss. Aftermath processes also interfere with the rescue of personal property and consequently add to this loss. The magnification may be greater here because the search and repair will often only be done by the losers themselves, other activities may demand their time, and they may feel unduly stressed by restrictions to their doing so.

Processes Operating at the Community Scale

1. Community Health. Communities, as well as individuals, are characterized by a state of well-being that suffers after major external insults. After a catastrophe, a community (take a person who has lost his health) would devote more time and resources to recovery and function less satisfactorily in normal activities. Market processes may have to be reestablished. Inventories may be destroyed; labor arrangements may be disrupted; and new business enterprises may have to be established. Everyone benefiting from those services would suffer.

2. Community Economics. Community economies also experience damage to the capital investment in their infrastructure. Losses are due to less

efficient operation during the aftermath and recovery periods. Repair (perhaps by recruiting replacement capability from outside) is required.

3. Community Loss. As a third part of this analogy, communities experience loss of things their citizens value collectively. In San Francisco, civic pride suffered with the destruction of "some of the finest buildings in the city." The city, as a place visited, personally or vicariously, lost identifiers of its character that could never be replaced. "The heart and guts of one of the world's best loved cities were gone" (Bronson 1959, p. 83). Some mentioned items were art collections, landmark buildings, and businesses that attracted clientele from throughout California. At the community scale, the process involved sudden damage, continuing loss as the city changed during restoration, and a recovery as a new civic pride grew around the reconstructed city.

Vital and land records were destroyed at city hall in San Francisco. "A thousand tales remain untold. Conflicts in documentation, and there are many, sprang from the fact that a single reporter was physically unable to see more than a tiny part of what transpired" (Bronson 1959). The press responded to public interest in how the rich and famous were affected by the disaster, Enrico Caruso in San Francisco. Human interest stories were also common. For example, six babies were delivered along Market Street in doorways or beneath the trees during the day of the fire in San Francisco.

Additional Processes Observed in San Francisco

The 1906 San Francisco earthquake and fire was by most measures the most severe catastrophe that the United States has experienced this century. The following processes, observed during that disaster period, provide a base for the impact analysis to follow.

1. Personal hardship was expressed in numbers of homeless, losses of and deprivations of basic services such as electricity, water supply, markets for purchasing daily needs, sanitation, etc. Conflicts arose between official efforts to effect orderly occupancy to supply these needs in refugee camps and individual preferences for greater independence by living in scattered shanty towns.

2. Communication breakdown. The interruption of communications with the outside and within the area of impact reduces the ability of relief efforts to concentrate on the right problems and causes tension for family and friends living elsewhere and wanting reports. It restricts the information base available for personal planning by the victims. Within the isolated disaster area, wild rumors begin to spread.

3. Transportation breakdown. Transportation stoppages and delays, frustrate the conveyance of essential food and supplies into the city and the flight of outward bound refugees.

4. Loss of basic infrastructure: water, electricity, health services. Stopping the use of home plumbing and circulating instructions on digging and maintaining latrine trenches.

5. Disruption of special care facilities. Inability to provide normal care for the incapacitated or the incarcerated, the aged or the infirm. Hospitals, prisons, insane asylums, and nursing homes have people who cannot be cared for temporarily or who escape and harm themselves or others.

6. Relocations in different time frames. The general catastrophe scenario is first for people to flee to a place of safety, then to collect more slowly in places of temporary shelter (standards for comfort increase with the duration of stay), and finally to reestablish themselves either at their original location or elsewhere. In San Francisco, transportation breakdowns interfered mostly with getting into and out of the city. With a population of 400,000 left homeless; 300,000 fled the city and about 70,000 of these never returned.

7. Vulnerability. A primary mental health problem was that of individuals surviving the primary event being left "nervous" enough to be traumatized by imagined precursors of repetition. The terror of reoccurrence generates positive feedback loops that adds to subsequent losses. Irrational action can be triggered by minor events.

8. Crime. Fear of looting, hope of being spared at the last moment, and efforts to save valued possessions prevented flight until the last possible moment, and added to the congestion during movement to places of personal safety. A common practice is to bring in the army to provide for the safety of the community, announce stiff penalties (shoot looters on sight), and gradually return responsibility to local officials.

9. Insurance concerns. Some insurance companies treated their San Francisco obligations with contempt. Three European companies denied refused to pay and withdrew from doing business in the United States. Three others settled after arbitrary percentage discounts to all claims.

10. Charlatans. Some vendors took financial advantage of desperate needs (lack of customer protection while law enforcement personnel are diverted elsewhere). Water was sold by the glass. In San Francisco, draymen who had charged $2 per day charged $75 to help people move their goods the day after the earthquake.

11. Health. The San Francisco experience was that the general health of the City was vastly better in the months following the fire compared to what it had been before (Bronson 1959, p. 125). Physically,

a. Many sickly left town.
b. Fresh air and exercise for all.
c. Liquor banned.

Mentally, new opportunities were created for people of vision to make a new city.

12. Expressions of desire to rebuild a better place. This could be as an investment or as an advertisement for venture capital. "We want to be part of the big boom the new San Francisco will have. We believe it will be a better and greater city than ever." "Like a powerful catalyst, the conflagration

quickened the detail of human experience. Simple acts of kindness were framed forever in the City's memory." new friendships. There remained "..the organization of a great city, including the apparatus of government and business, families, traditions, reputations, credits, and established relations with the rest of the world."

13. Corruption. The greed of corrupt officials and the San Francisco City Hall grew. Property owners paid under the counter for permits and inspections. Top officials were convicted and sent to prison. "Its housecleaning was as thorough as its physical cleaning by fire. A new clean government came to power" (Bronson 1959, p. 180).

V. PROCESS ANALYSIS.

The above evidence leaves no doubt that economic, environmental, and social values are magnified at property, community, and regional scales. The descriptive information in the appendices gave a good starting point for examining synergistic interactions and hypothesizing magnification processes.

The process analysis sought guidelines for defining thresholds between scales. These vary among the goals. An environmental super catastrophe may be only a mild economic disaster. The threshold depends on the size of the interaction arena with respect to the goal. For example, economic man interacts in the market place, species interact in habitat units, and people interact in social groups. Consequently, a threshold depends on impact magnitude relative to the relevant arena.

A. Classification. The reasonable starting assumption is that different types of damage vary greatly in propensity to magnification; consequently, one must know the types of damage occurring in order to make a reasonable magnification estimate. Orderly assessment requires a damage taxonomy that can be used to identify locations whose scaling effects are important. One can then systematically review damage types, explore processes, and approximate amounts of magnification. This section presents a trial taxonomy and then uses it to structure the following process analysis.

The taxonomy begins with the economic, environmental, and social, values expressed in goals G1 through G10. Other dimensions with potentially significant influences on impact are:

1. Property type: homes, industrial or commercial buildings, landscaping, agriculture, public and critical facilities, and hazardous materials are distinguished because of differences in the made and urgency of repair.

2. Property ownership: public, private, or corporate are distinguished because of differences in values served and resources available for restoration.

3. Response approach:

a. Restoration (more common for the affluent). The owner who repairs his property to a pre-catastrophe condition or replaces it in kind judges that the value retrieved justifies the cost.
b. Replacement (more common after larger events). Some owners replace damaged or destroyed property with a different design as an altogether different use than was there before.
c. Coping (more common for the poor). Other afflicted simply do the best they can in their circumstances because they cannot or do not find repair worthwhile. Here the damages are the costs of coping and other losses found in G2 through G10.

4. Indirect (technological external effects) and secondary (pecuniary external effects) impacts.

B. Analysis of Processes in the Economic Domain.

G1: Economic Value.
The flood wave resulting from dam failure causes massive destruction. Pate-Cornell and Tagaras (1986) used damage ratios estimating destruction of 90 percent of the property on the path of the wave and 10 to 15 percent in inundated backwater areas. Refinement of the analysis to map the severity factors and property-scale occupancy would give more reliable results.

A catastrophic dam break above a laterally confined floodplain would cause almost total destruction in the path of the flood wave at the property scale. Lesser losses would occur in tributary backwaters and after wave dissipation downstream. At the community scale, the damage ratio would depend on community juxtaposition within the floodplain but would be unlikely to approach 90 percent. Consequently, one tends to be dealing with complete destruction at the property scale and partial loss at the larger scales.

Where the destruction is complete, losses encompass the costs of relocation to a new site, the extra cost of temporary occupancy of the less favored location, restoration of the destroyed property, and return. Where the destruction is partial, the loss covers the costs of coping with the impaired functioning and repair. All of these costs may be increased by aftermath interferences.

The impairment may be worsened by deterioration during the aftermath period. Rapid salvage can recover some lost items, rapid cleanup stops the deterioration and thereby reduces repair cost, and rapid repair reduces lost value from property investment. Capacities for cleanup and repair are themselves impaired by the event and overloaded by the work to be done. The overload causes the demand to exceed the supply and raises costs. Capacities may be augmented by emergency help (but emergency help is notoriously inefficient) and are gradually restored as firms are reestablished and the backlog dwindles.

Income losses are important for agriculture and business, but most damage estimates are based on the purchase of repair services or replacement items in the market. Economists place a normative value on market prices where the transactions are too small to exert influence. However, a major catastrophe places a sudden demand that may exceed normal market transactions over a period of several years while simultaneously greatly reducing the capacity of suppliers to respond.

Some sort of dynamic economic model would be required to predict prices and assign normative values in this situation. Certain production segments may experience temporary large production reductions, and transport systems may not be able to make up the difference through importation. Baecher, Pate, and de Neufville (1980) suggest input-output analysis in the dam-break context for assessing intersectoral impacts (the secondary effects of losses in one production sector on others), but available models will not be reliable where the disaster is large enough to alter the matrix coefficients. Furthermore, the analysis would have to be on a time scale much shorter and with much greater market instability and uncertainty than assumed for most economic models.

Specifically, disasters add demand for repair and replacement items and reduce the ability of suppliers to provide them. The scale dimension to watch in determining whether to expect magnification would be the capacity of the suppliers serving the victims relative to the demand triggered by the event. Assessment is complicated by the variety of relevant capacities.

For example, economic loss is magnified by factors inhibiting rapid salvage of items that would otherwise become lost and rapid cleanup of possessions that would deteriorate while buried in mud and water or otherwise exposed to the elements. Cleanup delays add substantially to repair cost for damaged properties. Cleanup requires access to special supplies, but the labor is generally not handled through market processes. The labor cost can largely be considered a loss in "real income" and will be considered more in that section.

The principal process observed as causing repair cost magnification was the insufficient capacity of the regional construction industry to undertake the desired repair. Donations and relief measures help but are seldom efficiently directed. The impact may be reduced by importing workers at added cost. Individuals pay premium prices for quicker repair, added magnification occurs because the premium prices entice charlatans installing shoddy materials with inexperienced labor as well as crooks extracting payment but doing little if any work. The cost of second "repairs" adds to the loss.

Probably the best data source for examining additional processes during super catastrophes at the regional scale is the San Francisco earthquake and fire. That event generated a national relief program, vast refugee camps, massive resettlement of the working class into nearby cities, and housing reconstruction for over 500,000 people. While construction, communication, and transportation systems have advanced greatly over the last 80 years and the sparse numerical data cannot be used directly, the situation provides a reasonable starting point for conjecturing how similar devastation would be handled today.

Part of the rationale used for employing risk analysis in the economic evaluation of large public projects is that the collective risk aversion approaches zero for losses shared among large numbers of people (Baecher, Pate, and de Neufville 1980). However, even thought many people are impacted at the property scale, few communities are involved. One must consider risk aversion at the community scale as contributing to damage magnification.

A rich literature has recently been developing on applying the "contingent evaluation method" using questionnaires and related perception probing to estimate willingness to pay for items that are not directly evaluated by market processes (Cummings, Brookshire, and Schulze 1986). For example, Brookshire, Eubanks, and Sorg (1986) conclude their assessment of application of the concept to environmental evaluations by doubting its reasonableness because expressed environmental goals conflict with the assumptions of economic efficiency. An even larger limitation to application to environmental and social catastrophic impacts is that it relies on perceptions where the population at risk is poorly informed on the physical consequences of a major dam failure. One way, however, to address this difficulty would be to develop a computerized graphical display capability that can effectively convey dam-break flood hazard.

Process Review: Yancey et al. (1976) examined data on repair costs following a number of disasters and found magnification where the total damage exceeded the annual construction volume within an Economic Area defined by the Bureau of Economic Analysis but not in cases experiencing lesser damages. The largest quantified magnification was fourfold in Wilkes-Barre, Pennsylvania, following Hurricane Agnes when the ratio of normal repair cost to annual construction capacity reached 9.1.

The Yancey index gives two important dimensions for measuring capacity in the economic domain; a spacial dimension defined by the size of an economic trade area and a time dimension of one year. In this ratio, the economic trade area scales the community in which people interact in buying and selling goods and services. The year is an approximation of the maximum acceptable repair period. It is also the time unit used to report personal and business incomes.

In addition, the Yancey index provides a basis for hypothesizing thresholds for the other goals. Specifically, one can hypothesize that the threshold to use in going from the individual scale to the community scale should be based the domain in which individuals interact relative to the goal at hand. The index would then be the ratio of the impact of to the period of time required for the disturbed domain to effect recovery.

The magnification of economic loss is also important for financial (insurance) planning because of the impact on budgeting (settling claims). The benefits to be achieved by reducing magnification suggest additional possibilities for relief programs: after a catastrophe, victims would gain substantially from programs to sustain the delivery of goods and services at normal prices (prevent price gouging). Programs providing free repair (where government must often absorb very large price gouging) have become counter productive because they do not have price as either an allocation vehicle or as an incentive to consummate delivery. Programs for brokering repair services (providing information on vendors and costs) and facilitating the movement of temporary repair capacity into an area (whether governmental or industrial) should also be given greater attention.

The above analysis deals with repairing to restore a property to meet the income-generating and personal needs of an owner or manager. When one scales upward to the community level, one enters the domain of repairing to restore the ability of local business and government to serve public and civil needs. The repairs should restore facilities, replenish stockpiles, reestablish communications among buyers and sellers, and reinstate transport systems for goods and people. Civil needs encompass cultural and recreational items. Catastrophic damages encompass the costs of restoration and the losses suffered through market inefficiencies during the recovery period.

Occasionally, the destruction may be so large as to necessitate the replanning and reconstruction of large urban areas. This changes the mode from the relatively expensive repair of individual properties to mass construction and offers the potentials of a better planned community, more modern (disaster resistant) design, and urban renewal. However, dambreaks are too rare for flood proofing investment against reoccurrences to have much economic value.

Property Type. Magnification can be expected to vary greatly among property types because they differ in the activities involved in repair or replacement and the activities vary in the market factors influencing cost escalation. The analysis by Yancey et al. (1976) concentrated on buildings. Building repair magnification is probably greatest for residences and small commercial buildings where the owners have least experience in procuring least-cost help repair markets. The repair of larger buildings requires specialized equipment (probably drawing from a larger economic area) handled by owners with special resources. Agricultural and landscaping damages are probably less subject to magnification as owners either suffer losses or delay repairs. Infrastructure repair cost escalation is tied to the in-house repair capacity of the concerned utilities and mounts when local entities must contract with external sources. The costs of emergency repair of critical facilities or protecting the public against hazardous materials are particularly magnification -prone because quick action is required in a framework where cost is no object.

Responding Institution. Individuals, public entities, and companies vary greatly in their repair resources. Individuals are probably the most dependent on local markets, and large corporations are the most likely to draw resources from other locations. Public entities can usually obtain help from state and federal governments when events reach catastrophic proportions (but may feel pressured by the long time lags involved). The socially disadvantaged may be poorly informed as to help alternatives and needlessly do the work on their own.

Response Mode. Greater pressure for quick return magnifies the economic losses because repair is forced before the market can develop new channels to supply necessary goods and services. The replacement mode works to reduce costs because of the economics of mass construction and the advantages of more efficient design. Cases where victims cope with the losses have little economic magnification, but their social magnification may be quite large because of the burden placed on the poor and socially disadvantaged.

Indirect Impacts. Dealing with the losses caused by catastrophe detract from productive activities. The users of output from the local economy experience losses, delays, and higher prices. The largest indirect impacts are probably associated with firms withdrawing from business and local governments discontinuing services. After Agnes, one Pennsylvania community advertised to attract replacement businesses.

Followup. The magnification and higher-scale processes outlined above are important enough to deserve research attention. Some topics that should be particularly pursued are:

a. More precise estimation of construction capacity by activity type.
b. Inventory and analysis of impacts at the community scale requiring restoration.
c. Analysis of urban renewal experiences as a guide toward efficient community restoration.

Analysis of Processes in the Environmental Domain.

G2: Ecological Value.

One may question the existence of ecological damage on the grounds that floods, as fires, are recognized by ecologists as having a "cleansing" value. Dambreak floods, however, occur at sizes, times, and places that nature cannot produce. Ecological loss has been indexed (James et al. 1978) by the time period required for natural recovery to pre-event positions. One would definitely expect scaling magnification of the recovery period as destruction areas increase from scattered plants and animals (replaced rapidly), to habitats (taking years to restore), to species (beyond restoration). For threshold scaling, the spacial dimension would be relative to the geographical area occupied by a habitat, and the time dimension would relate to the duration of flooding required for a given habitat to be destroyed. One would only expert large ecologic magnification in ecologic areas positioned to be entirely disturbed by the flood.

Process Review. The above construct of economic loss can be integrated with general environmental information as a starting point for assessing the effect of catastrophe on loss in environmental value. A disaster may cause massive ecological disturbance. Aftermath and recovery processes are largely biological. Analogy with the economic domain leads one to hypothesize that environmental magnification occurs when local environments are disturbed to a point where important species must migrate back from a distance. This conceptualization requires measurement of the extent of a habitat in terms of the area of easy species movement and interaction.

Environments, like market areas tend to organize in "self-contained" units. Swamp, riverine, and alpine environments are examples. When the ecological disturbance is surrounded by its parent "unit," recovery should be relatively rapid (albeit variable with the type of unit and the extent of the disturbance just as economic repair costs). When the disturbance alters the entire unit beyond its ready restoration capacity, higher scale processes come to the fore.

Annual cycles probably pertain to species as well as economies because of the periodicity of the seasons. The ecological momentum of destructive processes through an aftermath period deserves further study. Recovery could be speeded by enhancing known contributors on the critical path toward ecological recovery.

Species Type. Recovery time varies over the impacted species and the interdependencies among them. The greatest magnification would occur with rare or endangered species, because they both draw from a smaller replenishing resource and the factors causing their numbers to diminish also slow recovery.

Responding Institutions. Natural environments recover through natural processes, but these can be enhanced or delayed by human intervention. The modern world also contains many imported species in "gardens" that must be carefully maintained to survive. A catastrophe would interrupt maintenance of these entities.

Response Mode. Natural biological processes doubtlessly vary in their resilience after disruption. They could be analyzed for important differences should a case arise where the issue deserves the research effort.

Indirect Impacts. The catastrophe diverts human effort from environmental maintenance, and reconstruction activity may cause environmental harm during the reconstruction period. Species not directly impacted by the flood could be affected indirectly through their food chains.

Followup. While these relationships contain interesting aspects, losses in ecological and other environmental values were given less attention in this study because of the a prior judgment of lesser importance as dam-break consequences. Ecological impacts are probably small except in local situations with specific problems. Any future studies should identify and concentrate on these.

G3: Aesthetic Value.

A catastrophe inflicts tremendous aesthetic loss. Reconstruction activity could add to aesthetic disturbance during the aftermath period. Aesthetic recovery would occur as reconstruction is completed and vegetation returns.

Process Review. Magnification would be associated with slower recovery when the devastation is more widespread. It would be reduced to the degree that collective personal preference begins to accept the changes in appearance. One would expect the scaling dimension to be related to the area that can be seen by eye from vista points.

Attraction Type. Attractions can be ranked aesthetically with the most attractive being the most vulnerable to damage and the least attractive being cases where removal would be an aesthetic gain.

Responding Institutions. Property owners who are particularly slow to repair damages property or landscaping may leave aesthetically displeasing reminders of past disasters.

Response Mode. Both human restoration and natural processes work to the aesthetics of damaged areas.

Indirect Impacts. Aesthetic disturbances may became a sign of urban blight or, worse yet, generate adverse reaction psychologically in people who associate them with unpleasant memories.

Followup. The effects identified above seem too small, compared with other losses, to devote much attention to estimating scale effects on the aesthetic damages from dam-break catastrophes. However, the psychological impacts of aesthetic deterioration is one topic that may deserve some study.

G4: Historic Value.

Individual sites of great historic, cultural, or religious value could be ruined by a major flood. One would not expect nonlinearity in summing losses over multiple sites. Magnification, however, may be more important when considering the impacts of losses of non-replaceable historic, cultural, or religious attributes of sites on the well-being of the community.

Process Review. Catastrophic conditions could have an important impact in preventing recovery and cleanup of salvageable items after a disaster. One reason why historic loss magnification is probably not important is that a restoration can reestablish general public satisfaction as was found in Europe after World War II.

Site Type. Historic value is concentrated in a few properties which become honored by antiquity or associations with particular events. The potential for loss magnification is probably tied to the relative importance of artifacts and the interference that catastrophe would pose for their recovery.

Responding Institutions. Sites of particular historical value are generally either owned by a public agency or historic foundation. A catastrophe is likely to pose many other restoration costs to these entities. A greater popular urgency for many of them may delay restoration activity for the historic sites and add to their loss. An offsetting factor may be that major losses may have sufficient national interest to be covered through financial appeals.

Response Mode. Restoration to original conditions requires specially trained labor, and obtaining it may cause significant delays. However, the more relaxed time frame should further reduce any magnification effect.

Indirect Impacts. Major historic sites have particular attraction to some individuals who in turn feel a major loss. The long term loss to future generations of lost contact with their heritage may be particularly important. In another dimension, tourism could be adversely affected.

Followup. Nevertheless, as an initial judgment call, this goal is probably of lesser importance for this study. The magnification of historic damages does not deserve further study other than for the possible goal of identifying and watching particularly noteworthy sites in hazard areas.

G5: Scientific Value.

Scientific loss would be caused by the destruction of data sources, experimentation, and information of scientific value.

Process Review. Neither scientific loss nor its magnification was mentioned in the popular descriptions of any of the cases reviewed. In some cases, a catastrophe could destroy major stashes of information of lasting scientific value, but losses to study areas or scientific equipment are seldom significant. On the other side, observations of catastrophe have important values, both scientifically and through their contribution to reducing future losses.

Site Type. Scientific value is concentrated in a few storehouses of rare information. Each is unique, and unique sites have less magnification potential. One would, however, store such items out of risk areas.

Responding Institutions. Scientific work is largely performed by corporations, governmental research units, and universities. All these institutions could suffer financial and personnel impacts that slow cleanup and restoration.

Response Mode. The normal immediate response mode would be to reorganize scattered information and restore experimental areas to the degree possible. Society may lose by being deprived of valuable knowledge, but this impact is generally small.

Indirect Impacts. Any loss or delay in application of important scientific information has ripple effects on potential users throughout society. Corporations could potentially suffer a major blow in product development. These impacts would be important were there evidence of significant losses.

Followup. Since scientific activity involves worldwide interaction, disruptions must be at a very large scale, and scientific damages were judged not to merit immediate further study.

G6: Pristine value.

A dambreak would scar a pristine environment; however, pristine environments are already altered by flow regulation below dams. Consequently, one would scarcely expect this goal to be important here.

Process Review. Officially-declared wilderness areas are unlikely below major dams. Individuals may consider certain smaller areas as pristine and derive the enjoyment value from them that others attach to wilderness. The loss of a pristine are would not be recoverable and thus not subject to magnification.

Site Type. Pristine areas vary considerably, and their differences should be considered in assessing the loss caused by catastrophe.

Responding Institutions. Responsible organizations may become involved in protecting pristine areas from further deterioration or attempt to restore impacted areas. These efforts could also be impaired by events reaching catastrophic scale.

Response Mode. The response combines protection from further deterioration and bearing the loss. The long time lags and the unique attributes counter any magnification.

Indirect Impacts. The primary loss lies in the meditative and recreative values of pristine areas.

Followup. Several potential impacts are noted above, but further study is not judged warranted for any of them.

D. Analysis of Processes in the Social Domain.

G7: Real Incomes.

Disasters impact people in many ways not covered in monetary value, and the magnitude of these losses led this study to devote considerable effort to identify and classify losses that people feel keenly. Secondly, people vary considerably in ability to cope with catastrophe. The literature records correlations with income and sex. The poor place greater reliance on social resources in coping whereas the wealthy depend more on economic resources. The poor worry more about job losses, and the rich more about business losses. Where the social resources are important, the scaling would be expected to depend on the size of the impacted area relative to the area occupied by the reinforcing social community.

Process Review. The case studies showed a wide variety of losses in real, as opposed to monetary, income. These were classified among disturbance of social reinforcing, interruption of personal time, unpleasant personal experiences, loss of community services, and loss of personal property. Losses in these six classifications involves distinctive processes as outlined below.

Social reinforcement contributes to human mental well-being by the support and presence of family, friends, and other kindred spirits giving help and fellowship. A large event separates people from these social resources. The aftermath period is one of growing fear and perhaps substantive information that key relationships will never be restored. Recovery occurs with the restoration of original relationships or the establishment of substitutionary ones. Social reinforcing takes place in several dimensions (family, neighborhood, and organizational memberships) and at several levels (local and regional). Quantification is very difficult, but the impacts of losing social reinforcement are believed subject to intense magnification because the important relationships can be confined to a small region that can suffer very severe impact (e.g. Buffalo Creek). Consequently, a smaller event can reach catastrophe classification.

Time interruptions provide a second major component of personal loss. Countless hours are spent in flight, making temporary arrangements for work and living, cleaning and restoring damaged property, and countless other unfamiliar and disturbing activities. The burden is particularly felt by busy people, even when people can be hired to do the manual work. This loss is also subject to major magnification because larger events scales spread people over larger areas and greatly complicate the arrangements. Frustrations add aggravation and can harm health in severe cases. Recovery occurs with the restoration of comfortable activity patterns.

Third, the many unpleasant experiences people suffer during a disaster event have many short and long term sequences that cannot be assigned a monetary value. These can have either physical or mental causes. The former can stem from exhausting over-activity and exposure to dampness and cold during the event and the physical discomforts of living in makeshift facilities afterwards. The mental anguish grows out of the shock of seeing possessions lost, homes destroyed, and the injury or death of friends and family. During the aftermath period, people relive their experiences over and over. Opportunities for conversations may gradually build therapeutic effects. These losses are also subject to severe magnification because physical and mental experiences largely relate to the area within walking distance of one's home. People who are temporarily visiting the impact area or have just moved into it probably feel less mental anguish.

The fourth identified loss in real income occurs as people lose the accustomed continuous ready availability of electricity, phones, streets, water and sewer, libraries, etc. They suffer when these are not available. Again magnification begins at a small scale, but probably larger than a local neighborhood. People do not mind nearly so much when their phone is out and they can walk across the street and use a neighbors as they do when all the phones are out. Aftermath effects occur as a consequence of people going to extra expense or suffering losses during the period of disconnected services. Recovery generally comes quickly after services are restored. Magnification comes as larger events extend the period of service interruption.

Fifth and finally, personal losses are important because many people view the loss of personal treasures and records that have little value to others as the largest damage that they suffer. Possessions are generally of unique value to specific individuals. Consequently, their loss is probably not subject to significant magnification beyond their additive value. However larger scale events can separate individuals from their possessions for larger periods and cause added loss by reducing recovery percentages.

Social Group. A second component of the analysis required to estimate losses in real income is to examine the distribution of these five classes of losses among social groups. The magnifications will depend on how the various losses are distributed among people with different coping capabilities and how the event and its aftermath have underlined the capability. Groupings are by income, sex, ethnic group, and social contacts. The literature, both experimental and scientific, show most of the five classes of loses listed above to vary with social grouping, closely knit local communities are particularly sensitive to social disruption. People with a wider variety of contacts are in a stronger position.

The loss of time seems most important to the particularly busy. In contrast, the poorer and less educated feel greater discomfort or even trauma at having to deal with unfamiliar situations without many of the coping mechanisms available to the more affluent. Consequently, the disadvantaged are more intimidated by the repair process. On the other hand, the middle and upper classes probably feel the loss of services and personal property more intensely; but they are better able to recover by going elsewhere or finding substitutes.

Responding Institutions. Governmental, charitable, religious, and fraternal organizations provide a great deal of support to help people during the aftermath and with the recovery from catastrophes. Communities face intense pressure from the catastrophe-induced demand for emergency services and temporary support functions. Simultaneously they face large expenditures in restoring basic services at a time when their own losses may have crippled their effectiveness. The nongovernmental institutions vary greatly in effectiveness. They work best in helping people with whom they were more closely identified before the event and generally suffer from acting more in response to outside perceptions than real local needs. Many of these activities are delayed by larger scale events to augment losses.

Response Mode. People establish new contacts for social reinforcement needs. They have few ways to salvage lost time and continue to feel the pressures for an extended period. Unpleasantness and personal losses probably harm morale and reduce the will to recover. Community services are repaired as quickly as possible with the cost being aggravated by the demands for additional help.

Indirect Impacts. The burdens that people feel personally detract from their ability to function. At the community scale, the event reduces institutional ability for effective performance and compounds the problems as disturbed people become a larger percentage of a community's population. The effects at both scales impact many people that were not harmed directly.

Followup. Of the ten goals, real income losses probably have the largest magnification, and the amount would be particularly large where the geographical area occupied by the community is small and concentrated in the floodplain. Real income impacts are the least studied but probably account for the most severe flood damage magnification. A great deal of attention should be given to studies to understand these processes and their impacts better. Specific priority research topics include:

a. Longitudinal recording and assessment of the five identified impact processes.
b. Clinical examination of the capabilities of various social groups to coping with losses.
c. Longitudinal study of community-scale performance i providing goods and services, both those commonly delivered by the public sector and the food and shelter more commonly purchased in the market place.
d. Hypothetical assessment of how these performance indicators may operate at the regional scale.
e. Studies to develop relief programs that more effectively meet basic identified needs.
f. Development of programs providing psychological treatment for risk groups who are less able to cope.

G8: Health.

Loss of life and health is the most publicized impact of catastrophe and another one expected to have a major scale effect. A community can absorb a few deaths more easily than the loss of large segments of its population. The loss of life may be increased when the number injuries exceed the treatment capacity of local health services. Living through a catastrophe impacts mental health.

The flood wave resulting from dam failure can take large numbers of lives. Pate-Cornell and Tagaras (1986) used a casualty ratio estimating the loss of 50 percent of the population in the path of a flood wave such as the which occurred below the sudden failure of Malpasset Dam in France in 1959 when no warning was possible.

<u>Process Review.</u> The headlines generated by natural catastrophes emphasize loss of life and numbers of people injured. Floods have an added health impact because they occur in inclement weather, expose people to the cold and wet, and cause many to become ill. Protection of life and health is the primary objective of emergency teams during major events.

The catastrophic events leaves many dead, injured, or trapped at locations requiring rescue. During the aftermath period, lingering threats to heath are found in contaminated water supplies and toxic materials carried into living areas by the floodwater. Some noted problems included raw sewage, hazardous chemicals, and insects.

Local health officials should continue their emergency activities until these situations have been rectified. However, this sustained capacity to operate on an emergency basis may be lacking, particularly when many of the required activities are outside the comfort area of the employees.

The added pressures and consequent exhaustion may add to the health problems of this group.

However, records also show a strong counter force that brings out the best in people. The challenge and the sense of helping through the results achieved by extra effort is a positive morale builder and has strong beneficial efforts.

The principle used in assessing damage cost magnification also seems to apply to health losses; however, the size of the health-care region and the time scale used to index capacity are both smaller than the market areas used in damage analysis. Hospital service areas are much smaller than the BEA regions, and the time period for initial treatment is no more than a few days. Both compressions would add to magnification. Fortunately, severe tests of community health care capacity are rare, but a more thorough search of the literature may uncover useful information.

The published reports on disaster-impacted areas suggest consequent mental illness to be as widespread and as severe as physical problems. Obviously, catastrophe experiences generate considerable trauma among survivors. Memories may bring intense guilt at not having saved someone or something or otherwise acted more rationally during the emergency. This hypothesis is reinforced by records of damages magnified by irrational actions.

Fear lingers in the hearts of people who have experienced the trauma (and aftermath) of a major disaster. The ability of a community to act effectively is reduced by irrational fears. Lesser fears can be expected among people living downstream from other dams. Any exodus would trigger economic deterioration. These effects have been noted at the community and regional scales after major wars. At the national scale, such fears would hamper the entire water resources program.

<u>Social Group</u>. The primary criterion for dividing people among social groups with respect to analyzing health impacts is differences in susceptibility to death or physical or mental illness. Certainly, age and general health prior to the event are important. Income and other social attributes may affect propensity to secure professional attention and proper medication.

<u>Responding Institutions</u>. Public, private and philanthropic rescue activities are widespread after a major disaster. Their primary goal is to reduce the loss of life and quickly provide people with medical attention to minimize adverse effects on their health. Rescue is also capacity limited, but the capacity can be significantly increased through emergency preparedness efforts. As a disaster moves into the community-scale, increasing interference and inefficiencies in this mobilization adds to the losses. These aspects of catastrophe deserve more attention.

Health care also encompasses treating people during and immediately after the event and continuing services, particularly in the mental health area, for sometime afterwards.

Response Mode. People unable to obtain health care when needed may suffer lingering or even permanent effects.

Indirect Impacts. People whose health suffers are a productivity minus that lasts for a long time both as it affects individuals made less productive. Also the burden on health care facilities renders people in the community with ailments unrelated to the disaster receive worse service.

Followup. The impacts of catastrophe on mental health are particulary deserving of further attention. Other studies are needed to pursue health care capacity, the impacts of its limitations, and how it can be most effectively augmented on an emergency basis.

G9: Educational Opportunities.

Educational and recreational opportunities would certainly be interrupted by a catastrophe, but no descriptions of the historical events showed the impacts to be either a major or subject to significant magnification.

Process Review. Provisions can be made for both activities on a temporary basis after a catastrophe. At the regional scale, a super catastrophe may begin to cause significant educational impacts.

Social Group. Less mobile social groups would feel these losses more strongly.

Responding Institutions. A burden would be placed on the community to restore these facilities, but the time frame would not be so demanding as to cause a major cost escalation problem. Public schools, governmental recreation facilities, private schools, and privately-owned entertainment centers would all be impacted to varying degrees.

Response Mode. The community normally acts to restore basic educational facilities quickly. People can improvise with respect to recreation, and this has not been noted to cause a problem.

Indirect Impacts. Minor.

Followup. After a dam break flood, schools would be closed, and recreational activities would be altered. However, quick recovery would generally occur. The losses are not anticipated as a major factor in magnification. Little reason was uncovered to give priority to studying this aspect further.

G10: Emergency Preparedness.

For this study, the catastrophe is the emergency requiring preparedness and police protection. One could examine the impact of one disaster on the ability of the community to cope with additional ones (simultaneous earthquakes, wars, etc.); however, these joint probabilities are low. A catastrophe necessitates the immediate police problems of protecting property from looting and maintaining order among crowds who may become desperate for food and shelter. Emergency preparedness also covers evacuation, temporary shelter, and orderly return. One suspects that these needs are not met efficiently during catastrophes and that these needs multiply as one goes to larger events.

Process Review. Prompt emergency action by local officials to deal with catastrophe can substantially reduce losses of life, economic damage, and adverse social impacts. People expect direct help during the event as well as protection of their personal safety and property during the aftermath period when they lose control over their personal "territory." However, looting (whether by hungry people looking for food or criminals stealing for profit) has generally not been as common as people feared.

The capacity of a community to provide emergency comes first. Warning and evacuation systems may become nonfunctional during major catastrophes. Over a longer period, shelter, services, and jobs must be found or people will move away to find the necessities of life. Forced moves are traumatic situations and become more so for a socially self-contained community or should the relocation become permanent.

Dams are overtopped by major hydrologic events. A meteorological event large enough to overtop a dam will probably cause prior widespread flooding below. Evacuation routes may be flooded before they are needed. Depth-area-duration curves can be used to examine the extent of such storms and plan emergency actions in the context of likely interference from simultaneous events.

Quickly assembled emergency help is notoriously inefficient. They don't know what to do and may alienate the local population by their ineptness and attitude. A larger problem lies in the fact that catastrophes are too rare for really experienced people to be active. A larger event adds to the number of people to be directed, and the added congestion becomes a considerable magnification factor.

Social Group. All social groups become more or less equal during the period of flight before pending catastrophe. The primary differences would be in recovery time where groups with more money or better contacts come out ahead.

Responding Institutions. A catastrophe places a sudden large burden on a wide variety of local governments and corporate and organizational entities. Many individuals prefer to go it alone and resent outside interference. Where an agency's response capacity is exceeded, it will have trouble acting effectively and could add to rather than reduce the losses.

Response Mode. The normal response is to quickly mobilize a program of rescue, supervised flight, temporary food and shelter, and repair assistance. One suspects that the capacity of the typical system is small, and that magnification of losses caused by performance inefficiencies begins with a fairly small event.

Indirect Impacts. Many people are harmed by the mass of fleeing refuges.

Followup. Study is needed for improving the effectiveness of emergency response. Most communities below major dams have a general program. They are unlikely to be specific enough to function well during a moderately sized disaster; and one can particularly doubt their effectiveness during a really large event. Many of the above descriptions give good advice on improving them.

VI. FIRST APPROXIMATIONS OF MAGNIFICATION MAGNITUDE

A. Principal Processes. Based on the above analysis, nine principal process arenas were selected as generating damage magnification (Table 1). The amount of loss growing out of that damage is determined as people choice between an active response to restore prior conditions and or passive acceptance and suffering losses over time. Certain choice determinants are hypothesized on Table 1 as determining whether a person responds actively or passively. The introduction of community-scale impacts depends on the size and juxtaposition of the disaster event and a measure of impact within that community. Judgments on these factors with respect to the 9 identified processes are listed on Table 1. The processes in all nine arenas operate in event, aftermath, and recovery time frames.

The interactions within and among these arenas may be represented by positively and negatively reinforcing feedback loops. Sorting out and quantifying these processes and simulating their collective impacts would require a research effort far beyond the scope of this study.

B. Magnification by a "Worst-Case" Scenario. If one orders the degrees of catastrophe in terms of deaths, Ayaswamy et al. (1974) estimate that 200,000 fatalities could result from a dam break failure is in the order of 1000 times the number caused by Hurricane Agnes (less than 200) or any other natural disaster ever experienced in the United States. Pate-Cornell and Tagaras (1986) reports the Auburn Folsom-South Central Valley Project review as stating that the collapse of a full Auburn Dam would imperil the lives of 750,000 persons in Sacramento. Such an event would far surpass all the catastrophes reported in the historical data and introduce interactions at the larger regional scales.

The scale effect of moving from personal interactions to community market and social interactions (given the above assessment that the environmental interactions are of relatively lesser importance) would be followed by movement into far reaching impacts on the economy, institutions, and politics. We can, at this point, only speculate on the impacts of an "Agnes Scale" catastrophe and then a "Super Dam Failure Catastrophe." Nine principal magnification processes are outlined on Table 1. The active sub-processes under each heading during impact, aftermath, and recovery, are outlined in Table 2. Hypothetical consequences of expansions to larger scales are listed in Table 3.

McCann et al. (1985) provide an approximate method for mapping the severity of flooding that would be caused by a dam break flood and estimating economic loss and the loss of life. While the scope of this project did not

Table 1. Hypothesized characterization of principal processes contributing to damage magnification.

Process	Active Response	Passive Response	Choice Determinant	Community Unit	Impact Measure
1. Disruption of repair and replacement capability	Repair cost escalated	Prolonged coping	Income, time adversion	Economic trade area	Annual construction capacity
2. Disruption of support from social group	Cost of community reestablishment	Prolonged coping	Cohesiveness, leadership	Gross residential area for social group	Percentage moved outside gross area
3. Disruption of personal time	Hiring special help	Prolonged coping	Income, ability, free time	Local service area	Monthly service capacity
4. Exposure to disturbing experiences	Flight, isolation	Shock recovery	Mobility	Residential territory	Percentage afflicted
5. Disruption of basic community infrastructure	Cost escalated reprovision, emergency and long term	Community coping	Revenues adversion	Utility service area	Annual repair capacity
6. Loss of personal property	Salvage substitution or replication	Pining	Imagination and resilience	Residential territory	Completeness of destruction

Table 1. Continued.

Process	Active Response	Passive Response	Choice Determinant	Community Unit	Impact Measure
7. Disruption of health care services	Cost escalated reprovision, emergency and long term	Transport elsewhere, community coping	Revenues	Hospital service area	Daily treatment capacity
8. Deterioration of mental health	Professional treatment	Prolonged coping	Income Family support	Gross residential area for social group	Monthly treatment capacity
9. Inefficiencies in emergency services	Planned program improvement	Delayed help	Revenues Expertise	Political entity	Daily service capacity

Table 2. Hypothesized time frame expansions for principal magnification processes.

Process	Impact	Aftermath	Recovery
1. Disruption of repair and replacement capability	Equipment destruction Labor disruption Transport interruption	Deterioration during restoration delays Enticement of poorly qualified	Equipment replacement Labor reorganization Transport restoration Capacity importation
2. Disruption of support from social group	Death and illness Group scatter	Lingering illnesses Mental disorientation	Group restoration Establishment of a new group
3. Disruption of personal time	Activity diversion	Management time	Problem solution
4. Exposure to disturbing experiences	Scenes witnessed Separation from loved ones	Poor decisions Absence from work	Health restoration
5. Disruption of basic community infrastructure	Disrupted services	Extra cost and worse service from temporary facilities	Restoration of normal service
6. Loss of personal property	Destruction or loss of personal effects	Additional loss or deterioration pending reestablishment	Psychological substitution, Physical replication
7. Disruption of health care services	Harm to facilities Injuries requiring treatment	Extra cost and worse service from temporary facilities Treatment for lingering cases	Facility restoration Return to normal community health
8. Deterioration of mental health	Fears growing out of scenes and separations	Continuing mental illness Reinforcement by more bad experiences	Return to normal mental health
9. Inefficiencies in emergency services	Disturbed preparations Interfering inclement weather	Inefficiencies in community shelter and restoration services throughout disruption period	Restoration of normal services

Table 3. Hypothesized scale expansions for principal magnification processes.

Process	Personal Scale	Community Scale	Regional Scale
1. Disruption of repair and replacement capability	Building and grounds damage	Disruption of local economy	Disruption of regional economy
2. Disruption of support from social group	Isolation from social group, personal injury	Scatter of social group	Disruption of social organization at the scale
3. Disruption of personal time	Mandatory personal time commitments	Mandatory activities for community employees	Management of regional recovery programs
4. Exposure to disturbing experiences	Personal encounters	Community failures to supply basic needs	Regional failures to support communities
5. Disruption of basic community infrastructure	Loss of community services	Loss of utility facilities	Breakdown of regional communication and transportation
6. Loss of personal property	Heirloom loss	Disruption of substitution opportunity	Large groups losing cultural ties
7. Disruption of health care services	Loss of health services	Loss of health facilities	Loss of regional health care capacity
8. Deterioration of mental health	Mental disturbance	Loss of work efficiency	Loss of regional spirit and character
9. Inefficiencies in emergency services	Missing or inefficient help	Disruption by refugees	Massive resettlement patterns

permit quantitative estimation, their approach would provide an excellent starting point for applying the magnification factors to follow.

A dambreak flood with about the same direct impact that Hurricane Agnes had on the Wilkes-Barre region of Pennsylvania, would cause a community-scale magnification of "Increased Cost of Repair or Replacement" of about 4.0. The amount could be substantially larger in other areas of the country or for different configurations or timing of the impacting event. The magnification with respect to the other eight factors would depend on the disaster size and its relative impact on the unit. The nine processes contributing to damage magnification as outlined in Table 1, the sub-processes continuing through the aftermath and recovery periods as outlined in Table 2, and the expansions into larger scales suggested in Table 3 provide a gross basis for approximating orders of magnitude for potential magnification.

The magnifications to be expected from a catastrophe with respect to the nine factors would depend on the dynamic interactions during the aftermath and the capacity of the community to commence recovery. Quantification could be in terms of a threshold where magnification begins and the amount of magnification per unit increase in event size. New thresholds and magnification coefficients would be introduced by a super catastrophe. Since magnification is defined as a multiple of the normal loss, the coefficient would be larger for cases where the "normal loss base" is smaller. These considerations were used to make the approximations of the magnification potential for the "worst-case scenario," a super catastrophe taking approximately 200,000 lives, shown in Table 4.

The following considerations were used in making the assessments shown in Table 4:

1. Agnes provided the starting point for judgments on the magnification factors placed on this table. A magnification of economic loss slightly larger than that experienced by Agnes is used because of the larger magnitude of the "Worst Case Scenario." The large capacity of the United States economy would place an upper bound to scaling with respect to economic impact.

2. The Pennsylvania social communities impacted by Agnes extended up the hill sides out of the flood plain and thus were not disrupted to the extent found at Buffalo Creek. A dambreak flood that would cause 200,000 deaths would be much more disruptive of social communities than any disaster that our country has thus far experienced. As a factor mitigating social disruption, the social groups in which Americans interact are becoming so widely dispersed that it would be increasingly difficult for an event to engulf them.

3. The magnification associated with the disruption of personal time is expected to exceed the escalation of repair costs because individuals generally obtain services over a local area that is much smaller than the total economic trade area. Also, people are quite sensitive to being suckered by charlatans.

Table 4. First Approximation Magnification Coefficients.

1.	Disruption of repair and replacement capability.	6
2.	Disruption of support from social group	20
3.	Disruption of personal time	8
4.	Exposure to disturbing experiences	50
5.	Disruption of basic community infrastructure	2
6.	Loss of personal property	6
7.	Disruption of health care services	3
8.	Deterioration of mental health	30
9.	Inefficiencies in emergency services	10

4. Society seems to be losing many family and small-group support mechanisms and consequently seems to be increasingly vulnerable to severe psychological disturbances. Mental disorders seem to be on the increase. A super catastrophe would expose people, communities, and regions to experiences more disturbing than any that the United States has suffered since the Civil War. One would consequently expect large magnification here.

5. The modern city dweller is dependent on services provided through community infrastructure. On the other side, utilities generally have the resources to recover quickly, people are mobile, and the disturbances resulting from disruptions that people accept as reasonable do not seem large. The replacement of aging, inefficient, or obsolete may be attractive. Magnification is also expected to be smaller here because the infrastructure repair costs themselves are so large. Magnification is also expected to be smaller here because the infrastructure repair costs themselves are so large.

6. The magnitude of the sense of loss that people feel from lost heirlooms is unknown. Estimates made from Kentucky data on the ratio of the personal value to the economic value of real property suggest a maximum factor of 2.25 (James 1968). The primary contributors to personal value were the length of time the property had been in the family, where the family would be required to move elsewhere, and the difficulty in purchasing acceptable substitute property. Except in cases where losses of personal property remove a sense of security that undermines mental health, one would expect this magnification to be about the same as it is for economic loss.

7. Health services in the United States have been able to respond effectively and rapidly to major disasters. The magnification in this area may largely be caused by large expenses incurred when rescue and care are operated in an emergency mode.

8. Mental health problems could magnify immensely with larger scale events. On the other side, people rise to the challenge of recovery; and mental health may actually be improved among the more active. This consideration was the basis for holding this multiplier smaller than that used for Process 4.

9. Our emergency services are geared to disasters much smaller than the "worst case scenario." One would expect gross inefficiencies and some counter productive activities with the larger events.

VII. LOCATION ANALYSIS

The analysis to determine the magnification caused by the failure of a specific dam could employ the following steps:

1. Employ one of the available models for routing flood waves downstream following a major dam break. The results should be expressed on a flood-severity map showing the maximum depths and velocities of flooding over the extent of the inundated area. Federal agencies have

mapped the areas subject to inundation below a number of major dams for purposes of evacuation planning.

2. Map current land use over this area. The land use depiction should encompass natural and anthropocentric properties relevant to measuring losses with respect to all of the nine principal processes outlined in Table 1.

3. For each of the nine principal processes:

a. Estimate the property-scale damage to be expected by integrating land use with flood severity based on these two maps. Pate-Cornell and Tagaras (1986) provide ratios for estimating damages and casualties.
b. Make a judgment as to whether this loss is sufficient to cause community-scale magnification by comparing the property-scale damage with the "impact measure" in Table 1.
c. For processes where community-scale impact seems probable, use information from the literature to make the expansions indicated in Tables 2 and 3. The numbers on Table 4 provide a general order of magnitude to use as a start. This assessment should consider both the magnification of property-scale processes and the introduction of new processes at the community scale.

4. For each of the nine principal processes:
a. Make a judgment as to whether the community-scale losses are sufficient to cause regional-scale magnification.
b. Use the above principles to estimate a general order of magnitude. This assessment should consider further magnification of property-scale processes, magnification of community-scale processes, and the introduction of new processes at the community scale.

VIII. RESEARCH SUGGESTIONS

A. Topics. A number of research suggestions are provided in presenting followup ideas for more careful delineation of damages within the ten goal domains. Other thoughts on topics that should be studied further include:

1. Descriptions of the impact processes that occur during a catastrophe and of how they have been altered by "protection" systems. Items include the movement of flood waves, how people respond in ways that reduce or add to the losses, and how communities act in ways that reduce or add to the total loss experienced in their boundaries.

2. Documentation of the aftermath and recovery dimensions of economic, social, and environmental impacts (concentrating on the nine principal processes listed in Table 1) associated with historical catastrophes or with events at the time they occur.

3. Scientific analyses of documented impacts in order to develop theoretical constructs for explaining what occurred and for use in assessing the consequences of future situations.

4. Analyses of reconstruction processes, with particular emphasis on reconstruction at the community and regional scales, and the time period required for recovery of the local and regional economies, environments, and social systems.

B. Ultimate Goal. As an ultimate planning tool, one can dream of a multiple feedback loop simulation model that encompasses event, aftermath, and recovery processes and the interactions among them to estimate catastrophe and super catastrophe consequences. The research recommended above to develop understanding of the major processes is seen as an initial step to this ultimate goal.

APPENDIX I

DESCRIPTIVE REPORTS ON MAJOR CATASTROPHES

Combining Contemporary Journalistic Reports with
Assessments and Analyses by Later Observers

I. JOHNSTOWN FLOOD, MAY 31, 1889

Information synthesized from New York Times reports.

Storm Event

The flood was caused by the breaking of a dam at the foot of a mountain lake, about nine miles up the valley of the South Fork of the Conemough River. The lake, between 200-300 feet above the level of Johnstown (population 25,000, is 3.5 miles long and 1 to 1 1/4 miles wide. In some places it is 100 feet deep. At the time, it held more water than any other reservoir natural or artificial in the U.S. The lake had earlier been quadrupled in size by artificial means and was held in check by a dam from 700 to 1,000 feet wide. The dam was 90 feet in thickness at the base and tapered to a little more than 20 feet at the top with a height of 110 feet.

Steady rains over the preceding 48 hours increased the volume of water in all the small mountain streams which were already swollen by earlier rains. From available information, something in the nature of a cloud burst must have been the culmination of the struggle of the water against the embankment.

Dam Failure

According to Herbert Webber (a guard at the South Fork Club), for three days before the first outburst, the water of the lake forced itself out through the interstices of the masonry, so that the front of the dam resembled a large watering pot. The force of the water was so great that one of these jets squirted full thirty (30) feet horizontally from the stone wall. At this time, the streams feeding the lake resembled torrents and were carrying 3,000,000 gallons of water hourly.

Webber was present when the dam began to give way. At about 12:45 p.m. (May 31), the stones in the center of the dam began to sink because of undermining, and within 8 minutes a gap of 20 feet was made in the lower half of the wall face. By 1 o'clock, the top masonry fell in, and the remainder of the wall opened outward like twin gates. It did not take more than 5 minutes for the lake to drop 50 feet.

Warnings

Recognizing the potential danger the dam posed to residents downstream, it was inspected once a month by the Pennsylvania Railroad Engineers. The inspections showed that nothing less than some convulsion of nature would tear the barrier away.

For over a year, there were fears of an accident of the magnitude that occurred. The foundations of the dam were considered to be shaky in the spring before the disaster. Many increasing leakages were reported from time to time.

Webber said he had repeatedly called the attention of the members of South Fork Club (owners of the dam) to the many leakages. He was always told that the dam was all right; that it had been "built to stand for centuries" and that its giving way was impossible. Webber next laid his complaints before the mayor who promised to investigate but did nothing.

Opinions are divided as to whether sufficient warning was given to residents on the day of the disaster. According to people who live in Johnstown and other surrounding towns, ample warning was given to the Johnstown folks by the railroad officials and by other gentlemen of standing and reputation. In many cases, these warnings were utterly disregarded.

Severity

- The Little Juniata, Frankstown Branch and Juniata Rivers that for most of the year are mere brooks, were over thirty (30) feet deep.

- The flood depth was over 20 feet in Johnstown.

- Lake level dropped 50 feet in 5 minutes.

Damages

- Below the dam for a distance of 3/4 mile stretched a mighty mass of wreckage, 40-60 feet high and 700-800 feet wide. The wreckage contained dead persons.

- Dead bodies could be seen in the river as far away as Pittsburgh (100 miles from the scene of the disaster).

- At one point on the river, a telegraph operator counted 63 bodies in 20 minutes floating past on the day of the disaster.

- At 6 o'clock on the day of the disaster, a Superintendent of the Pennsylvania Railroad (Robert Pitcain) telegraphed from San Hollow west of Johnstown, that he had seen about 200 persons afloat on gondola cars, shanties, etc. and that the disaster was appalling.

- A telegraph operator and San Harbour, in the Pennsylvania Railroad tower, said that at least 75 bodies had floated past that point.

- The scene of the disaster was cutoff entirely from all communication. Even 48 hours after the disaster, communication had not been restored.

- Houses, bridges and factories were overwhelmed in the twinkling of an eye. Also destroyed were railroads and telegraph lines.

- All railroad and wagon bridges were swept downstream in a watery avalanche. Countless houses that were never dreamed to be in any danger of flooding were also swept away.

- The Pennsylvania Railroad was submerged for a distance of 30 miles. The Blairsville Railroad bridge was swept away together with a train of loaded coal cars which had been run upon it with the idea of holding the bridge in place. The bridge was 875 feet long with 500 feet of trestle.

- Western Union's nearest point of communication was New Florence, 14 miles west of Johnstown. It was impossible to communicate with that locality from the east.

- A week after the disaster, careful estimates placed the number of bodies recovered at half of those that had perished. Out of a population of 30,000, 18,000 had made themselves known to the Registration Office. It was estimated that some of the people missing had left town and that about 10% of the survivors would fail to make their identity known. City officials estimated that at the outside, not more than 21,000 or 22,000 would be accounted for; leaving 8,000 or 9,000 dead.

- It was estimated that about $3,000,000 would be required to clear the wreckage from Johnstown and its vicinity.

Assessments

- It was alleged that the dam was formerly a small affair that had been enlarged by the South Fork Club to hold four times as much water as before. Referring to the enlargement of the dam, Engineer Church (formerly Chief and then Consulting Engineer of the Aqueduct Commission) said that on general principles it was unwise to enlarge any masonry dam that had not originally been built for future enlargement. From the little definite information available, he was inclined to think that the wasteway of the dam was too small to pass the unusual amount of water coming downstream, and that the dam had failed on that account.

In response to safety concerns raised by opponents of the great Quaker Bridge Dam, (a dam under consideration for construction at the time) he said, "the new dam will have provisions made for safely carrying off a flood 60 times greater than ever occurred in that locality and the dam itself will be able to hold back all the water that can be forced against it. And even if the dam should break and its waters be precipitated into the Hudson, the river would not be affected sufficiently to even show a rise at Sing Sing."

II. GALVESTON, TEXAS, HURRICANE, SEPT. 8, 1900
As reported in the New York Times

Galveston Island on which the City of Galveston is situated, is 28 miles long and 1 1/2 to 3 1/2 miles wide. It is 4-5 feet above tide level.

Severity

- Wind speed of over 80 mph.

- Water was 3 feet in the rotunda of the Tremont Hotel and 6 feet in Market Street. In a great majority of cases, the streets were submerged to a depth of 10 feet. The highest level of land in the city was 4-5 feet under water.

- Relief trains sent out to Galveston had to return as they could not get closer than 6 miles of Virginia Point where the Prairie was covered with lumber, debris, pianos, trucks and dead bodies.

Damages

- Four bridges, the main link between Galveston and the mainland, were swept away by the terrible force of wind and water in the bay. Three of the bridges were for railroad use, and one was the Galveston County Public Wagon and pedestrian bridge.

- All forms of communication between Galveston and the outside world were disrupted. Telegraph and telephone lines were destroyed.

- The water works and power house were wrecked. Severe water shortage was threatened. The city was in darkness.

- At least 5,000 families had no shelter.

- Death toll estimated at 5,000.

- Property loss was estimated to be $15 to $20 million.

Reconstruction

- Five days after the disaster, some businesses put men to work to begin to repair the damages. However, most commercial interests seemed too uncertain to follow the lead of those showing faith in the rapid rehabilitation of the island city. Most businessmen were waiting to see what the attitude of the railroads, especially the Southern Pacific, would be. Reporters felt that the decision of the transportation lines, more than anything else, would restore confidence and speed reconstruction.

III. SAN FRANCISCO EARTHQUAKE AND FIRE, APRIL 18, 1906
As reported in the New York Times, April 19.

Earthquake

- Over 500 dead and $200,000,000 worth of property destroyed.

- Nearly half of the city is in ruins.

- 50,000 homeless and 1,000 injured.

- Water supply fails.

- Telegraph and telephone cutoff for a time. Western Union was completely out of business. Only the post office managed to send out a wire.

- Electric power was cutoff.

- Street cars could not operate since tracks were badly damaged. Ferry boats also ceased operation.

- Tall steel frame structures stood the strain better than did brick buildings. A portion of City Hall which cost more than $7,000,000 collapsed. The new post office, one of the finest in the United States, was badly shattered.

Fires

- Immediately after the earthquake, fire started.

- The fire department could not respond to the emergency because the water supply was cutoff. Hence dynamite was used to blow down buildings so as to control the spread of the fire. This, however, proved futile.

- The south side of Market Street, from 9th Street to the bay, was soon ablaze. The fire covered a belt two blocks wide. On this main thoroughfare were many of the finest edifices in the city. They included the Grant, Parrott, Flood, Call, Examiner and Monadnock buildings and the Palace and Grand Hotels. These were either destroyed or badly damaged. At the same time, commercial establishments and banks north of Market Street were burning. Claus Spreckels, a fifteen story stone and iron building was consumed by fire. Banks and commercial houses, supposed to be fire proof (though not of modern build) burned quickly.

- Dynamite available was not sufficient to handle the emergency hence the mayor made an urgent appeal to the governor for more.

- Chief of police ordered the closure of every Saloon in the City so as to prevent 'drink-crazed' men from rioting in the streets.

- Mayor Schmitz ordered bakeries and milk stations to reserve their supplies for the homeless.

- The mayor established a base of rescue. Rescuers jumped into collapsed buildings and pulled out the dead, the dying and the injured. Practically every physician volunteered his assistance, and soon a well equipped medical corps was organized and began ministering to the injured.

- Provisions were made to place tents in every park in the city.

- Every possible precaution was taken to guard property. Police turned out on guard, and the governor and General Funston (commanding the Pacific Division of the U.S. Army) were asked to send troops. Soldiers were ordered to shoot down vandals caught robbing the dead.

- The insane asylum at Agnew was a total wreck. 270 inmates were killed out of a total of 700 people. Hundreds of inmates who escaped are roaming the streets in a state of panic.

- Provisions were sold at fancy prices, and even water was sold by the glass.

- The Southern Pacific Railroad carried out of town all those who wanted to leave. No one was allowed to enter, and those who left were not able to get back for a while.

- On April 19, the following resolution was adopted by Congress:

The Secretary of War is hereby authorized and directed

-- to loan to the Mayors of the cities of San Francisco, Berkeley, Oakland, Alameda and such other cities on the Pacific Coast as have sustained damage, under such regulations and restrictions as he may deem proper, a sufficient number of tents to temporarily shelter such persons as may have been rendered homeless and lost property by the earthquake;

-- to issue rations and supplies and to render such other aid to the destitute and others unable to provide for themselves;

-- to work with the Secretaries of Treasury and of the Navy in extending relief and assistance to stricken people to the extent of the use of Naval vessels, revenue cutters, and supplies under their control on the Pacific Coast.

April 20

- 200,000 or about half of the population of San Francisco spent the night under open sky in the parks and other open spaces in the city.

- There was the threat of famine. Troops and Police seized every unburned grocery and bakery in the city and husbanded all their resources.

- Show of goodwill came from all parts of the country. Congress appropriated $1,000,000 for the benefit of the suffers, and President Roosevelt signed it before dark so as to make the money available immediately.

- Victims of the disaster invaded the few buildings that remained in the hope of finding something to eat. At the Ferry Building, a crowd of thousands gathered begging for food and transportation across the bay. Even men of wealth could not obtain food with all their money. Expressman charged $10 to $50 to haul a load of baggage or give any aid to refugees. The situation became so critical that Mayor Schmidt sent the following message to Governor Pardee: "Send all supplies and tents possible to Golden Gate Park. Have bakeries in small towns bake all the bread they can. We want bedding, food, and tents."

- Entrepreneurs were already planning to start reconstruction. The following advertisement was placed in the New York Times by the United Cigar Stores Co.

"We have had ten of our stores and warehouses destroyed in San Francisco (fortunately among our own people no lives were lost). Our own loss of close to $300,000 measures small in our grief and sympathy for our friends and customers. However, this is our policy: We have sent ten of our best men including our Treasurer, Director of Construction and General Superintendent there, with orders to open TWENTY new stores immediately. We believe the city will be rebuilt at once. We understand the damage from earthquake was small and in the rebuilding steel construction will undoubtedly remove the possibility of future disaster from fire or earthquake. WE WANT TO BE PART OF THE BIG BOOM THE NEW SAN FRANCISCO will have. We believe it will be a better and greater city than ever, and we will back our judgment with our money."

Reports on Reconstruction of the City
(edited Haas et al. 1977)

More than half of the housing and at least two-thirds of the jobs in San Francisco were destroyed by this disaster. Free transportation was given as an incentive to victims willing to leave the city. 300,000 victims availed themselves of this opportunity. Between 65,000 and 75,000 never returned.

Housing
First Phase

- Temporary housing was supplied in authorized and unauthorized camps.

- The first authorized housing took the form of 8,000-10,000 tents supplied mainly by the U.S. Army. These tents housed more than 20,000 people during the summer of 1906. Unauthorized tent and shack camps housed about as many more. Health and sanitation were worse but less rigid living conditions meant greater freedom. Tents were feasible because of the mild climate of California summers.

Second Phase

- Erection of substantial wooden 2- and 3-room "cottages," organized in official camps in city parks and plazas close to jobs and the destroyed central area. 4,750 cottages were occupied before the first severe winter storm (January, 1907). One year after the disaster, 6,200 cottages were available to house 20,000 (5 percent of the homeless population).

- Within 26 months of the disaster, the cottages were moved to private property and made permanent structures. There was a high vacancy rate in the cottages (late 1906) and high attrition when the cottages were moved from refugee camps to private property in 1908. This is an indication that the two moves (from tents to temporary cottages and then to permanent homes) were enforced prematurely for most of the families. This was particularly true for refugees families who were unskilled, foreign-born, and headed by women and old people for whom housing and suitable rents did not exist. The pressure to move apparently came from upper- and middle-class citizens who projected their own return to normalcy (in jobs and homes) to be the condition of all social groups in the city. There seems to be a tendency for refugee camps to turn into permanent homes for the disadvantaged.

- In order to insulate the lower class from the housing market at a time when rents were uncontrolled and extreme, authorities intended to allow them to occupy emergency housing until no longer than 1910. However, in 1911, many families in San Francisco had still not returned to homes obtained through the housing market.

- Middle and upper classes were forced to compete for housing in the market in the summer of 1906. About 8,000 housing units were constructed between August 1906 and October 1907. This represented a replacement of about one-third of the destroyed housing in the first eighteen months (seems low for at least 250,000 people made homeless). Thereafter, the rate of housing construction fell to about half of this rate until 1911 by which time the city's building stock had been replaced.

<u>Business</u>

- A decision to rebuild in San Francisco was made by a major bank four months after the 1906 earthquake. Other large financial institutions, insurance, real estate and banking institutions followed. Their chosen locations defined the extent of a new financial district.

- As soon as the locational decisions of these financial institutions had outlined the financial district, department stores began to build in boundaries that defined a new apparel shopping district. Hotels came third. Large hotels established the outlines of a new hotel district.

- It generally took longer for businesses formerly located near the edge of the central district to reestablish themselves. These activities were forced to take suboptimal locations for up to eight years. As a result, some businesses either failed or relocated outside of the disaster-stricken city. The resulting employment losses were generally to blue collar and, to a lesser extent, semi-skilled and unskilled workers. In the manufacturing sector for example, there were 450 fewer jobs in San Francisco three years after the disaster than there were before it (1904). The exodus of manufacturing plants dropped San Francisco's share of manufacturing employment in the Bay Area from 33% in 1904 to 23% in 1909 and 1914. This lower percentage was still holding in 1914.

- Employment in middle- and upper-class occupations--office, administrative and financial services, and retailing--increased relatively and absolutely between 1906 and 1915.

- Other businesses that particularly suffered from the disaster were the wholesale and manufacturing concerns dependent upon the low rents of old and amortized buildings in near-central locations, close to the external economies that come from the concentration of hundreds of linked activities in a tightly circumscribed area. In San Francisco, 894 small business establishments, many of the above type, received Relief Committee loans to rehabilitate. Two years after the disaster, only half were self-supporting while most of the remainder (351) were not in business. Of these, 211 were never again able to establish a business enterprise despite the grants of the Relief Committee.

- The financial pressures during disaster recovery placed greatest stress on the lower social class. They were dislocated for the largest period. Many were forced to locate on land unclaimed by the more affluent to suburbanize to East Bay towns, or to leave the Bay Area altogether.

- Most of the lower class, however, found moving permanently or temporarily to other Bay Area towns to be not viable. Transport costs and travel time were too high for them to live in the East Bay and work in San Francisco.

- Most lower class decided to leave in 1906 and others did so after the enforced closing of the refugee camps 1907-08. A large proportion of the 300,000 people that left San Francisco in the two weeks after the disaster were of the lower socioeconomic classes. Seventy-four % of the unskilled sampled in 1906 failed to return to the Bay Area by 1907, and 87% of them had gone from the Bay Area by 1911.

IV. FAILURE OF SAINT FRANCIS DAM, MARCH 13, 1928
Reported in the New York Times.

The Saint Francis Dam was part of the Owen Valley Aqueduct System that supplies the City of Los Angeles and other communities in the San Fernando Valley with water for irrigation and domestic purposes. The dam was located in the mountains northwest of the city on the Santa Clara River about 75 miles above the ocean.

At 1 o'clock in the morning (March 13, 1928), the dam gave way and 88,000 acre feet of stored water was instantly rushing on a mad race to the sea. The dry bed of the Santa Clara River provided the initial flow, but soon the bank broke and a plain up to 60 miles wide was at the mercy of the flood.

The State Engineer (Edward Hyatt, Jr.) said that according to his reports, the dam was in perfect condition before the break and that it had been inspected regularly under state supervision.

Warnings

Mrs. A. M. Rumsey, a postmistress at the nearby town of Sangus, said that for ten (10) days before the dam break, ranchers "talked of nothing else" but leaks in the structure and the possibility of the disaster.

A motorist reported that while driving up the canyon road, he saw an unusual quantity of muddy water coursing through the ordinarily dry sttream bed. He drove up to the dam and noticed that the water behind the buttress was within 3 feet of the top and that the spillway gates were apparently closed, although there was a good stream running down the canyon. Further down the road, the motorist saw a gang of workmen drilling holes apparently in preparation for dynamite blasts to blow off the shoulder of a hill not more than 200 feet from the dam.

At the time of failure, warnings were telephoned to residents below the dam but apparently insufficient time was available for people living in the upper part of the canyon to flee.

Severity

- The dam break occurred at 1 a.m. and in 3 hours, the flood wave was 20 miles down the valley moving at about 10 feet per second.

- Silt deposited in some sections of the Santa Clara River bed was 30 feet deep.

- Only the central section of the dam was left standing. The east and west sections had been eroded away by the water released from the reservoir stretching 5 miles up the canyon from the dam site.

Damages

- The Los Angeles municipal power house below the dam was demolished.

- 500 homes were destroyed or greatly damaged.

- Ten important bridges were destroyed including the railway bridge between Ventura and Oxnard. The State highway bridge at Castaic and the steel bridge of the Southern Pacific branch from Sangus to Montalvo were also destroyed.

- State and county highways washed out at numerous points.

- Telegraph and telephone lines disrupted.

- 1500 persons were left virtually homeless, and many of these were, temporarily at least, destitute.

- Livestock killed and drowned.

- 20 lineal miles of citrus orchards were buried under many feet of mud and silt.

- 10,000 acres of orchards had been swept over by the flood. Preliminary surveys indicated that probably \$500/acre would have to be spent to restore the silt covered area. At the time of the disaster, the orchard land was valued at about \$5,000/acre.

- Property loss was estimated at \$15,000,000 to \$30,000,000.

- Death toll estimated at 400.

Assessment of the Failure 36 Years Later
(Griswold 1964)

Dam Description

The 2-year old concave bulwark, containing 137,000 cubic yards of reinforced concrete, rose 205 feet above the narrow streambed in San Francisquito Canyon. Its crestline measured 700 feet. The dam was 180 feet thick at its base and tapered to 16 feet at the top. Behind it lay a four-mile long reservoir. At the moment of the disaster, the dam held about 12 billion gallons of water.

Severity

- 10,000 ton chunks of concrete, the size of bungalows were tumbled as far as 3/4 mile by the towering dark wall of water that lunged down the San Francisquito Canyon.

- Only the dams center section, 205 feet high and about 100 feet wide resisted the tremendous pressures.

- The plunging torrent from the broken dam, swelled to a flow greater than 500,000 cfs, reached a depth of 125 feet as it tore at the curves of its tortuous channel.

- One and a half miles down the canyon, stood Los Angeles' Municipal Power Plant No. 2. It was a two-story building of heavily reinforced concrete, containing two-100 ton dynamos. Close by huddled a settlement of 65 persons.

- Five minutes after the dam crumbled, this community was swept away.

- The power house, struck by a flood wave that rose even higher than 125 feet, was obliterated as if it had been a tent.

- Half an hour after the collapse, the plunging waters were still 50-feet deep and scoured out the contents of the canyon.

- 38 miles below the dam, the flood wave was 25 feet high.

Damages

- An estimated 450 lives were lost. Even 36 years after the disaster, an accurate count is not available.

- 8,000 acres of productive land were laid to waste.

- Unnumbered herds of livestock and flocks of poultry were killed.

- Economic losses were estimated at $10 million.

Reasons for Failure

- 72 year old William Mulholland, Chief Engineer of the L.A. Water and Power Dept. took full responsibility for the dam's design and location. Said he, "If I was to build St. Francis Dam again, I would build it in the same manner, but not in the same place. That place where it was built was vulnerable against human aggression."

- "Unfortunately," the investigators appointed by the Governor to seek out the cause for dam failure wrote, "in this case the foundation under the entire dam left very much to be desired." The rocky cleft of the canyon, which the dam straddled, consisted of an insubstantial mica schist on the east side and an even less substantial reddish conglomerate on the west, the report explained. The two rock formations met, under the west wing of the dam, along a "dead" earthquake fault, ideally designed by nature for seepage. To make matters worse, the conglomerate "even when dry was of decidedly inferior strength ... when wet, became so soft that most of it lost almost all rock characteristics." The investigators concluded that "the ultimate failure of this dam was inevitable, unless waster could have been kept from reaching the foundation."

V. LYNMOUTH, ENGLAND FLOOD, AUGUST 15, 1952
(Delderfield 1953)

Heavy rains on the night of August 15, 1952, caused the biggest flood from the smallest area ever known in England. Lynmouth is a fishing and vacation village immortalized by poets Shelley and Southey and by Blackmore in the novel, Lorna Doone.

The flood produced a wall of water up to 40 feet high and moving at 20 mph. Bridges, 10-ton boulders went through walls like bullets through paper, water scouring undercut the foundations of buildings that had been untouched for 200 years. The river drops several hundred feet in the last half-a-mile to the sea.

A total of 34 people were drowned. 93 houses and buildings were destroyed, 28 bridges, 132 vehicles.

Some descriptive phrases:

p.28 - "The party .. was in pitch darkness and soaked to the skin, in complete ignorance of what was happening elsewhere and had an overriding anxiety about the whole situation."

p.29 - "Time ceased to exist for most of those concerned"

p.31 - "A particularly violent roar was heard above the general tumult."

p.34 - "Some ideal of the awful force of the water may be gleaned from the fact that the body of nine-year-old Kenneth Bowen, who was swept away from the same house, was found under a slab in a butcher's shop in the Watersmeet Road."

p.38 - "At intervals in the hours that followed, the sixty occupants of the hotel mounted floor by floor until they were at the top of the building. Provided with rugs, blankets, and eiderdowns but without light, heat, food or drink, they sat together as the interminable hours dragged by. It was an agonizing period of suspense.

In the direct course of the flooded rives and in the path of the pounding debris, the hotel received a severe battering for hours on end. The very walls seemed to rock and the groaning and straining of timbers, together with the roar of the waters, the thunder and lightning, and the whimpering of terror-stricken children was a nightmare experience, which will never be forgotten by those who were unfortunate enough to take part in it."

p.41 - the greatest bravery was being shown in every corner of the little town."

p.44 - scores of people were trapped in buildings beside the river with a cliff rising steeply behind them.

p.65 - the force of the scouring water caused so much destruction that the town was not recognizable even by those who knew it best.
p.66 - The Rhenish Tower, which must have figured in millions of holiday snapshots, had disappeared.

p.86 - "Perhaps as heartening to the people as anything else was the concern and interest displayed in their trouble by Her Majesty's Ministers and other important personages."

Large amounts of volunteer labor, government sponsored workers, and donations had the town reopened by early September.

VI. NEW YORK TIMES ACCOUNT OF HURRICANE CAMILLE, AUGUST 18, 1969
Reports by Associated Press in the New York Times.

- Wind speeds of up to 150 mph with high tides and tornadoes.

- 200,000 people fled inland from Mississippi's coastal area during the day.

- According to the police superintendent, Gulfport (30,000) was completely destroyed, and the Memorial Hospital was calling for help. The city had no power and no communication with the outside.

- The Weather Bureau warned of tides driven by the winds to heights of up to 20 feet in the area of maximum storm power.

- Red Cross reported that 394 evacuation shelters had been set up in the storm area. Reports indicated that 44,541 refugees were in the shelters with more coming in.

- In Gulfport, nearly all refugee centers had run out of food and water before the storm arrived.

- Most of the low lying areas in Louisiana were cleared early in a scramble that started with the first warnings.

- Traffic on highways leading inland from Mississippi's coast was frequently bumper to bumper during the day. Many of Alabama's coastal exodus headed for Mobile. Authorities said 5,500 refugees were in the city's seven emergency centers.

- Rising tides covered highways near the coast in Mississippi and Alabama. Other South Mississippi highways were closed in the night by the highway patrol because of debris.

- The Mississippi River Bridge was closed to traffic. The world's longest bridge, the 26-mile causeway across Lake Pontchartrain was blocked off.

- Most of the city's activity was in groceries and drug stores and they were jammed on a Sunday when they would normally be closed. Customers were trying to buy flashlights, flashlight and radio batteries or candles. But they were no where to be found.

- Long lines formed at gasoline stations.

August 19

- Civil defense officials in Mississippi reported 100 dead from along the Coast and expected the toll to increase to between 150 and 200.

- Fires burned out of control because fire fighting units could not reach them. Communications were disrupted.

- Most of the Gulf Coast was without electricity, gas or drinking water.

- Red Cross reported its shelters housed more than 70,000 persons in Louisiana, Alabama, and Mississippi during the night.

- The Buena Vista Hotel on the Coast of Biloxi had water 8 feet deep on its ground floor, destroying all the facilities of radio station WLOX.

Reports on Effects in the Construction Industry

Hurricane Camille caused substantial shortages of both labor and materials for reconstruction along the Mississippi Gulf Coast. Mr. George P. Hopkins, Jr. (past president of the Mississippi Gulf Coast Chapter of the Associated General Contractors) appeared before the Senate Subcommittee on Disaster Relief of the Committee of Public Works to describe the situation five months after the disaster. He felt that the amount of work required for restoration exceeded their industry's capabilities as they existed before the disaster. Asked, whether construction costs in the area after the disaster had gone up disproportionately to the rest of the country, Mr. Hopkins replied:

> "I would say immediately following the storm, when the tremendous influx came into the area and at one time we checked with the Better Business Bureau, we had over 700 foreign construction firms or individuals in the area. I would say yes, the costs did go up. Even in my own business the people that we had subcontracted on some items such as roofing, and that sort, I couldn't hire them for twice what I paid them 6 months before. In that line, I am talking about the shinglers. They saw an opportunity and they hit it . . . . To some extent, it is not completely justified, but you can understand that when a man has 15 places he is going to go, he is going to go where he can do the best . . . . In my own business, I had at least a half dozen of my men quit and go into the construction business because of this fact." (Hopkins, 1970).

- The primary shortage in the aftermath of the disaster was labor. Common laborers who got $2.00 per hour prior to the disaster were getting up to $7.00 per hour in the post-disaster recovery period. Labor costs were typically more than doubled.

- There was also a critical shortage of skilled laborers such as plumbers and electricians. This necessitated importing skilled workers from other market areas at premium rates. The importation aggravated the shortage of living accommodations, caused rents to rise, increased subsistence costs, and contributed to the high labor costs.

- Increased demand also caused difficulty in obtaining construction materials and equipment. In addition valuable supplies were destroyed by the hurricane. The resulting shortage increased the cost of building materials and equipment. For example, a cherry picker with operator which rented for $12-16 per hour prior to the storm, rented for $25 per hour during the period following the disaster. The shortage of building materials would have been worse had stockpiled items not been available from military and other government depots.

- The availability of federal money and low interest loans from the Small Business Administration (SBA) increased the demand for immediate repairs. Many complained that prices went up substantially, even astronomically, under the temptation of money brought in by SBA, insurance adjustments, and other monies. This was brought out by Mr. Hopkins in his testimony before the Senate Subcommittee on Disaster Relief of the Committee on Public Works. On the price gouging problem, he said:

> "I know it has happened, but I cannot speak from personal experience. I have talked to people who have been approached and the prices presented to them were out of line. I can give you one personal experience. Immediately after the storm an insurance adjustor came to me from another area and said 'Look, this is an estimate I have on damage. What is it?' I said, 'Well, I have not the time to go look at it, but you tell me what you have done and how you would adjust it.' And he told me this figure. From his figure I could tell him he was reasonable. I told him to go back to the owner with the estimate he had, which should have been $10,000 instead of $19,000. He went to the owner and gave him the estimate and they settled for $10,000. This is the only case I came across personally, but it has happened." (Hopkins, 1970)

Reports from Congress
Congressional Record, Sept. 3, 1969

Damages

- Representative Colmer of Mississippi reported that millions of dollars of timber, as well as the tung oil orchards and the pecan industry, on the shoreline and the interior, were devastated. Conservative estimates show $1 billion in damage. Thousands of homes, hundreds of beautiful motels and hotels, and many miles of highways were destroyed. Possibly as many as 300 people lost their lives.

- Representative McCormack from Massachusetts suggested that, if the disaster loan law and other existing laws were not adequate to meet some of the situations, Congress should act very rapidly and very quickly to pass additional legislation.

- Representative Keith from Massachusetts stressed the need for a national disaster policy on the part of the Federal Government, to replace the present piecemeal approach to the problem. The largest damages from hurricanes are due to the abnormally high tides for which there is no insurance. Citizens can collect insurance for wind, rain, and flood damage; but they cannot collect for the damage caused by the abnormally high tides which inevitably accompany the storms. There should be a national policy covering such situations.

Assistance Provided by the USDA

- Over 3 million pounds of food from school lunch and commodity distribution supplies were transported to hurricane victims.

- On a typical day, 38,975 storm victims received food through USDA to take home to feed their families, and 25,215 received food from USDA stocks at mass feeding stations.

- Jeep-mounted mist sprayers were used to treat the beach areas with malathion insecticide so as to kill flies, mosquitoes, and other pests which spread diseases.

- The Agricultural Research Service moved to combat another insect threat, fire ants. These ants were scattered by the winds and waters into homes and debris. 100,000 pounds of poison bait was used to protect workers and refugees. Many were already reported bitten by the fire ants and some required hospitalization.

Comments

Poisonous, disease spreading, and obnoxious insects could easily be carried by a dam break flood. This requires added medical facilities for treating victims and care to find poisons for removing the insects that will not lead to later environmental or health problems.

VII. FLOODS IN BRISTOL, ENGLAND, JULY 11, 1970

Background

As reported by Smith et al. (1980), the flood occurred in the early hours of July 11. The extent of flooding was unexpected as the flood peak coincided with a spring high tide. Those flooded had minimal previous flood experience. Homes were covered with the stinking mud of diluted sewage.

Results

- The flooding significantly increased physical and psychiatric ill-health. Physical problems were more common in males and psychiatric problems in females.

- There was a large increase in the attendance of men living in flooded areas to general practitioners. Women's attendance increased much less. The increased attendance was most pronounced among people whose homes had had more than 4 ft of water through them.

- Hospital referrals and admissions were more than doubled for a year after the floods. The greatest increase was among men.

- The mortality rate among flood victims rose by 50%. The most pronounced rise was in the age group of 45 to 64 where male deaths rose from 7 to 20 and female deaths from 5 to 9. These deaths occurred mainly in the third 3-month period after the flooding.

Analysis

Possible factors making the population of Bristol vulnerable to the stress resulting from the flood would include the unexpected nature of the event and a general lack of flood experience. The high proportion of older people in the community may have also contributed.

Comments

These reports do not cover the causes of physical illness or the reasons for greater incidence among men. One would suppose that the sewage contained slowly acting virus or toxics. Men may have been more actively involved in cleaning the putrid mass from the homes. Women could have been psychologically impacted by a greater sense of loss of cherished possessions and by seeing their husbands' health deteriorate.

VIII. HURRICANE AGNES

Reports by John Darnston in the New York Times

June 20, 1972

An overnight torrent of rain brought more than 10 inches in 24 hrs. Flood waters reached depths of 15 feet in some low lying areas in Westchester County. Flooded railroad tracks halted traffic for hours. Traffic was chaotic on local streets and approaches to the city in parts of Northern New Jersey, Rockland and Westchester Counties, and Southern Connecticut. More than 10,000 telephone were reported out in Scarsdale. Many local streets were impassable. There were no traffic signs advising motorists which streets were safe.

June 23, 1972

Twenty-six persons dead and many missing. Bridges in affected areas were washed out and some communities, such as Wellsville, became virtual islands. Many of the dead were motorists who drove off washed out bridges or who suddenly found themselves in the middle of swirling waters.

Virginia: 6 persons drowned and at least 5 missing. Property damage estimated to be in the millions; 46 primary highways and 600 secondary highways closed because of flooding. Chesapeake and Ohio Railway closed its tracks for 165 miles. Drinking water declared unsafe in many communities. Thousands of people without electricity and telephone service.

North Carolina: 2 dead; 27 roads impassable.

Maryland: 12 persons reported missing or dead. 100,000 homes without electricity.

Delaware: 1 person dead.

Pennsylvania: 13 persons were dead and 9 missing. Harrisburg, the State Capitol was closed off.

June 24, 1972

Over 75 persons died since storm started. Five states declared disaster areas. The Washington area water supply for 1.2 million people was threatened. Sewage backup posed health threat.

Damage was particularly heavy along the Susquehanna River. In places, the river rose 32 feet; 10 feet above flood level.

In Virginia, the James River crested more than 35 feet breaking the record of 30 feet set in 1771. In the southern tier of New York, the Allengheny started to spill over 25 foot high dikes.

June 25, 1972

100 dead and more than 1/2 million homeless.

June 26, 1972

122 persons dead since start of floods.
By states, this breaks down to:

Pennsylvania	47
New York	23
Virginia	17
Maryland	15

Total estimated damage amounts to $1.6 billion.

Later Analysis by Allee, Barnaba and Schempp (1975)

Severity

Landslides contributed to the disruption of communication routes, including highways, railroads, pipelines and power transmission lines. A total of 24 counties were included in a declared Presidential Disaster Area.

Normal Damages

Total property damage $3.5 billion

- Agricultural: $102 million made up of the following:

Crops	$\$71 * 10^6$
Land	$\$25 * 10^6$
Buildings	$\$3 * 10^6$
Livestock	$\$0.32 * 10^6$
Fences	$\$0.515 * 10^6$
Machinery & Equipment	$\$1.7 * 10^6$

- Death toll: 122 people.

- Personal income in the hardest hit counties (Chemung and Steubeng) fell by 15.3% of 1971 levels or by a total of $121 million.

Congressional Reactions

Hon. Charles A. Vanik of Ohio; June 28, 1972.
Source: Congressional Record, 92nd Congress, 2nd Session Vol. 118, June 1-29, 1972.

Wind and rain caused extensive damage particularly in communities which lie along the shore of Lake Erie.

Congressmen request Federal assistance for the protection of nonpublic shorelines in areas where benefit-cost ratios would justify such Federal assistance.

Even though Hurricane Agnes caused some damage, he argued that erosion is the main concern of the residents.

In some places, 30 feet of shoreline disappear every year into the waters of the lake.

By the year 2020, 535 acres of land are expected to be lost within a 4-mile stretch. The present value of the property amounts to $18.9 million.

Total tax revenue lost to the community would be $3,861,000.

Intangible: 80% of eroded material will remain suspended in the lake thereby increasing pollution.

Cost of totally protecting 4 mile shoreline (11,700 feet long section) is $2,547,000 or $217/ft.

Corps of Engineers should not use market discount rate to appraise projects.

Corps of Engineers should change the procedure whereby only 50 years lifespan is assigned to projects for economic analysis even though some projects have 200 years of useful life.

Later Assessments

- Hurricane Agnes caused property damage to the tune of $3.5 billion. As a result of this high property damage, demand for contractors who could accomplish repair work was high. It was so difficult to get competent contractors that, the Navy's Seabees and the Air Forces' Red Horse Squadrons (Engineers) helped the Army Corps of Engineers get electricity into homes. The Navy assigned 100 men who had the expertise to restore power to 200 homes a day. The Corps of Engineers employed up to 800 contract workers a day in the Scranton and Wilkes-Barre regions (two severely hit areas) to clean up houses and businesses immediately after the disaster.

- The Corps of Engineers, charged with supervising the repair work done by private contractors under its repair program, was quickly faced with the problem of depleted building supplies in warehouses as far away as Philadelphia.

- In addition there was an acute shortage of labor. Laborers who could be obtained were often unskilled, expensive and undependable.

- The shortage of building supplies and labor resulted in high repair costs. For example, one company was hired under the Mini-Repair Program (i.e. replacement of doors, windows, stairs, and electrical, plumbing and heating systems) to repair 1000 flood damaged homes in Wyoming Valley. Estimated cost of repair by the Corps of Engineers was $1.4 million. The company repaired only 808 homes and charged the federal government over $3.5 million. The company blamed the high costs on unforseen high prices for supplies and labor.

- Imported labor was brought into the region. These extra costs were also included in the expenses of the company mentioned above. The expense sheet showed a cost of more than $400,000 for mobilization, which included flying in personnel from such far away places as Montana, Idaho, California and North Dakota as well as local living expenses and equipment costs (Philadelphia Inquirer, 1974; reported in Yancey, 1975).

- Inspections made by the Corps of Engineers of houses repaired under the Mini-Repair Program showed poor quality workmanship. The work done by some contractors was so bad that they became known among Corps inspectors as the "Dirty Dozen." One such company bid on so many mini-repair contracts that it fell weeks behind its scheduled completion dates. Some of the contracts awarded to that company had to be taken away and given to other contractors, thus compounding the delays and increased costs. (Philadelphia Inquirer, 1974; reported in Yancey, 1975).

- In the aftermath of Agnes, con men and flim-flam artists entered the disaster areas. They posed as contractors and offered to put houses back into shape. After a gullible or frantic homeowner made a down payment, the "contractor" would never return (Corp of Engineers, 1972).

Comments

These losses were distributed over a much larger area than one would expect as the direct result of a dam-break flood. However, the sort of meteorological event that would generate hydrologic dam failure is also likely to cause dispersed flooding over a large area. One can speculate as to the marginal additional losses had a major dam in Pennsylvania failed during Agnes.

The project pushed by Representative Vanik demonstrates a sort of "free loading" within past disaster politics. The Lake Erie problem is a continuing loss that is quite different than the sudden losses resulting from Agnes flooding in Pennsylvania. Yet, political trading lets others capitalize. One can expect a major disaster to place pressures on the Federal budget that far exceed relief and rehabilitation costs to the directly affected community as other areas also receive benefits through the political bargaining inherent in passing special legislation.

IX. BUFFALO CREEK FLOOD, WEST VIRGINIA, FEBRUARY 1972

Background

The flood occurred on 26 February 1972. It resulted from the collapse of a coal mine waste dump that had become a dam storing the flows from Buffalo Creek. During a period of heavy rain, the waste heap collapsed without warning; 132 million gallons of water and sludge rushed down the 18-mile long valley of Buffalo Creek completely demolishing the first villages hit; 125 people were killed and 4,000 of the areas 5,000 inhabitants were made homeless (Erikson, 1976a).

Litigation was initiated by 625 survivors of the Buffalo Creek flood who refused to settle with the coal company claims office. In an out of court settlement, the survivors were awarded $13.5 million, $6 million of which was distributed on the basis of a point system as compensation for psychological damages (Stern, 1976).

Results

- Disabling psychiatric symptoms such as anxiety, depression, changes in character and lifestyle, and maladjustments and developmental problems in children were still evident more than 2 years after the disaster in over 90% of the people examined (Titchener and Kapp, 1976).

- Collective trauma (defined by Erikson, 1976a as a blow to the tissues of social life that damages the bonds linking people together and impairs the prevailing sense of community) existed side by side with individual trauma at Buffalo Creek. This is reflected in the impact on the Buffalo Creek victims of the loss of their community (Erikson 1976b). Erikson, and Lifton and Olson (1976) felt that the placement policy in the refugee camps (first come-first severed with no regard for former neighborhood ties) contributed greatly to the disintegration individual (and family) social support systems from their communities.

- Death or survivor guilt: the guilt of having survived while others perished and a feeling that one could have done more to help others (Lifton and Olson, 1976).

- Death imprint and death anxiety: memories and images of the disaster associated with death, destruction and dying. This was often manifested by an acute fear of rain and water. Afterwards, even minor rains generated irrational behavior to watch for floods (Lifton and Olson, 1976).

<u>Contributing Factors</u> (Lifton and Olsen, 1976)

- The suddenness of the disaster and absence of warning: Relief workers estimated that during the first 24 hours after the event, 88% of the 4000 persons displaced by the water exhibited shock and incoherent thinking.

- Widespread losses: Virtually no one who lives in the valley was untouched by the flood.

- The callousness of the Coal Company: The public felt that the coal company was to blame for the accident and that they didn't care for anything except coal.

- The continuing relationship of survivors to the company: Most people still worked at the mines harboring bitter resentment while at the same time being financially dependent on the company.

- Community isolation: The area is geographically isolated and has been socially self-supporting. This meant that there was little external social or moral support to call on when the community broke down.

<u>Comments</u>

We are in times when court awards for "pain, suffering, mental anguish, psychological harm" far exceed direct medical payments. A "magnification" factor calculated from the ratio of total awards to direct awards would greatly inflate losses. One could examine law cases and supporting literature on estimating these losses to build a basis for thinking about how these losses would multiply during a major disaster. Perhaps an "Act of God" reduces or eliminates legal responsibility, but the distinction between manmade and natural causes should have little effect on the suffering that actually occurs.

We also see in Buffalo Creek the impacts of destroying "community" support systems in an area where the people had no outside family or friends to turn to. In contrast, San Francisco was a new community where nearly everyone had the resort of going back "home".

Also, Buffalo Creek people were largely dependent on a non-cash economy. They grew their food, traded services, helped each other out during times of trouble in the "pioneer" spirit of pitching in to rebuild a fire-destroyed home in a day as a community effort. Suddenly this entire support system was gone. One could probe the literature to analyze this as a "community" as opposed to "individual" trauma.

X. RAPID CITY, SOUTH DAKOTA, FLOOD, JUNE 9, 1972
White (1975)

Severity

- Torrential rains (more than half of the 24-inch annual average) over a 99-square mile catchment caused surface runoff to cascade into the stream. Flows down the canyon carried trees, boulders, and buildings. Canyon Lake swelled in volume to ten times its normal 640 acre feet. Within 6 hours of the start of the rains, the Canyon Lake dam burst.

Damages

- 231 lives lost.

- In December 1972, the Corps of Engineers estimated 635 buildings and 312 trailers had been destroyed and that property damage amounted to $82 million.

Congress

Efforts by Representative James Abourezk (South Dakota)

July 20, 1972

- Rapid City had more than 1,000 jobs, upward of 5,000 homes and hundreds of businesses either completely destroyed or severely damaged.

- He advocated lowering the interest rate on Small Business Administration disaster loans to 1%.

- Sought some sort of grant or forgiveness of loans. Presently $2,500 of disaster loan may be forgiven.

- Asking for up to 90% forgiveness of disaster loans.

- In Rapid City, a 90% forgiveness feature would cost the Government roughly $45 million--not even one third of what has been given to foreign governments for disasters in the last six years.

September 27, 1972

- More than one foot of rain fell.

- Dams broke.

- Water crushed more than 1,000 homes.

- 240 persons dead.

- The flood cut a swath several blocks wide through the entire length of Rapid City. Homes, cars, trees, etc. were strewn along that path.

- The dam is out and if heavy spring flooding occurs from all the snow that accumulates in the Black Hills in a typical South Dakota winter, the high flow will be repeated.

- People of Rapid City have decided not to permit any development in that flood zone. The city will rebuild on safer, higher ground and place a park as a memorial to those who died and suffered where it would not be safe to locate businesses and homes.

- Rapid City plans to use the Urban Renewal Program. Has applied for $87 million.

- Property tax base has been dealt a devastating blow.

- Tourism did not materialize as people stayed away from Rapid City despite urgings to the contrary.

- Loss is between 15-33%.

- Unemployment remains high. Hundreds of businesses were lost in a town of 43,000 people.

Comments

The Federal assistance programs do drive up prices by bringing more reconstruction money into the community than the local construction industry can assimilate, particularly in a city so isolated from others of its size.

One wonders whether the feeling of loss presented by Congressman Abourezk continues 14 years later or whether the new and improved city after reconstruction is actually more thriving.

XI. AUSTRALIAN FLOODS OF 1974: CASE STUDIES OF THE EFFECTS OF DISASTER ON HEALTH

a. Richmond River Flood (Smith et al., 1980)

Background

In March 1974, a 100-year flood on the Richmond River inundated the northern New South Wales town of Lismore causing major property damage and community disruption. Most shops were inundated to a depth of over 2.5 m (8.2 ft) above floor level and about 400 houses (out of 1900 in the flood-prone area) were inundated to depths of up to 3 m (9.8 ft).

Results

After-the-flood studies documented several negative health effects:

i. Smith et al. (1979), (reported in Smith et al., 1980) found that 8% of flooded households claimed that the flood had an adverse effect on health. Older people (over 45) or those with over 0.5 m (1.6 ft) of water in their homes were most affected.

ii. Petroff and Leatch (1975) (reported in Smith et al., 1980) found that the flood precipitated an increase in outpatient attendances at their psychiatric clinic in Lismore.

iii. Further studies by Smith et al. (1980), showed that while the flood does not appear to have increased the number of hospital admissions or deaths, it may have affected the pattern of admissions especially among those whose houses were severely flooded (ie. had more than 1 m (3.3 ft) of water over the floor). In this group, the number of male admissions doubled while the number of female admissions halved.

Although there was no overall change in total numbers of deaths, deaths from heart disease increased significantly in the year following the flood for the whole of Lismore. No satisfactory explanation was found for this trend.

b. Brisbane Flood

Background

According to Smith et al. (1980), in January 1974, a substantial proportion of Brisbane, including the business district was flooded. About 13,000 dwellings were affected. 7,500 were flooded and nearly 100 were totally destroyed. 12 lives were lost. The population had no prior flood experience and was completely unprepared and did not comprehend the flood warnings issued.

Results

- No increase in mortality after the flood was observed.

- Significant increase was observed on the number of visits to general practitioners, hospitals, and specialists. Among those seeking medical care, the predominant symptoms were persistent psychological symptoms which include irritability, nervous tension and depression.

- Consumption of sleeping tablets and psychotropic drugs rose.

- The impact of the floods on health was greatest for people over 35 years of age, probably because they were more likely to be householders.

- Women under 65 years of age had more psychiatric symptoms than men, but this sex difference disappeared in those over 65 years. The higher level of psychiatric symptoms in women is thought to be due to the fact that the housewife is confronted with the damage all day. The men are back at work.

Comments

Homes are an economic investment to which we acquire great personal attachment. Their sudden loss is a traumatic blow that women, who feel the primary responsibility in our society for their attractiveness, experience more deeply than men.

XII. SAN FRANCISCO BAY REGION FLOODS OF JANUARY 1982
As described by Brown (1982)

Severity

Twenty-five inches of rain in 32 hours dropped on the coastal mountains initiating many hundreds of debris flows. Debris consisted of mud, rock, and trees. Flowrates exceeded 10 ft per second and destroyed bridges, pipelines, communication networks and roads. Early estimates indicated a storm return period of over 100 years. Detailed analyses later indicated that at most locations rainfall amounts were 1- to 40-year range.

Losses

Public property	$\$109 * 10^6$
Private	$\$172.4 * 10^6$
Homes damaged or destroyed	6,500
Businesses	1,000
Deaths	33

Synergism

- No regional flood warning system is available to provide real-time data on rainfall intensity and accumulated volumes and on corresponding stream flows. Rainfall amounts were found to be 150 to 250 percent above those forecast by the National Weather Service.

- No regional centralized system exists for transmission of the data to emergency response centers for interpretation.

- Despite abundant information about geologic and hydrologic hazard areas produced and distributed during the past two decades, local governments consistently permitted development in those areas during that time.

- Many flood control channels, bridges, culverts and other drainage systems proved inadequate to handle the combination of water and debris that resulted from the intense storms, even though the systems were designed to carry the volumes of water that actually occurred.

- Debris control structures such as those found in Southern California, Japan, and Italy are virtually nonexistent in the San Francisco region. Limited damage from earlier debris flows, the small number of places where debris flows occur repeatedly and the limited population on hillslopes and in canyons have apparently combined as factors against construction of debris basins or similar structures.

Comments

1. Flood frequency analysis depends on the parameter being analyzed. The parameter could be rain (over many time periods), flow, flood stage considering the accentuating effect of the debris, or damage. This complexity is often insufficiently reckoned into engineering design.

2. The relatively large portion of the damages inflicted on public property, particularly when added to public responsibility for losses to private property, places a large financial burden that reduces services and values received from services for years.

APPENDIX II
NOTES AND COMMENTS ON SUPPLEMENTAL READINGS

1. Dam Safety

Baecher et al. (1980) presented a procedure applying utility theory, estimation of economics damages, and historical rates of dam failure in the low-probability/high-consequence (LP/HC) risk analysis of dam safety programs. Utility theory provides valuable background for assessing dam-failure losses, but catastrophic losses impact individuals far beyond their most imaginative anticipations. The application should come through studies for helping people quantify utility by communication with computer graphics and studies for measuring utility at a larger scale from a community perspective.

In his review of potential dam failures, Ayaswamy et al. (1974) state that as many as 200,000 fatalities could now be caused by a major dam failure in California. Pate-Cornell and Tagaras (1986) quote the U.S. Department of the Interior review of the proposed Auburn Folsom-South Central Valley Project as stating that a "sudden and complete collapse of [Auburn] dam when the reservoir was full would imperial the lives of 750,000 persons." Niehaus et al. (in Waller and Covello, 1984) make the case that engineering designs that reduce the expected value of losses often increase the potential for catastrophe. For example, aviation advances concentrate deaths in airplane accidents in a few large events and thus reduce high-probability/low consequence risks by accentuating LP/HC risks. In the same way, reservoir storage controls lesser flood events even while creating the possibility of much greater losses from a dam failure.

A wide variety of issues that arise in LP/HC studies were discussed at a conference whose proceedings were edited by Waller and Covello (1984). In addressing the uncertainties in estimating the probabilities of these rare events, J. B. Russell (1984) reported that the conference consensus was that "no source of information should be overlooked if it can be used to more accurately assess the frequency of low-probability events." Minarick and Kukielka (1984) emphasized the importance of precursor events and event chains that precede a catastrophe. Precursor sequences may be particularly important harbingers of synergistic factors. Ballestero et al. (1984) used this concept to partition raw extreme event data into subsets characterized by physical meteorological processes that lead to major storms. Distributions were fit to each subset and then aggregated.

The effect of human error on losses experienced during low-probability events could be evaluated by using "human reliability analysis" in assessing system reliability and safety (Swain 1984). The Office of Nuclear Regulatory Research (1983) includes human error probabilities in its guide to performance of probabilistic risk assessments for nuclear power plants. The probabilities are based on tasks that are behaviorally similar in terms of cues, interpretations, response requirements, and responsibilities. Hall (1984) discusses quantification of human performance drawn from experience in nuclear power plants. He states that cognitive errors occur through misdiagnosis of an off-normal event. Procedural errors are usually not severe unless multiple errors occur sequentially.

While experiences gathered from the nuclear power industry may be helpful in assessing human reliability, the human errors made by people caught in unexpected catastrophic events would be expected to be much greater than that by trained people regularly encountering hazardous situations in nuclear power plants. The subjects of human error in unfamiliar circumstances and the effectiveness of training in reducing human error during events that are unlikely to occur during a lifetime are worth investigating.

It is difficult to assess the human contribution to "magnification" during events larger than any that have ever occurred in North America. However, one can speculate and novelist scenarios may be the best medium to use. Vlachos (1977) discusses the use of scenarios in social impact assessment.

Thompson and Parkinson (1984) discuss the unacceptability approach, which views risks that exceed a given degree of consequence to be strictly unacceptable without regard to probability. This is based on the ethical principle that one is morally justified in risking only what one can afford to lose.

Situation-specific indicators can be used to distinguish between high-consequence/low-probability risk and low-consequence/high-probability risk according to Thompson and Parkinson (1984). The standard indicators of death, injury, and property damage should be supplemented with 1) Community and Cultural Indicators, 2) Profitability Indicators (largely for low consequence risks), 3) Probability Indicators (largely for uncertainty), and 4) Exposure Indicators (classifying people according to perceived risk and ability of individuals to achieve long-term goals).

Many people consider high-consequence risks to be of greater moral significance than the more familiar medium- and low-consequence risks. This attitude may grow out of a philosophical commitment to the unacceptability approach. LP/HC risk threatens not only lives but also the social, economic, and emotional support structures which bind people into a community. This logic would assign nations a still greater value.

"The community represents a value perhaps above and beyond human life." (Thompson and Parkinson 1984, p. 559.) Points given to support this view are:

1. A community is a thing of intrinsic value.

a. A prerequisite for any moral action.
b. Basic needs and happiness are contingent upon the social and economic structures provided by the community.
c. Such basic community forms as family, friends, and church represent the highest fulfillment of human purpose.

2. Loss of community causes suffering and mental anguish. "The sudden loss of the entire system of support and society represents a severe emotional trauma for survivors of a tragedy." (Erikson 1976a).

3. Loss of community means a loss of institutions and artifacts of recognized cultural value.

Meyer (1984, p. 338) states that "an external diseconomy may result from the imposition of catastrophic loss risks upon the neighbors of a facility potentially subject to a catastrophic accident." A large dam imposes such risks.

Regulatory agencies are more risk adverse where many people are simultaneously at risk and require greater safety (Committee on Safety Criteria for Dams, 1985). "Federal guidelines for dam safety" (Committee on the Safety of Existing Dams, 1983) require preparation of an emergency action plan, commensurate with the dam size and location, based on a postulated dam failure and flood inundation maps. The plan should be coordinated with local civil-preparedness officials and cover notification, evacuation, stockpiling repair materials, and inventory, local repair forces, and training operating personnel. One caution is to avoid overlooking consequences at the catastrophic and super catastrophic scales. The plan itself can be effective during disaster only to make matters worse during catastrophes.

The determinants of popular perceptions of riskiness should be identified. People have a clearer understanding of the benefits and hazards associated with dams and are thus more willing to accept them than they are willing to accept nuclear power plants, for example. The perceptions of risk differ although the probabilities may be similar. "Actuarial knowledge of the fatality risks of dams does not readily clarify decisions concerning dam safety." (Baldewicz 1984, p. 81)

There is a need to develop a theory of risk perception that predicts how people will respond to new hazards and management strategies. (Slovic 1984) Two goals are to improve communications of policy-makers with the lay public and to structure effective educational efforts.

2. Repair Cost Escalation

Yancey (1975) explored 15 factors for use in determining whether repair costs escalate after a catastrophe. The four principal ones were found to be:

a) The amount of direct damage measured in dollars.

b) The capacity of the local construction industry measured by the dollars worth of construction annually within the market area. The larger the construction activity, the greater is the potential to supply the increased repair requirements resulting from a natural disaster. The regional annual volume of contract construction in dollars can be used to index local construction capacity.

c) Unemployed labor force measured in the monthly wages that the unemployed would draw if they had jobs. The greater the level of unemployment of local construction workers, the greater is the local potential to supply increased demands.

d) Income distribution: After a disaster, individuals with higher incomes are more concerned about repairing their property quickly than they are with repair prices. On the other hand, the poor cannot afford high repair costs and can only wait until the prices come back down or ask the government or some other group to finance the necessary repairs. Knowledge of the fractions of the affected population with incomes in various brackets thus provides an indication of cost escalation potential.

3. Health Impacts

Health impacts increase with the severity of the flood experience. Logue (1978) and Melick (1976) found that persons whose homes had been flooded perceived a more serious effect on their health than others in the same community whose homes were not flooded. The physiological wear-and-tear on people experiencing the flooding of their homes reduces natural defenses against illness. The flood group is more likely to be forced out into the wet and cold, has greater economic concerns that may inhibit seeking help, postpones attending to health problems, and is sicker when they finally seek health care.

Parker (1977) reports that 25% of victims questioned 10 weeks after a tornado reported deterioration in physical health, but only 11% indicated this after 14 months had passed. Takuma (1978) reported that many earthquake victims complained of ill health after the quake, but the number decreased over a 7-week period. Faich and Rose (1979) found that hospital admissions for myocardial infarction increased and mortality from all causes, especially ischemic heart disease, increased in the five days following a blizzard. Studies of postflood populations found longer durations of illnesses (Melick, 1976), and increased numbers of visits to general practitioners and hospitals for a year following the flood (Abrahams, et al, 1976).

4. Psychological Impacts

Disasters may generate such psychological reactions as acute grief, anxiety, anger, hostility, resentment, depression, and loss of ambition among adults. Marital and family discord, increased use of tranquilizers and psychoactive medications, and excessive alcohol consumption have been observed. Children develop phobias, reoccurring sleep disturbances and nightmares, and a lack responsibility. They lose interest in school.

Green et al. (1985) found in a long-term study of psychological impairment of survivors of the Beverly Hills supper club fire that differences in an individual's experiences during the fire were significantly predictive of their later psychological functioning. Experiences such as bereavement, life-threatening, extent of danger, time waiting to know status of friend or loved one, and helping search and rescue affected the primary stress response symptoms such as depression, anxiety, sleeplessness, social isolation, suicide, substance abuse, hostility, or belligerence. Persons experiencing bereavement or life-threatening experience showed more symptoms one year after the fire than at two years. Those experiencing searching and waiting experiences maintained symptoms over a longer time, because of their prolonged uncertainty about the impact of experience. Prolonged uncertainty of such events as Three Mile Island also was shown to predict long-term impairment.

One would also expect repair cost escalation to add to the mental anguish. People are forced to choose, for themselves and their families, between continuing discomfort or paying for repairs at perceived exorbitant costs. They have to deal with people of poor reputation or maybe just different cultural roots. They may be taken economically while their personal finances are at low ebb.

According to a report in Science News (1985), people living near Mount St. Helens were still suffering emotional problems due to the volcano's eruption five years earlier. Residents suffering significant property loss or personal loss were nearly 12 times more likely than others to experience a psychiatric disorder, and rates of mental disorders among women who experienced such losses were about twice as high as for men. The intensity of their reactions decreased in the second and third years after the eruption. The major impact was caused by the flood which occurred as a result of the eruption. Another study showed increased mental disorders and stress responses among residents in a town covered with volcanic ash. Their stress reactions lasted at least seven months.

Logue (1978) found that, five years after Hurricane Agnes, emotional and physical distress lasted about a year longer with flood victims than in a control group.

Six months after the accident at Three Mile Island, nuclear plant workers showed psychophysiological symptoms, anger, and extreme worry, primarily among nonsupervisory workers, and especially those having preschool children (Sills et al, 1982). An NRC survey (Flynn, 1979) found symptoms of stress including overeating, loss of appetite, difficulty in sleeping, feeling trembly or shaky, trouble thinking clearly, irritability, and outbursts of extreme anger which diminished over time.

Titchener and Kapp (1976) state that more than 80% of a group of survivors of the Buffalo Creek flood showed a traumatic neurotic syndrome, and the symptoms and resulting character changes persisted for months, even years after. Almost all reported anxiety, grief, and despair. The anxiety later led to obsessions and phobias about water, wind, rain, and other reminders that the disaster could reoccur. Not only have individuals been traumatized, but the entire community.

Erikson (1976) states that loss of communality resulting from the Buffalo Creek flood has impaired individuals' recovery as well. Survivors not only suffer demoralization because of personal loss, but because they have lost their or perceive they have lost most of their moral anchors. They were scattered throughout the valley when relocated and felt great suspicion to their new neighbors. They perceive that relative strangers are less moral than familiar neighbors. They suspect breakdowns in morality such as increased use of alcohol, that outsiders have not been able to substantiate. Their sense of disorientation has continued for years after the disaster, which is uncommonly long.

Erikson suggests this exceptional response occurred because the survivors had few individual resources to cope because they had for so long used their abilities for the community, and didn't know how to use them for their own needs. The community was stronger than the individuals. It lost the quality that gave power to the individuals to care, console, and protect each other in disaster.

Gibbs and Levine (1982) discusses the long-term effects of stress from the presence of a chronic hazard, namely toxic wastes from a landfill. The residents of Love Canal were evacuated several times, lost most of their possessions due to fear of contamination, and forced to live in college dormitories and motels for extended periods. Children exhibited behavioral problems and marriages were strained. There was fear of chromosomal damage, cancer and other health problems from exposure to toxics. President Carter signed a bill to evacuate the families permanently from Love Canal due to mental anguish.

Kinston and Rosser (1974) state that during the threat phase preceding a disaster there seems to be a universal denial of the potential disaster as an attempt to adapt to an unnatural situation. They site cases where evacuation was minimal, such as the Hawaiian tsunami of May, 1960. By not acknowledging the threat, they avoid physical inconvenience and psychic distress.

During the initial impact, the first major shock is to the individual, whose feeling of personal invulnerability is suddenly reversed. A second major shock follows when the amount of destruction is realized. Reactions swing between terror and elation, invulnerability and helplessness, abandonment and escape. Their subsequent recovery from this shock depends on whether the disaster was a "near miss" or a "remote miss", and on the actual amount of loss experienced. Panic is very rare, rather feelings of helplessness or bewilderment, docility, and indecisiveness, among others, which is the "disaster syndrome".

During the recoil after first impact, people often react with hyperactivity, loss of efficiency, irrational behavior, and otherwise obtain emotional release. They are often obsessively preoccupied with the personal implications of the event.

During the early aftermath fear and apprehension often persist, often due to the idea that the disaster will reoccur (such as aftershocks in an earthquake). New disasters are fantasied and rumors rapidly spread, often with the aid of the media.

Survivors have difficulty mourning their dead unless they know the bodies have been identified, and their attempts to find missing persons often interfere with relief operations.

The memory of the disaster persists, with the survivors often forced to relive it over and over again. Often they feel regrets or recriminations over actions taken before or during the disaster.

There are some therapeutic factors in the disaster, such as the relief that threats and dangers come from the outside. The immediate needs are obvious, immediate, and generally physical, such as food and shelter. Danger, loss, and suffering are public and immediately present, so past and future are unimportant, and survivors who are not so badly affected feel relatively less deprived.

Initially, people tend to give or accept help without restraint, but this is followed by feelings of hostility, greed, suspicion, envy, and competition. They resent relief organizations which give compensation based on need, not losses.

Following destruction, people prefer to move back and rebuild. This seems to be due to feelings of fate, feelings that such events are random occurrences, and that leaving will cause further disaster. People may also wish to repair the damage and master the event, or refuse to be scared away. Very few move away, and those who do tend to for "neurotic" reasons.

Melick et al (1982) discuss some characteristics and mediating variables affecting the individual's reaction to disaster. Whether a disaster is natural or man-made, some events are accepted by victims as acts of God. However, in other cases victims attach blame to someone or something, for example the Buffalo Creek flood, Love Canal, and Three Mile Island. They suggest that preventable disasters (such as a dam break due to human negligence) may be more stressful than nonpreventable events.

The time factor associated with the impact of the disaster and recovery is important with respect to the potential effect on the survivors' health. Victims of Hurricane Agnes felt that the recovery period was about 18 months. For an event such as Love Canal, where the threat was present for a much longer period, long-term effects may endure much longer.

It is also important to distinguish between losses resulting from damages that can be measured objectively and the stresses perceived during the event. The Buffalo Creek flood had major impacts in both categories. Three Mile Island resulted in little objective loss but high perceived stress.

Other factors include whether the community is prepared for the event, perhaps due to earlier disasters, whether evacuation is carried out on a large scale, and whether the event seems to have an irrevocable effect on the victim's life, such as Love Canal.

Carver and Scheier (1981) suggest that the relationship between prior performances and future expectancies depends on whether the outcomes are contingent on factors the person controls. "Increments in expectancies (following successes) or decrements in expectancy (following failure) were greater and more frequent when the task was described as skill based than when the task was described as chance based. . . . prior performances affected expectancies of future performances only when the outcomes were believed to have been determined internally." p. 189.

These outcome expectancies affect the way a person reacts to hazards. People who perceive a discrepancy between a hazard and acceptable environmental risk attempt to reduce the discrepancy if they have any hope of success. If their expectancies are unfavorable, people attempt to physically withdraw from the situation. If that is not possible, they may have a sort of mental withdrawal as they think about other things, refuse to consider the hazard further, and avoid any reminders.

Carver and Scheier (1981) also emphasize that a person's outcome expectancy determines his or her emotional reaction. If a favorable expectancy is viewed as a product of personal effort or ability, heightened self-esteem results. If it is viewed as resulting from outside help from others or by luck, gratitude follows. On the negative side, an expectancy seen as a result of a person's own inadequacies or failings lowers self-esteem. If the expectancy is perceived as caused by others, frustrations commonly lead to anger and resentment. Disasters are negative, and both of these last two responses are commonly reported among their victims.

From these initial reactions, the feedback loops of control theory can be extended to longer run applications to anxiety-related behavior. In the context of this study, one can consider the effects of the impact of a dam-break flood on behavior through the aftermath and recovery periods. Results of two studies suggest that self-focus increases awareness of fear or anxiety cues and interrupts normal activities. Responses to these interruptions seem to be determined by the person's outcome expectancy. "Even with fear salient, if expectancies are positive, the result is renewed efforts and concentration on the goal. If expectancies are negative, however, interruption leads to withdrawal." p. 241.

Also, fears or anxieties lead to earlier withdrawal by persons who perceive negative outcomes and tend to increase efforts by confident persons with positive outcome expectancies. Thus, anxiety or fear can be facilitating or debilitating. However, some level of fear probably becomes debilitating for even confident people. ". . . although we have not experimentally addressed the possibility, it may be that even relatively high levels of anxiety are facilitating for people who are very confident." p. 228.

If people with low outcome expectancies cannot physically withdraw from a hazard situation, they tend to experience mental withdrawal into thoughts or perceptions irrelevant to their surroundings. This reduces their performance or usefulness as functioning members of society. They work halfheartedly and are easily interrupted by physical anxiety cues or frustrations in their tasks. Poor outcomes reinforce perceptions of an unfavorable expectancy, cause further withdrawal, and lead people to focus on task-irrelevant information. One empirical data source for further work in this area would be to study reactions and behavior during and after a catastrophic dam failure.

5. <u>Preventative Response</u>

There seem to be conflicting signals in the literature on how hazard experience affects the performance of subsequent mitigation measures. In investigating the relationship between attitudes towards hurricanes and hurricane adjustments, Baker and Patton (1974) found that experience with past hazards was strongly related to successful preventative actions. (Comment: probably also to reduced personal and community trauma. In fact one could hypothesize trauma and lack of training as the primary contributors to inefficient actions during catastrophes.)

Saarinen (1979) discusses the linkage between prior hazard experience and subsequent mitigation measures. People can be misled by limited or biased experience. Saarinen uses an example to illustrate this point.

"In investigations following Hurricane Camille, which struck the Mississippi Coast in 1969, it was found that many people assessed their safety according to memories of an earlier smaller storm which stuck in 1947. This may have been a fatal mistake for many as most among the 123 dead were drowned while trying to ride out the storm in a residence near the water front." (p. 2, 1979). (Comment: In our terminology, disaster experiences may lull people into complacency against subsequent catastrophe.)

Carter, Clark and Leik (1979), in a study of response to hurricane warnings, found that prior experience with hazard situations did not enhance either preparedness or evacuation under warning. In a later study, Carter (1979) found that people without hurricane experience evacuate earlier than those who have experienced a hurricane. The latter group waits for firm confirmation of the necessity for evacuation. Clark and Carter (1980) note that experience with hurricanes raises "threshold" levels, that is, the body of evidence required before one is satisfied that evacuation is necessary. (Comment: Experiences may also include realization of event magnitude variability, unnecessary evacuations, personal or neighbor losses to looters, or difficulties in returning to implement repairs.)

The logic generally used in setting policy for government programs to help to influence people exposed to natural hazards is (Baumann and Sims, 1980): 1) provide information on the risk and education on proper mitigation measures; 2) such information will make the public under threat aware of the nature of the risk and the options that they have for doing something to reduce their losses; and 3) such awareness will result in the public under threat adopting protective measures. Records of past events indicate that is does not necessarily follow that distributed information will cause the public to know what to do and do what it should. Reasons for breakdown in this conventional logic are given by Saarinem (1979) and Mileti et al. (1975).

In studying the warning systems for tornadoes, flash floods and hurricanes, Carter (1979) found that at least one-third of the public does not automatically follow official announcements. However, 90 percent will evacuate if they are convinced an event is serious. Hence a major task of a warning system is to convince skeptics. In interviewing families who were ultimately evacuated in the 1965 Denver floods, Drabek and Stephenson (1971) found that many of them interpreted the official broadcast warnings simply as "information." They felt that something as serious as the need to evacuate would be personally communicated to them in some way other than by radio or TV. Baumann and Sims (1980) have provided some insights and directions on warnings:

1. The warning must be clear;
2. The warning must convey an appropriate response;
3. The warning must be perceived as coming from a credible source;
4. The warning must be reinforced socially at the local level;
5. The medium used to disseminate the warning is important; and,

6. The type of appeal must be considered and assessed.

Quarantelli and Dynes (1972) discuss common beliefs and perceptions about social behavior during natural disasters which do not appear to be valid, but which are often considered when officials are planning for anticipated disasters.

a. Panic flight. Due to fears of people panicking, officials put out warning bulletins cautiously or at the last minute. Media often reports entire communities fleeing on approach of a flood or hurricane. Actually the majority of inhabitants usually do not leave - it is usually tourists and transients who flee. Also most evacuations are orderly, with people helping others to get away. In the face of a flood threat in Denver in 1965, 92% of families who left together.

In evacuating Three Mile Island an estimated 74 to 90% stayed with friends and relatives. The median distance traveled was 85 to 100 miles. About 180 stayed at the official evacuation center during one day, although as many as 800 may have stayed there for a short time. At one time, there were more reporters than evacuees at the center (Sills et al. 1982).

During Hurricane Carla in 1961, over 500,000 people left their homes, but although there was at least four days warning, most residents never left their home. About 35% stayed in their homes and 22 percent with friends and relatives. In a New England city hit by two hurricanes in succession, only about 4% evacuated.

U.S. News and World Report (1985) report that people along the coast tended to stay in their homes during hurricanes until Camille killed 256 in 1969. Since then most states passed mandatory evacuation laws that allowed police to arrest the foolhardy. During Hurricane Elena, officials in Louisiana ordered evacuations three times over a four-day period with most of the population responding. Fewer than 15 out of 1500 inhabitants of Dauphin Island, Alabama, refused to move the mainland. It has been hit by three hurricanes in the last 16 years, and inhabitants continue to rebuild.

b. Shock. Only in a minority of cases do victims exhibit a shock reaction, usually apathy. This is generally short-lived and only seems to occur in the aftermath of sudden, violent disaster.

c. Help. Disaster victims react immediately to their plight, first seeking help from family and friends, then from churches or other similar groups. If not available, then victims seek help from more impersonal official organizations, police or welfare departments. Only as a last resort do they turn to the Red Cross or civil-defense agencies.

Quarantelli and Dynes (1972) found that during the 1971 earthquake in San Fernando, California, when over 80,000 had to evacuate homes downstream of weakened dams, fewer than 7% sought housing aid from public agencies. During the large evacuation preceding Hurricane Carla, more than 75% went to other-than-public shelters. In a flood in Yuba City and Marysville, California, less than 20% went to the 38 Red Cross shelters available in 13 towns in the disaster area.

d. During the 1953 tornado in Flint, Michigan, persons in the disaster area rescued and took to hospitals between 2/3 and 3/4 of the over 900 casualties within three to four hours and without significant aid from formal organizations. Even in large disasters, most victims never come in contact with outside agencies.

e. Outside agencies tend to underestimate local resources and flood a disaster area with unneeded supplies. There are usually more than enough volunteers, so much so that they cannot be effectively used. This often overwhelming response of volunteers from outside the immediate disaster area is known as convergence.

f. There is very little evidence that wide-scale looting occurs. However, most victims perceive that looting occurs, even when it cannot be substantiated. This is due to rumors - They heard of others' property being stolen.

g. Time. In the initial period after disaster, differences of class, rank, and age are unimportant as people work side by side to rescue injured and clear debris. Morale may be high. People compare their losses to others' losses and to what might have happened. However, the heightened sense of community creates a wall that excludes outsiders with needed skills and resources such as Red Cross rescue teams.

i. The media tend to exaggerate disaster impacts. Orderly evacuations are reported as persons fleeing in near-panic. Officials usually overestimate losses of life and property. Reports focus on destruction and despair or on unusually tragic aspects, which may be true but are not representative. In the Alaska earthquake, initial estimates circulating in Columbus Ohio were 1000 dead in Anchorage alone; Chicago papers estimated 500 dead; in Seattle it was 300; and in Anchorage it was 100. The actual number of deaths was 7.

Danzig et al (1958) studied the effect of a threatening rumor on a community which experienced a major flood. After flood waters receded, people returned to their homes to clean up. A day after a rumor that water was coming over the dam upstream was received over the radios on the fire-trucks used to pump out residences and was rapidly spread by word-of-mouth and phone. Nearly a third of those who heard the rumor fled, with 90% of those who lived in the area of town already flooded. Officials delayed action until it was verified false, and then transmitted the news to local radio stations and directly to the public. Several denials of the rumor had to be broadcast before people would return.

j. Disaster victims like to pass off their experiences as atypical and heroic. Stories of looting and exploitation reinforce their own sense of decency. They act as a necessary counterpoint to the reality of the event.

The psychological impact of disaster may be minimized by a willingness to admit the possibility of the disaster occurring yet also maintain a belief in survival. Anticipation or worrying about the coming event can reduce the risk of being overwhelmed by the event.

Green et al (1985) suggest that a person's individual disaster experience is a good indicator of future psychological functioning, while Pearlin and Schooler (1978) have identified factors which predict how persons will cope with stress. Those with higher education and income show better coping ability, probably because they have access to more effective coping techniques. Men do better than women, for personality characteristics and response repertoires shown to have some effect in controlling stress are found predominantly in men. No significant overall difference was found between young and old.

This information may be used predicted reactions to risk before an event, allowing identification of persons likely to need clinical care, or be used to predict mental health outcomes for specific events.

Kinston and Rosser (1974) suggest that specialized psychiatric skills could be useful in all phases of a disaster. This is rarely done and interventions by psychiatrists are actively resisted in the early phases by other helpers and by the victims in the later phases. It is not known what priority psychiatric help should have relative to other relief. However in Yugoslavia the psychological impact of disaster is considered in planning relief services.

Apart from conventional methods for treatment of individuals, there is not much information on special problems in treating on the community level where there is prevalent death, disablement, material loss, and bereavement. The authors feel that an obvious role for psychiatrists would be to set up groups to help the community work through its shared experiences constructively.

Kinston and Rosser (1974) also suggest that all responsible persons involved in disaster relief should understand psychological first-aid in order to establish effective human contact with disturbed or upset survivors. Separations of loved ones should be prevented. To minimize confusion, anxiety, and guilt, processes such publishing lists of dead and injured, establishing effective communication and information centers, and quelling rumors must be accelerated. Also, competition between relief organizations should be dealt with quickly. This will reduce the often experienced hostility of victims to relief agencies.

Omohundro (1982) found that after an oil spill in the St. Lawrence River, residents were as disturbed by the lengthy cleanup as they were by the pollutant itself. When asked what aspect of the spill they found most upsetting, 24% of the answers concerned quality of the cleanup, the money spent, the leaders of the cleanup, and other items directly related to the relief operation, while only 14% mentioned factors related directly to the pollution of the environment. There was much overlapping and gaps in federal, state, and local government organizations involved resulting in confusion about responsibility. Elected officials and government agencies received the most negative rating of oil spill participants from respondents. Providing and managing public information was a critical but difficult task, consequences included conflicting perceptions, rumor epidemics, incorrect referrals for information, and ultimately a decline in morale.

Due to the fact that it is important to respond to oil spills with maximum speed, the relief agencies generally act independently of the oil spill society. Thus, victims become alienated from the relief agency that is supposed to help them. The Coast Guard was often blamed for many of the difficulties, even for the accident itself. The Coast Guard was in charge of almost all available compensation to the victims and were suspected of arbitrary judgments, using biased criteria, and bending to political pressure. This created feelings of hostility and anger in the victims.

Barton (1969) discusses the capacity of formal organizations to deal with the great amount of decision and administrative work in the aftermath of a disaster. In several cases ad hoc groups were set up to bypass local government and coordinate the efforts of outside relief organizations, local offices, and volunteers. (Comment: These plans seem oriented toward a local disaster than the catastrophes and supper catastrophes examined here. Many of the same principles apply, but greater geographical separation would be preferable. We should also give greater thought to the susceptibility of computer software and data banks to the types of forces leashed by natural disaster. How should these be stored for better protection?)

6. Disaster Planning by Businesses

Dissmeyer (1983) describes the management response to a fire that gutted the Norwest Bank building in Minneapolis on Thanksgiving Day 1982. By implementing a disaster contingency plan devised months before, all vital records were preserved intact. Basic services were provided to the public the next day, and all major functions were brought back to normal within a week, although they were housed in temporary quarters. An article in Management Review (1983) states that the cost of preparing the contingency plan for the Norwest Bank was about $27,000.

A management policy committee oversaw everything. Copies of transaction data were transferred daily to an operations center several blocks away, and another backup system kept duplicates of these. Vendors flew in replacement equipment (microcomputers, word processors, communications gear, etc.) over the weekend. Customers were informed through the media of alternate locations for banking services. Some 300,000 square feet of temporary office space was located and leased.

The authors recommend the following contingency plan features:

Prepare for a wide range of disasters - earthquake, flood, fire, tornado, power failure, civil disorders.

Preserve the integrity of the processes, not just individual items, and make sure that departmental plans fit together.

Have sufficient detail so key managers know who does what and how to reach them.

Spell out priorities as ranked by someone or a committee.

Involve every department from the earliest stages when formulating the plan.

Update the plan regularly.

(Comment: These descriptions fit disasters better than catastrophes as being considered here. One can wonder what additional features would be added for dealing with a true catastrophe.)

Colby (1985) quotes John Nugent, senior consultant at Norwest Bank, as stating that a Texas study showed that, of companies which experience disaster, 43% never reopen, and 29% of those who do reopen are closed again within 2 years. Some 95% of the businesses having disaster recovery plans failed to test them in advance. Norwest spent $55,000 to get paper documents cleaned by a salvage vendor.

The Office of the Comptroller of Currency issued Banking Circular 177 in 1983 required the CEO and directors of each national bank to have contingency plans and evaluate them annually for adequacy. The outcome is to be recorded annually in the minutes of the annual meeting. Campbell (1985) credits the Norwest fire and the power blackout in New York in 1983 as events causing business managers nationwide to think seriously about disaster contingency planning.

John Nugent (personal communication) stated that a recent survey by Chubb and Sons Insurance Company showed that 91% of the businesses that suffered a data processing center disaster went out of business within five years. Also, the Management Information Systems Research Center at the University of Minnesota performed a study in 1978 on the effect of a data processing center disaster on various types of businesses. Banks had a tolerance level of only 2 days without data processing facilities before they experienced a significant loss of business. Insurance companies could tolerate 4 weeks to a month, and manufacturing industries fell in between.

Campbell describes three necessary levels of protection:

1. Identification of the major business functions so that provision can be made for continuing each one with minimum disruption.

2. Regular technical backup of important business information by duplicating files and databases and arranging for a standby facility to provide processing during an emergency or disaster. Using microcomputers complicates backup and recovery, since most data and software is not properly safeguarded for backup.

3. Planning to preserve the major networking-hardware (automatic teller machines; fund transfer mechanisms; brokerage services; voice, data, and facsimile communications).

From the general management perspective, a business should examine the potential impact of the disaster on revenue loss, additional expenses, loss of customer confidence, and legal liabilities. Also, many banks use other banks, financial service organizations, or service bureaus to support their business;

and these may become unavailable. Banks generally show a high level of interest but so far most contingency plans are confined to the technical aspects of computer processing. Their lack of concern for major business functions show a scaling weakness analogous to governments that review potential damages to their facilities but give lesser consideration to preserving their fundamental functions.

Comment: These plans seems more oriented toward a local disaster than the catastrophes and super catastrophes examined here. Many of the same principles apply, but greater geographical separation would be preferable. We should also give greater thought to the susceptibility of computer software and data banks to the types of forces leased by natural disaster. How should these be stored for better protection?

The ABA Banking Journal (1985) discusses two disasters striking individual banks. A tornado destroyed a bank in Barneveld, Wisconsin on a Friday. A banker from a neighboring town called vendors and fellow bankers and over the weekend gathered resources so that the bank could open on Monday for business in a rented trailer.

The second case concerned a bank in Galveston hit by a hurricane in 1983. When a hurricane standby was issued, outside signs were removed, generators checked, and inventory taken of emergency items such as flashlights. When a hurricane warning was issued, computers were shut down, windows taped, and safe deposit boxes oiled to prevent rusting due to high humidity.

Advertising Age (1985) reports earthquake impacts on Mexican business. Tourism was hard hit by travelers' anxieties. Ad agencies were hurt as clients cut back advertising budgets in order to rebuild. Newspapers temporarily lost revenues from movie ads amount to 2 or 3 full pages daily. Most of the ad agencies are U. S. controlled or dominated, and the U. S. home offices organized relief efforts.

Chemical Week (1983) discusses the effect of a flood in Louisiana on shippers. Shipments were delayed a day or more because a major railroad trestle was washed away and flood-swollen rivers slowed barge progress and raised tow rates. Railroads had to reroute, and delays caused extra charges there too. Chemical feedstocks were brought in by truck as the major roads were still open, but highway transport is much more costly.

Industry Week (1982) discusses southern Italy's attempt to rebuild after the Naples earthquake caused significant damage to 1449 businesses with 100 or more employees. There is hope of a rebirth of industry including advanced plants in energy, light transport, and telecommunications.

Significant natural disasters seem to inspire a higher concern for disaster contingency planning by businesses. After major hurricanes and earthquakes, business and industrial journals often publish articles on emergency preparedness and planning. An articles in Factory (1961) discusses the lessons learned in the aftermath of Hurricane Carla. Some large manufacturers, such as Westinghouse, had workers flown in from other parts of the country (New York and Denver, in Westinghouse's case) to aid in cleanup and recovery of vital equipment. They also obtained equipment and replacement parts from large equipment manufacturers before the hurricane struck. Westinghouse sent motors to 20 different shops located as far as 300 miles away for repair. They also made commitments to such service shops before the storm struck.

An article in Iron Age (Starin 1962) suggests utilizing retired workers for fill-in duties, providing alternate headquarters, establishing reporting centers for employees away from plants, and joining mutual aid associations for pooling equipment and personnel. Weimer (1977) also suggests that any contingency plan should include mechanisms to provide local officials with ready estimates of damages and the portion not covered by insurance in order to justify state or federal assistance.

Davis (1973), in an article prompted by Hurricane Agnes, tells of a free course offered by the Defense Civil Preparedness Agency in industry and business emergency planning. He also urges that businesses' emergency plans become a part of the community emergency plans and that they get involved with the community planning.

7. Rebuilding and Relocation

Kinston and Rosser (1974) state that following destruction, people prefer to move back and rebuild. Very few move away, and those who do tend to for "neurotic" reasons. Examples include Managua, now rebuilt for the third time after earthquakes destroyed it. This seems to be due to feelings of fate, feelings that such events are random occurrences, and that leaving will cause further disaster. People may also wish to repair the damage and master the event, or refuse to be scared away (or preserve social relationships, e.g. Buffalo Creek).

Nineteen percent of all respondents to an NRC survey (Flynn, 1979) said they had considered moving (30% within a five-mile radius). However, as of end of July, 1979, less than three-tenths of 1 percent had moved due to the accident. Many families report stress and continuing threat, but few are so concerned as to relocate.

A report in U.S. New & World Report (1985) states that for most communities hit by a natural disaster, it takes only a year or two to rebuild completely. According to James Morentz, author of Hazard Monthly, a journal on disaster relief, local and private funds typically provide two to three times more aid than the federal government. Fort Wayne, Indiana, hit by flooding in 1982, implemented flood-control measures while rebuilding and when hit by a major flood in 1985, suffered little damage. In Johnstown, PA, however, hit by a flood in 1977, relief efforts suffered from duplication and disorganization, causing resentment among victims. Some areas may never come back. The Brownwood subdivision in Baytown, Texas, hit by Hurricane Alice in 1983 was hit so badly it had to be abandoned.

During World War II, most of Warsaw was destroyed. Ciborowski (1964) writes that of 957 historical buildings, 782 were completely demolished, 141 partially destroyed, and 34 remained. An important provision in the plan to rebuild Warsaw stated that all destroyed monuments of the past and relics of material and cultural progress, such as churches, cathedrals, the Royal

Palace, and the Old Town were to be restored, at the same time adapting them to modern ways of living. Berlin's central areas , including most of the slum districts, were also hard hit during war time bombing. Modern, safe housing was rebuilt, and new factories as well (Armstrong, 1973)

Rebuilding is not always for the better. Torry (1978) cites the case of Managua, Nicaragua, where thousands of low and middle-income houses were built with help of outside aid. Due to credit bottlenecks and skyrocketing prices uncontrolled by officials, most of poor could not afford to buy them so many stood empty. Houses were undesirable to middle-income because of location, small size, and repetitive rows of houses.

This phenomenon has occurred in urban renewal attempts. Hays (1985) reports that there was great pressure from opponents to public housing to locate new units in areas already occupied by the poor, putting a stigma on it which was further increased by construction of new projects in slum areas. Any family with ambitions of upward mobility would avoid "the projects", even though the rent was cheap. Therefore the most economically deprived and those attracted to the projects as an excellent place to commit crimes were left, leading to inevitable deterioration.

8. Relationship Between Probable Maximum Precipitation (PMP) and Area

$$R = \sqrt{D}\left[a + \frac{b}{\sqrt{A + C}}\right] \text{ ; Fletcher (1950)}$$

in which:

R = rainfall depth

A = area

D = rainfall duration

a = the shift of the axis of rainfall divided by $\sqrt{D}$

b = parameter representing the particular hyperbola chosen for the fitting

C = the shift of the axis of square root of area

For U.S. rainfalls, Fletcher found the following relationship:

$$R = \sqrt{D}\left[0.5 + \frac{266}{\sqrt{A + 19.2}}\right]$$

where R is in inches; D is in hours; and A is in square miles.

The above equation is valid for A up to 200,000 square miles.

Horton (1924) gave the depth area relationship as:

$$\bar{P} = P_o e^{-KA^n}$$

in which

$\bar{P}$ = the average depth of rainfall for a given duration

A = area

P_o = the highest amount at the center of the storm

K,n = constants for a given storm.

Using storm data of five great northern storms, Horton (1924) found that the 24-hour rainfall amount could be represented by

$$\bar{P} = 16\ e^{-0.0883\ A^{0.24}}$$

and for five great southern storms by

$$\bar{P} = 22\ e^{-0.112\ A^{0.25}}$$

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