*Source: D.K Sander*

Figure 3-8 Road washed out in flooding in Washington State

earthquake, cellular-to-cellular communication posed only a small problem (some cell sites lost power); however, communication between cellular and land-based systems was disrupted because so many people were using the system.

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**Disaster hazard effects on system components.** To complete step 2 of the vulnerability assessment process, the effects of disaster hazards are evaluated for each component of the total system. This can be accomplished using a form for each type of disaster, or a matrix of the hazard summary and effects on components. An example is shown in Figure 3-9.

## STEP THREE: ESTABLISH PERFORMANCE GOALS AND ACCEPTABLE LEVELS OF SERVICE FOR THE SYSTEM

A water system is considered a lifeline because water is essential to the safety and health of the population it serves. Water systems should not be hazardous to their personnel or the public. A utility should develop specific goals and acceptable levels of

| System Components — Likely damage, loss, or shortage due to hazards | Earth-quakes | Hurri-canes | Tornados | Floods | Forest or brush fires | Volcanic eruptions | Other severe weather | Waterborne disease | Hazard-ous material | Structure fire | Construction accidents | Transportation accidents | Nuclear | Vandal, riots, strikes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Administration/operations** | | | | | | | | | | | | | | |
| Personnel | ■ | ■ | | | | | ■ | ■ | | | ■ | ■ | ■ | ■ |
| Facilities/equipment | ■ | ■ | ■ | ■ | ■ | ■ | | | | ■ | | | ■ | ■ |
| Records | ■ | ■ | ■ | ■ | ■ | | | | | ■ | | | | ■ |
| **Source water** | | | | | | | | | | | | | | |
| Watersheds/surface sources | | ■ | | ■ | ■ | ■ | | ■ | ■ | | | | ■ | ■ |
| Reservoirs and dams | ■ | ■ | | ■ | | | | ■ | ■ | | | | ■ | ■ |
| Groundwater sources | | | | ■ | | | | ■ | ■ | | | | ■ | |
| Wells and galleries | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | | | | ■ |
| **Transmission** | | | | | | | | | | | | | | |
| Intake structures | ■ | | ■ | ■ | | ■ | ■ | | | | | ■ | | ■ |
| Aqueducts | ■ | | | | | | | | | | ■ | ■ | | |
| Pump stations | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | | ■ |
| Pipelines, valves | ■ | | | | | | ■ | | | | ■ | | | ■ |
| **Treatment** | | | | | | | | | | | | | | |
| Facility structures | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | ■ | ■ |
| Controls | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | | ■ |
| Equipment | ■ | ■ | ■ | ■ | ■ | | | | | ■ | ■ | ■ | ■ | ■ |
| Chemicals | ■ | ■ | ■ | ■ | ■ | | | | | ■ | | | | ■ |
| **Storage** | | | | | | | | | | | | | | |
| Tanks | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ |
| Valves | ■ | | | | | | ■ | | | | | ■ | | ■ |
| Piping | ■ | | | | | | ■ | | | | | | | |
| **Distribution** | | | | | | | | | | | | | | |
| Pipelines, valves | ■ | ■ | | | | | ■ | ■ | ■ | | ■ | | | ■ |
| Pump or PRV stations | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | | ■ |
| Materials | ■ | ■ | | ■ | ■ | | | | | ■ | | | | ■ |
| **Electric power** | | | | | | | | | | | | | | |
| Substations | ■ | ■ | ■ | ■ | ■ | | ■ | | | ■ | ■ | ■ | ■ | ■ |
| Transmission lines | ■ | ■ | ■ | ■ | ■ | | ■ | | | ■ | ■ | ■ | | ■ |
| Transformers | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | | ■ |
| Standby generators | | | | ■ | | | | | | ■ | | | | ■ |
| **Transportation** | | | | | | | | | | | | | | |
| Vehicles | | ■ | ■ | ■ | ■ | | ■ | | | | ■ | ■ | | |
| Maintenance facilities | ■ | ■ | ■ | ■ | ■ | | ■ | | | ■ | | ■ | | ■ |
| Supplies | | ■ | | ■ | ■ | | | | | ■ | | | | ■ |
| Roadway infrastructure | ■ | | | ■ | | ■ | ■ | | | | ■ | ■ | | ■ |
| **Communications** | | | | | | | | | | | | | | |
| Telephone | ■ | ■ | ■ | ■ | ■ | | ■ | | | ■ | ■ | ■ | | ■ |
| Two-way radio | | | | | | | | | | | | | | ■ |
| Telemetry | ■ | | ■ | ■ | ■ | ■ | | | | | | | | ■ |

Figure 3-9 Disaster effects matrix

service under disaster and recovery conditions. The following are specific goals to consider.

## Goals

**Life safety.** A water system's primary goal should be to preserve the health and safety of its personnel and the public. Meeting this goal should be considered a continuous function of the system — before, during, and after a disaster. Examples of life-threatening or injury-causing conditions are

- failure of distribution system
- failure of dams
- distribution of contaminated water
- release of hazardous materials, especially chlorine
- collapse of structures such as water towers

**Fire suppression.** Most fire-suppression activities depend on the potable water distribution system During disasters, particularly earthquakes, there may be many fires to fight. Fire-suppression capabilities should be made available immediately after a disaster. or as soon as possible.

**Public health needs.** Water is essential to life and health. However, some needs are more immediate than others. The following list is of public health needs and the allowable time without potable water being available. Times are guidelines only and depend on the magnitude of the disaster.

- hospitals — continuous need
- emergency shelters — immediate need
- kidney dialysis — 24 hours
- drinking water — 72 hours
- personal hygiene, waste disposal — 72 hours

**Commercial and business uses.** Many businesses depend on water for their operation, for example, restaurants, car washes, and many manufacturing companies. However, nearly all business could not function for long without potable water for drinking, waste disposal, and cooling water for air conditioning and other process systems. Also, many commercial structures are protected with fire sprinkling systems that should not be left without a water supply.

## Service Priorities

Establishing priorities for service is an important part of completing this step of the vulnerability analysis. Most medical facilities need continuous service; contact them to determine approximate daily needs or estimate their needs from utility records. Other priorities should be police and fire departments, and the emergency operations center. For medical facilities and other priority customers, it is a good idea to have a record of a contact person or persons, their phone numbers, reasons for needing priority service, approximate daily needs, and an alternative on-site source if one is available. A sample form to record service priorities is found in chapter 5 (Figure 5-8). Priorities need to be reviewed and updated annually.

## Water Requirements

Water requirements under disaster conditions can be assumed or estimated only in terms of the nature and magnitude of the disaster, user needs, and the capabilities of

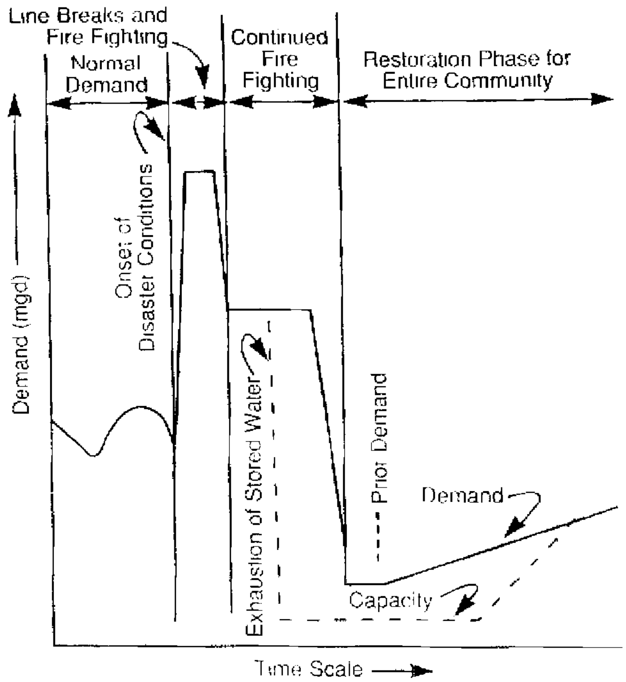



Figure 3-10 Water demand under normal and emergency conditions

the system itself Although highly approximate, a plot of the anticipated water demand under a set of circumstances could be developed (Figure 3-10). The figure shows the normal fluctuation of water demand against time before the disaster, then shows the demand following a major earthquake. In this hypothetical case, a number of water lines and mains are broken, significant fire fighting is under way, and the reservoir supplies are being depleted rapidly. Assuming further that workers were unable to valve off broken mains and that the fire-fighting requirement continued, reservoirs would likely be emptied and the water supply system would not be able to supply the amount of water required to continue fire fighting under such emergency conditions. The priority need is also shown on the curve of Figure 3-10.

From a water supply viewpoint, the amount of water that can be supplied has been sharply reduced and is unable to meet the requirements of the community (the supply is deficient). The demand for water would have to be met by importing water from other sources, such as tank trucks or by fire-pumper relay. In the worst case, demand simply could not be met. Eventually, restoration of capability within the water utility would permit the production of water equal to demand, and, as the community recovered, this capability would continue to match the community's demand. This process could take considerable time.

## STEP FOUR: IDENTIFY CRITICAL COMPONENTS

With the first three steps complete, a utility has identified the most probable disaster-hazards effects on major components and has established service priorities and performance goals The priority demand can also be thought of as the minimum needed for health and safety. Identifying the critical components of the system, or its "subcomponents" (for example, a run of old cast-iron main could be considered a subcomponent of the distribution system), is the final step in the vulnerability analysis.

Critical components are those vulnerable to failure, or partial failure, because of a disaster hazard. Failure of a critical component will reduce the ability of the system to meet minimum health and safety performance goals. The best way to approach this step is to select a scenario of a particular disaster. Focus on the components that are interrelated with other components so as to make the entire system inoperative; these are the most vulnerable components.

Repeated application of this process of assuming various disasters, constructing anticipated demand curves, determining measures required to meet minimum health and safety demands, and subsequently identifying critical components eventually will isolate the most critical components in the entire water supply system. These components are ones of particular interest in predisaster protective measures.

A computer model of the distribution system can be used to simulate disaster conditions. For example, the model can show the effects on water supply if the treatment plant or a storage tank is off-line. Refer to AWWA Manual M32, *Distribution Network Analysis*, for more information.

## Example

The following is a brief example of a vulnerability analysis of a water system in an earthquake-prone region. Figure 3-11 is a schematic of a hypothetical system: Seismic City. This example was developed by the ASCE TCLEE* Water and Sewerage Committee and the Seismic Risk Committee.

The following paragraphs illustrate the first two steps of a vulnerability analysis: identifying the system components and the potential effects of earthquake hazards.

**Water system description.** Water is supplied primarily by the water treatment plant, which draws raw water from the Seismic River. During peak demand periods in the summer, wells 1 and 2 are operated. Standpipes 1 and 2 float on the low-pressure zone. Both pump stations 1 and 2 pump the water up to the high-pressure zone. The reservoir floats on the high-pressure system. Water is delivered to the west side of the Seismic River through two river crossings; one buried and one hung on a bridge. The average daily system demand is 10 mgd (37.5 ML/d) and peaks at 18 mgd (67.5 ML/d) during the summer. The treatment plant has a capacity of 13 mgd (49 ML/d). Each well has a capacity of 4 mgd (15 ML/d).

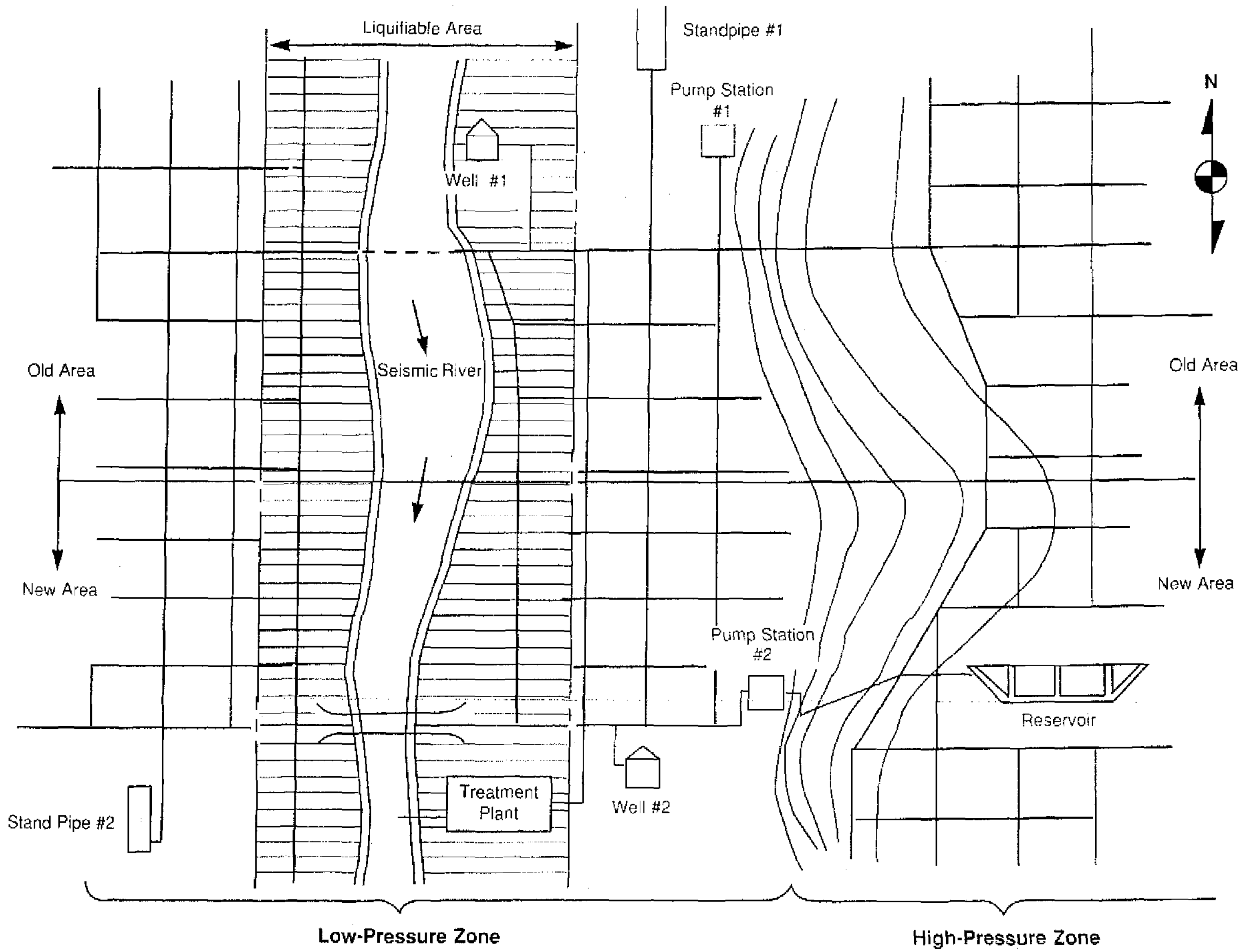
**Geologic setting.** Seismic City is located in seismic zone 3. Until recently, magnitude 7.2 earthquakes 31 mi (50 km) from the city were considered to be the maximum credible earthquake. Recent studies have raised the concern for a magnitude 8.5 earthquake centered 62 mi (100 km) to the west. The Seismic River, which has meandered across a significant part of the valley through the years, has left alluvial deposits along its course. The soils nearer the valley walls and East Hill are of glacial origin and are stable.

**System components**

*Well 1*

- constructed 1948
- founded on liquefiable ground

*American Society of Civil Engineers, Technical Council on Lifeline Earthquake Engineering, 345 E. 47th St., New York, NY 10017.




*Source: Kennedy/Jenks Consultants Engineers and Scientists (1993).*

Figure 3-11 Schematic of Seismic City water system

- building — unreinforced roof not anchored to walls
- buried piping — cast iron
- control cabinets unanchored
- wall discharge piping — no lateral support or flexibility
- engine-generator set (added 1975)

*Well 2*

- constructed 1983
- constructed on glacial till
- building — reinforced masonry, roof anchored to walls
- buried pipe — ductile iron and flexible coupling
- electrical cabinets, equipment, and piping adequately supported
- no engine-generator set

*Water Treatment Plant*

- constructed 1971
- constructed on liquefiable material
- structures — pile supported; yard piping, river intake — no pile suppo
- uses reactor (flocculator) clarifiers
- chlorine supplied in 1-ton (900-kg) containers (unanchored)

Equipment and piping has no special lateral support except engine-genera provided for plant operation, raw-water pumping, and pumping to the system.

*Pipelines*

- transmission/distribution in "old" area — constructed 1948
- transmission/distribution in "new" area — constructed 1971+
- buried river crossing — constructed 1948
- bridge/bridge crossing, multispan concrete girder bridge — constructed

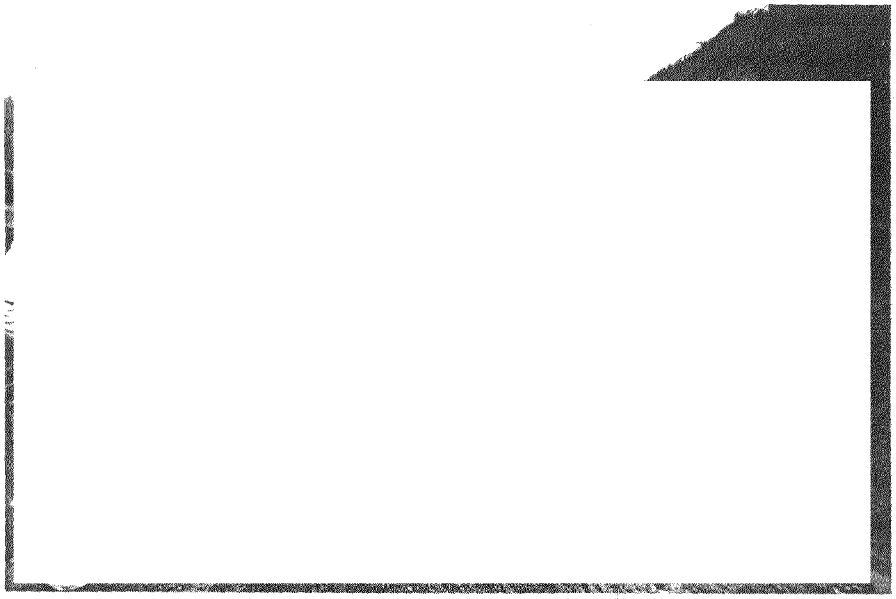
*Pump Station 1*

- constructed 1957
- founded on glacial till
- building — wood frame
- buried pipe material unknown
- piping designed to resist pressure at bends (thrust)
- electrical cabinet anchorage unknown
- no engine-generator set

*Pump Station 2*

- constructed 1971
- founded on glacial till
- building — masonry reinforcing; roof attachment
- buried pipe material unknown
- piping designed to resist pressure at bends (thrust)

- electrical cabinet anchorage unknown
- no engine-generator set



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