

## **7.0 DISRUPTION OF UTILITY AND TRANSPORTATION SYSTEMS**

The previous chapters dealt with each of the major natural hazards impacting Lane County including floods, winter storms, landslides, wildland/ urban interface fires, earthquakes and volcanic hazards. These chapters evaluated each of the hazards and the risk arising from the hazards as they impact the buildings, infrastructure and people of Lane County.

Each of these hazards may result in not only damage to buildings but also damage to and disruption of utility and transportation systems. Mitigation projects may be formulated to reduce or avoid such damage and disruptions and a few examples were discussed in the previous chapters. In this sense, evaluating the potential damage and disruption of utility and transportation systems from each hazard is part of the risk assessment for each locality affected by a natural hazard.

However, disruption of utility and transportation systems may have impacts on the affected community which are far broader than the direct damage and corresponding direct loss of service. In this sense, disruption of utility and transportation systems may be viewed almost as a hazard. As for other hazards, the probability, duration, and extent of such outages can be assessed and the impacts (risk) associated with such outages can be quantified. Among the major utilities, loss of electric power generally has the most widespread impact on other utilities and on the community as a whole. Therefore, this chapter deals with electric power outages in more detail than for the other utility and transportation systems.

### **7.1 Transportation Systems**

Streets, roads, and highways are subject to closure during flood events because of high water levels on road surfaces. This type of closure may occur during either a major flood event on the larger rivers and streams in Lane County and surrounding areas or during winter storms as a result of localized flooding on smaller drainage systems. In major floods or major winter storms, such road closures may be widespread. If flow velocities are low, then such closures are usually due primarily to water depth and there is generally little damage to the road system; reopening the road simply requires waiting for the water level to drop and then cleaning up mud and debris on the road surface.

However, if flow velocities are higher then erosion of the road surface or undermining of the road may occur. This type of damage is most common in hilly areas with relatively steep slopes and occurs most often on smaller roads rather than on major highways. Reopening such roads requires repair of the damaged road surface.

The flood of February 1996 provided ample evidence of the impact of flooding on roads. For example, in Lane County, there were dozens of flood-caused road closures. These closures included major routes such as US 101 North and South of Florence, Highway 36 in three locations, Highway 126 at Noti, the Marcola Road in the Mohawk Valley, and the McKenzie Highway at Milepost 24. Even Interstate 5 had water flowing across it just north of Eugene near the Boston Mill Road overpass. In addition numerous smaller roads also had closures.

For Lane County, the map in Chapter 7 (Winter Storms) shows more than 60 locations (primarily highways and roads) that have been repeatedly affected by winter storms (primarily localized flooding).

Some sites of road closures are difficult to mitigate without large scale flood control projects. However, mitigation is possible at many locations with high potential for road closures. Common measures include raising the road surface to reduce the probability of water overtopping the road or improving local drainage (e.g., culvert upsizings).

Risk assessments for road closures must include a measure of the importance of the road for transportation as well as an evaluation of the direct physical damages to the road. In many cases, the disruption of transportation has a larger economic impact than the direct physical damages.

To evaluate and prioritize hazard mitigation projects for roads, we suggest three measures of the relative importance of a road:

- 1) number of vehicle trips per day,
- 2) detour time around a road closure, and
- 3) road use as primary access/egress, including emergency vehicles.

The number of vehicle trips per day is an obvious measure of the importance of a road. All other factors being equal, a road with 500 trips per day is more important than a road with 50 trips per day and thus should have a higher priority for mitigation projects. However, a better measure of the importance of a road is obtained if the detour time is also considered. If traffic loads were equal, a mitigation project on a road where a closure required a one hour detour would have a higher priority than a road where a closure only required a five minute detour. More accurately, it is the combination of traffic load and detour time that provides a measure of the impact of road closure. The product of number of trips per day and the detour time gives a measure of the number of vehicle-hours of delay that result from a closure. Consider the following example:

**Table 7.1  
Calculation of Vehicle-Hours of Delay from Road Closures**

Road	Trips per Day	Detour Time (hours)	Vehicle-Hours of Delay per day of Closure
A	500	0.10	50
B	100	1.00	100

In this example, Road A has five times the traffic of Road B, but because the detour time is much longer for a closure on B than on A, the number of vehicle-hours of delay is greater on Road B than on Road A. On this basis, mitigation of the hazard causing the closure would have a higher priority on Road B than on Road A.

The number of vehicle hours of delay is a proxy for the economic impact of the closure. The current FEMA value (for benefit-cost analysis purposes) for the

economic impact of lost time due to road closures is \$32.23 per vehicle hour of delay (What is a Benefit?, FEMA 2001). This value is based on national average wage and benefits level and national average vehicle occupancy data, along with the assumption that an hour of leisure time is worth the same to a person as an hour of work (a common economic assumption). Then, for example, 100 vehicle hours of delay per day has an estimated economic impact of \$3,223 and so on. For the vast majority of roads, with “typical” traffic loads, using a economic value of \$32.23 per vehicle per hour of delay provides a reasonable measure of the economic impact of road closures. Everything else being more or less equal, roads which serve as primary access/egress routes and/or serve many emergency vehicles may be given a higher priority for mitigation.

For completeness, we note that roads are networked systems and a more accurate analysis of the relative priority of mitigation projects to reduce road closures should consider the network characteristics of a local road system. However, network analysis is complex, requires specialized expertise and is expensive. Network analysis may be justified for very expensive projects, such as a multi-million dollar relocation of a bridge to reduce the potential for flood washouts. However, the simple three parameter prioritization methodology suggested above is probably sufficient for evaluation of most small to medium sized mitigation projects.

Rail systems are subject to the same sorts of closures as are road systems. Evaluation and prioritization of mitigation projects for rail systems would follow a methodology closely analogous to that discussed above for road systems, with economic impact parameters appropriate for a rail system.

Other transportation systems (air, ports, ferry) are also subject to disruption due to the impacts of hazards. The analysis of such systems is roughly similar to that discussed above, but mitigation projects for such systems are encountered far less frequently than are mitigation projects for roads. Moreover, most such projects are not directly applicable to or a low priority for Lane County and thus not considered further.

## **7.2 Utility Systems - Overview**

Evaluation of hazard mitigation projects for utility systems have some commonalities between systems that we briefly review before addressing each major utility system in turn.

Utility systems such as potable water, wastewater, natural gas, telecommunications, and electric power are all networked systems. That is, they consist of nodes and links. Nodes are centers where something happens - such as a pumping plant, a treatment plant, a substation, a switching office and the like. Links are the connections (pipes or lines) between nodes.

Risk assessments for utility systems are similar to risk assessments for buildings, in that the inventory of utility components is overlaid on the hazard map and the vulnerability of utility components is evaluated for the hazards impacting the utility. A major difference arises, however, because of the networked nature of utilities. As a simple example, consider an electric utility which suffers damage to 10% of its

transmission lines. The extent of service outage might be essentially zero if there are redundant lines with sufficient capacity to handle the demand for electric power. Or, the extent of service outage might be 100% if the damaged lines provide the sole power feed for a community. Thus, the operating characteristics and network characteristics (especially the amount of redundancy) must be considered.

**In conducting risk assessments or evaluating hazard mitigation projects for utility systems, the networked nature of such systems must be considered. The extent or lack of redundancy for particular elements in a system profoundly affects the extent to which a given level of damage results in system outages.**

The general procedure for conducting a risk assessment or evaluating a hazard mitigation project for a networked utility system is outlined below in six steps.

- 1) Overlay utility system components with hazard maps,
- 2) Estimate the vulnerability of each component to impacts from each hazard,
- 3) From the estimated amount of damage to the system and the system's network operating characteristics, estimate the extent and duration of service outage,
- 4) From the damage estimates and the resources available, estimate the restoration time,
- 5) From the service outage (number of customers and duration) estimate the economic impacts of such loss of service, and
- 6) If a mitigation project is being evaluated estimate the reduction in direct damages and the reduction in service interruption attributable to mitigation project.

An important caveat for conducting risk assessments or evaluation of hazard mitigation projects for networked utility systems is that specialized expertise is often required. The analyst must thoroughly understand the operating characteristics of utility system components and their vulnerability to each hazard as well as thoroughly understand the network operating characteristics of the system as a whole. In the absence of sufficient experience and expertise risk assessments or evaluation of hazard mitigation projects may produce inaccurate and misleading results.

**CAVEAT: conducting risk assessments or evaluation of hazard mitigation projects of networked utility systems often requires specialized expertise to produce meaningful results.**

For reference, a detailed discussion of how to evaluate seismic hazard mitigation projects for water systems is given in the American Society of Civil Engineers monograph "***Guidelines for the Seismic Upgrade of Existing Water Transmission Facilities***," (J. M. Eiding, editor, 1999; chapter by K. A. Goettel "Seismic Upgrades of

Water Transmission Systems: When Is It Worth It?”). Very similar principles apply to evaluating hazard mitigation projects for other utility systems for any type of hazard.

The following sections briefly review utility systems with emphasis on identifying the system components which are most vulnerable to damage and loss of service from hazards covered in this Mitigation Plan: flooding, winter storms, landslides and earthquakes. Such components are thus logical targets for high priority mitigation projects whenever important components are subject to the hazards.

### **7.3 Potable Water Systems**

Water treatment plants, including those in Lane County, are often located in flood prone areas and are subject to inundation when raw water enters the filters, sedimentation or flocculation basins, resulting in loss of capability to treat incoming raw water properly. Water system control buildings and pump stations may also be subject to flood damages. Public or private water systems with wells as the water source are subject to outages when flood waters contaminate well heads; this is a common problem for smaller water systems.

Water transmission or distribution pipes are rarely damaged by flood waters, unless there are soil settlements or major erosion, because the lines are sufficiently pressurized (for water quality) to prevent intrusion of flood waters. Water transmission or distribution pipes are, however, subject to breakage when they cross landslide areas or in earthquakes. Water treatment plants are also subject to earthquake damages to the building and to process and control equipment.

Water systems, including Lane County’s water systems, are also highly vulnerable to electric power outages. Many water systems include pumped storage systems where water is pumped to storage tanks which are typically located 60 to 200 feet above the elevation of water system customers. Such tanks generally contain no more than 1 or 2 days of storage beyond typical daily usage (for reasons of water quality). Thus, electric power outages of more than 1 or 2 days may result in loss of potable water due to the inability of pumping plants to pump water. The most logical mitigation projects to minimize such outages are to provide back-up generators at key pumping plants or to provide quick connects so that portable generators (if available) can be quickly installed. Water treatment plants are also subject to outages due to loss of electric power.

Common mitigation projects for water systems include flood protection for treatment plants, providing back-up power, moving pipes from active landslide areas, and seismic upgrades for treatment plants.

### **7.4 Wastewater Systems**

Wastewater systems are often highly vulnerable to flood impacts. Rising water may cause collection pipes to backup and overflow. Intrusion of storm water into collection systems may result in flows that exceed treatment plant capacities, resulting in release of untreated or only partially treated flows. Treatment plants are often located

in flood plains, at low elevations, to facilitate gravity flow. However, such locations also facilitate flood damages. Wastewater treatment plants may be inundated, resulting in full or partial plant shutdown or plant bypass with corresponding release of untreated or only partially treated flows.

Lift stations and treatment plants are also subject to loss of function due to electric power outages, with resulting overflows or releases. Collection pipes are also subject to breakage due to landslides. However, such impacts are not particularly common, since most wastewater collection systems are in more urbanized areas with only selected areas subject to slides. Wastewater pipes are, however, subject to breakage in earthquakes. Wastewater treatment plants are also subject to earthquake damages to the building and to process and control equipment.

Common mitigation projects for wastewater systems include flood protection for wastewater treatment plants, providing back-up power for nodes such as lift stations, moving collection pipes from active landslide areas, and seismic upgrades for treatment plants.

## **7.5 Natural Gas Systems**

Natural gas transmission and distribution pipes are not usually affected by flooding, because the pipes are pressurized. However, compressor stations may be subject to inundation damage or loss of electrical power to run electrical and mechanical equipment.

Transmission and distribution pipes are also subject to rupture in slide areas. Buried utility pipes are very subject to failure in small ground movements. Movements as small as an inch or two are often sufficient to break the relatively brittle pipe materials. Possible mitigation projects for natural gas systems include providing back-up power for important nodes (e.g., compressor stations) and moving pipes from active landslide areas.

## **7.6 Telecommunications Systems**

Telephone (land lines and cellular) systems, broadcast radio and TV systems, and cable TV systems may all be vulnerable to damages and services outages from hazards. However, in general, such systems have proved to be somewhat less vulnerable to service outages than other utility systems. System nodes (broadcast studios, switching offices and such) are subject to flooding if located in flood-prone areas. However, because of the importance of such facilities, few are located in highly flood-prone sites.

Similarly, few such facilities are likely to be located in landslide prone areas. Cellular towers in hilly areas, however, may be more subject to landslide hazards.

Buried communications (copper and fiber optic) and cable television cables are usually flexible enough to accommodate several feet of ground movement before failure. Thus, while major landslides may rupture such cables, minor settlements or

small slides are not nearly as likely to impact such cables as they are to break buried gas or water pipes.

Above ground communications and cable television cables are subject to wind-induced failures from tree falls and pole failures. However, such failures are about ten times less common than failures of electric power lines. The better performance of communications cables arises in part because the electrical cables are always highest on the poles, thus a falling branch is usually first resisted by the power cables. Also, because the voltage levels in communications cables are much lower than those in power cables, the communication cables are not subject to “burn down” or shorting if wind-swayed cables touch each other or get too close.

Some telecommunications facilities are subject to failure as a result of loss of electric power. However, key facilities almost always have backup battery power and/or generators. Therefore, telecommunications facilities are generally much less vulnerable to outages from loss of electric power than are water or wastewater systems.

Possible mitigation projects for telecommunications systems include flood proofing of important nodes, adding back-up power, relocating facilities out of active slide areas and seismic retrofits.

## **7.7 Electric Power Systems**

The electric power system is central to the functioning of a modern society. The impacts of loss of electric power are large: residential, commercial and public customers are all heavily dependent on electric power for normal functioning. Furthermore, as discussed above, other utility systems, especially water systems, are heavily dependent on electric power for normal operations. Loss of electric power, therefore, may have large impacts on affected communities, especially if outages are prolonged.

Electric systems have three main parts: generation, transmission, and distribution.

Generation is the production of electric power. Generating plants can be hydroelectric, fossil fuel (oil, gas, or coal), nuclear, or various renewable fuels (wind, solar, biomass, etc.). Most of the electric power consumed within Lane County is thus produced elsewhere and transmitted via high-voltage transmission lines. The Bonneville Power Administration (BPA) is the primary source of power for Lane County. BPA's power comes from hydroelectric facilities (57%) operated by the Corps of Engineers or the Bureau of Reclamation, from a nuclear plant (3%), from interchanges and wheeling (37%) of power transmitted by BPA but not owned by BPA and from other sources (3%). Through the Pacific Interties (high voltage AC or DC transmission lines) power is moved back and forth between California, the Pacific Northwest and western Canada.

The transmission system is a network of high voltage lines (500 kV and 230 kV) and substations which transmit power between generation plants and the local distribution system. The distribution system is a network of lower voltage lines and substations

which carries power from transmission system substations to neighborhoods and eventually to individual customers.

Power outages in Lane County are most likely to result from disruption of the transmission lines carrying power from outside Lane County or within Lane County, or damage to the local distribution lines within Lane County. The generating plant system has sufficient redundancy so that failures of one or more plants do not usually lead to significant power outages. However, because of the limited generation capacity within Lane County, major disruptions in the transmission system would result in substantial curtailment of available power. A major ice storm in the Columbia River area could conceivably fail all of the 500 kV transmission lines feeding Lane County from the north. However, the transmission system has enough redundancy that the power needs of Lane County would likely be met by a combination of local generating capacity and transmission of power from California.

However, a severe ice storm with 2 to 4" of ice over much of Lane County could result in failure of all north-south 500 kV and 230 kV transmission lines within Lane County. Such a failure, which is unlikely, but certainly not impossible, would probably entail widespread power outages for 2 to 5 days.

The most frequent power outages, however, are due to failure of the local subtransmission or distribution system lines. Winter storms are the most frequent cause of significant electric power outages, with wind being the primary culprit. Electric distribution lines, the low voltage lines that deliver power to neighborhoods, are the most vulnerable electric system component in winter storms. Failures most commonly result from tree falls or from "burn downs" when wind-swayed cables touch or get too close to each other and short circuit. Distribution system failures may also be due to utility pole failures. Distribution lines may also fail due to ice loading in excess of design specifications or from landslides or debris flows or flooding which knock out utility poles.

Failures of distribution system lines are thus the most common failure mode for electric power systems. Power system outages are more common and of longer duration in rural areas compared to urban or suburban areas. Rural areas are more prone to electric outages because they have a higher percentage of above-ground lines and are more likely to have hilly areas with high concentrations of trees and higher wind speeds than in flatter terrain. In rural areas, with lower population density, there is also a higher ratio of length of distribution lines per customer. With a longer length of exposed line, the probability of an outage is higher for a rural customer than for an urban customer. Also to note is that an outage to the rural customer usually means loss of water because wells are run by an electric pump. In addition, cooking, providing water to livestock and agriculture and heating all become a problem.

Once a portion of a power distribution circuit fails, all customers in that part of the circuit lose power. The duration of the power outage depends on the number of outages and the number of repair crews available for repairs. A typical power utility repair crew (2 or 3 people with a bucket truck) can restore power to a distribution circuit with common types of damage in 1 or 2 hours after arriving at the damage site.

Electric transmission lines (110 kV and higher) are less vulnerable to winter storm damage because of more robust design specifications. Also, such lines are usually higher above the ground and much less prone to tree branches falling on lines. Furthermore, because of the higher voltage (compared to distribution lines), power utilities must diligently pursue tree trimming programs to avoid flashovers from lines being too close to trees. Nevertheless, transmission lines do sometimes fail due to large tree falls, rapid growth of trees near lines, unusually high winds or heavy ice loads.

Lane County is subject to outages of electric power primarily due to line failures. One possible failure mode would be the transmission lines that feed Lane County from the north and south. There are numerous trunk distribution lines both inside and outside the metro area. As such, every one of the utilities have large trunk feeders coming out of our substations not just EWEB common failure modes would be failures of the trunk distribution lines within the Eugene/ Springfield Metro Area and failures of distribution circuits or service drops from distribution lines to individual buildings. All of these failures are most likely due to tree falls during wind storm events.

Mitigation projects to reduce the frequency and duration of electric power systems include: augmenting tree trimming programs and hardening lines and poles in locations where ice loading or wind effects result in repeated outages. In some cases, adding connections to improve redundancy of power feed paths and adding disconnect switches to minimize areas affected by any given failure are also worthwhile. In addition to such “hard” mitigation possibilities, there are also “soft” or planning mitigation projects. For example, enhancing mutual aid agreements with nearby utilities can reduce the duration of major outages by increasing the number of crews and equipment for making repairs. Other planning/logistics measures such as ensuring that adequate supplies of parts and equipment are available may also reduce the duration of future outages.

For Lane County, augmenting tree trimming programs, especially for the transmission lines and the trunk distribution lines is probably the most effective mitigation measure. In selected locations upgrading lines and poles to better withstand loads from trees, wind and ice may also be appropriate. If there are key links in the systems that are highly prone to repetitive failures, undergrounding of limited portions of such links may also be appropriate.

## **7.8 Impacts on Lane County and Mitigation Action Items**

The probable impacts of disruption of transportation and utility systems on Lane County, which were summarized above, are also covered in each of the other hazard Chapters (6-12, 14, 15). Each of these chapters includes an impacts table which summarizes probable impacts on roads, bridges, and utility systems.

The following table contains action items for mitigation of disruptions of utility and transportation systems, from the master Action Items table in Chapter 4.

**Table 7.2  
Mitigation Action Items for Disruption of Utility and Transportation Systems**

Hazard	Action Item	Coordinating Organizations	Timeline	Ideas	Plan Goals Addressed					
					Public Awareness	Life Safety	Protect Property Minimize Losses	Partnerships & Implementation	Emergency Services	Protect Environment
<b>Utility and Transportation System Disruption Mitigation Action Items</b>										
Short-Term #1	Educate and encourage residents to maintain several days of emergency supplies for power outages or road closures		Ongoing	pg. 4-4 pp. 13-5 to 13-9	X	X			X	
Short-Term #2	Review and update emergency response plans for disruptions of utilities or roads		1-2 Years	pg. 4-4 pp. 13-5 to 13-9	X	X			X	
Short-Term #3	Ensure that all critical facilities in Lane County have backup power and emergency operations plans to deal with power outages		1-2 Years	pg. 4-4 pp. 13-5 to 13-9	X	X			X	