Hospital and Water System Earthquake Risk Evaluation: Executive Summary

Report to the Oregon Health Authority

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Executive Summary

A pilot project to evaluate the risk of hospitals and water systems from earthquakes triggered by the Cascadia subduction zone was conducted by the Oregon Department of Geology and Mineral Industries (DOGAMI) in partnership with the Oregon Health Authority (OHA), which has oversight responsibilities on hospitals and drinking water safety for the state. This project was initiated shortly after the release of the 2013 Oregon Resilience Plan by the Oregon Seismic Safety Policy Advisory Commission (2013).

The first goal was to establish a working partnership between OHA and DOGAMI to better understand and improve seismic preparedness of hospitals including their resilience to magnitude 9 Cascadia subduction zone earthquakes and tsunamis. The second goal was to improve awareness of seismic risks to hospital and water system operators in the project study region and to encourage action to increase community resilience, particularly by hospitals. Through site visits, project efforts have successfully provided information helpful to hospitals and water system operators to take steps to better prepare to respond to and recover from future earthquakes.

In accordance with needs identified in the 2013 Oregon Resilience Plan, DOGAMI 1) conducted vulnerability assessments of hospitals, 2) improved the inventory of water systems, 3) conducted vulnerability assessments of water systems, and 4) considered interdependencies between hospitals, water systems, and transportation.

The main tasks involved 1) gathering data on hospitals and water systems, 2) inputting the data into Federal Emergency Management Agency (FEMA) Hazus MH (short for Hazards United States Multi-Hazards) loss estimation software, 3) applying the Hazus loss estimation model to obtain damage, loss, and functionality information, 4) assessing lifeline interdependencies of the hospitals in the region to understand their resilience, including water, transportation, fuel, electricity, and communications, and 5) writing this report.

The project region, which stretches about 50 miles from coastal Lincoln City to McMinnville in the Willamette Valley, has a high seismic hazard due to the close proximity to the Cascadia subduction zone and its potential to trigger a magnitude 9 earthquake and tsunami. The area includes part of the Oregon Coast Range and sections of the Yamhill River and several other rivers. The area includes a population of approximately 96,000 people. Key project facilities include two hospitals, five water systems, and sections of U.S. Highway 101 and Oregon Highway 18 between Lincoln City and McMinnville.

The DOGAMI earthquake model for this study included 1,000-year probabilistic ground-shaking motions, which incorporate Cascadia earthquakes, soils that may amplify ground shaking levels, co-seismic landslide hazards, and liquefaction hazards.

Results

From major earthquake shaking, the project area is estimated to incur up to $5.1 billion in building losses, up to 80,000 damaged buildings, up to 13,000 displaced people, and about 1,900 people requiring public shelter. The area is estimated to suffer up to 2,000 people who require medical aid, up to 600 people who require hospital care, up to 90 people with life-threatening injuries, and up to 180 fatalities (refer to Table 3 and Figure 37 in the report).

Hospitals. For each hospital, information on service population, number of beds, construction type and year, replacement value, geologic seismic hazards, and lifeline dependencies have been summarized. Lifeline dependencies of Samaritan North Lincoln Hospital, herein referred to as Lincoln City hospital, and Willamette Valley Medical Center, herein referred to as McMinnville hospital, include water, transportation, fuel, electricity, and communications. The eastern half of the Lincoln City hospital is built on loose, sandy soils that appear to be liquefiable (Wes Spang, oral commun., January 6, 2014). McMinnville hospital is a complex of three modern buildings.

Note that the estimates listed in the table below regarding hospital functionality do not explicitly take into account estimates for the water system's functionality; those estimates are provided in the following section on water facilities.

Estimates of probability of at least moderate damage and level of functionality in hospitals after a major Cascadia earthquake

		McMinnville Hospital	
	Lincoln City Hospital	**Two Taller Buildings**	**Shorter Building**
Probability of at least moderate damage from a major Cascadia earthquake			
	90%	63%	38%
Estimated level of functionality* by bed count			
Day 1 and Day 3	2%	14%	43%
Day 7 and Day 14	10%	36%	61%
Day 30	42%	73%	77%
Day 90	52%	76%	79%

*Does not take into account water system functionality.

On the basis of the number of available hospital beds and the estimated casualties, both hospitals will experience severe, extended bed shortages. Lifeline services should be expected to be severely disrupted by a major earthquake. Lifeline service interruptions may further reduce the functionality of these hospitals. The report provides several options that can be considered in disaster planning and disaster response.

Water facilities. Many local water systems involve dams and reservoirs as the water source, miles of transmission pipelines, in-town water reservoirs, and pumping stations before the system begins distributing water to communities. For each of the water facilities, information was gathered on geologic seismic hazards and water treatment plant (WTP) and major water system components,

including system replacement value, construction type and year of buildings, city reservoirs (tanks), pump stations, and transmission piping systems. Water usage by Lincoln City hospital and McMinnville hospital are approximately 15,000 gallons/day and 47,000 gallons/day, respectively.

DOGAMI collected data and modeled five water systems for the study: City of Lincoln City, McMinnville Water and Light, Grand Ronde, Sheridan, and Willamina. Additional default water system data were gathered for communities including Dallas, Amity, and Dayton. It is estimated that over 10,000 km of water transmission and distribution pipeline exists in the study region; a major Cascadia earthquake would cause over 5,700 pipeline leaks and 3,500 pipeline breaks. Of the roughly 35,000 households, the number of households without water service are estimated at 31,000 on day 1 after the earthquake; 30,000 on day 3, 27,000 on day 7, 19,000 on day 30, and none (0) on day 90. Of the 88 facilities associated with the water systems, 65 are estimated to have at least moderate damage from a major Cascadia earthquake.

Estimates of probability of at least moderate damage and level of functionality for five modeled water systems after a major Cascadia earthquake

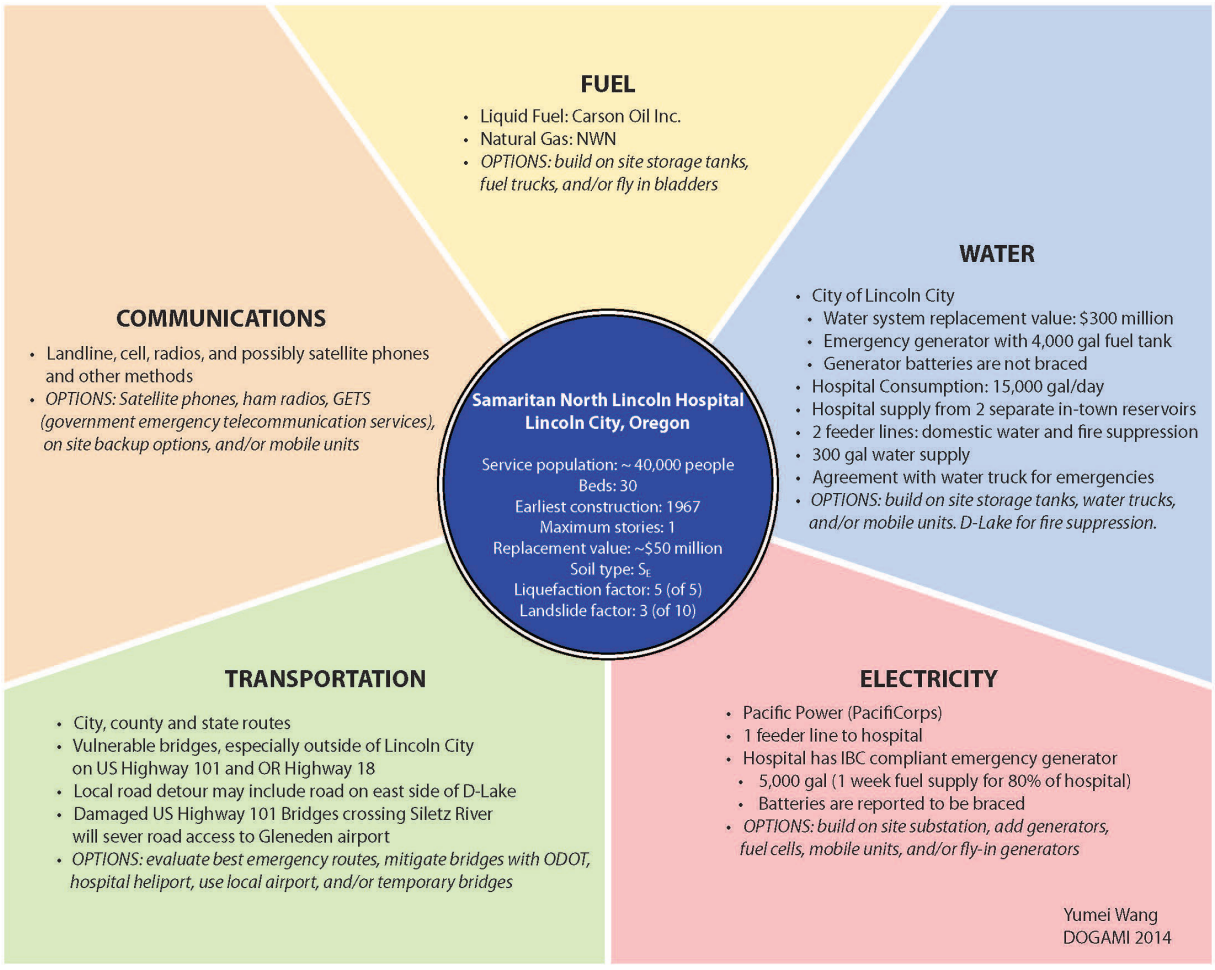
Water Treatment Plant	City of Lincoln City	McMinnville Water and Light	Grand Ronde	Sheridan	Willamina
Probability of at least moderate damage	50%	39%	90%	97%	51%
Estimated damage cost*	~ $51 million a $300 million	~ $61 million of $500 million	~ $5 million of $11.2 million	~ $29 million of $40 million	> $1 million of $10 million
Estimated level of functionality**					
Day 1	52%	61	22%	14%	49%
Day 3	80%	86	46%	23%	83%
Day 7	86%	91	54%	27%	91%
Day 14	87%	92	57%	31%	91%
Day 30	91%	94	64%	40%	94%
Day 90	99%	99	88%	72%	99%

*Damage cost shows two values: the first is the estimated damage cost; the second is the assumed replacement cost for entire water system.
**Lifeline service interruptions may further reduce functionality of water services.

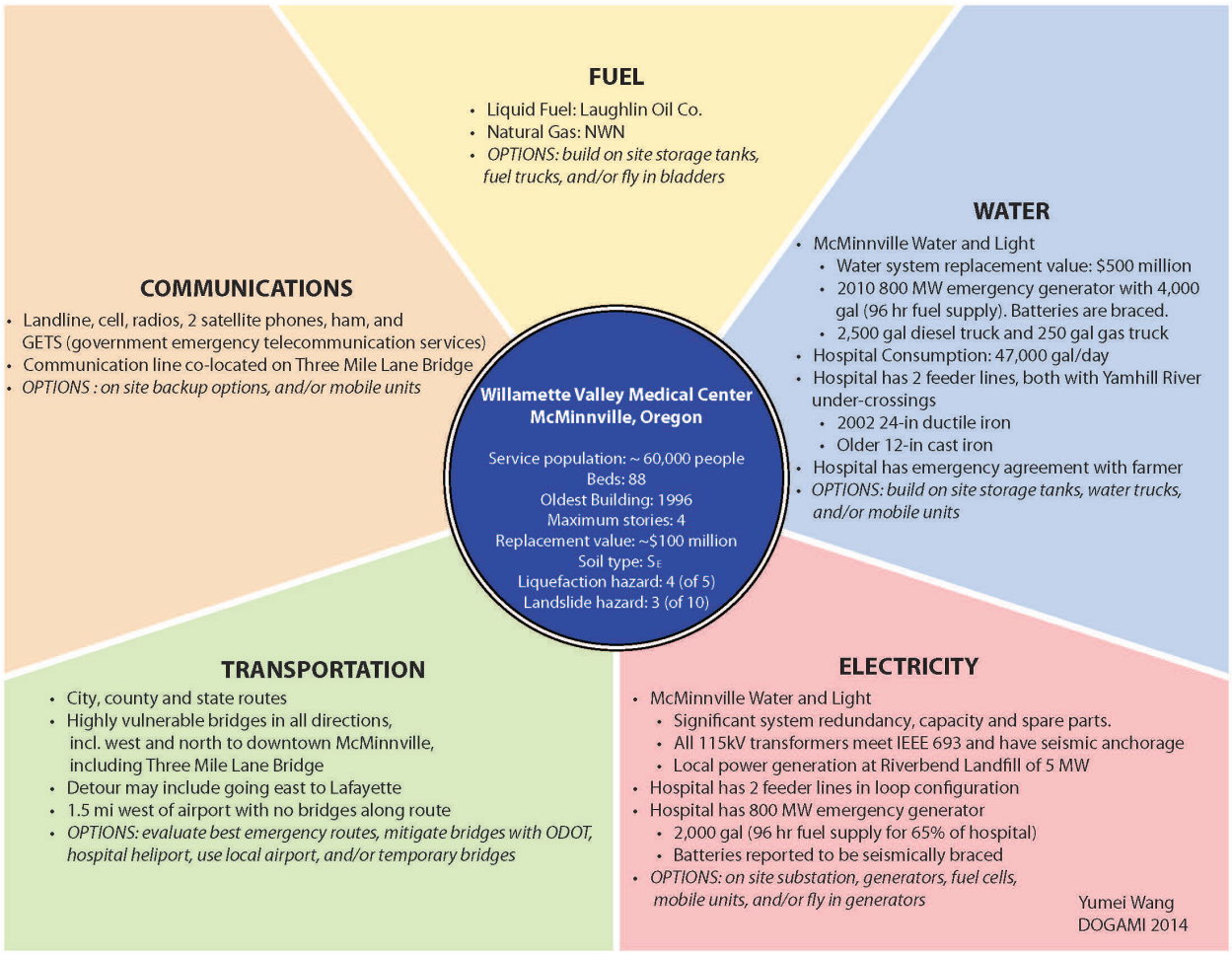
Highways connecting Lincoln City and McMinnville. Our results indicate that 41 of the 169 bridges included in this study are estimated to have at least moderate damage from earthquake shaking. This estimate includes several bridges along coastal Highway 101 in Lincoln City, including those crossing the Siletz River; several bridges along Highway 18 between Lincoln City and McMinnville, including Bear Creek and Slick Rock Creek bridges (between ODOT mileposts 3 and 6); and several bridges in the greater McMinnville area, including bridges west of the McMinnville hospital between ODOT mileposts 45 and 47, and the Three Mile Lane bridge. Three Mile Lane bridge is part of a spur of Highway 18 located between downtown McMinnville and the McMinnville hospital. In addition to damage to bridges from earthquake shaking, damage would occur from tsunami flooding to road segments in low lying portions of Highway 101 especially near the Siletz River; from landslides especially toward the western

portion of Highway 18 (ODOT mileposts 13 to 18); and from liquefaction especially between Sheridan and McMinnville. On a project regional scale, it is likely that there would be transportation connectivity problems within the city limits of Lincoln City and McMinnville as well as the on the route between Lincoln City and McMinnville.

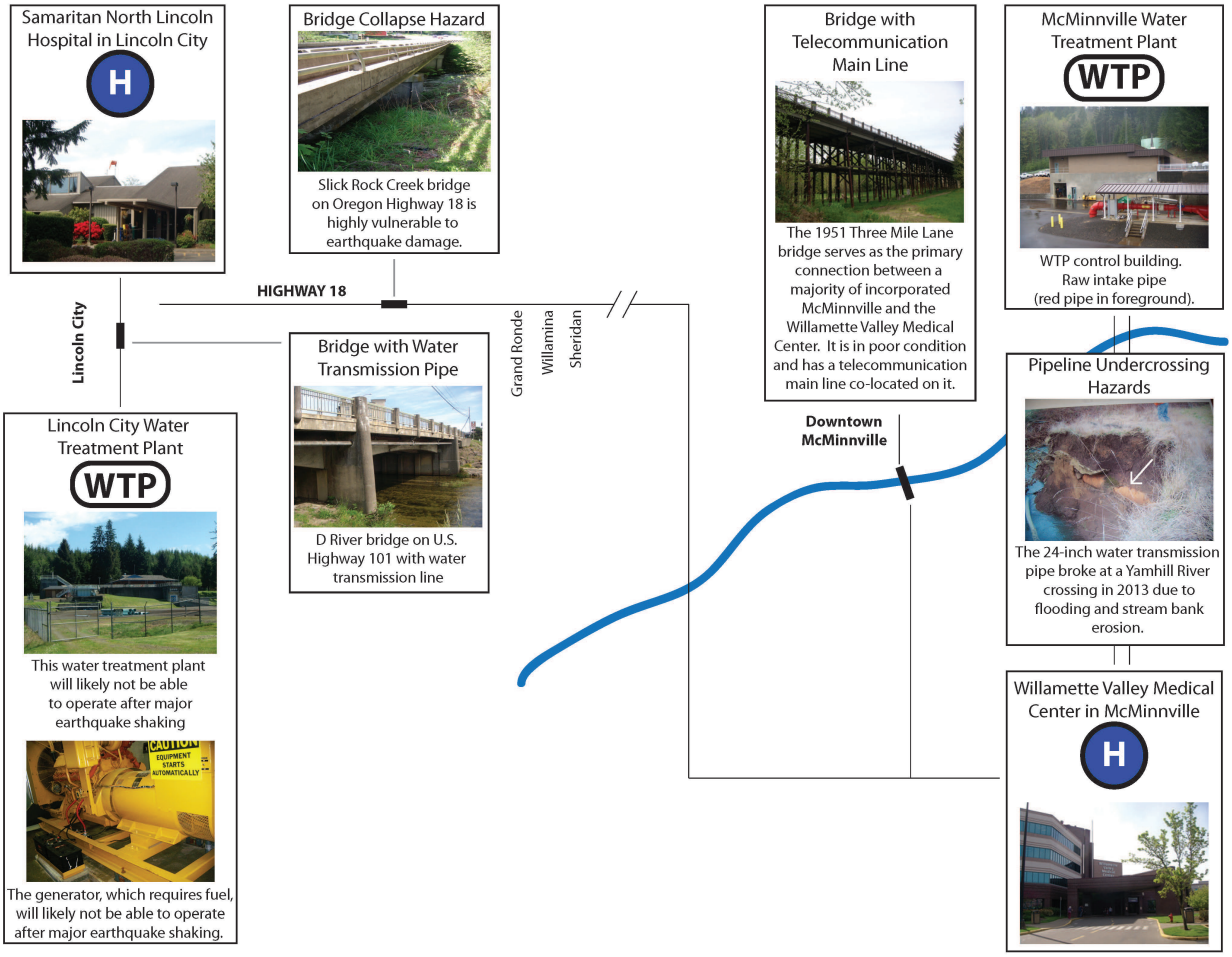
Hospital Interdependencies. All modern hospitals—including Lincoln City and McMinnville hospitals—and communities depend on lifeline services including water, transportation, fuel, electricity, and communications. Specific hospital interdependencies are shown in the below figures (which are Figure 40 and Figure 41 in the report.) All communities, including the project communities, have a number of critically important facilities that rely on vital pathways that connect people or supplies in order to operate. Damage to critically important facilities or pathways, or both, can disrupt connections and services. Some complex connections in the project area between critically important facilities and the pathways connecting them are illustrated below (which is Figure 42 of the report). Hospitals and water treatment plants are the critically important facilities in this study; bridges on or near Highways 101 and 18 and the water transmission pipeline that crosses under the Yamhill River as well as associated bridges and telecommunication lines are vital pathways, or lifelines.



Hospital interdependencies: Lincoln City hospital relies on people, hospital infrastructure and supplies, fuel, water, electricity, transportation, and communications.



Hospital interdependencies: McMinnville hospital relies on people, hospital infrastructure and supplies, fuel, water, electricity, transportation, and communications.



Schematic of critical facilities and pathways in the project area include the two hospitals, two water treatment plants, and the highways and pipelines connecting them. The blue line is the Yamhill River.

Conclusions

DOGAMI concludes that:

- Hospitals are important community safety nets in disasters. Hospitals therefore require a high level of ***resilience*** — they should be built and operated to sustain *limited damage*, have *reliable emergency methods* to operate immediately after major earthquakes, and *recover efficiently* to provide services.
- Both pilot study hospitals have seismic vulnerabilities and are expected to incur significant hospital bed shortages for over 90 days after a Cascadia earthquake.
- Both pilot study hospitals have complex water, transportation, and other lifeline dependencies. After a Cascadia earthquake, hospitals are expected to incur severe reductions in functionality due to lifeline damage. Damage to the local water systems and transportation network will slow the response and recovery of hospitals, and hospital services for community members will be impaired.

- Bridges near both pilot study hospitals are expected to incur significant damage during and after a Cascadia earthquake. Bridge damage will limit movement of staff and injured community members as well as supplies such as potable water, gasses, and medications to and from the hospitals.
- All pilot study water systems have seismic vulnerabilities and complex lifelines dependencies and are expected to incur severe reductions in functionality after a Cascadia earthquake. Water service to the hospitals using the normal water pipeline distribution system is expected to be down for weeks to months.
- Specific important results are:
    - Lincoln City hospital is estimated to incur significant damage due to its proximity to the Cascadia subduction zone and will slowly recover to operate at about 52% bed capacity in 90 days. A number of bridges that connect the community and hospital, including bridges crossing the Siletz River, are expected to incur major damage and impede citizen access to the hospital complex.
    - Although the McMinnville hospital has modern seismic structural engineering, design, and construction, it is expected to have a severe reduction in function due to shaking damage. It is expected to recover to about 76% bed capacity in 90 days. A number of bridges that connect the community and hospital, including the Three Mile Lane bridge and nearby Highway 18 bridges to the west of hospital complex, are expected to incur major damage and impede citizen access.
    - The transportation route between Lincoln City and McMinnville will be impassable immediately after a major Cascadia earthquake, which will impede coastal community members from accessing inland hospitals.
- DOGAMI and OHA communications to project partners and site visits to the hospitals and water facilities helped to increase seismic awareness and encourage mitigation actions.
- Hospitals should coordinate with lifeline owners, including local water and transportation districts, to improve hospital resilience.
- Community resilience, including reliable hospital services in earthquake disasters, requires hospitals, lifeline owners, and other partners to conduct resilience planning in order to better protect citizens on a local and regional scale.

Recommendations

Top-priority recommendations. DOGAMI recommends that:

- The pilot project results and this report are shared with project participants and OHA partners to increase awareness about the need to improve seismic resilience. This could involve developing and distributing a fact sheet, publishing this report, and providing workshops in the project area and elsewhere.
- OHA and hospital partners encourage and conduct regularly scheduled seismic site visits by appropriate authorities (such as OHA Health Security, Preparedness and Response representatives) to all of the statewide hospitals and the water districts that serve those hospitals to enhance resilience.
- OHA and hospital partners require seismic preparedness standards for drinking water systems that serve hospitals.

- OHA and hospital partners proactively encourage hospitals to meet safety and preparedness regulations in Oregon Revised Statute 455.400 and The Joint Commission Emergency Management standards EM.02.01.01 and EM.02.02.09.
- OHA and hospital partners encourage hospitals to conduct comprehensive seismic vulnerability assessments and, from the findings, develop long-term mitigation plans to increase hospital resilience. Any significant mitigation actions should be integrated into relevant hospital plans, such as emergency operation plans, capital investment plans, long range master plans, and risk management plans.
- OHA and hospital partners encourage hospitals to engage in community and regional resilience planning that specifically addresses hospital lifeline interdependencies, such as:
    - Establishing partnerships between water districts and hospitals that focus on the reliability of water services to hospitals.
    - Establishing partnerships between transportation districts and hospitals that focus on the reliability of routes to hospitals. For example, until selected bridges are mitigated in McMinnville, community members may need to plan to take extensive transportation detours to access the McMinnville hospital, such as using the bridge that is 5 miles east of McMinnville on the SE Lafayette Highway that crosses the Yamhill River.

Recommendations for future efforts. DOGAMI recommends that:

- Comprehensive seismic evaluations that include structural, non-structural, business continuity and lifeline service vulnerabilities are conducted for all hospitals across the entire state of Oregon.
- Resilience metrics that establish a baseline condition and allow for tracking of improvements are established for hospitals and used by OHA and hospital partners. Resilience metrics can be tied to community resilience planning efforts.
- Hospital resilience planning workshops are conducted using best available information to help reduce losses and speed recovery. As an example, the hospitals in this pilot project should use the damage and functionality estimates from this study to help plan for improving resilience. The workshop may use SWOT (strengths, weaknesses, opportunities and threats) analysis workgroup techniques and develop SMART (specific, measurable, attainable, realistic and timely) goals. Hospital resilience planning should address how to provide reliable services by having more reliable staff, flow of goods, and infrastructure performance including lifeline services (e.g., fuel).
- Community resilience planning workshops are conducted using best available information to reduce losses and speed recovery. Workshops may use SWOT workgroup techniques and develop SMART goals. Community resilience planning should address specific characteristics, including local hospitals, clinics, water systems, schools, fire stations, police stations, shelters, and city halls. As examples for communities in this pilot project: Lincoln City should consider future tsunami damage, and McMinnville should consider future damage relating to their large building portfolio of unmitigated, historic buildings. Mitigation actions should be identified and, where appropriate, integrated into relevant community plans such as business plans, city plans, neighborhood plans, and family plans. Tax incentive, local bonding, and other measures may be needed to improve community resilience.