State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist

OPEN-FILE REPORT O-20-02

OREGON COASTAL HOSPITAL RESILIENCE PROJECT: RESILIENCE PLANNING MAPS AND GUIDANCE

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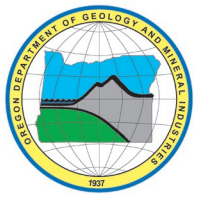

2020

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Oregon Department of Geology and Mineral Industries Open-File Report O-20-02
Published in conformance with ORS 516.030

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LIST OF SITE AND REGIONAL RESILIENCE PLANNING MAPS

Maps are oversize PDFs. From north to south–

Samaritan North Lincoln Hospital, Lincoln City, regional map, 32 x 50 inches
Samaritan Pacific Communities Hospital, Newport, regional map, 32 x 40 inches
Peace Harbor Hospital, Florence, regional map, 40 x 36 inches
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EXECUTIVE SUMMARY

This publication is intended to help hospitals with their efforts toward building disaster resilience.

The Oregon Coastal Hospital Resilience Project is a partnership among the Oregon Department of Geology and Mineral Industries (DOGAMI), Oregon Health Authority (OHA) Health Security, Preparedness and Response (HSPR) including the HSPR Healthcare Preparedness Program (HPP) regional liaisons, and the eleven hospitals along the Oregon coast. The goal of the project is to help hospitals better prepare for a magnitude 9 Cascadia subduction zone earthquake and tsunami.

A magnitude 9 Cascadia earthquake is expected to produce destructive ground shaking. The tsunami could arrive at the coast in as soon as 10 minutes. Due to expected highway damage, coastal communities will be geographically isolated and will experience long-term disruptions to emergency fuel and water supplies (Wang, 2017). Hospitals are expected to be severely impacted, which will limit their ability to provide healthcare services in communities when there will be a high demand for those services (Wang, 2018).

Hospitals serve as community safety nets. Even during extreme events, they need to be resilient—they should incur only minimal losses and recover quickly to provide healthcare services. Leaders from all eleven coastal hospitals are committed to preparing the hospitals to provide healthcare services immediately after a Cascadia earthquake and tsunami (Wang and others, 2019). Hospital personnel have discussed their need to develop resilience action plans to prepare for future Cascadia disasters. Guidance for reducing hospital building (structural and nonstructural) vulnerabilities and on achieving reliable water and power services has been developed (Wang and Norse, 2019).

Due to collapsed highway bridges the Oregon coast is expected to experience extreme transportation immobility. The lack of transportation options will create isolated, geographic "islands," causing challenges for hospitals to provide healthcare services. A hypothetical post-Cascadia earthquake "coastal island" map for the entire Oregon coast illustrates expected long-term transportation disruptions and can be used for regional coastal disaster planning purposes. Current transportation planning activities involve state and U.S. military support.

Coastal communities will experience a convergence of an unprecedented number of injured people; hospital personnel trapped on "islands" limiting their ability to access their hospitals; and the necessity to triage patients to receive less than standard-of-practice care. Hospitals are encouraged to strive for high post-Cascadia performance levels as defined by the "Triple 3 Resilience Target" (Cutts and others, 2015). The aim is to meet immediate infrastructure needs within three days, to meet basic needs within three weeks, and to modernize infrastructure within three years.

This report includes 1) information on previous work completed as part of the Coastal Hospital Resilience Project, 2) the project's seven key messages including examples of recent resilience activities, 3) Triple 3 Resilience Target response and recovery goals for a Cascadia earthquake and tsunami, 4) a "coastal island" map, which shows expected post-Cascadia earthquake geographic boundaries due to impassable U.S. Highway 101 bridges, 5) hospital resilience planning maps for the eight central and south coast hospitals and a discussion of map uses, and 6) and recommendations for future work, including strengthening partnerships and coastal transportation planning for response and recovery.

The components of this report are meant to raise community awareness of impacts to water and power systems for the hospitals among other activities. Hospital personnel can continue to work with community partners including water districts, electricity providers, fuel suppliers, county emergency managers, and many others to build disaster resilience.

INTRODUCTION

The Oregon Coastal Hospital Resilience Project has been a partnership among the Oregon Department of Geology and Mineral Industries (DOGAMI), Oregon Health Authority (OHA) Health Security, Preparedness and Response (HSPR) including the HSPR Healthcare Preparedness Program (HPP) regional liaisons, and the eleven hospitals along the Oregon coast. The goal of the project is to help hospitals better prepare for a magnitude 9 Cascadia Subduction Zone earthquake and tsunami. DOGAMI's role was to develop a better understanding of the needs of the coastal hospitals to provide post-Cascadia medical services so that DOGAMI could provide technical assistance to OHA and the hospitals to help improve hospital preparedness for Cascadia earthquakes.

A magnitude 9 Cascadia earthquake is expected to produce destructive ground shaking for 5 minutes and result in a tsunami, a series of high, powerful waves, that could arrive at the coast as soon as 10 minutes after the onset of the earthquake. A Cascadia earthquake and tsunami will be catastrophic in nature. Although all western Oregon is expected to incur significant damage, the coastal area will experience the strongest shaking as well as destructive tsunami forces, resulting in a significant number of casualties. Due to damaged highways between the coast and the U.S. Interstate 5 corridor as well as north and south along coastal Highway 101, coastal communities will experience geographic isolation (Wang, 2017). Isolation will hamper emergency response efforts.

Oregon's coastal hospitals are especially vulnerable due to their close proximity to the Cascadia fault and the expected long-term disruptions in emergency fuel and water supplies. In addition, many hospitals were built to older seismic building codes that have since been determined to be inadequate to withstand a Cascadia earthquake. Given their current conditions, hospitals are expected to be severely impacted (Wang, 2018). This will limit their ability to provide healthcare services at a time when there will be a high demand for services in their communities.

Hospitals are a key component of the health system that supports emergency response. It is critically important for hospitals to remain operational because they serve as community safety nets. This means that hospitals should have a high level of resilience to ensure they can provide health services after a Cascadia disaster. Hospitals should be built or mitigated so that after such an earthquake they sustain only limited damage. Hospitals also need to have emergency methods that allow them to operate immediately after major earthquakes, including reliable lifelines services such as power and water. Hospitals must be able to incur only minimal losses and recover quickly to provide services.

Leaders from all eleven of the coastal hospitals are committed to preparing the hospitals to be able to provide healthcare services immediately after a Cascadia earthquake and tsunami (Wang and others, 2019). Hospital personnel have discussed their need to develop resilience action plans to prepare for future Cascadia disasters. Guidance on reducing building vulnerabilities (structural and nonstructural), and on developing reliable water and power services were developed (Wang and Norse, 2019).

This report is intended to help hospitals with their journey of building disaster resilience. The report includes 1) information on previous work completed as part of the coastal hospital resilience project, 2) the project's seven key messages including examples of recent resilience activities, 3) Triple 3 Resilience Target response and recovery goals for a Cascadia earthquake and tsunami, 4) a "coastal island" map, which shows expected post-Cascadia earthquake geographic boundaries due to impassable U.S. Highway 101 bridges, 5) hospital resilience planning maps for the eight central and south coast hospitals and a discussion of map uses, and 6) recommendations for future work, including strengthening partnerships and coastal transportation planning for response and recovery.

The hospital resilience planning maps were created to assist hospital staff with the development of robust hospital resilience action plans. Hospital personnel and their partners provided input on individual maps to emphasize local assets and features. Guidance on how one might use the maps is included.

PREVIOUS WORK FROM THE COASTAL HOSPITAL RESILIENCE PROJECT

OHA HSPR and DOGAMI have been working on the Coastal Hospital Resilience Project since 2017. The project was undertaken due to the recommendations in a HSPR-funded pilot study involving two hospitals (Wang, 2017), which was initiated in response to the serious statewide seismic vulnerabilities outlined in the 2013 Oregon Resilience Plan (Oregon Seismic Safety Policy Advisory Commission [OSSPAC], 2013).

To date, four project publications have been issued, as described below.

Key findings in DOGAMI Open-File Report O-17-01, Oregon hospital and water system earthquake risk evaluation pilot study (Wang, 2017), include assessments of two hospitals, and their water systems, highway transportation, and lifeline interdependencies. One hospital, Samaritan North Lincoln Hospital, is located on the coast in Lincoln City; the other, Willamette Valley Medical Center, is located inland in McMinnville. Results revealed that the coastal hospital will incur very high levels of damage and be cut off from the U.S. Interstate Highway 5 corridor. Thus, a typical practice of transferring patients from coastal hospitals to inland hospitals will not be possible. Hospital dependencies on critical lifeline services (fuel, water, electrical power, transportation, and communications) and the ways to prepare for emergency conditions are illustrated.

A top recommendation from DOGAMI Open-File Report O-18-03, Oregon coastal hospitals preparing for Cascadia (Wang, 2018), is to create a coastal hospital resilience network to accelerate resilience activities. This study also revealed that coastal hospitals are not well prepared to provide medical services after a Cascadia event. Coastal hospitals rely on resources from the I-5 corridor as well as their local communities, both of which will be severely compromised. More partnerships and preparations are needed.

DOGAMI Open-File Report O-19-01, Summary report on the 2018 Oregon Coastal Hospital Special Leadership Event (Wang and others, 2019), documents the first meeting among leaders of all the coastal hospitals. State officials informed hospital leadership that the coast may be isolated for three weeks and their leadership on disaster preparedness is needed. This report also includes hospital resilience planning maps for the three north coast hospitals, each with tsunami hazards: Columbia Memorial Hospital in Astoria, Providence Seaside Hospital in Seaside and Tillamook Regional Medical Center in Tillamook.

DOGAMI Open-File Report O-19-02, Resilience guidance for Oregon hospitals (Wang and Norse, 2019), contains plain-language guidance on hospital buildings, emergency power, and emergency water planning. Tips on preparing to be operational after a catastrophic earthquake under conditions where coastal communities will be geographically isolated are provided. Information on how hospitals can plan to have continuous power during a three-week isolation period, and beyond, is outlined. Also included are seven key messages for building resilience.

Seven Key Messages: Resilience Activities in Progress

As part of the Coastal Hospital Resilience Project, OHA and DOGAMI emphasize seven key messages to hospitals as a way to encourage hospital resilience (Wang and others, 2019; Wang and Norse, 2019). “The seven key messages provide a foundation for hospitals to develop activities that lessen vulnerabilities, protect necessary infrastructure and build community partnerships that will allow them to withstand, adapt, and recover from a Cascadia earthquake” (Akiko Saito, OHA HSPR Director of Emergency

Management Operations, written communication, December 11, 2019). During the project period, all coastal hospitals have made strides on improving disaster resilience.

Although these seven key messages are in general alignment with traditional disaster preparedness practices, the messages were specifically developed for coastal hospitals to prepare for a Cascadia earthquake, and are perhaps more holistic and broadly community based. The seven key messages are:

- Identify alternate care sites
- Plan to be locally self-sufficient for three weeks
- Evaluate seismic vulnerabilities and prepare using the guidance documents
- Develop a hospital resilience action plan
- Engage in the Oregon Coastal Hospital Resilience Network
- Partner with the community, including the county emergency manager and power and water service providers
- Be a community resilience champion

Key message 1. Identify alternate care sites

If a hospital is in a defined tsunami hazard zone or includes buildings that were built before 1995, then the hospital is likely to experience significant damage. If the damage prevents use of the hospital, then it would be important for the hospital to have an alternate care site. DOGAMI provided maximum-considered tsunami-arrival-time information specific to hospital sites to the leadership of the four hospitals in the tsunami hazard zone. This information is included in each of the coastal hospital resilience maps, which are part of DOGAMI Open File Report O-19-01 and this publication. Hospital decision makers should adopt defense options, such as creating efficient tsunami evacuation routes and by protecting the hospital with wave energy dissipating structures (e.g., protective wall structures). Some hospitals have partnered with nearby schools that can serve as alternate care sites. Some of the schools have been seismically retrofitted by using grant funds from the State Rehabilitation Grant Program (http://www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab).

Key message 2. Plan to be locally self-sufficient for three weeks

Due to expected impaired transportation systems, it is possible that it will take three weeks for state and federal agencies to provide emergency assistance. Although the State's goal is to provide a much faster response, it may take longer than three weeks for some isolated areas to receive outside help. Some hospitals are already partnering with their county emergency managers and others to prepare for disasters. Emergency management processes typically involve the State providing support to the counties, and the counties providing support to the hospitals, cities, and others in their jurisdiction.

As part of this project, OHA and DOGAMI worked with the U.S. Navy and the Oregon National Guard to discuss disaster response by sea, including use of a Navy medical ship such as the USNS *Mercy*. More discussion is included in the Recommendations for Future Work section.

Key message 3. Evaluate seismic vulnerabilities and prepare using the guidance documents

The Cascadia Region Earthquake Workgroup (CREW) prepared three guidance documents to help hospital staff identify seismic vulnerabilities with hospital buildings, emergency power, and emergency water. The guidelines provide helpful information and recommend resources for hospitals to withstand a Cascadia event and operate after the event. The guidance documents are available as part of DOGAMI Open-File Report O-19-02 (Wang and Norse, 2019):

- Preparing Hospitals for Earthquakes: Structural and Nonstructural Issues

- Emergency Power for Hospitals: Preparing for Cascadia
- Emergency Water for Hospitals: Preparing for Cascadia

Hospital buildings constructed before 1995 are likely to have structural deficiencies with respect to earthquake shaking and may be evaluated by qualified engineers using standard of practice methods in accordance with Oregon building codes. Hospital buildings with seismic vulnerabilities may be eligible for up to $2.5 million per building from the State Rehabilitation Grant Program (http://www.orinfrastructure.org/Infrastructure-Programs/Seismic-Rehab).

Even when the electrical grid has outages, hospitals require electrical power to operate. For emergency power, we have recommended the use of seismically certified emergency generators along with adequate fuel supplies, maintenance equipment, and related supplies (e.g., fuel filters) to last for a minimum of three weeks (Wang and others, 2019; Wang and Nourse, 2019). We have also encouraged the development of local microgrids (Wang and others, 2019; Wang and Nourse, 2019). For example, controlled systems that can be isolated from the main power grid that are composed of a solar array coupled with battery storage and integrated with an emergency generator system (Banse, 2019).

As with power, hospitals require water to operate. Thus, making plans for reliable water supplies is warranted. For emergency water, we have recommended that hospitals have on-site emergency supplies as well as work with experts from their local water district (Wang and others, 2019; Wang and Nourse, 2019). If possible, new reliable water storage tanks with earthquake resistant piping should be built near or at the hospital to ensure an adequate supply.

Key message 4. Develop a hospital resilience action plan

It is likely that the results from the seismic evaluations on hospital buildings, emergency power, and water (from key message 3) will reveal many seismic deficiencies. Strategies for prioritizing and mitigating deficiencies and weaknesses can be the basis for a resilience action plan. In addition to strengthening buildings and power and water supplies, hospitals should address other areas to improve disaster resilience.

Needed resilience actions may be wide ranging in scope. Some actions may involve infrastructure, whereas others may involve people, practices, policies, or partners. Some may be easy to conduct or may need to be performed repeatedly, such as increasing awareness and engaging in training exercises. Other actions may be costly and require long-range financing or are otherwise challenging, such as requiring political consensus or passing local bonds for hospital facility or water system improvements. Some actions may provide high resilience benefits whereas others may provide only minimal benefits but still be worthwhile. All these actions should be integrated into a holistic long-term resilience plan and set in motion. Progress on the actions should be tracked. The plan should be supported by hospital leadership, and maintained and updated to reflect changing needs.

DOGAMI, OHA, and our partners have shared an abundance of diverse information that can be integrated into hospital resilience action plans. Information was shared at numerous meetings, on-site consultative visits, at conferences, through fact sheets, emails, and phone correspondence, and via webinars. For example, the August 30, 2018, Oregon Hospital Resilience joint webinar, presented by the Oregon Association of Hospital and Healthcare Systems (OAHHS); OHA Health Security, Preparedness and Response (HSPR); and DOGAMI, presentations included:

- State seismic rehabilitation grant funding (Oregon Business staff),
- an application of grant funds (Oregon Health and Sciences University), and

- ShakeAlert pilot projects and how hospitals could receive earthquake early warnings on the order of seconds or tens of seconds (https://ohaz.uoregon.edu/shakealert) (University of Oregon).

At the on-site consultative visits that occurred throughout 2018 and 2019 at all 11 coastal hospitals, DOGAMI staff discussed techniques to improve the resilience of hospital buildings and emergency power and water supplies. Another example involves ways for hospital personnel to cope with difficult working conditions during a disaster. Because it will be necessary for hospital staff to triage rapidly many patients and work conditions will be strained, OHA HSPR recommends adopting the Oregon Crisis Care Guidelines (Oregon Medical Association, 2017; OHA, undated).

A final example involves microgrid technology and state financing opportunities. DOGAMI organized two presentations for the September 25, 2019, Region 3 Healthcare Preparedness Partners meeting held in Coos Bay: one on microgrids by Siemens engineers, and a second on state financing opportunities presented by the Governor's Office. The following day, DOGAMI and OHA conducted an on-site consultative visit to the Coquille Valley Hospital where results from the Siemens preliminary microgrid analyses were shared with hospital leadership and a site-specific microgrid feasibility evaluation was conducted by Siemens and hospital facilities staff.

Key message 5. Engage in the Oregon Coastal Hospital Resilience Network

Despite the fact that all of the coastal hospitals face a similar hazard setting with the Cascadia subduction zone, currently there is no established means for all hospital personnel to communicate or to gather on a regular basis. This holds true for hospital leaders, hospital emergency planners, hospital facilities personnel, and others. At the 2018 Coastal Hospital Special Leadership Event, DOGAMI and OHA HSPR strongly recommended that all the coastal hospitals collaborate with each other in order to accelerate their resilience activities (Wang and others, 2019).

Many resilience actions have already been taken or are being planned at individual costal hospitals. A clear benefit of working together is the ability to share knowledge, resources, and experiences so that, collectively, hospitals have the opportunity to make better and faster progress. An Oregon Coastal Hospital Resilience Network should involve the regional Healthcare Preparedness Partners (Wang and others, 2019) as well as new partners.

As demonstrated by the 2018 Oregon Hospital Resilience joint webinar [by Oregon Association of Hospital and Healthcare Systems (OAHHS), OHA Health Security, Preparedness and Response (HSPR) and DOGAMI], and by the 2019 Oregon Hospital Resilience track at the OAHHS Rural Summit, OHA HSPR and OAHHS are committed to supporting a new Oregon Coastal Hospital Resilience Network to help facilitate disaster resilience activities.

Key message 6. Partner with the community, including the county emergency manager and power and water service providers

It is critical for hospital personnel to work with others on disaster planning so that hospitals will have the necessary staffing, resources, and services to allow for continuous operations. Hospitals need power, water, fuel, medical supplies, food, and many other resources. It is important for hospital staff to work with water service providers, electricity service providers, fuel suppliers, and many others to prepare for disasters.

Hospital personnel must work closely with county emergency managers because the county is responsible for assisting with community emergency response needs during disasters, including the needs of hospitals. As one example, hospital staff need to provide the county emergency manager

information on their emergency fuel requirements for hospital emergency generators so that information can be integrated into the Oregon Department of Energy's State Fuel Action Plan (ODOE, https://www.oregon.gov/energy/safety-resiliency/Pages/Petroleum.aspx).

As a project-related example, one hospital is now partnering with the local fire district on their business continuity plan. If transportation systems and normal communication systems become inoperable due to earthquake damage, the fire chief has agreed to assist hospital leadership with communications. If hospital leadership cannot get to the hospital but can get to the nearest fire station, fire district personnel would help facilitate communications using the fire district's communication systems.

Key message 7. Be a community resilience champion

Although many advancements on hospital resilience are underway, it may be especially fruitful when hospital leaders explicitly demonstrate their leadership on preparing for Cascadia events and improving disaster resilience. Keeping in mind that everyone in the community relies on healthcare services, it is valuable for community members to know that hospital leaders are not only addressing routine needs but also preparing for extreme circumstances. When hospital personnel take steps to improve hospital resilience and share this information with others, it may encourage others in the community to take prudent actions.

As more examples, some hospital staff (e.g., from Lower Umpqua Hospital) are working with their local water districts to ensure that their hospitals have reliable water supplies, while PeaceHealth in Florence has improved its on-site water supplies by drilling ground water wells (Banse, 2019). Hospital CEO, Dr. Lesley Ogden has replaced the outdated Samaritan Lincoln City Hospital with a new disaster resilient hospital that opened in February 2020 (Banse, 2019).

Cascadia Disaster Resilience Goal: Triple 3 Resilience Target

Resilience is ability to recover quickly and well from a shock, such as a natural disaster. Currently the state of Oregon is considered to be prepared for more frequent disasters, such as severe winter storms. However, the state is expected to incur significant damage in a magnitude 9 Cascadia earthquake and accompanying tsunami (Wang, 2018). Critical services are expected to be severely compromised due to damage to infrastructure, including lifeline systems involving fuel, water, wastewater, electricity, major highways, and communications and critical community infrastructure involving schools, fire, police, and healthcare.

According to the Oregon Resilience Plan (OSSPAC, 2013), estimated time periods to restore critical services are long. **Table 1** shows that for coastal communities, critical services are expected to take many months to years to be restored. Along the I-5 corridor (e.g., Willamette Valley), critical services are expected to take one or more months to be restored (OSSPAC, 2013).

Table 1. Estimated time to restore critical services.

	Coast	Willamette Valley
Critical Services	**Estimated Time to Restore Service (months)**	
Fuel	no information	no information
Water	12–36	1–12
Wastewater	12–36	1–12
Electricity	3–6	1–3
Highway (Tier 1)	12–36	6–12
Communication	6–12	6–12
Schools	18	18
Fire	36	2–4
Police	36	2–4
Healthcare	36	18

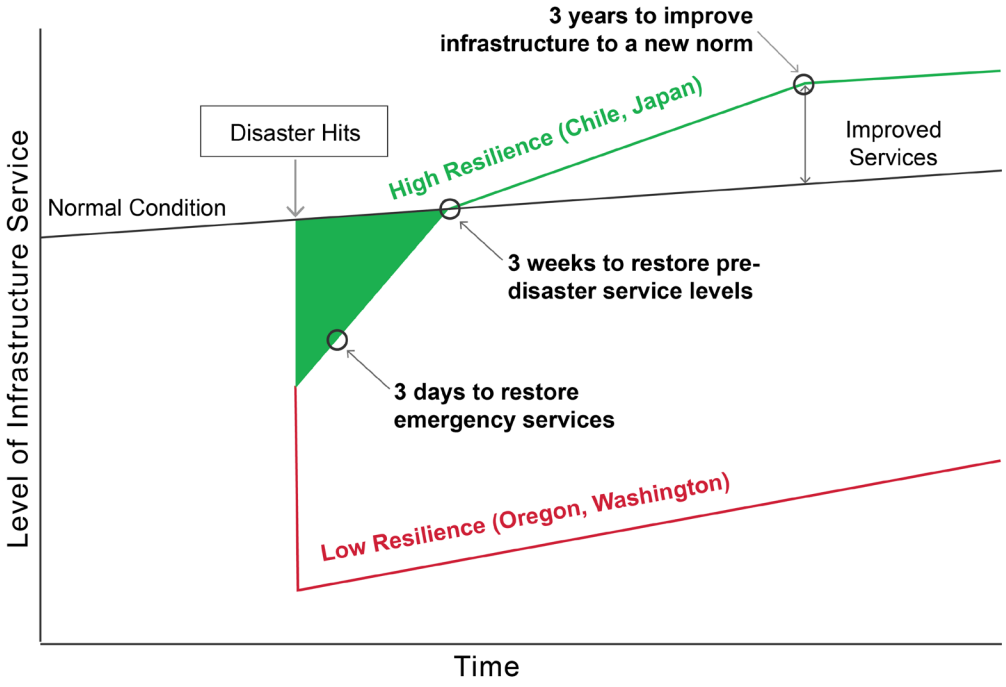
Source: Modified from the Oregon Resilience Plan (OSSPAC, 2013; Kent Yu and Jay Raskin, oral communication, 2018).

Although many advancements have been made to prepare for a future Cascadia disaster, Oregon is currently not well prepared for a Cascadia earthquake and tsunami (OSSPAC, 2013). As indicated in the Oregon Resilience Plan, which adopted a 50-year resilience building horizon, improving infrastructure systems and their post-disaster services will take time (Brown and Harryman, 2018).

The Triple 3 Resilience Target framework (Cutts and others, 2015) lays out theoretical response and recovery timeframes for services provided by critical infrastructure after a catastrophic Cascadia earthquake disaster (**Figure 1**). Mike Harryman, State Resilience Officer (written communication, November 27, 2019) has stated:

> "Regardless of the current expected performance of lifeline systems as outlined in the Oregon Resilience Plan, it remains important to set goals on the performance of lifeline services for planning purposes. The Triple 3 Resilience Target to meet immediate infrastructure needs within three days, to meet basic needs within three weeks, and to modernize infrastructure within three years is the State's long term goal for recovering critical infrastructure services—and we've already made some excellent progress."

Figure 1. The Triple 3 Resilience Target framework to meet immediate infrastructure needs within three days, to meet basic needs within three weeks, and to modernize infrastructure within three years (after Cutts and others, 2015). See text for explanation.



Reading the graph in **Figure 1** from left to right, service levels operate at the normal condition until a disaster hits. If losses are too high and recovery is too slow, then an area has a low level of disaster resilience (red line) — this was the case for Oregon's level of preparation in 2013 (ORP, 2013). On the other hand, if losses are minimized, response and recovery are well paced (as represented by the solid green triangle), and services are improved to higher than pre-earthquake levels, then an area has high resilience (green line) — this is Oregon's long-term goal. The Triple 3 Resilience Target calls for minimal losses combined with:

- three-day recovery for emergency services (i.e., response)
- three-week recovery to restore basic utility services to pre-disaster service levels
- three-year recovery and upgrades to achieve improved critical infrastructure systems

The proposed service recovery time periods were largely achieved after the 2010 magnitude 8.8 Maule, Chile, and 2011 magnitude 9.1 Tohoku, Japan, earthquakes. Although it may be possible for services in some areas to be restored before Triple 3 Resilience Target timelines, it will be difficult for all services in all areas to meet the target timelines. Nonetheless, it is helpful to illustrate that as a society we can work to reduce the expected losses, quicken the response and recovery time, and rebuild better. The Triple 3 Resilience Target is a proposed post-Cascadia event goal developed to complement the Oregon Resilience Plan.

Until the Triple 3 Resilience Target time periods can be met, it is important for hospitals to plan around severely compromised critical infrastructure services including power and water (Wang, 2017, 2018; Wang and others, 2019; Wang and Norse, 2019). Furthermore, if hospitals will not be able to provide a normal level of care due to an interruption in critical infrastructure services, OHA recommends that

hospital administrators adopt the Oregon Crisis Care Guidelines (Oregon Medical Association, 2017) and hospital personnel be familiar with how to provide care in such a situation.

POST-CASCADIA EARTHQUAKE "COASTAL ISLANDS"

On the Oregon coast it will be especially challenging to address transportation mobility after an earthquake due to the combination of high earthquake shaking levels, expected damage to the highways, ports, and airports, and tsunami hazards. U.S. Highway 101 is a linear feature with little to no redundancy, meaning it does not have many convenient alternate routes. For example, a highway section with major bridge may be the only river crossing for many tens of miles. In addition, in many places, transportation by air and water will be compromised when transportation is urgently needed. Transportation by air is typically faster than transportation by water. However, watercraft are abundant along the Oregon coast and will be helpful for response and recovery in the aftermath of a disaster. For additional discussion, see the section **Resilience Planning Involving Transportation**.

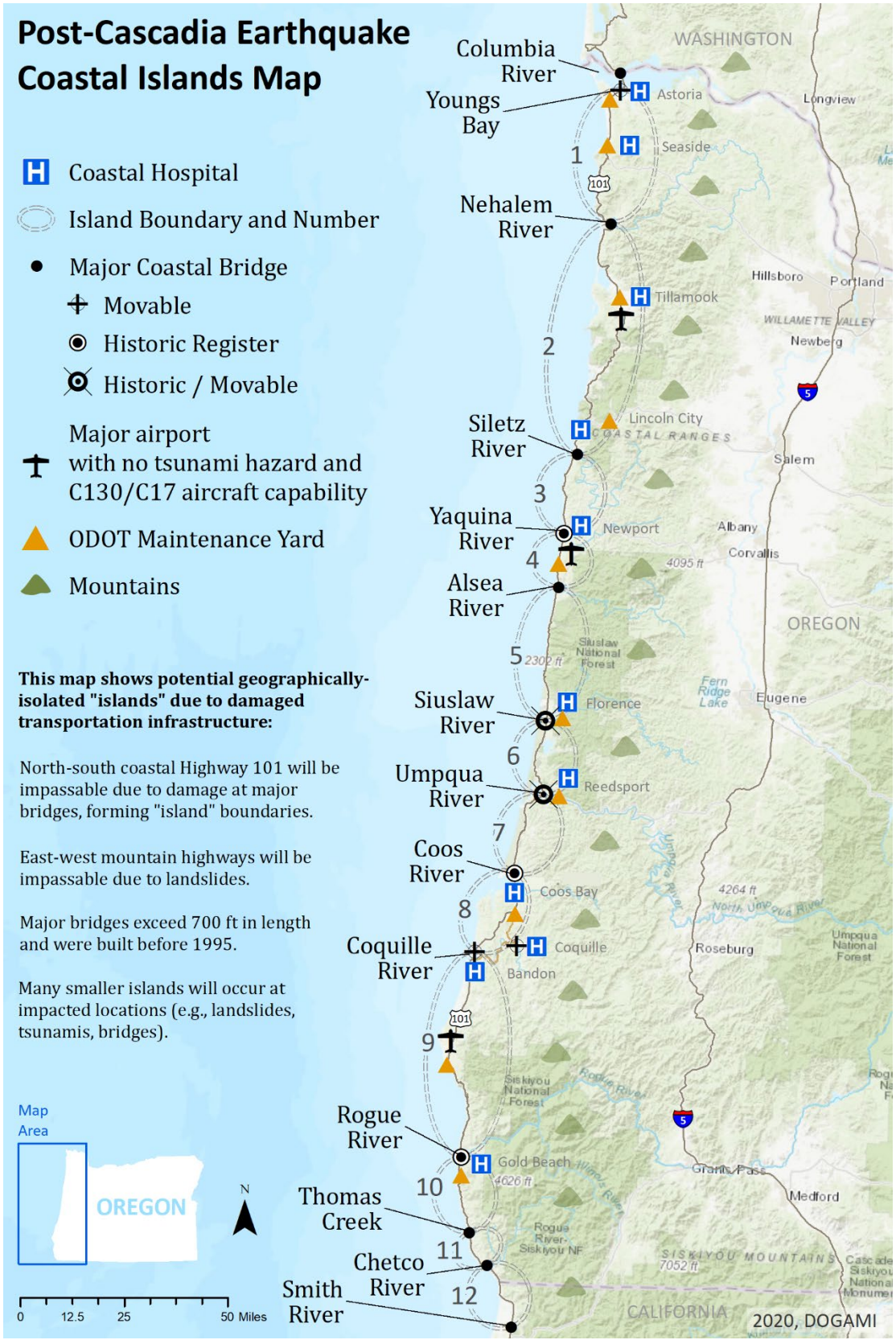
The Post-Cascadia Earthquake Coastal Islands map (**Figure 2**), which includes the locations of the eleven coastal hospitals, was developed as part of this resilience project so that hospital personnel and their partners could have an improved awareness of what to expect along Highway 101 after a Cascadia event, if the event were to occur today. The map shows a hypothetical but likely geographical isolation pattern in broad terms after a Cascadia disaster. Major bridges that exceed 700 ft in length and were built before 1995 are expected to incur significant shaking damage and be rendered impassable. At the same time, all east-west oriented Coast Range highways are expected to be impassable due to bridge damage and landslide debris blocking the roadways (CH2M Hill, 2012a,b; Wang, 2017). Major "island" borders are expected to be defined by inaccessible bridges along coastal Highway 101. The "islands" map shows thirteen river bridges: twelve major bridges along the Oregon coast and one bridge across the Smith River in Northern California. One inland bridge near Coquille and small section of road following the Coquille River are also included.

The thirteen rivers with major bridges over them are, from north to south:

- Columbia River and Youngs Bay
- Nehalem River
- Siletz River
- Yaquina River
- Alsea River
- Siuslaw River
- Umpqua River
- Coos River
- Coquille River
- Rogue River
- Thomas Creek
- Chetco River
- Smith River, Northern California

Within each major island, many smaller, isolated islands would be created after the disaster. Smaller islands will be due to bridge damage; tsunami flood damage along roadways; liquefaction-damaged roads; landslides; damage to buildings, dams, levees, and infrastructure; downed trees; and more. Many large landslides are expected and may take months to mitigate.

Figure 2. Post-Cascadia earthquake "coastal islands" map.



Of the thirteen major bridges, three are "movable" bridges (**Figure 2**). Movable bridges are part of river navigation systems, such as lift bridges. Movable bridges tend to be especially vulnerable to strong earthquake shaking due to their movable parts, such as large counterweights and gears. Certain movable bridges can be seismically retrofitted, but costs are very high.

Three bridges are on the historic register (**Figure 2**). Due to their construction age, they may have especially high seismic vulnerability. These bridges often have a recognized cultural value; therefore, seismic retrofit options may be extremely limited. Seismic retrofits of older bridges to a high seismic performance level, that is, where they can operate shortly after a Cascadia earthquake, are expensive. Two bridges are both movable and historic.

ODOT maintenance yards and major airports are shown on the map (**Figure 2**) because they may play an important role in disaster planning, response, and recovery. Heavy earth moving equipment, such as bulldozers, and materials, such as aggregate and culverts, are commonly stored at ODOT facilities. ODOT may help clear and restore critical roadways that impact hospital operations.

Three airports capable of handling large heavy aircraft (e.g., C130 and C17) and that are not exposed to tsunami hazards are shown on the map (**Figure 2**). These airports are located in Tillamook, Newport, and Cape Blanco, which is near Port Orford between Bandon and Gold Beach. The airports may help with transporting medical patients and supplies from the north, central, and south coast, respectively.

It will likely take on the two or more years to reopen the major bridges that form the borders of the major coastal islands (U.S. DHS, 2019). As shown on **Table 2**, the two-year reopening estimate is based on these assumptions: there is significant bridge damage that does not involve soil liquefaction, the bridge spans over a river and is over 150 ft in length. Bridges with damage that involves liquefaction are estimated to take longer to reopen (US. DHS, 2019).

Table 2. Bridge reopening time estimates (U.S. Department of Homeland Security, 2019, Table 1).

Damage Level	Damage Type	Consideration	Bridge Length (ft)	Reopening Time	Repair Type
None	None	None	N/A	0 days	None
Moderate	Minor or none	None	N/A	2 weeks	Bridge inspection and minor or no repairs
Significant	Any significant damage type	Bridge not over waterway or impassable topography	> 50	2 weeks per 50 ft. of bridge length	Temporary road
			≤ 50	2 weeks	
	Significant damage without soil liquefaction	Bridge over waterway or impassable topography	> 150	2 years	Major bridge rehabilitation or replacement
			≤ 150, > 50	14 months	
			≤ 50	7 months	
	Significant damage with soil liquefaction	Bridge over waterway or impassable topography	> 150	2.5 years	Major bridge rehabilitation or replacement and subsurface strengthening
			≤ 150, > 50	1.5 years	
			≤ 50	8 months	

Due to collapsed highway bridges creating geographic islands, the Oregon coast is expected to experience extreme transportation mobility, creating severe challenges for hospitals to provide post-Cascadia healthcare services. Coastal communities will experience a convergence of hospital personnel being trapped on "islands," thus limiting their ability to access their hospitals to perform work; a significant increase of injured people who require care; and an urgent need to triage patients and evacuate critical patients by air.

Hospital personnel should not rely on certain older, longer bridges to be functional after a Cascadia event. The coastal islands map (**Figure 2**) shows that hospital personnel may not be able to access their hospital, for instance, if they live on a different island. Information on the coastal islands map should help inform hospital business continuity plans. As an example, it will not be possible to send patients inland by road as is the common practice due to impassable roads (e.g., from landslides in the mountainous Coast Range) between the coast and the U.S. Interstate 5.

The coastal islands map may be useful to hospital emergency planners and others because it demonstrates the major points of weakness for transportation along the Oregon coastal highway. The map may be used to inform other planning activities, such as determining where and how critical patients might be air transferred to an "inland" hospital and where and how medical supplies might be delivered. Another purpose of this map is to motivate hospital and planners to develop alternate routes for access in and out of their regions by air, land, and sea. Additional discussion is included in the **Hospital Resilience Planning Maps** and **Recommendations for Future Work** sections of this report.

HOSPITAL RESILIENCE PLANNING MAPS

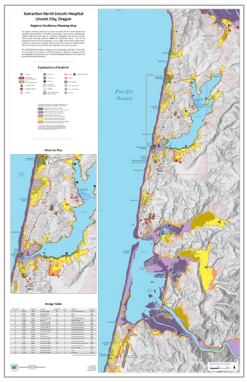
As part of the Coastal Hospital Resilience Project's technical assistance, hospital resilience planning maps were developed with and for each hospital. The resilience planning maps include hazards, assets, and features considered to be helpful in disaster resilience planning, including tsunami hazard information. DOGAMI worked with hospital staff, and the hospital staff members were encouraged to work with their partners. When possible, map review at an on-site consultative meeting was performed along with community partners. The map shows the hospital as a central feature of each community. Each hospital was provided with full-size laminated copies of their map(s). The laminated maps can be displayed but can also be annotated by using erasable felt pens during resilience planning work sessions.

The main purpose of these maps is to help with planning before the Cascadia earthquake and resulting tsunami occurs. The hospital resilience planning maps are intended to encourage hospitals to conduct resilience plans and for hospitals to engage with community partners to plan community resilience goals and activities. As an example, the maps can be used as a tool to encourage community activism to seismically improve water and power systems for the hospitals and broader community. Similarly, the maps can be used as part of planning activities that involve local planners, the state, and U.S. military for emergency response and recovery. The maps are considered to be "working" maps and are not a static final product. Additional discussion about possible uses of the maps is included in the Recommendations for Future Work section.

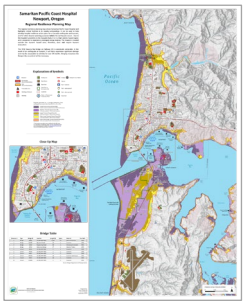
This section of the report describes the map information, the way it is displayed on the maps, and how it can be useful to hospitals and their partners. Resilience planning maps included in this report and listed from north to south are for:

- Samaritan North Lincoln, Lincoln City
- Samaritan Pacific Communities, Newport
- PeaceHealth Peace Harbor, Florence
- Lower Umpqua Hospital, Reedsport
- Bay Area Hospital, Coos Bay
- Coquille Valley, Coquille
- Southern Coos Hospital and Health Center, Bandon
- Curry General, Gold Beach

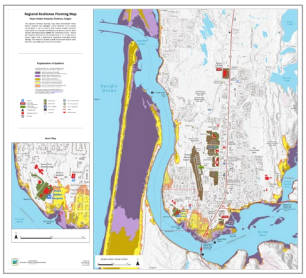
Below are small images of the resilience planning maps for these eight hospitals. Full-size maps are provided with this report.



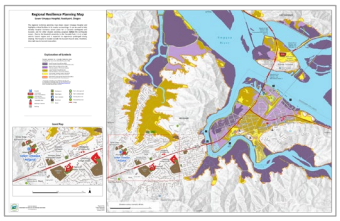
Samaritan North Lincoln, Lincoln City
Regional Map, 32 x 50 inches



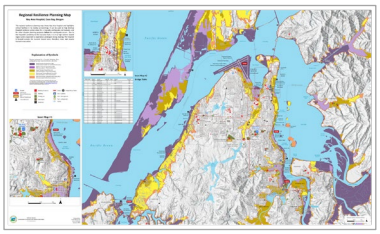
Samaritan Pacific Communities, Newport
Regional Map, 32 x 40 inches



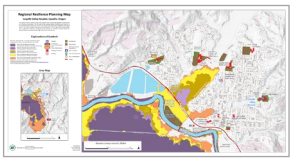
PeaceHealth Peace Harbor, Florence
Regional Map, 40 x 36 inches



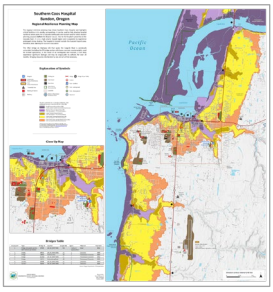
Lower Umpqua Hospital, Reedsport
Regional Map, 44 x 28 inches



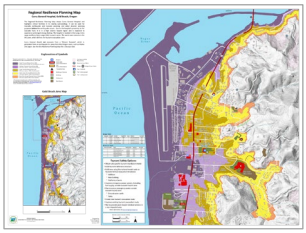
Bay Area Hospital, Coos Bay
Regional Map, 50 x 30 inches



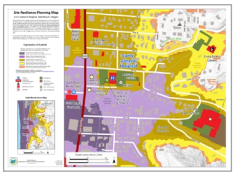
Coquille Valley, Coquille
Regional Map, 38 x 20 inches



Southern Coos Hospital and Health Center, Bandon
Regional Map, 36 x 38 inches



Curry General, Gold Beach
Regional Map, 40 x 30 inches



Curry General, Gold Beach
Site Resilience Planning Map, 30 x 22 inches

DOGAMI Open-File Report O-19-01 (Wang and others, 2019) includes maps for these three hospitals:

- Columbia Memorial Hospital, Astoria
- Providence Seaside Hospital, Seaside
- Tillamook Regional Medical Center, Tillamook

The maps for these three hospitals were displayed at the Oregon Coastal Hospital Special Leadership Event held in 2018 (Wang and others, 2019).

Resilience Planning Map Uses

These resilience planning maps can:

- Help users visualize the geographic locations of important facilities to the hospital. Facility examples include community points of distribution, possible fuel points of distribution, and local fire and police departments.
- Help users recognize the proximity of facilities and features, such as open areas and boat docks, to the hospital. This allows each hospital to better understand and plan options for off-site patient care and movement.
- Provide helpful presentation material for internal and community resilience planning by visualizing the geographic locations of important facilities to the hospital. One important goal is to encourage productive conversation among hospital personnel, local emergency managers, water districts, and nearby partners and their resources.
- Assist hospitals (and their partners) with tsunami hazards in examining and improving their tsunami safety plans. For facilities with tsunami hazards, tsunami safety plans may include the necessity and feasibility of constructing defensive tsunami measures, such as protective wall systems or vertical evacuation structures. For hospitals with tsunami hazards, text included on each resilience planning map describes general tsunami information for the specific hospital.

Please note that the hospital resilience maps are not tsunami evacuation maps. Tsunami evacuation maps are designed to be a simple, clear tool for determining individual evacuation routes, whereas resilience planning maps are intended to help understand hazards and prompt resilience activities. Both are planning tools, useful before a disaster. The DOGAMI tsunami evacuation brochure website address (www.OregonTsunami.org) is included on the resilience planning maps.

Information on Resilience Planning Maps

Tsunami *hazard* information on maps

Scenarios for tsunami inundation after a Cascadia subduction Zone earthquake vary in size from small (SM) to medium (M), large (L), extra-large (XL), and extra-extra-large (XXL). Each resilience map includes these five tsunami hazard zones. The boundary between the tsunami hazard zone and tsunami safe zone is defined by a red line, which is equivalent to the tsunami evacuation zone line of maximum inundation (Priest and others, 2013).

Tsunami hazard information shown on these resilience planning maps:

- Tsunami hazard zones (SM, M, L, XL, XXL)
- Tsunami line of maximum inundation

Tsunami *evacuation* information on maps

In the event of a tsunami, hospitals that have tsunami hazards may want to be prepared to quickly evacuate patients and staff out of the tsunami hazard zones using the most efficient routes available. Persons who do not successfully escape a tsunami may be severely injured or worse. Established and potential post-tsunami areas of assembly are identified on each map. These areas include any parking lots and open areas that could be considered for potential tsunami evacuation sites. This information will help hospitals develop their best evacuation routes. Hospitals can also choose to build tsunami protective walls

or tsunami vertical evacuation structures, or to relocate to reduce or eliminate tsunami risk. Similarly, non-hospital facilities that in the tsunami zone may also choose to address tsunami risk.

Tsunami evacuation information shown on these resilience planning maps:

- Possible areas of assembly – parking lots
- Possible areas of assembly – open areas
- Existing areas of assembly (as defined in the current version of DOGAMI tsunami evacuation maps; assembly areas are periodically updated by local authorities)

Additional tsunami resources, including the below information, are available at https://www.oregongeology.org.

- Local tsunami hazard zones: DOGAMI Open-File Report O-13-19 (2013) https://www.oregongeology.org/pubs/ofr/p-O-13-19.htm
- Tsunami evacuation maps (including assembly areas) https://www.oregongeology.org/tsuclearinghouse/pubs-evacbro.htm
- Tsunami inundation maps
- https://www.oregongeology.org/tsuclearinghouse/pubs-inumaps.htm
- Original scientific publication: DOGAMI Special Paper 43 (2011) https://www.oregongeology.org/pubs/sp/p-SP-43.htm

Facilities located on maps

Each map includes the names and locations of buildings of special interest, which are shown in red. Buildings and facilities of special interest shown on these resilience planning maps:

- Hospital
- Hospital helipad
- Hospital expansion areas (if applicable)
- Other nearby health care facilities as requested by hospital personnel
- City fire and rescue
- City police department
- Local elementary and high schools
- Oregon Department of Transportation facilities
- Other facilities as requested by hospital personnel

Local fuel supply resources located on maps

Each hospital has its own fuel supply on site, and this location is shown on each map. In addition, each map shows locations of above and below ground fuel tanks near the hospital. Each map shows locations of local cardlock facilities, which are fueling sites restricted by requiring an issued access card to obtain fuel. In addition, a possible delivery location for additional fuel supplies, known as a community Fuel Point of Distribution (FPOD), may be identified on the map. Possible FPOD locations have been identified by county emergency management often with the input from local partners. FPOD locations are coordinated with the Oregon Department of Energy for emergency fuel planning purposes consistent with the Oregon Fuel Action Plan, which is available at: https://www.oregon.gov/energy/safety-resiliency/Documents/Oregon-Fuel-Action-Plan.pdf (ODOE, 2017; Wang and Nourse, 2019).

Fuel supply information shown on these resilience planning maps:

- Area cardlock facilities
- Fuel tanks, above ground

- Fuel tanks, below ground
- possible FPOD locations

Water system facilities located on maps

Water treatment plants and water reservoirs (tanks) may be located on the resilience planning maps. Facilities are not always displayed on the maps because they are located off the mapped boundaries or at the request of the hospital or local water district.

Bridges located on maps

Bridge locations are included on the resilience planning maps. Next to each bridge symbol are important details about the bridge's construction material, number of spans, length, date built, mile post number, and if the bridge is a movable bridge. This information allows hospital personnel and local planners to have access to information about bridges that are constructed along potential evacuation routes as well as routes to critical facilities, such as fuel supplies. Some bridges may have been retrofitted or are being replaced.

Bridge information was obtained from the Oregon Department of Transportation and includes the following where available:

- Mile post number
- Construction material
- Number of spans
- Date built
- Bridge length
- Movable bridge location

Community Points of Distribution located on maps

A designated location where the public can pick up emergency supplies following a disaster is called a Community Point of Distribution (CPOD). Typically, local CPODs are determined by the county emergency manager. Each resilience planning map includes the location of the designated CPOD for that area. Potential new CPOD locations are suggested on maps where the hospital might benefit from a closer distribution point.

General information on maps

Each resilience planning map provides general geographical information. Topography around the hospitals is represented, and contours are shown in regions that exhibit variable elevations. The regional transportation network, including all local roads, highways, and interstates is displayed, along with the regional hydrology network, including rivers, streams, and the ocean, where applicable. Each map also includes building footprints as well as the location of the regional airport.

General base map information shown on these resilience planning maps:

- Transportation network (Interstates, highways, local roads)
- Hydrology network (ocean, rivers, and streams)
- Building footprints
- Surrounding topography with contour lines
- Airport location

Additional information on maps

Because each hospital has unique circumstances, additional helpful information may be included on the maps. For example, mapped landslide hazard areas that overlap hospital evacuation routes are shown. In the event of an earthquake, these landslides may be re-activated and evacuation routes could be blocked. Additional information that may be shown on these resilience planning maps:

- Landslide hazard areas
- Electrical substations
- Levees
- Airport capability data
- Boat docks and ramps
- Possible microgrid location

RECOMMENDATIONS FOR FUTURE WORK

The Coastal Hospital Resilience Project provides a critically important starting point for hospital personnel to prepare their hospitals for future Cascadia earthquakes and tsunamis. Hospital leaders from all coastal hospitals and hospital personnel were made aware of the expected impacts from a Cascadia earthquake and tsunami and the importance of building disaster resiliency including creating a strong Oregon Coastal Hospital Resilience Network at the 2018 Oregon Coastal Hospital Special Leadership Event (Wang and others, 2019). Hospital leaders are each fully aware of their institutional supporters, including OHA Health Security, Preparedness and Response (HSPR), and the Oregon Association of Hospital and Healthcare Systems (OAHHS) (Wang and others, 2019).

As part of this project, many hospital personnel expressed that they have begun to think, and act, more broadly. Many realized that for coastal communities to quickly recover, not only must hospitals be functional, but the whole community should be getting better prepared. It will take continued dedication and effort to better prepare hospitals as well as working with community partners to help the hospitals and the broader community.

Hospital Resilience Planning

In order for coastal hospitals to provide medical services in a post-Cascadia environment, many partners including hospital personnel must continue to build disaster resiliency. Hospital personnel are aware of the project's seven key messages, are making progress on them, and are working toward the Triple 3 Resilience Target (Wang and others, 2019; Wang and Nourse, 2019; Banse, 2019).

Making progress requires building stronger partnerships. Hospital personnel will need to work with their lifeline infrastructure providers and with new resources to make necessary improvements. Oregon Business Development Department and the Governor's Regional Solutions may play an important role with financing opportunities (https://www.oregon4biz.com/; https://www.oregon.gov/gov/admin/regional-solutions). Oregon Emergency Management is leading the state's effort on the national exercise called Cascadia Rising, which will take place in June 2022. Planning for this exercise is underway; OHA HSPR has encouraged coastal hospitals to participate. Recently, the Department of Land and Conservation Development has started to engage coastal hospitals on local natural hazard mitigation planning efforts. This may, in time, allow hospitals to apply for Federal Emergency Management Agency (FEMA) and other federal disaster preparedness funds.

Due to project activities, hospital personnel have renewed energy to invest in their emergency plans and policies to support Cascadia earthquake and tsunami preparedness. Some hospital personnel have developed new partnerships with their local water district with the aim to build new water tanks to supply the hospitals in a post-disaster situation. In a similar vein, some hospital personnel have developed new partnerships with the local public works and are discussing ways in increase their emergency fuel supplies by adding a new fuel tank. Hospital personnel are exploring building a microgrid to supply locally generated, post-disaster electrical power. Some hospitals are focusing on regional emergency communication systems by establishing new reliable systems involving portable tactical repeaters (Dave McNeel, written communication, October 23, 2019). Some have committed to become ShakeAlert pilot projects. Some have developed new community partnerships to ensure that they can collaborate before and after a Cascadia disaster, ranging from working with grocery stores to funeral homes.

Resilience Planning Involving Transportation

Highway transportation is expected to be significantly impaired for months to years. Preparing for post-Cascadia transportation options will require continued planning at the local, state, regional, and federal levels. Planning could involve state agencies such as Oregon Department of Transportation (ODOT), Oregon Military Department, Oregon Emergency Management, Department of Aviation, State Parks and others. Planners have many useful resources, including ODOT's Seismic Lifelines Evaluation (CH2M Hill, 2012a,b) and Oregon Office of Emergency Management's "Island Mapping Pilot Project" (https://www.oregon.gov/oem/hazardsprep/Pages/Cascadia-Island-Mapping.aspx).

Uses of Post-Cascadia Earthquake Coastal Islands Map

The Coastal Islands Map (**Figure 2**) can be used to help with resilience plans. Possible next steps for hospitals, local emergency managers, transportation, and other partners are to meet to conduct and develop local transportation analyses and plans. This could include determining if road detours exist that could be used to reconnect major islands, expected road blocks, or other discontinuities. If existing detours are absent or not viable, then identifying locations of undeveloped river crossings with the potential to create new vehicular crossings could be done. For example, river locations with characteristics such as 1) shallow depths, 2) low water flows, 3) narrow widths (to minimize the crossing distance), and 4) nearby roads for access could be identified in advance (Tom Wall, Argonne National Laboratory, oral communication, December 6, 2019).

Planning could also include air and water options. Typically, emergency response by air may be the fastest method, even if airports experience some damage. Local assets including public airports, private runways, heliports, hardstand spaces (with robust pavement), open paved areas, and open unpaved areas could be integrated into plans. Similarly, identifying the local water transportation options, including ports and boat ramps and beaches, could be helpful. Information on post-disaster transportation by air and by water is discussed in the next sections.

Post-disaster transportation by air

Transportation by air will be necessary in a post-Cascadia disaster environment. **Table 3** lists the 15 public airports, from north to south, along the Oregon coast. Additional information on each airport, including runway length, runway weight-bearing capacities, and if tsunami hazards are present, is included in the table. Other air transportation options are possible, including at heliports and even makeshift landing locations, such as sections of roadways.

Five of the 15 airports have robust runway capacities that allow for heavier aircraft, including C130 and C17 cargo airplanes: Astoria, Tillamook, Newport, Coos Bay, and Cape Blanco (near Port Orford). It should be noted, however, that both the Astoria and Coos Bay airports are on near-sea-level sites and have significant tsunami hazards (see hospital resilience maps in this report and in Wang and others [2019]). Both airports are located in the tsunami inundation zone that DOGAMI has identified as the "small" tsunami zone, meaning these airports are expected to be inundated and damaged by even small tsunamis generated by a Cascadia earthquake. As such, these airports would likely require significant clean up and repair before being available for emergency operations. Tillamook, Newport, and Cape Blanco (near Port Orford) airports may be the current best options for emergency response activities on the north, central, and south coasts, respectively.

Table 3. Airports along coastal Oregon.

Airport	Location[1]	Capable of Supporting C130/C17 Operations?	Runway ID	Runway Length	Runway Surface	Weight-Bearing Capacity (pounds; k is thousands of pounds)
Astoria (AST)	in tsunami evacuation zone	yes, if undamaged	8/26	5,794 ft	asphalt	single wheel 60k double wheel 76k double tandem 119k
	—	—	14/32	4,467 ft	asphalt	single wheel 60k double wheel 76k double tandem 119k
Seaside (56S)	in tsunami evacuation zone	—	16/34	2,211 ft	asphalt	single wheel 12k
Nehalem Airport (3S7)	in tsunami evacuation zone	—	15/33	2,350 ft	asphalt	single wheel 12.5k
Tillamook (TMK)	—	yes, if undamaged	13/31	5,001 ft	asphalt	single wheel 60k double wheel 75k double tandem 125k
Pacific City (PFC)	in tsunami evacuation zone	—	14/32	1,860 ft	asphalt	single wheel 12.5k
Siletz (S45), in Lincoln City	—	—	17/35	3,297 ft	asphalt	single wheel 11k
Newport (ONP)	—	yes, if undamaged	16/34	5,398 ft	asphalt	single wheel 75k double wheel 120k double tandem 170k
	—	—	2/20	3,001 ft	asphalt	single wheel 33k double wheel 50k double tandem 84k
Waldport (R33)	in tsunami evacuation zone	—	16/34	2,000 ft	turf	single wheel 6K
Florence (6S2)	—	—	15/33	3,000 ft	asphalt	single wheel 12.5k
Lakeside (93S)	—	—	14/32	2,150 ft	turf	single wheel 6k
Coos Bay (OTH)	in tsunami evacuation zone	yes, if undamaged	4/22	5,980 ft	asphalt	single wheel 120k double wheel 215k double tandem 340k dual double tandem 800k
	—	—	13/31	4,470 ft	asphalt	single wheel 120k double wheel 190k double tandem 305k dual double tandem 735k
Bandon State (S05)	—	—	16/34	3,601 ft	asphalt	single wheel 12k
Port Orford/ Cape Blanco State (5S6)	—	yes, if undamaged	14/32	5,100 ft	asphalt	single wheel 115k double wheel 185k double tandem 340k
Gold Beach (4S1)	in tsunami evacuation zone	—	16/34	3,200 ft	asphalt	single wheel 12.5k
Brookings (BOK)	—	—	12/30	2,901 ft	asphalt	single wheel 11k

Source: John Wilson, Oregon Department of Aviation. [1]The XXL tsunami zone (Priest and others, 2013).

Post-disaster transportation by water

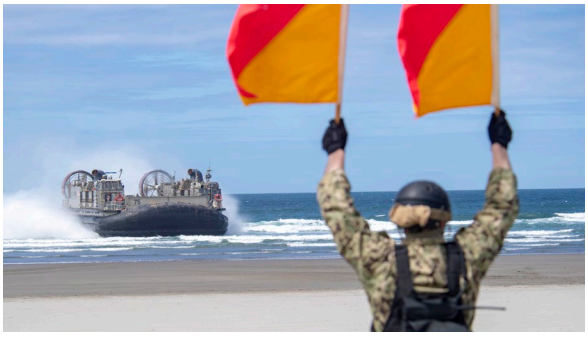
Transportation by watercraft will be necessary in a post-Cascadia environment. The thirteen Oregon coastal ports, from north to south are (Oregon Blue Book, Port Districts of Oregon, https://sos.oregon.gov/blue-book/Pages/local/other-ports.aspx):

- Port of Astoria
- Port of Garibaldi
- Port of Tillamook Bay
- Port of Newport
- Port of Toledo
- Port of Alsea, Waldport
- Port of Siuslaw, Florence
- Port of Umpqua, Reedsport
- International Port of Coos Bay
- Port of Bandon
- Port of Port Orford
- Port of Gold Beach
- Port of Brookings Harbor

Similar to airport facilities, the capacities and capabilities of port facilities vary. Furthermore, all of the ports have significant tsunami hazards and are expected to be inundated and damaged by a Cascadia event. All ports would likely require significant cleanup and repair before being able to resume even limited emergency operations. Other transportation options over water are possible, involving at boat ramps, private boat docks, beaches, and even makeshift locations, such as sections of roadways.

Transportation methods involving water will likely span a large range and vary over time. For example, small personal watercraft may be used to cross rivers soon after the tsunami hazards are over. U.S. Coast Guard, local government, and private fishing boats may be used to help with emergency response, such as ferrying people requiring medical attention over water bodies to help the injured get to hospitals. Also, emergency planning with the U.S. Navy to land landing craft, air cushion (LCAC), or hovercrafts on Oregon beaches is underway (**Figure 3**). Similarly, starting in 2019, initial discussions among U.S. Navy, Oregon Military Division, OHA, and DOGAMI to deploy a naval hospital ship began. Although non-military disasters are not the Navy's top priority, mobilizing a naval hospital ship would require the highest authorization, and transport time could be several weeks, their vast capabilities could support the entire coast.

Figure 3. U.S. Navy landing craft, air cushion (LCAC) during a June 2019 exercise near Sunset Beach, Oregon.



Source: https://www.dvidshub.net/image/5434117/lcac-lands-oregon-dsca-exercise. Photo by Chief Petty Officer Alan Gragg, June 3, 2019. The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.

ACKNOWLEDGMENTS

Funding for this project was made possible by the Centers for Disease Control and Prevention via a federal grant to the Oregon Health Authority (OHA) (Grant: 6 NU90TP921916), which passed funds through OHA-DOGAMI agreement number 161011, DOGAMI contract number 632171985. The views expressed in written materials or publications do not necessarily reflect the official policies of the U.S. Department of Health and Human Services, nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government.

The authors are especially grateful to Akiko Saito, Oregon Health Authority (OHA), Public Health Division Health Security, Preparedness and Response (HSPR), Director of Emergency Management Operations, who has been instrumental in supporting this project and provided a review of this report. Kathryn Richer, Multnomah County, Susan Lamb, OHA, Beth DePew (retired) and Edwin Flick, OHA, serve as the Healthcare Preparedness Partners (HPP) regional liaisons for Regions 1, 2 and 3, respectively. Deanna Henry, Oregon Department of Energy (ODOE) emergency preparedness manager, has responsibilities on emergency fuel allocation. Laura Gabel, DOGAMI geohazards section supervisor (former), and Katie Kopania, Centers for Disease Control and Prevention, provided reviews of this report. These individuals were an integral part of the project team and critically important to the success of the project. Without their expertise and dedication, this project would not have been possible. The authors gratefully acknowledge their contributions.

DOGAMI is indebted to the many hospital partners for their dedication to serve their communities, in particular:

- Eric Thorsen, Columbia Memorial Hospital, Astoria
- Paula Larson, Columbia Memorial Hospital, Astoria
- Matthew Lindstrom, Columbia Memorial Hospital, Astoria (former)
- Kendall Sawa, Providence Seaside Hospital, Seaside
- Billie Grigoraitis, Providence Seaside Hospital, Seaside
- Erik Meyer, Providence Seaside Hospital, Seaside
- Michael Kubler, Providence Hospital, Portland (former)
- Dale Ellsworth, Providence Seaside Hospital, Seaside
- Eric Swanson, Tillamook Regional Hospital, Tillamook
- Wayne Alvarez-Rojas, Tillamook Regional Hospital, Tillamook
- David Butler, Tillamook Regional Hospital, Tillamook (former)
- Leslie Ogden, Samaritan North Lincoln Hospital, Lincoln City and Samaritan Pacific Communities Hospital, Newport
- Chris Lemar, Samaritan North Lincoln Hospital, Lincoln City
- Jon Connor, Samaritan Pacific Communities Hospital, Newport
- Ericka Mason, Samaritan Health Services, Newport
- Micah Goettl, Samaritan Health Services, Corvallis
- Jason Hawkins, PeaceHealth Peace Harbor Medical Center, Florence
- Patrick Kirby, PeaceHealth Peace Harbor Medical Center, Florence
- Eli Davis, PeaceHealth, Springfield
- Roni Dersham, PeaceHealth, Springfield
- Ryan Fowler, Lower Umpqua Hospital, Reedsport
- Kevin Hague, Lower Umpqua Hospital, Reedsport
- Randy Gore, Lower Umpqua Hospital, Reedsport
- Don Marr, Lower Umpqua Hospital, Reedsport
- Russ Johnston, Bay Area Hospital, Coos Bay
- Karl Delzotti, Bay Area Hospital, Coos Bay
- Jeff Lang, Coquille Valley Hospital, Coquille
- Ernie Fegles, Coquille Valley Hospital, Coquille
- Amy Fine, Southern Coos Hospital and Health Center, Bandon
- JoDee Tittle, Southern Coos Hospital and Health Center, Bandon (former)

- Dennis Jurgenson, Southern Coos Hospital and Health Center, Bandon
- Virginia Razo, Curry General Hospital, Gold Beach
- Dana Miller, Curry General Hospital, Gold Beach
- Andy Stubbs, Curry General Hospital, Gold Beach
- Katie Harris, Oregon Association of Hospitals and Healthcare Systems
- Matt Stormont, Oregon Health and Sciences University (former)

DOGAMI acknowledges many community partners, including those involved with the healthcare preparedness coalitions, public health officials, county and city personnel, citizens involved with Medical Reserve Corps (MRC), Community Emergency Response Teams (CERT), and others. These county emergency managers supported this project:

- Tiffany Brown, Clatsop County Emergency Manager
- Gordon McCraw, Tillamook County Emergency Manager
- Jenny Demaris, Lincoln County Emergency Manager
- Patence Winningham-Melcher, Lane County Emergency Manager
- Wayne Stinson, Douglas County Emergency Manager
- Mike Murphy, Coos County Emergency Manager (retired)
- Gabriel Fabrizio, Coos County Emergency Manager
- Phillip Nel, Coos Health and Wellness Public Health Emergency Preparedness Manager
- Jeremy Dumire, Curry County Emergency Manager

DOGAMI acknowledges state agency personnel who supported this project, in particular:

- Michael Harryman, Office of Governor Kate Brown
- Alex Campbell, Office of the Governor, Regional Solutions
- DeWayne Hatcher, OHA HSPR
- Eric Gebbie, OHA HSPR
- Nick May, OHA HSPR
- Peter Mackwell, OHA HSPR
- Jill Snyder, OHA HSPR
- Adam Schulz, Oregon Department of Energy
- Albert Nako, Oregon Department of Transportation
- Bruce Johnson, Oregon Department of Transportation
- John Wilson, Oregon Department of Aviation
- Martin Balakas, Oregon Military Department
- Robert Lee, Oregon Army National Guard
- Gloria Zacharias, Oregon Business
- Sean Stevens, Oregon Business

We thank our federal partners, including:

- Peter F. Roberts, Captain and Fleet Surgeon in the U.S. Navy Medical Corps Third Fleet
- Brian Sauerhage, Commander in the U.S. Navy Third Fleet
- Jason Fuchs, Lieutenant in Norad and U.S. Northern Command, Joint Regional Medical Plans and Operations
- James “JW” White, Defense Support to Civil Authority Planner in the U.S. Army North

- Steve Obrien, FEMA
- Jim Gonzalez, Emergency Management Specialist in U.S. Army Corps of Engineers
- Jaysen Goodwin, U.S. Department of Homeland Security
- Jason Osleson, U.S. Department of Homeland Security
- Tom Wall, Argonne National Lab

Finally, the authors appreciate the support from Oregon Department of Geology and Mineral Industries (DOGAMI) past and present personnel including Brad Avy, Robert Houston, Laura Gabel, Deb Schueller, Jon Allan, Dania Ballard, Alyssa Pratt, Jed Roberts, and Kim Riddell.

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APPENDIX:
SITE AND REGIONAL RESILIENCE PLANNING MAPS

Maps are oversize PDFs. From north to south–

Samaritan North Lincoln Hospital, Lincoln City, regional map, 32 x 50 inches
Samaritan Pacific Communities Hospital, Newport, regional map, 32 x 40 inches
Peace Harbor Hospital, Florence, regional map, 40 x 36 inches
Lower Umpqua Hospital, Reedsport, regional map, 44 x 28 inches
Bay Area Hospital, Coos Bay, regional map, 50 x 30 inches
Coquille Valley Hospital, Coquille, regional map, 38 x 20 inches
Southern Coos Hospital, Bandon, regional map, 36 x 38 inches
Curry General Hospital, Gold Beach, regional map, 40 x 30 inches
Curry General Hospital, Gold Beach, site map, 30 x 22 inches