Resilience Planning at Local Levels – Necessity for Considering Dependencies

Kent Yu, PhD, PE, SE, Principal
SEFT Consulting Group
Beaverton, Oregon
Community Member Needs

Source: Erica Kuligowski 2015
Understand the Situation
Link Social Dimensions and Built Environment

Source: NIST CRPG 2015
Cascadia Subduction Zone

Known Cascadia Earthquakes along the Cascadia Subduction Zone in Northern California, Oregon, and Washington:
- Earthquake of Magnitude 9+ (fault breaks along entire subduction zone)
- Earthquake of Magnitude 8+ (fault breaks along southern half of subduction zone)

Seismicity

Modified from Weaver and Shedlock, 1996.
Shift from Life-safety to Resilience

The ability to **prepare for** and **adapt to** changing conditions and **withstand** and **recover rapidly** from disruptions (from PPD-21)
The Oregon Resilience Plan

50-year Comprehensive Plan

- Cascadia Earthquake Scenario
- Business/Workforce Continuity
- Coastal Communities
- Critical & Essential Buildings
- Transportation
- Energy
- Information and Communication
- Water & Wastewater

(download it from
NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems

Google NIST Resilience Planning Guide for a free download
Recovery of the Built Environment

Organize around restoring functionality over time

When is each cluster and system needed for recovery?

- Survival
- Safety and Security
- Belonging
- Growth and Achievement

Source: National Disaster Recovery Framework
Target States of Recovery for Building & Infrastructure

<table>
<thead>
<tr>
<th>Phase</th>
<th>Time Frame</th>
<th>Focus of Attention</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1 to 3 days</td>
<td>Initial response</td>
</tr>
</tbody>
</table>

EOC’s, Hospitals, Police and Fire Stations, Emergency Shelters (Animal Shelters)

Lifeline Infrastructure to provide services to this group of buildings
# Target States of Recovery for Building & Infrastructure

<table>
<thead>
<tr>
<th>Phase</th>
<th>Time Frame</th>
<th>Focus of Attention</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>1 to 4 weeks</td>
<td>Workforce housing restored – ongoing social needs met</td>
</tr>
</tbody>
</table>

**Essential County/City Services**

Residential Housing,

**Schools/Daycare Centers,**

Community retail centers,

Financial and Banks

Buildings – “safe and useable during repair”

Lifeline infrastructure provide services to this group of buildings
# Target States of Recovery for Building & Infrastructure

<table>
<thead>
<tr>
<th>Phase</th>
<th>Time Frame</th>
<th>Focus of Attention</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>2 to 36 months</td>
<td>Long term reconstruction</td>
</tr>
</tbody>
</table>

- **Industrial Buildings**
- **Commercial buildings**
- **Historic buildings**

**Building** - “Safe and usable after repair” “Safe but not repairable”

**Complete 100% reconstruction of lifeline infrastructure within less than 3 years**
Functionality Needs For Recovery

• **Short-Term**: Secure, Rescue, Stabilize, Clear Routes
  • Clusters: Critical Facilities, Emergency Housing
    Related Infrastructure Systems

• **Intermediate**: Restore Neighborhoods, meet social needs
  • Clusters: Housing, healthcare, main street, schools, Churches
    Related Infrastructure Systems

• **Long-Term**: Community Social and Economic Recovery
  • Clusters: Commercial and Industrial Businesses
    Related Infrastructure Systems
Lifeline Dependencies

Interdependencies will make disaster recovery much more difficult. The earthquake will damage all systems at the same time.

To restore water service, you need electricity.
To reopen roads, you need to restore fuel supplies.
To restore fuel supplies, you need electricity.
To restore electric service, you need to reopen roads.

(ASCE TCLEE)
Cascading Effects

Power System INTERNAL
Cascading Failure (2003 NE Blackout)

Approximate Timeline

1:30pm  2:00pm  2:15pm  3:30pm  4:15pm

Electricity generating plant goes offline during high demand period.
High strain nut on nearby high-voltage power lines due to loss of generating plant.
First of several power lines come in contact with trees and trip relay.
Control room software bug delays alarm and response by operators for over an hour.
Transmission lines overloaded when load transferred to them causing trip relays.
Over 200 power plants forced to shut down due to transmission grid disruption.
Blackout affected estimated 50 million people in Northeast U.S. and Canada.
Cascading Effects

Power System 
EXTERNAL 
Cascading Failure (2003 
NE Blackout)

ENERGY (ELECTRIC) – Loss of electric power (blackout) affects 50 million people in Northeastern US and Canada
BUILDINGS – Hundreds of people trapped in elevators
TRANSPORTATION – All trains into and out of New York City were shut down
ENERGY (LIQUID FUEL) – Fuel could not be pumped at gas stations due to loss of electric power
COMMUNICATIONS (TWO-WAY SYSTEMS) – Generator, communication and loss of battery back-up caused cell site failures
COMMUNICATIONS (ONE-WAY SYSTEMS) – U.S. television networks could not broadcast
WATER – Loss of electricity for pumps caused a loss of system pressure and boil-water notice
Dimensions of Dependencies

• Internal and External
• Time
• Space
• Source

(These dimensions may not be independent)
Internal and External Dependencies

• Internal Dependency (examples)
  • Physical Infrastructure System
  • Equipment and Repair Supplies
  • Operations Center (and more)
  • Employees

• External Dependency (examples)
  • Transportation
  • Power
  • Communication (and more)
  • Financial

(It is also good to consider who may depend on your system)
Time Dimension

- Recovery Phases
  - Short-Term, Intermediate, and Long-Term
- Dependencies may change from one phase to another
- Performance goals, and restoration sequence and pace are influenced by external dependencies of other infrastructure systems and community needs.

(Source: FEMA, 2014)
Water and Wastewater Performance Goal

<table>
<thead>
<tr>
<th>Functional Category: Cluster</th>
<th>(4) Support Needed</th>
<th>Overall Recovery Time for Hazard – Routine, Expected or Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td></td>
<td>Phase 1 – Short-Term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Days</td>
</tr>
<tr>
<td>Raw or source water and terminal reservoirs</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Raw water conveyance (pump stations and piping to WTP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well and/or Treatment operations functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission (including Booster Stations)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backbone transmission facilities (pipelines, pump stations, and tanks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water for fire suppression at key supply points (to promote redundancy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCADA or other control systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale Users (other communities, rural water districts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospitals, EOC, Police Station, Fire Stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Housing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Shelters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing/Neighborhoods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potable water available at community distribution centers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water for fire suppression at fire hydrants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community Recovery Infrastructure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other clusters</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: NIST CRPG 2015
**Example Summary Resilience Matrix**

Example: Expected, Community, Moderate

<table>
<thead>
<tr>
<th>Functional Category: Cluster</th>
<th>Overall Recovery Time for Hazard and Level Listed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected Hazard Level</td>
</tr>
<tr>
<td></td>
<td>Phase 1 – Short-Term (Days)</td>
</tr>
<tr>
<td></td>
<td>Days 0</td>
</tr>
<tr>
<td>Critical Facilities</td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>90%</td>
</tr>
<tr>
<td>Transportation</td>
<td>90%</td>
</tr>
<tr>
<td>Energy</td>
<td>90%</td>
</tr>
<tr>
<td>Water</td>
<td>90%</td>
</tr>
<tr>
<td>Waste Water</td>
<td>90%</td>
</tr>
<tr>
<td>Communication</td>
<td>90%</td>
</tr>
<tr>
<td>Emergency Housing</td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>90%</td>
</tr>
<tr>
<td>Transportation</td>
<td>90%</td>
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<td>Water</td>
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<td>Waste Water</td>
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<td>Communication</td>
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<td>Housing/Neighborhoods</td>
<td></td>
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<td>Water</td>
<td>90%</td>
</tr>
<tr>
<td>Waste Water</td>
<td>90%</td>
</tr>
<tr>
<td>Communication</td>
<td>90%</td>
</tr>
<tr>
<td>Community Recovery</td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>90%</td>
</tr>
<tr>
<td>Transportation</td>
<td>90%</td>
</tr>
<tr>
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<tr>
<td>Waste Water</td>
<td>90%</td>
</tr>
<tr>
<td>Communication</td>
<td>90%</td>
</tr>
</tbody>
</table>

*Source: NIST CRPG 2015*
Space Dimension
Space Dimension

(Source: City of Portland, 2012)
Space Dimension

Source: Oregon Resilience Plan
State Response/Recover Strategy

1\textsuperscript{st} tier
2\textsuperscript{nd} tier
3\textsuperscript{rd} tier

Source: Oregon Department of Transportation
Space Dimension

Source: Carmen Merlo
Space Dimension

Unreinforced Masonry Buildings
City of Portland

City of Portland URMs
- Fully Upgraded URM
- Partially Upgraded URM
- Unknown Status URM
- Unreinforced Masonry

Liquefaction Susceptibility
- Moderate
- High

Data Source: 2015 BDS URM data

December 9, 2015
City of Portland | Bureau of Development Services | Geographic Information System

The information on the map was derived from digital data-bases on the City of Portland, Bureau of Development Services GIS. Care was taken in the creation of this map but it is provided "as is". The City of Portland cannot accept any responsibility for error, omissions, or positional accuracy, and therefore,
Source Dimension

(Courtesy of Yumei Wang, DOGAMI)

Additional Examples

• Wholesale Water Supplier
• Wholesale Power supplier
• Centralized Warehouse of A Healthcare System

Dependency Coordination

- SF Lifeline Council
Dependency Coordination

- LA DWP – Integration of Power and Water

(source: Shinozuka et al. 2004)
Resilience In Action

1. Resilience Planning at local levels
   - Port of Portland
   - Portland Water Bureau
   - Tualatin Valley Water District
   - Eugene Water & Electric Board
   - City of Gresham (Water System)
   - Beaverton School District
   - Portland Bureau of Environmental Services (RFP)

2. OHA/DOGAMI Study: Multi-City Healthcare, Transportation, Water System Assessment
Remarks

- Start from Social Needs (to define performance goal)
- Consider Dependencies (no more silo approach!)
- Dependency relationship is complex and multi-dimensional
- Consider various dimensions of dependencies within each service provider
- Community-wide Coordination
- Strategies to Reduce Dependencies
Beaverton School District: Resilient Schools

South Cooper Mountain High School
- 3-story plus partial Basement
- 330,000 SF
- 2,200 Students
- $98 M

New Middle School at Timberland
- 2-story
- 165,000 SF
- 1,100 Students
- $43 M
Beaverton School District

- 3rd Largest School District in OR
  - ~40,000 students
  - 51 schools
  - Increase 2,600 students since 2006
  - Additional 5,400 students by 2025
- $680 Million Bond Program - Think Big!
  - Passed in May 2014
  - Largest bond program in the State
- Seven New Schools
Resilience Goals

• Schools function as emergency shelter within 72 hours
• Education resumes within 30 days
• Realistic and flexible
  • Not possible to be completely self-sufficient emergency shelter
  • Adaptable with ability to add more systems as resources become available
• Shelter pre-designation likely leads to prioritized, resilient upgrade of infrastructure systems supporting the schools
• Groundbreaking project with a focus on two schools
  • South Cooper Mountain High School
  • New Middle School at Timberland Development
• Report out $ associated with resilience improvements
Issues and Challenges

• Community Development
  • Silo mentality, without coordination
  • Lack of consideration of dependencies

• Current approach to address emergency shelter needs
  • Pre-designated shelters with seismic performance undetermined
  • Ad hoc
    • Lack of reliable lifeline support to make shelters functional

• Lack of public funding for resilience building
  • Public funding available to address legacy projects (FEMA, SRGP)
  • No incentive funding for new construction

• Project Schedule/Budget Constraint
Resilience Investment - Uncertainty

Steady Resilience Investment  
Delayed Resilience Investment
Strategies for Shelter Needs

• Short-Term
  • School building is safe to use as a shelter
  • EM agencies to provide utility services

• Long-Term
  • School building is safe to use as a shelter
  • Utility services quickly restored to the shelter

• Strike a balance between current and future shelter needs and limited economic resource for resilience improvements
Stakeholder Workshop

• **Local Emergency Response**
  - American Red Cross
  - Washington County Emergency Management
  - TVFR, City of Beaverton

• **Lifeline Service Providers**
  - Electricity (PGE) and Gas (NW Natural)
  - Water (City of Beaverton, TVWD) & Wastewater (Clean Water Services)

• **Beaverton School District**
  - District Administration and Project Managers
  - Design team for High School
  - Design team for Middle School

• **State Agencies**
  - Oregon Emergency Management
  - Portland Metro Regional Solutions

Workshop at TVFR Command & Business Operations Center on February 10th, 2015
Stakeholder Workshop

- Vision for new BSD schools and 2014 bond program
- Emergency Shelter: Current Practice (Capacity, duration, and Level of human services)
  - American Red Cross
  - Washington County Emergency Management
- New, Integrated approach: building Resilience into School Design
  - Identify shelter needs: capacity, duration, and level of human services
  - Categorize support for human services into three categories: Brought in, design flexibility, and hard construction
  - Built-in facility features
  - Utility services required
  - Resources, challenges, and champion
Shelter Needs

• A safe and usable building

• Minimum Requirements
  • Thermal Comfort: a wide temperature range is acceptable
  • Natural Ventilation: Bring in fresh air
  • Lighting: battery lanterns and flash light

• Desirable shelter features
  • Emergency Power: lighting, powering medical devices and personal devices
  • Water Supply: drinking and personal hygiene
  • Wastewater: holding tank or operating wastewater system
Two circulation systems provide on-site distribution of supplies and services.
1st Floor Plan

- **NORTH MAIN GYM**
- **AUXILIARY GYM**
- **AEROBICS / DANCE ROOM**
- **COMMONS – SLEEPING**
- **COMMONS – DINING (SEATING CAPACITY APPROX. 336)**
- **KITCHEN**
- **SPACE FOR GENERATOR**
- **CONNECTION FOR PORTABLE WATER TANK**
- **COVERED AREA FOR PETS (WITH HOSE CONNECTION)**

**Connection for Portable Water Tank**

**Covered Area for Pets (With Hose Connection)**
High School Resilience Feature - Seismic

- Risk Category IV – Structural/Seismic Design
- Non-structural Component
  - Equipment (required to operate after EQ) Seismically Certified
  - Components required for use as shelter: Category IV seismic bracing
  - Others: Category III seismic bracing

<table>
<thead>
<tr>
<th>Area</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Gym</td>
<td>160</td>
</tr>
<tr>
<td>Auxiliary Gym</td>
<td>80</td>
</tr>
<tr>
<td>Aerobics/Dance Room</td>
<td>30</td>
</tr>
<tr>
<td>Commons</td>
<td>90</td>
</tr>
<tr>
<td>Classrooms (50 rooms @10 people/room)</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>860</strong></td>
</tr>
</tbody>
</table>
High School Resilience Feature – HVAC & Power

• Heating
  • Likely acceptable, supplemented with jackets or blankets as needed.

• Ventilation and Cooling
  • Hot weather: indoor temperature = outside temperature
  • Natural ventilation thru doors and windows, and exhaust fans

• Emergency Power
  • 500 KW emergency generator, with 96-hour run time fuel storage
  • Power lighting and ventilation fans in common areas and gym (plus two outlets in kitchen for water boiling)
  • Equipment Seismically Certified: Generator, ATS, ventilation fans
  • Components required for use as shelter: Category IV seismic bracing
High School Resilience Feature – Water

- Be included in the BWD’s backbone system to receive water within 24 hours (after the system is upgrade to its resilience goals)
- Resilient design of piping between water main and the school
- Provide Stub-outs to allow use of portable water tank to supply water to kitchen, locker rooms & showers, drinking fountains in common spaces, and restroom serving Dining Commons
- Seismic bracing of water pipes per Category IV requirements
- ARC or others provide portable shower units
- ARC or others provide appropriate fire watch
High School Resilience Feature – Wastewater

• Long term: Be included in the CWS’s wastewater backbone system to restore services within 1-2 weeks (after the system is upgrade to its resilience goals)

• Short Term: ARC or others provide portable toilets

• Resilient design of piping between sewer main and the school

• Seismic bracing of plumbing system components per Category IV requirements
High School Resilience Feature – Gas & Telecom

• Natural Gas
  • Emergency shelter not dependent on natural gas
  • Install seismic shutoff valve to reduce potential fire hazard

• Telecommunication
  • EM agencies to bring in portable communication systems (COLTs or COWs)
  • BSD has its own radio system, which may be operational
# High School Resilience Feature - Cost

<table>
<thead>
<tr>
<th>Resilience Feature</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Design building structure’s lateral-force resisting system for seismic Risk Category IV</td>
<td>$500,000</td>
</tr>
<tr>
<td>2) Provide 500 kW emergency generator with 96-hour runtime fuel storage. Emergency generator, switch gear, ventilation fans, and other equipment that is expected to be operational after an earthquake should satisfy the special certification requirements of ASCE 7-10, which is referenced by the OSSC</td>
<td>$330,000</td>
</tr>
<tr>
<td>3) Provide electrical service to power lighting and ventilation fans in common areas and gymnasium on emergency power; does not provide heated or conditioned air</td>
<td>$8,000</td>
</tr>
<tr>
<td>4) Provide stub-outs at building exterior to allow use of portable water tank and associated pump to supply water to key building areas: kitchen, locker rooms &amp; showers, drinking fountains in common spaces and restrooms serving the Dining Commons</td>
<td>$15,000</td>
</tr>
<tr>
<td>5) Provide two electrical outlets in kitchen on emergency power to allow hot plates for water boiling, etc.</td>
<td>$5,000</td>
</tr>
<tr>
<td>6) Provide natural gas seismic shutoff valve at meter</td>
<td>Negligible</td>
</tr>
<tr>
<td>7) Provide hardened water service line from BWD water line to building</td>
<td>TBD</td>
</tr>
<tr>
<td>8) Provide hardened sanitary sewer service line from CWS sewer line to building</td>
<td>TBD</td>
</tr>
<tr>
<td>9) Provide seismic bracing/anchorage design of nonstructural components based on Risk Category III requirements except that those components required for use of the school as emergency shelter (as specified in Sections 5.5 and 5.6) satisfy Risk Category IV requirements</td>
<td>Negligible</td>
</tr>
<tr>
<td>Approximate Total</td>
<td>$900,000</td>
</tr>
</tbody>
</table>
Oregon ASCE Members Make Resiliency a Priority in School District

By Ben Walpole

September 17, 2015

The Civil Engineering Blog & News Network

ASCE Roundup

ASCEnews

It's not easy to face up to the frightening prospect of a major earthquake and tsunami striking your community.

Two years ago, the state of Oregon adopted a resilience plan with a 50-year strategy to address the threat posed by the Cascadia Subduction Zone. The plan takes a “not-if-but-when” approach to disaster, and it can make for scary reading.

But the Beaverton School District – led by several ASCE members – is not intimidated, seeing the state plan as a means to build a more resilient community. Seven new schools will be built over the next several years will all apply the resilience plan’s recommendations.

“It was evident to the school district that we had this special opportunity at a key moment in time with the construction of these seven schools,” said Dick Steinbrugge, P.E., M.ASCE, executive administrator for facilities at Beaverton. “It was sort of a call to action with regard to the Oregon Resilience Plan.”