OUTLINE

• Earthquakes
• Distribution
• Emergency Water
• Restoration
• Future Seismic Mitigation
• Conclusions
Earthquakes

Northridge January 17, 1994, 4:31 am
$M_w \ 6.7 \ (USGS)$
Blind Fault

Kobe January 17, 1995, 5:46 am
$M \ 7.2 \ (JMA) \ M_w \ 6.7 \ (USGS)$
Nojima Fault
Water Supply

Los Angeles - Population 4 million
- Los Angeles Aqueducts-50%
- Metropolitan Water District - 26 Agencies-34%
- Local groundwater-15%
- Water Recycling -1%

Kobe - Population 1.5 million
- Hanshin Water Authority - 9 cities+4 towns-75%
- Local- 25%
Distribution System Performance

San Fernando Valley

- Compression or tension bell and spigot joints
- Rigid joints
- Corrosion older steel mains
- Old riveted tanks
- Pumping and chlorinating stations good performance
WATER SYSTEM DAMAGE
NORTH RIDGE EARTHQUAKE
JANUARY 17
1994
<table>
<thead>
<tr>
<th>Facility</th>
<th>Damage (damage/total)</th>
<th>Cost (Million $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam</td>
<td>0 /14 dams</td>
<td>0.32</td>
</tr>
<tr>
<td>Treatment plant</td>
<td>1 /1 plant</td>
<td>2.1</td>
</tr>
<tr>
<td>Raw water conduit (aqueduct)</td>
<td>14 repairs / *</td>
<td>4.5</td>
</tr>
<tr>
<td>Transmission main (Trunk Line)</td>
<td>60 repairs /700 km</td>
<td>**</td>
</tr>
<tr>
<td>Distribution Reservoir</td>
<td>7 /86</td>
<td>12.0</td>
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<tr>
<td>Distribution pipe</td>
<td>1,013 repairs /11,740 km</td>
<td>5.2</td>
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<tr>
<td>Service connection (w/o cust. pipe)</td>
<td>208+ repairs /700,000 lines</td>
<td>**</td>
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<tr>
<td>Other (including bldg)</td>
<td>District Yards, etc.</td>
<td>17.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>41.0</td>
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</tbody>
</table>

* 65km of 660 km of aqueducts in the seismic region
* * Distribution pipe costs includes all pipe
Distribution System Performance

Kobe

-- Cracked pipe body
-- Joint failure
-- Fitting damage
-- Property pipes due to building collapse
-- S and S-II joints good performance
-- Flexible joints good performance
-- Tanks and pumping stations good performance
## Kobe Damage

<table>
<thead>
<tr>
<th>Facility</th>
<th>Damage (damage/total)</th>
<th>Cost (billion ¥)</th>
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</thead>
<tbody>
<tr>
<td>Dam</td>
<td>1 /3 dams</td>
<td></td>
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<tr>
<td>Treatment plant</td>
<td>2 /7 plants</td>
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<td>Raw water conduit (aqueduct)</td>
<td>2 lines /43 km</td>
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<tr>
<td>Transmission main (Trunk Line)</td>
<td>6 lines /260 km</td>
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<td>Distribution Res. and tanks</td>
<td>1 /119 tanks</td>
<td>1.9</td>
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<tr>
<td>Distribution pipe</td>
<td>1,757 failures /4,002km</td>
<td>13.5</td>
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<tr>
<td>Service connection/customer pipe</td>
<td>89,584 repairs /650,000 lines</td>
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<td>Other (including building)</td>
<td>Head office, Tobu Branch, etc.</td>
<td>4.1</td>
</tr>
<tr>
<td>Total</td>
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<td>29.0</td>
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</table>
Emergency Water Supply

San Fernando Valley

-- Public and private tanker trucks
-- Bottled water companies
-- Fire Engine interdepartmental pumping
-- Boil water notice issued for drinking and cooking
Emergency Water Supply

Kobe
- Dual tanks
- Underground cisterns
- Tank trucks
- Fire hydrant spigots
- Portable tanks
- No boil water notice-concern gas+fire
Water System Restoration

San Fernando Valley

- Seven operating districts
- Mutual aid
- Specialized private contractors
- Block by block after cleared for pressure and water quality
Los Angeles Water System Restoration
Recovery Rate

Days

Service Recovery (%)
Water System Restoration

Kobe

- Five operating districts
- Mutual aid
- Repairs hampered by blocked streets from collapsed buildings
- Access to city limited by damaged highways and railroads
- System water pressure not sufficient to locate leaks
Kobe Water System Restoration

Recovery Rate

Weeks
Future Seismic Mitigation

San Fernando Valley

– Prestressed concrete tanks
  -- Trenchless technology
– Riveted steel pipe replacement
– Combination with water quality improvements
– SLAA Terminal Hill improvements
– Dams analysis
Future Seismic Mitigation

Kobe

-- Expand use S and S II Joints
-- Expand use flexible joint installation
-- Enhance telemeter control for emergency shut off valves for tanks and service zones
-- Large Capacity Transmission Main
-- Water supply stations for citizens, water trucks, fire engines
-- Hanshin combined Amagasaki and Kabutoyama WTP by constructing a new Amagasaki WTP
Conclusions

- Same magnitude EQ
- Previous seismic improvements good for tanks, some pipe, pumping and chlorinating stations
- Difference in pipe breaks and restoration time
- Permanent ground deformation
- Liquefaction
- Building Collapse
- Difference infrastructure configuration, geotechnical siting, construction, social needs, political and financial philosophies
Acknowledgments

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Fight On