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# 2011 Japan Earthquake/Tsunami – Lessons Learned

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国土交通省

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# 1. Overview of Damage and Restoration

- Overview of Damage caused by the Tohoku Earthquake and Tsunami

- Recovery of Damaged Facilities

# Overview of Damage by the Tohoku Earthquake

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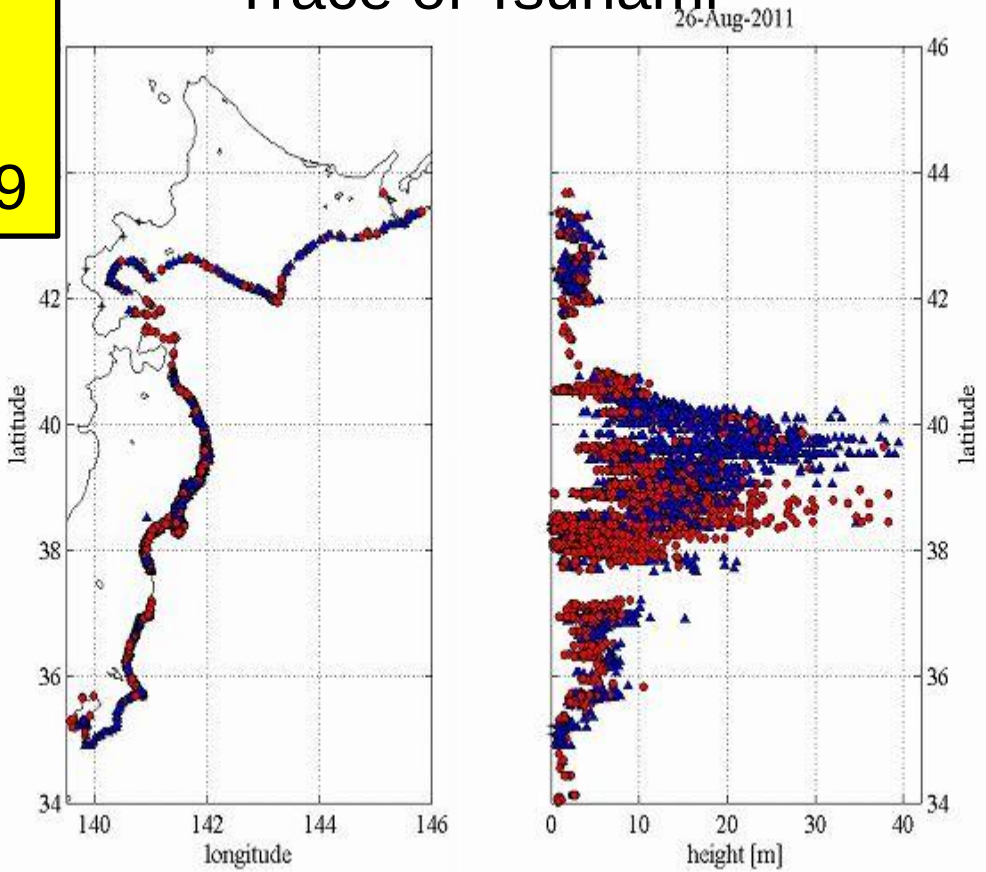
The earthquake of magnitude 9.0 occurred on March 11, 2011 and destroyed many lives and properties in the north-east region of Japan.

- Dead and missing toll 18,564
  （as of 10 April 2013）
- Fully or partially destroyed houses 398,679

Town heavily damaged by tsunami (Ofunato, Iwate)

## Trace of Tsunami




Source: East Japan earthquake Tsunami Joint Survey Group (as of Sept. 2, 2011)

● inundation height

▲ run-up height

# Tsunami attack, March 11, 2011

Entrance of the bay of Kuji Port

The tsunami at Kamaishi Port

# Damage to Ports and Harbours

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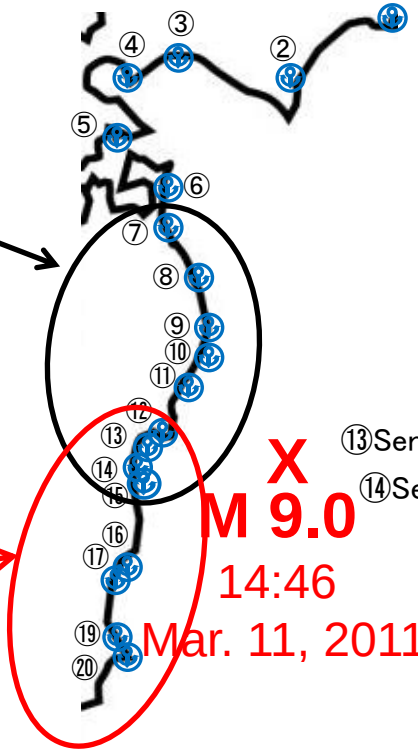
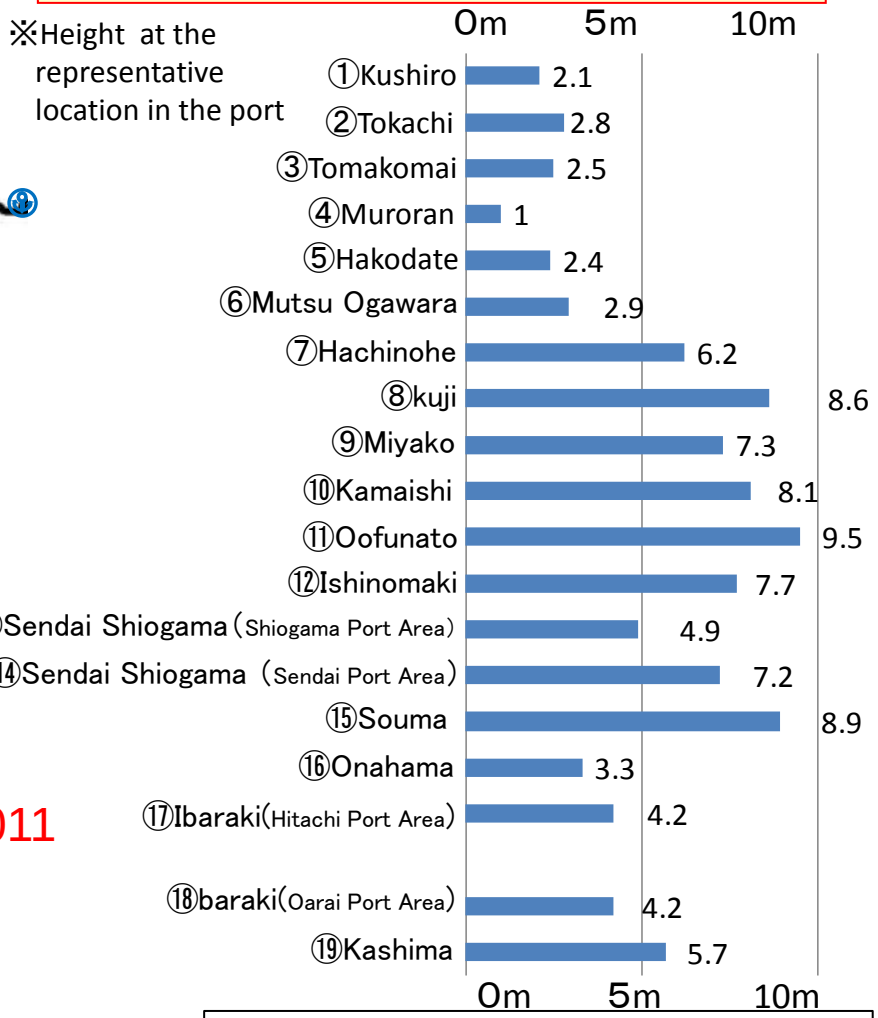
- 29 ports (including local ports) were damaged
- Overall damage to public port facilities : approx. 413.8 billion yen

Damages by Tsunami are significant

Damages by earthquake vibration are significant




## Distribution of Tsunami Height ※




Source: Japan Meteorological Agency, and Japan Coastal Engineering Committee

# Damage of Port Facilities (Hachinohe Port)

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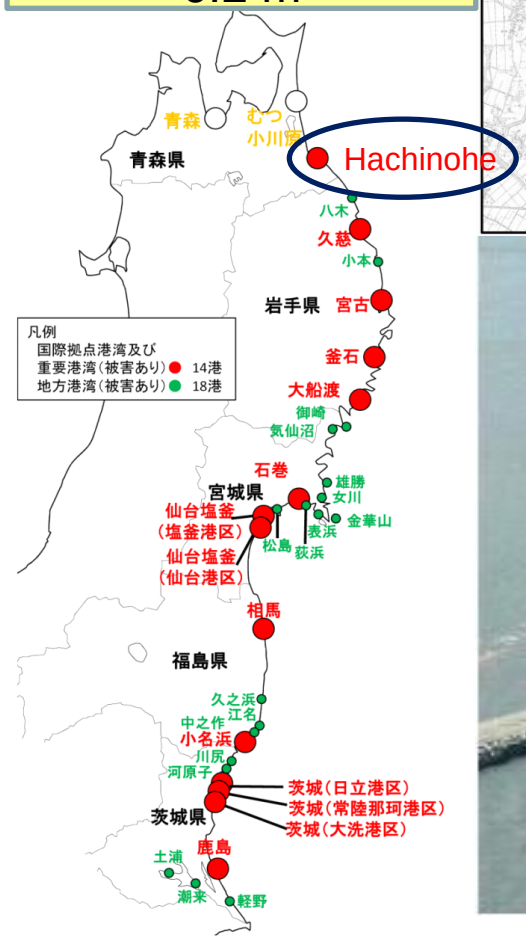
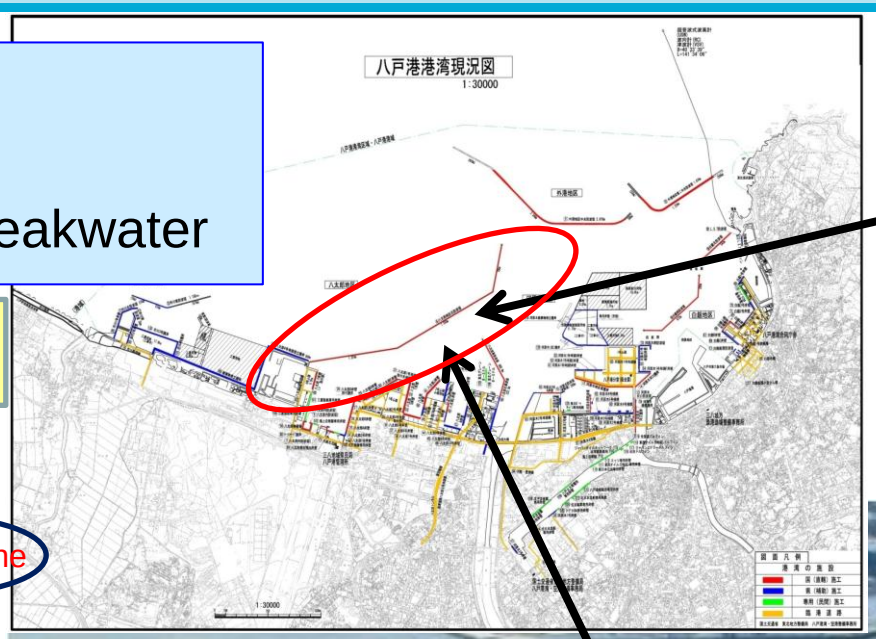
【Hachinohe port】
- Overturning and submergence of Breakwater

Tsunami Height : 6.2 m




North Breakwater

North Breakwater

# Damage of Port Facilities (Kuji Port)

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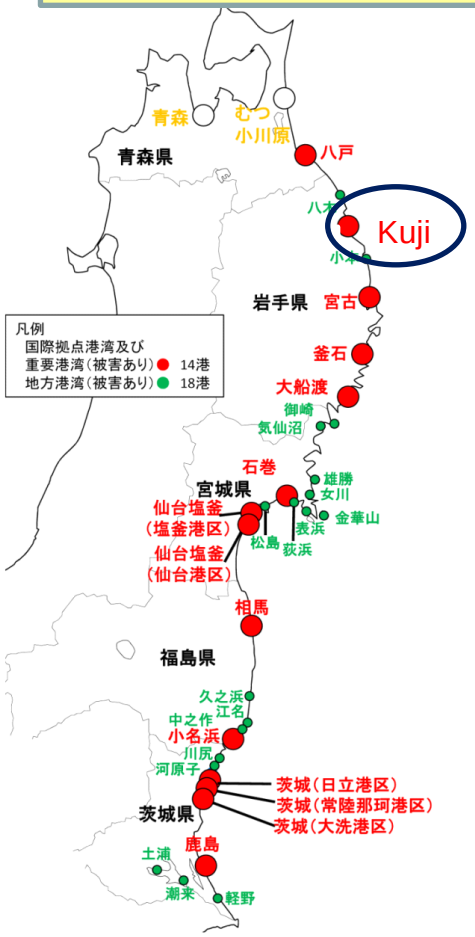
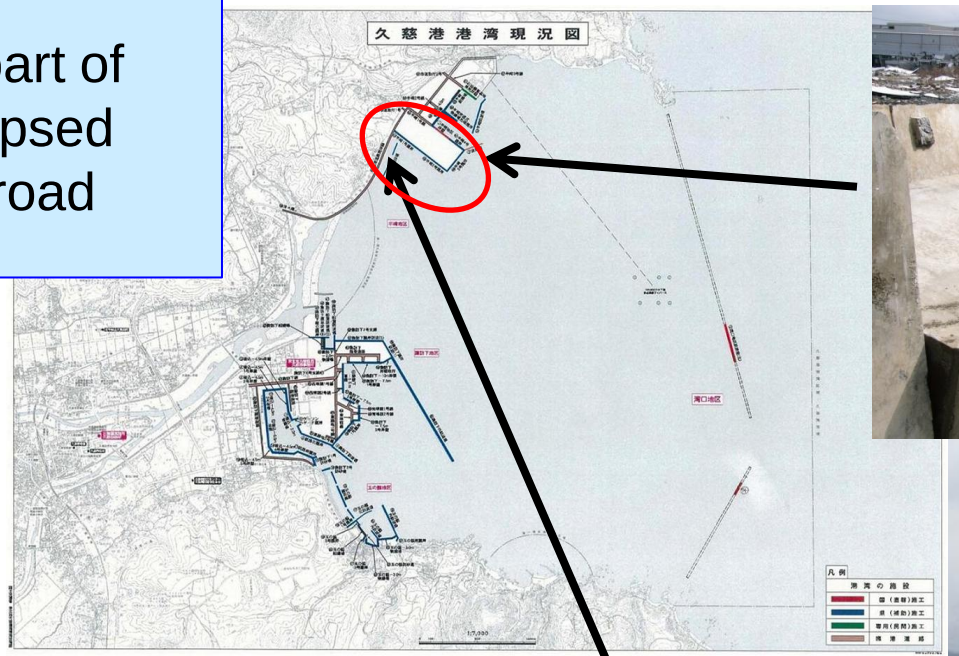
【Kuji Port】
- Concrete of upper part of breakwater was collapsed
- Seawalls of harbor road were damaged

Tsunami Height : 8.6 m




**Seawall of harbour road damaged**

# Damage of Port Facilities (Miyako Port)

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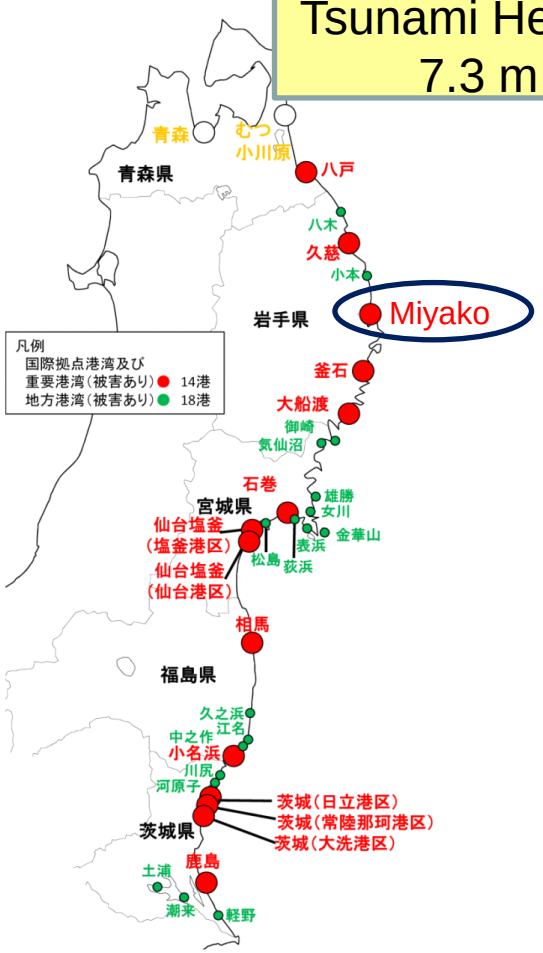
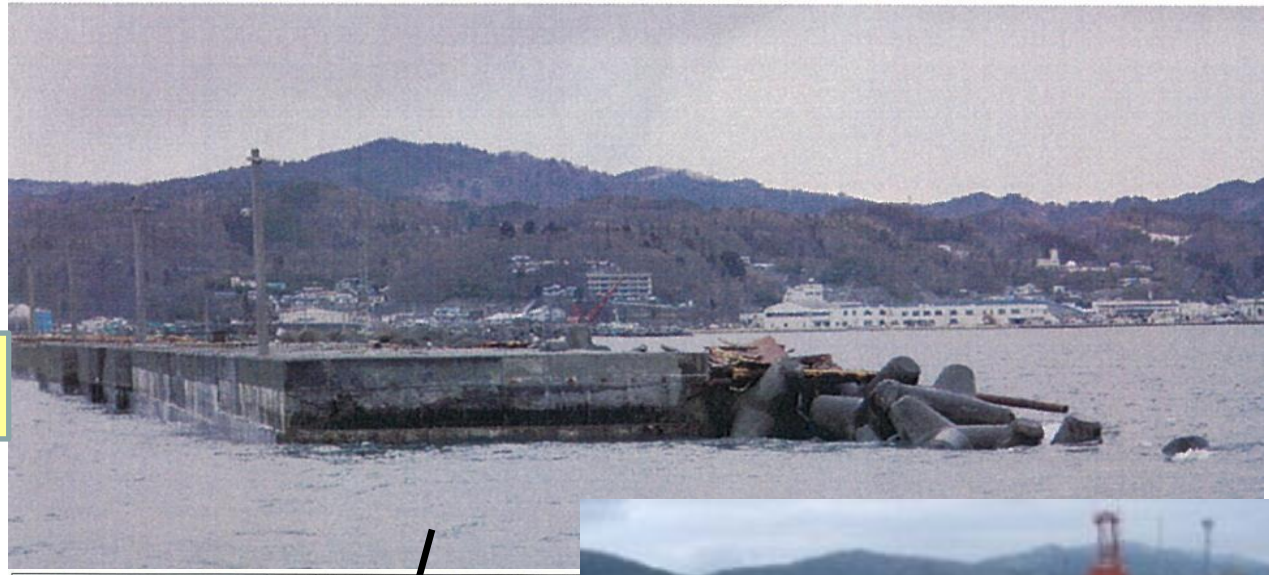
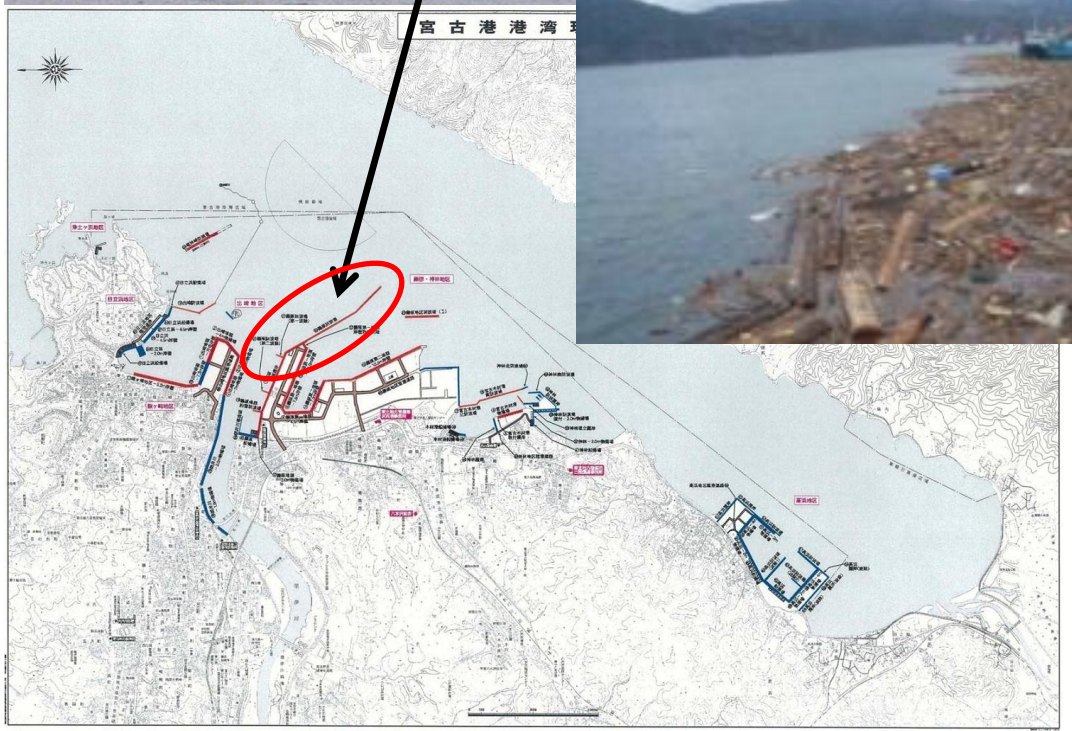
【Miyako Port】
- Floating wreckage inside port（drift-wood）
- Overturning and destruction of breakwater

Tsunami Height : 7.3 m



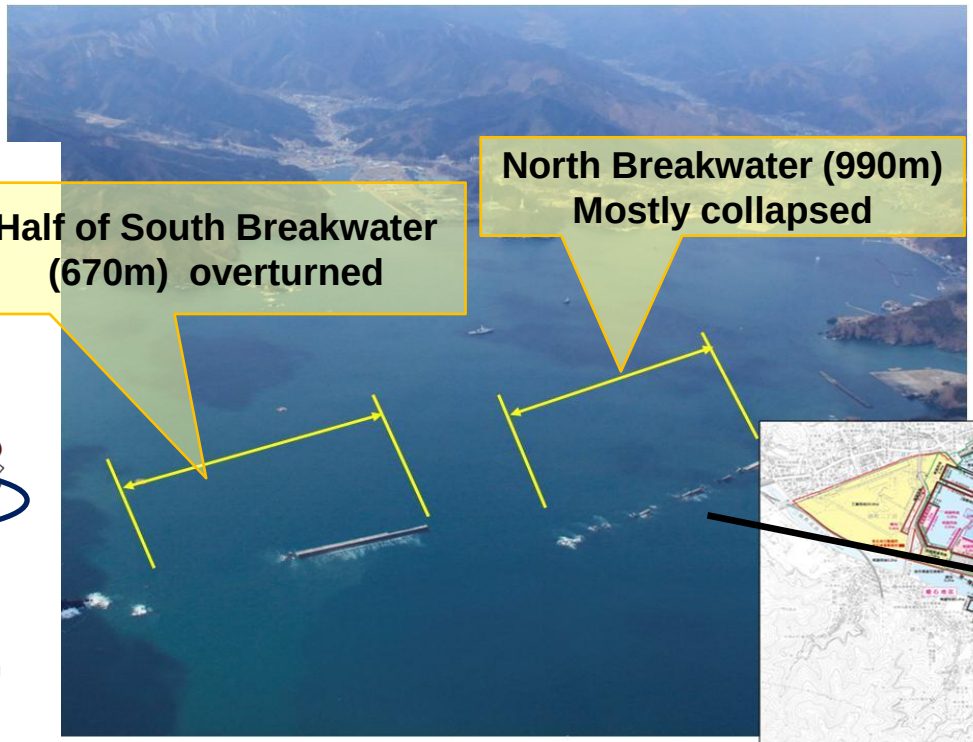





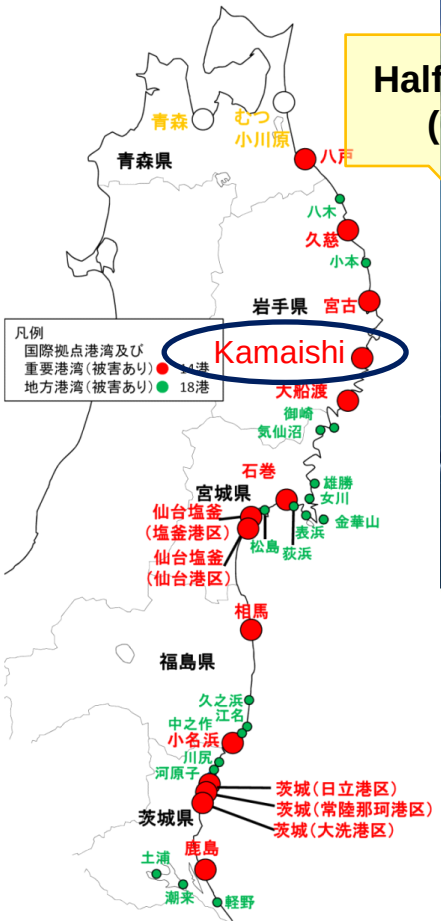
# Damage of Port Facilities (Kamaishi Port)

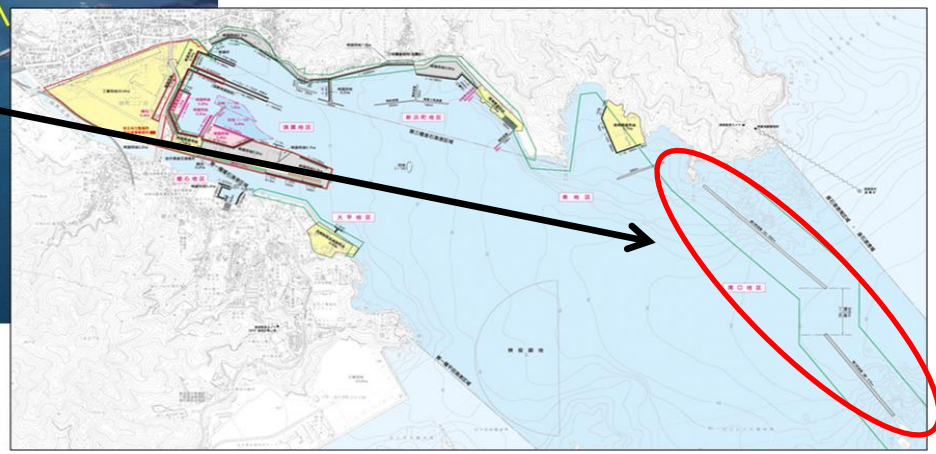
【Kamaishi Port】
- Overturning and Submergence of Tsunami Breakwater

Tsunami Height (inside of port):8.1 m







# Damage of Port Facilities (Ofunato Port)

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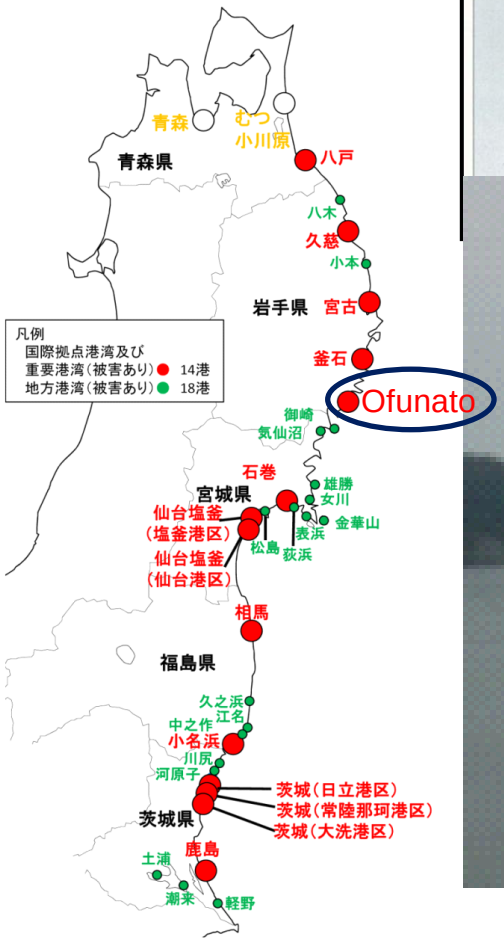
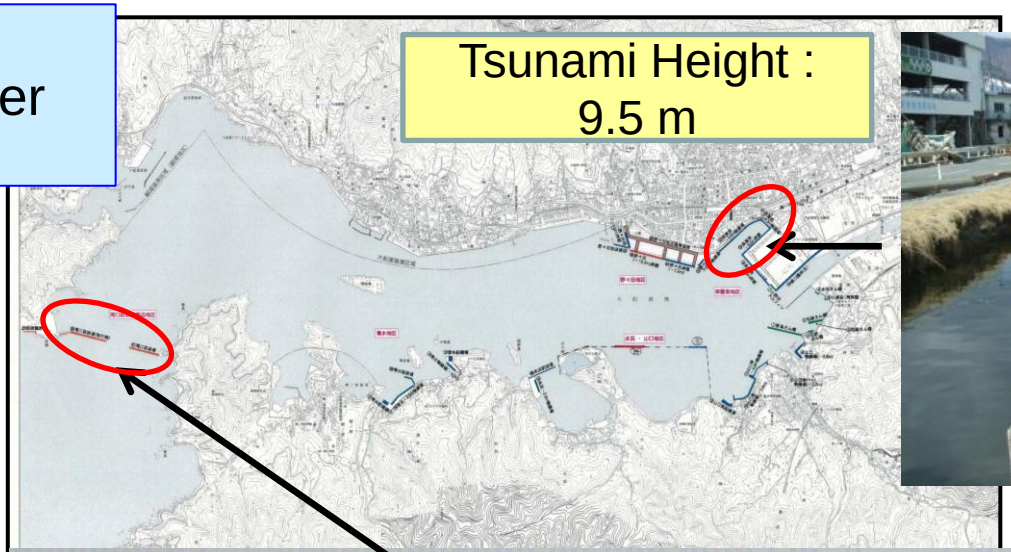
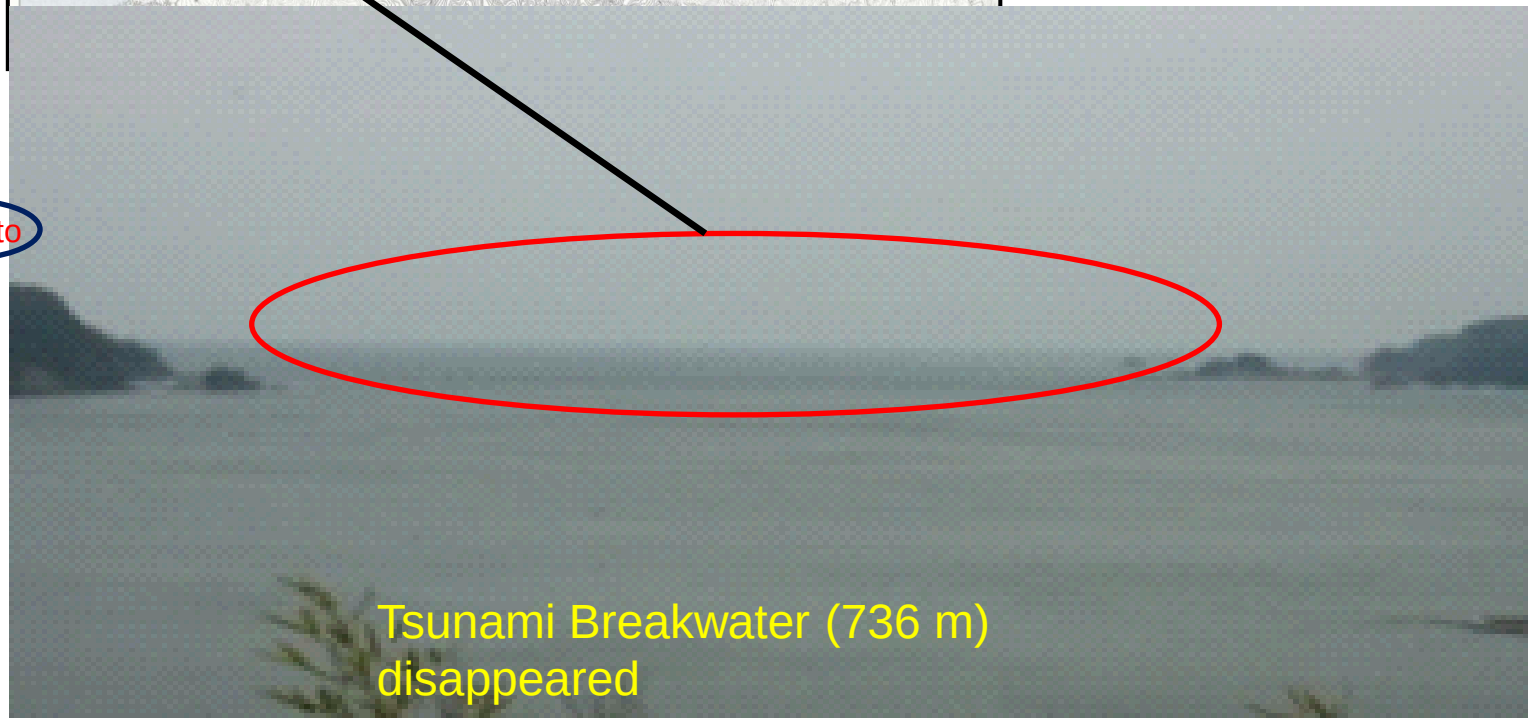
【Ofunato Port】
- Tsunami Breakwater Overturned




Breakwater damaged



# Damage of Port Facilities (Ishinomaki Port)

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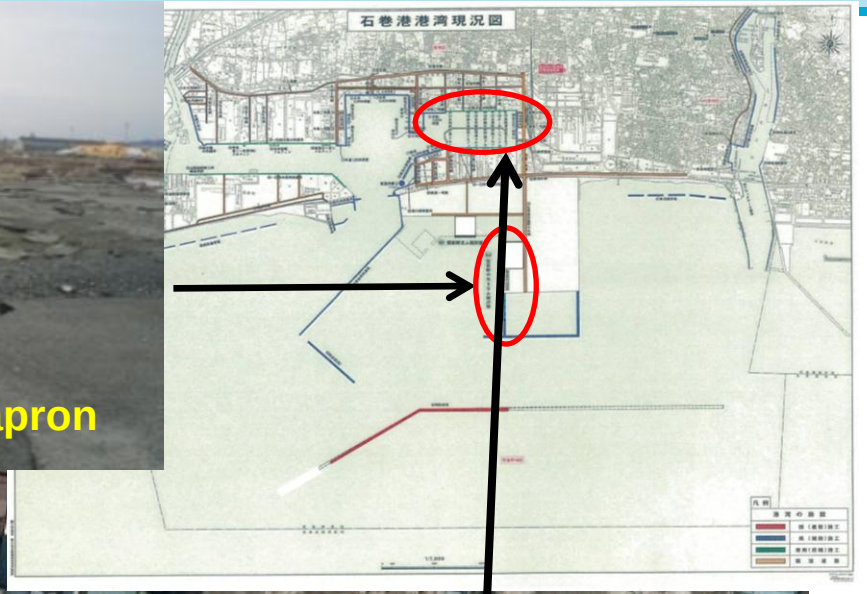
【Ishinomaki Port】
- Quay collapsed
- Subsidence of Quay surface

Tsunami Height : 7.7 m

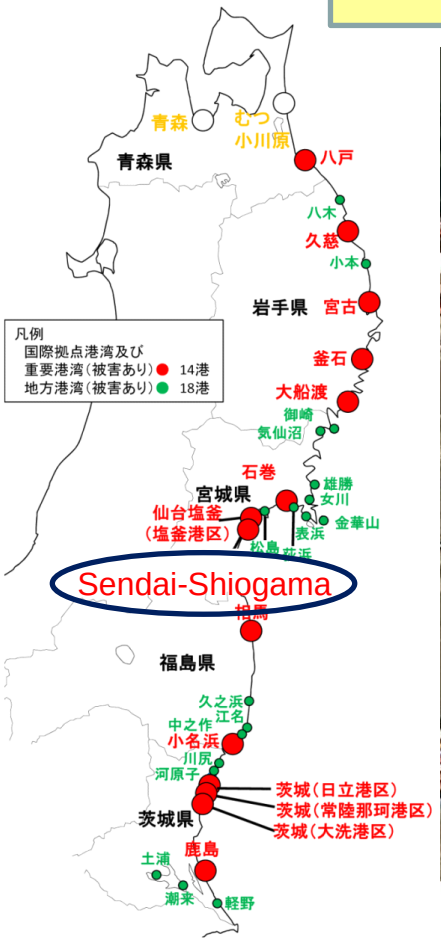


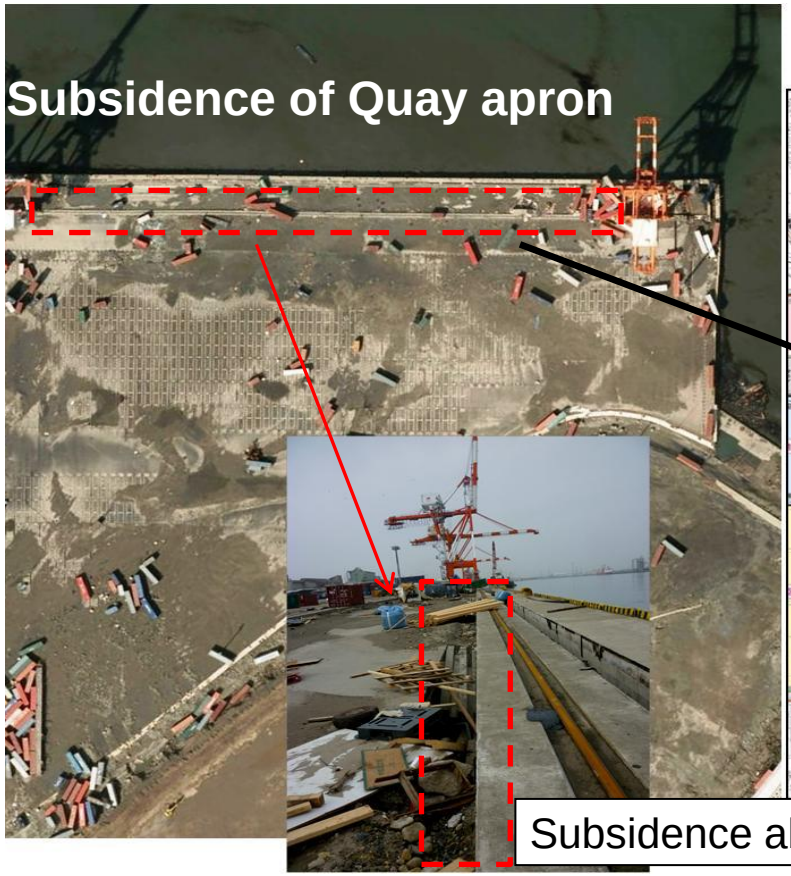


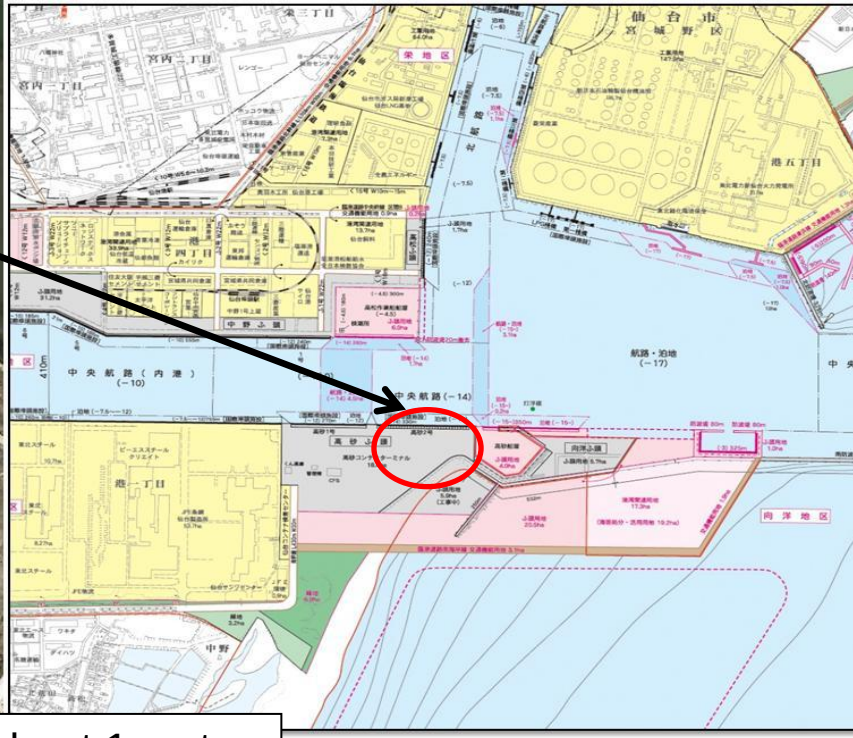

# Damage of Port Facilities (Sendai Port)

【 Sendai Port 】
- Containers scattered in container terminal
- Subsidence of quay surface

Tsunami Height : 7.2 m

Subsidence about 1 meter

# Damage of Port Facilities (Soma Port)

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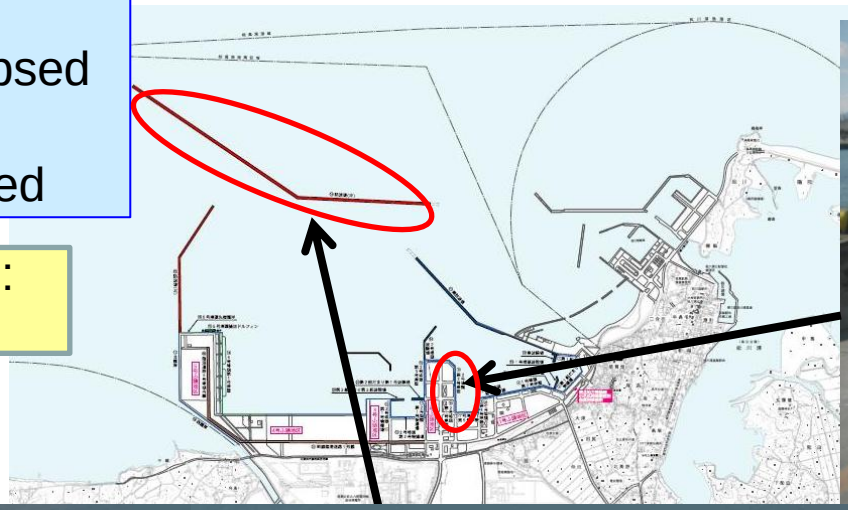
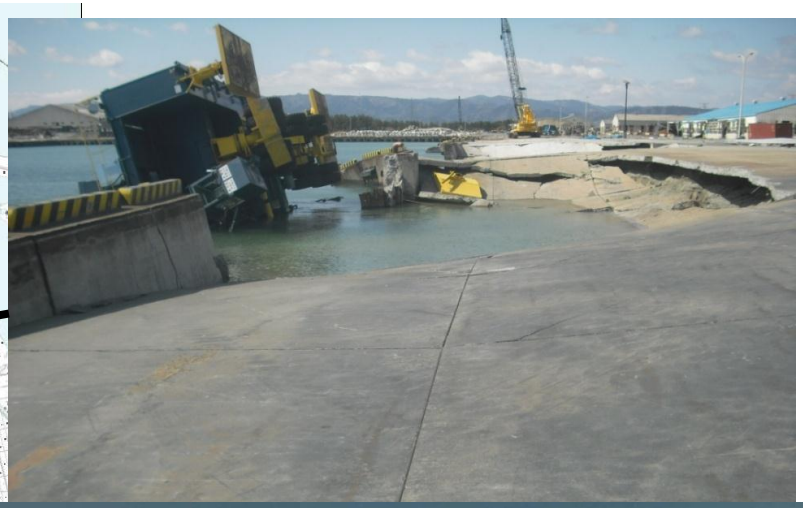
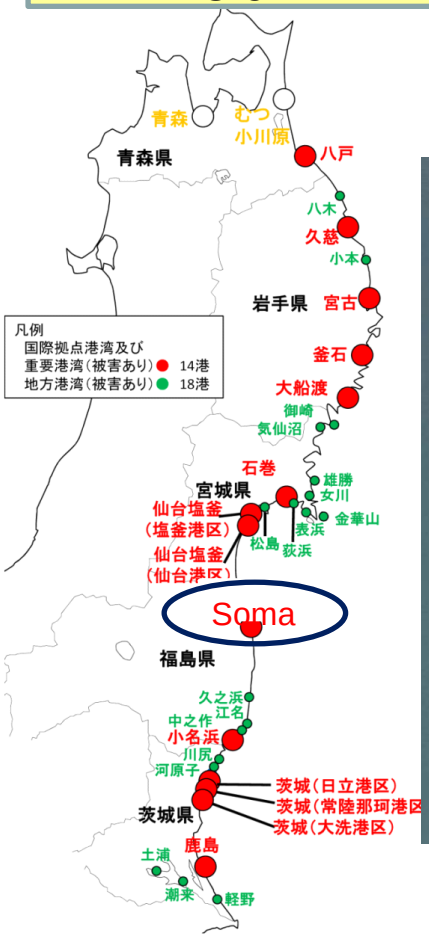
【 Soma Port】
- Breakwater collapsed and submerged
- Quay wall collapsed

Tsunami Height : 8.9 m








# Damage of Port Facilities (Onahama Port)

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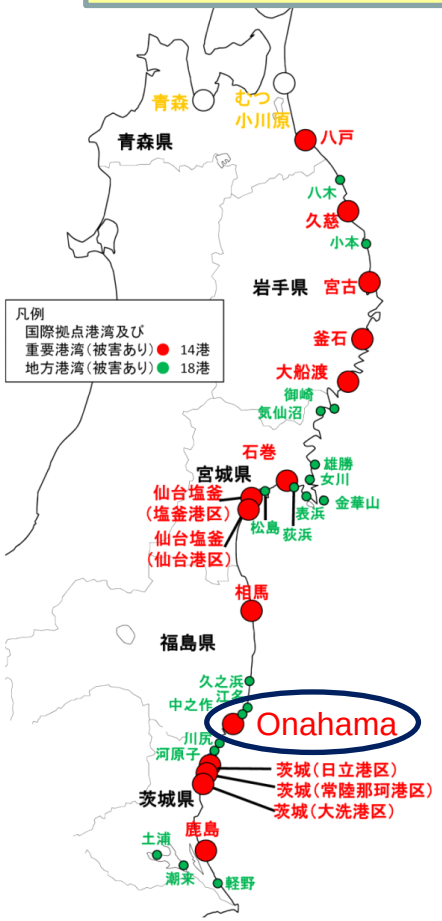
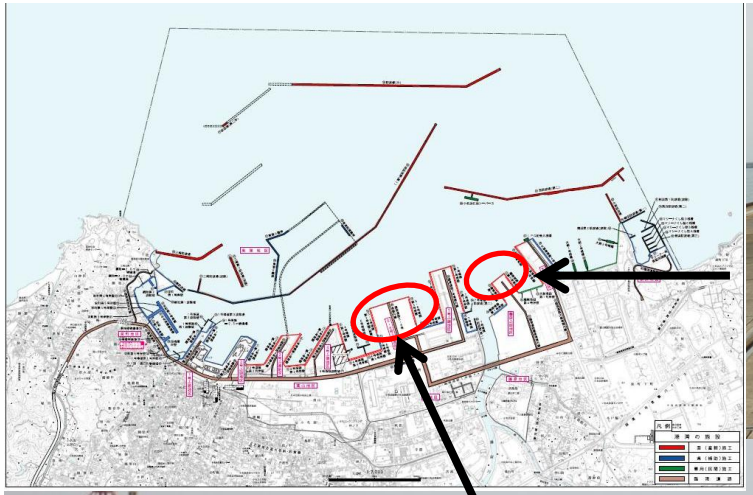
【Onahama Port】
- Subsidence and Collapse of Quay surface
- Container Crane damaged

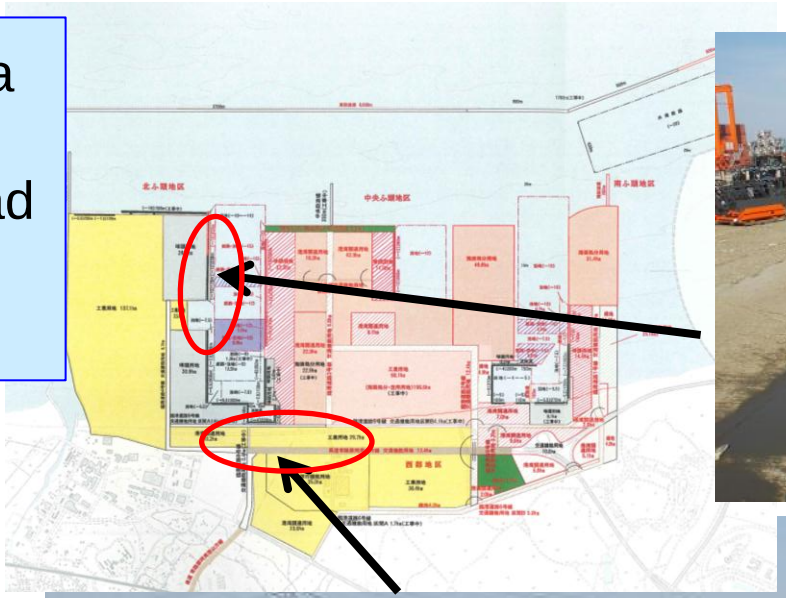
Tsunami Height : 3.3 m

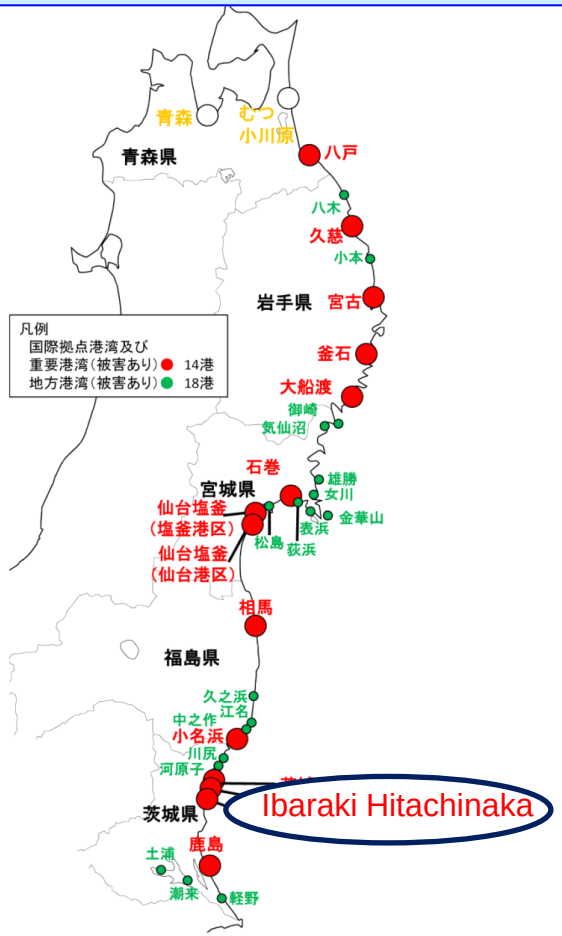



# Damage of Port Facilities (Ibaraki Port – Hitachinaka District)

【 Ibaraki Port - Hitachinaka District 】
- Subsidence of harbor road
- Rail of container crane damaged






# Damage of Port Facilities（Kashima Port）

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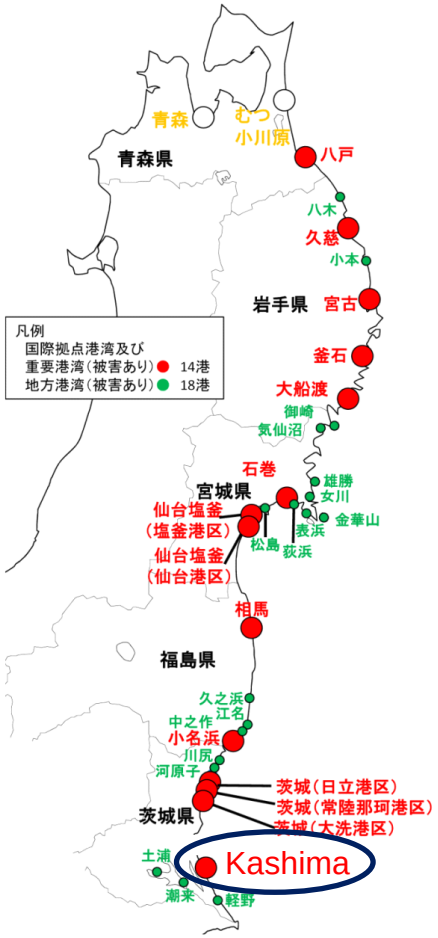
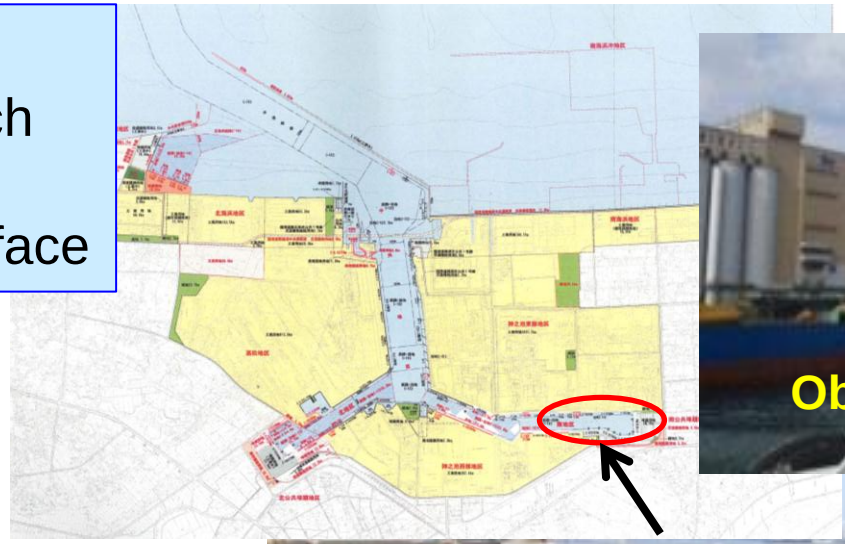
【Kahima Port】
- Obstacles in approach cannel（containers）
- Collapse of quay surface

Tsunami Height : 5.7 m




# Recovery of Damaged Facilities

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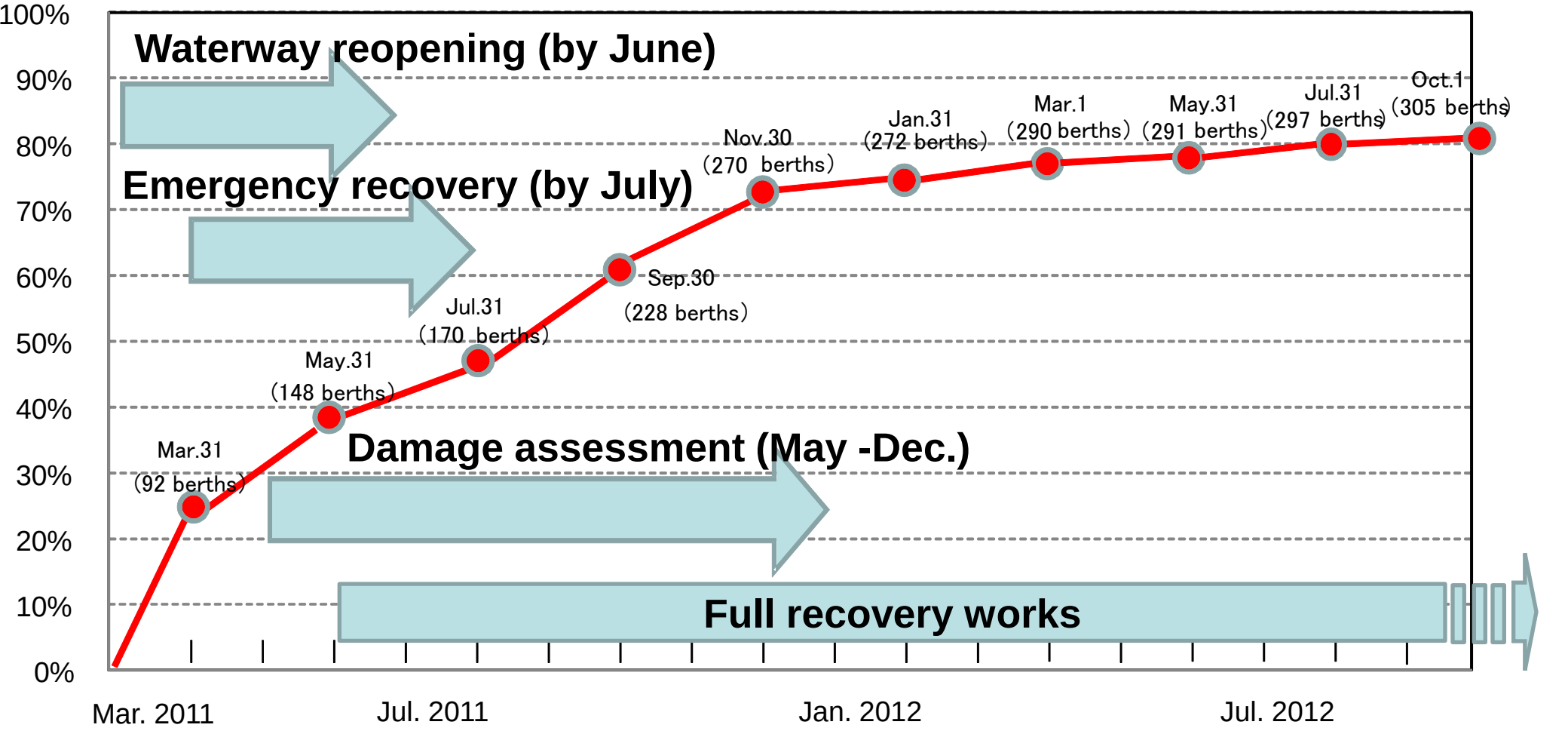
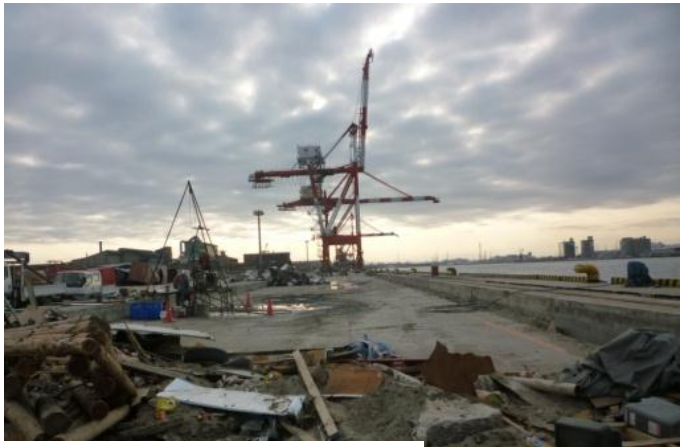
- Recovery target
  Important port facilities (major public berths) : within 2 years
  Tsunami Breakwaters (Kamaishi and Ofunato) : within 5 years
- Current situation (as of March 31, 2013)
  more than 80 % (312 / 373 berths) are available

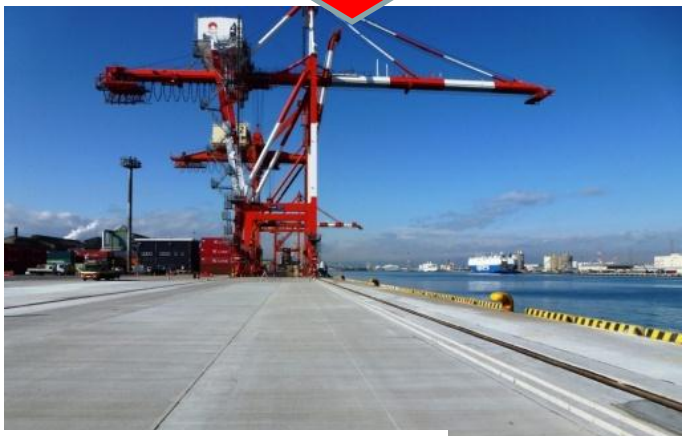


# Restoration of Port Facilities (Sendai Port)

- Domestic container line restarted after 3 months (June 2011)
- International container line restarted after 6 months (September 2011)
- North American line restarted on January 2012



【Apr. 18, 2011】



【Dec. 12, 2011】

【Mar. 4, 2012】



NYK ARGUS【Jan. 22, 2012】after 10 months

# Restoration of Port Facilities (Hachinohe Port)

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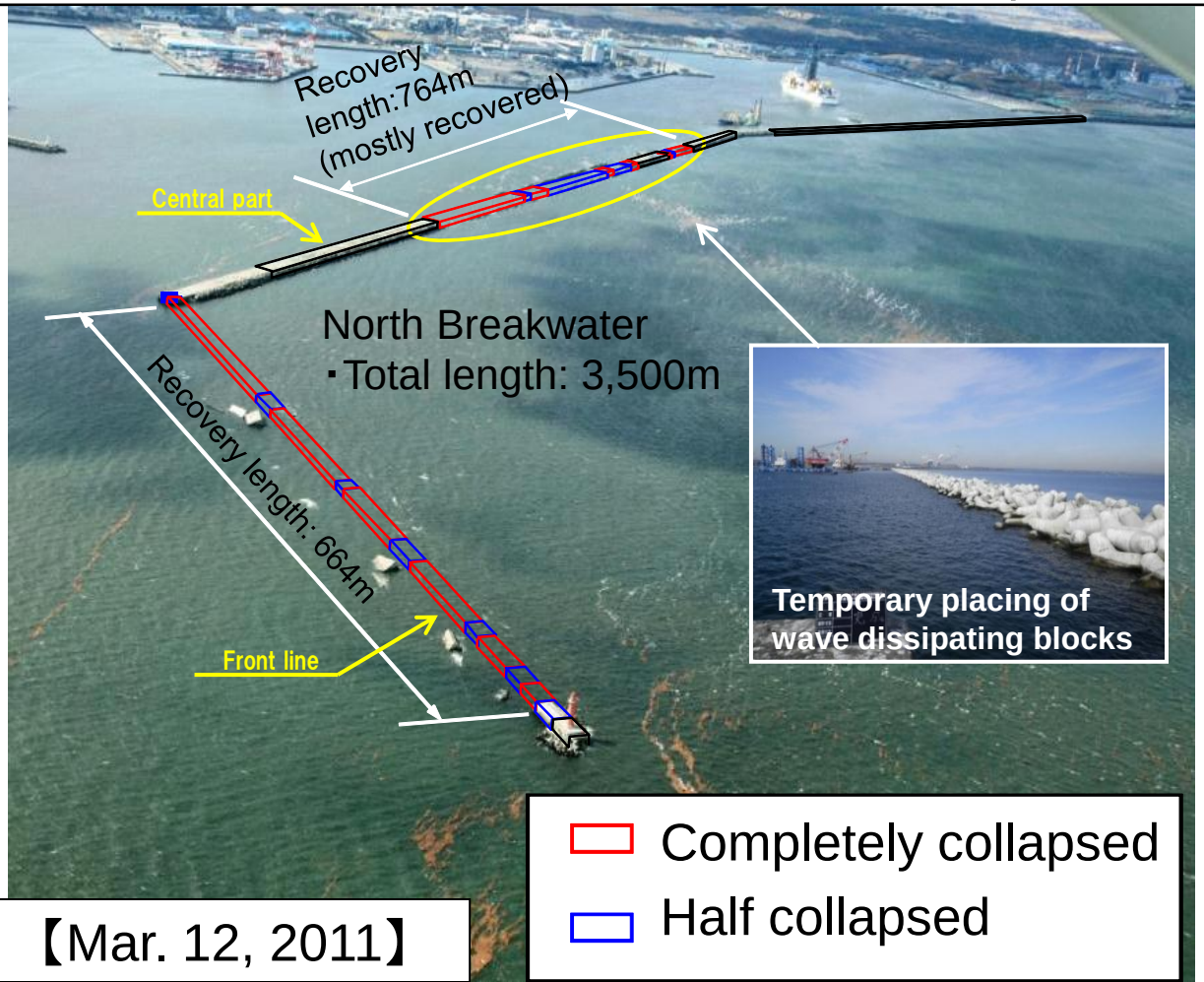
- Cargo handling problems had occurred by severe wind and wave in winter with damaged breakwater.
- By putting blocks into the damaged site as early restoration, the cargo handling problems has dramatically reduced.
- Restoration of breakwaters has almost completed.




【Mar. 12, 2011】

【Mar. 12, 2011】

【Jul. 24, 2012】

# 2. Imminent Threat of Large-Scale Earthquake and Tsunami

- Imminent Large-Scale Earthquakes and Tsunami
- Estimation of Tsunami and Damage

# Imminent Threat of Large-Scale Earthquakes

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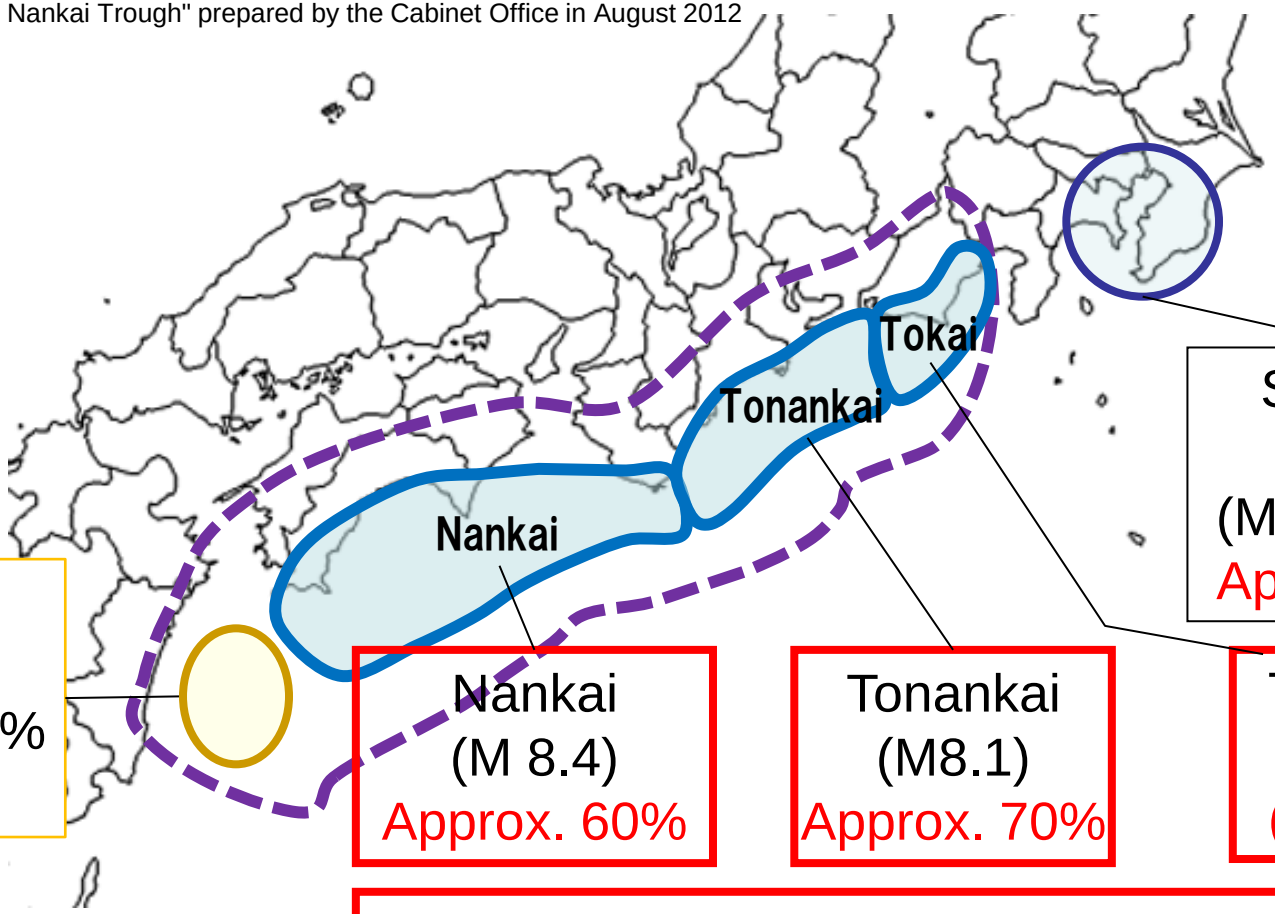
- Occurrence probability of Major Earthquakes along the submarine trenches in the upcoming 30 years

Hypocentral region presented in the Central Disaster Management Council 2003

Hypocentral region shown in "Expected Tsunami Height and Inundation Area (Secondary Report) and Assumed Damage (Primary Report) Caused By Huge Earthquakes in the Nankai Trough" prepared by the Cabinet Office in August 2012




Southern Kanto (M=6.7 - 7.2) Approx. 70%

Hyuga Nada (M7.1) Approx. 70 - 80%

Nankai (M 8.4) Approx. 60%

Tonankai (M8.1) Approx. 70%

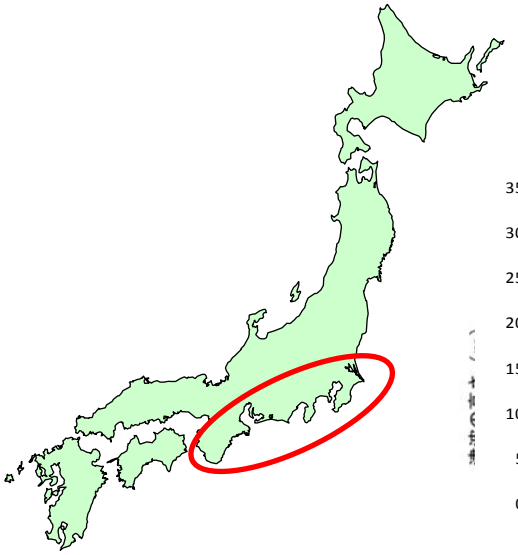
Tokai (M8.0) 88% (for reference)

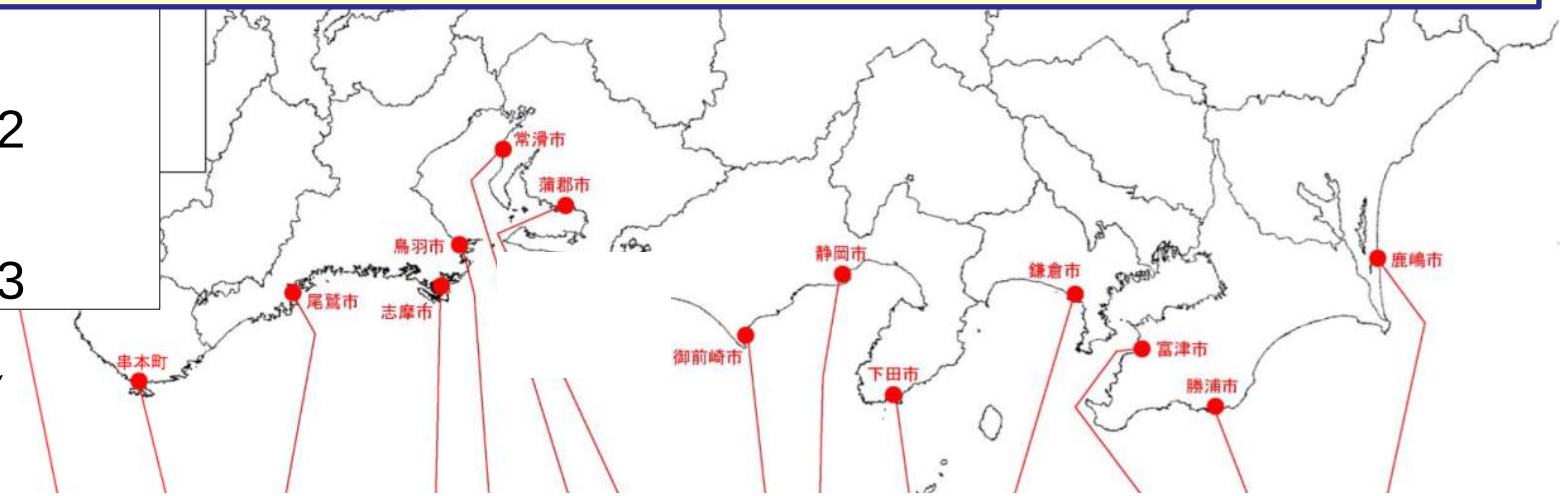
In case of consolidated type of 3 earthquake (M9.0)

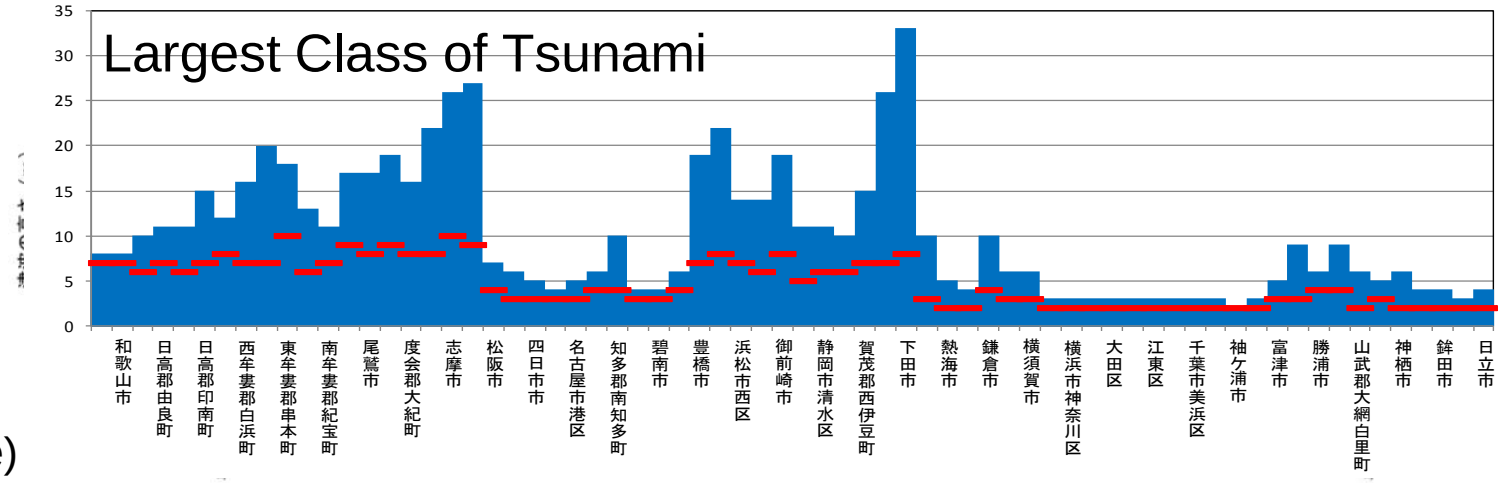
# Imminent Threat of Tsunami - Estimated Tsunami Height

An extremely wide area would be attacked by a huge tsunami.
- Tsunami height
  More than 10m : 11 prefectures and 90 cities
  More than 20m : 6 prefectures and 23 cities

- Tsunami height estimated in 2012
- Tsunami height estimated in 2003






(Source: Cabinet Office)

# Imminent Threat of Tsunami - Estimated Tsunami Height

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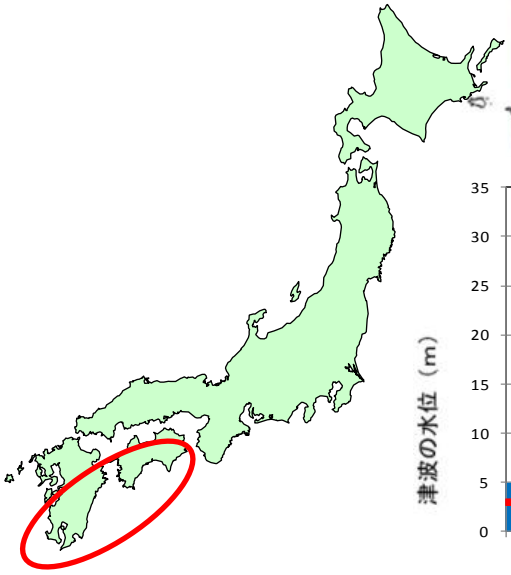
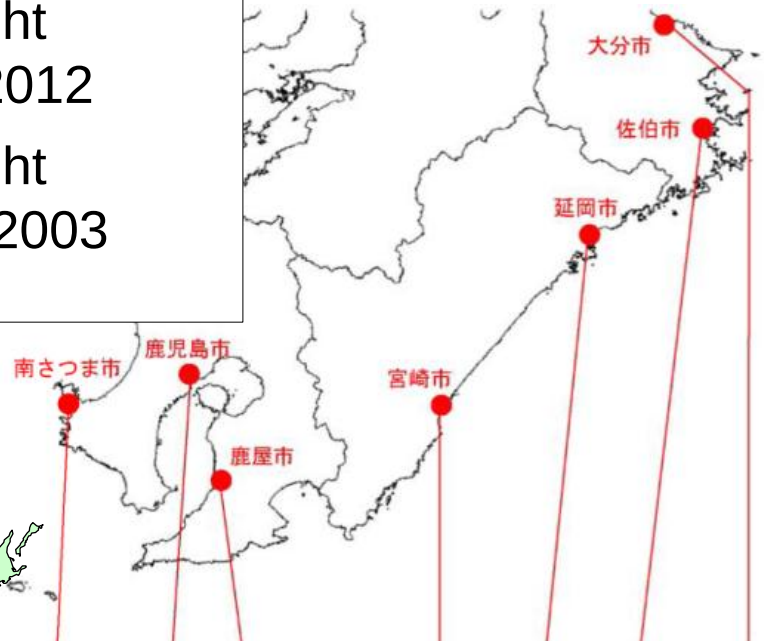
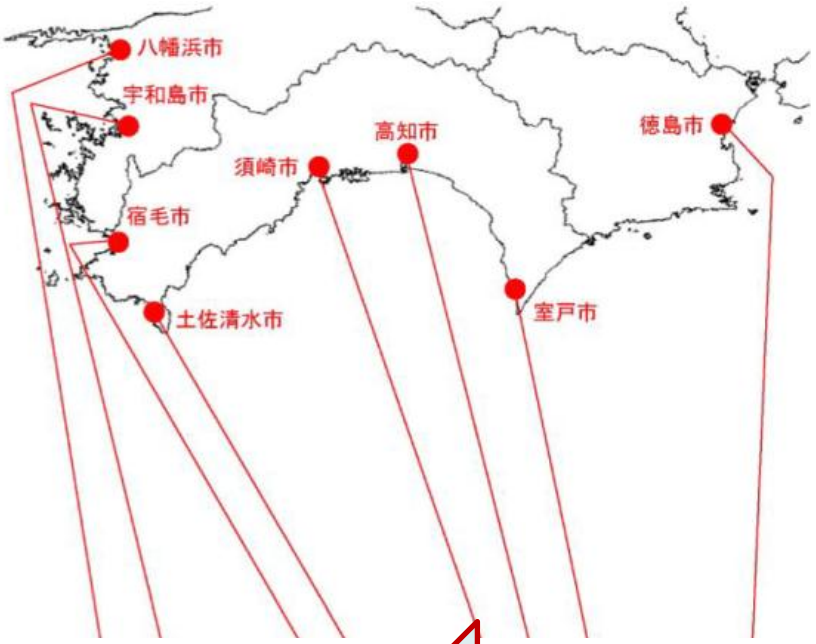
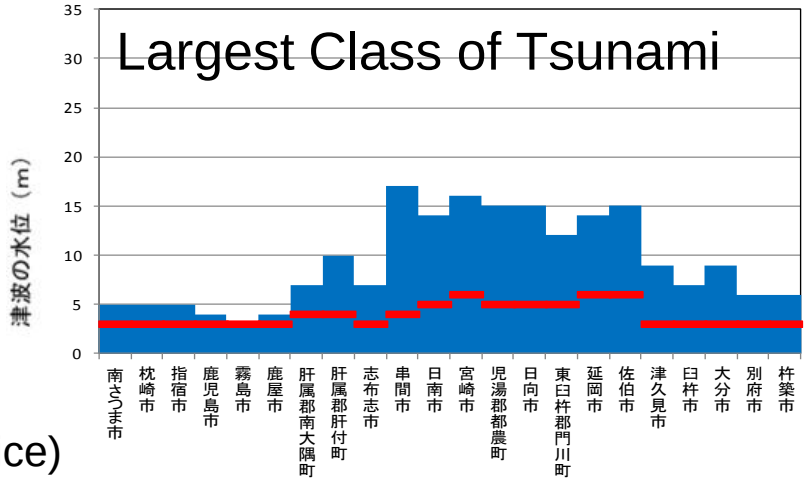
## Estimated maximum economic damage : about 220 trillion yen

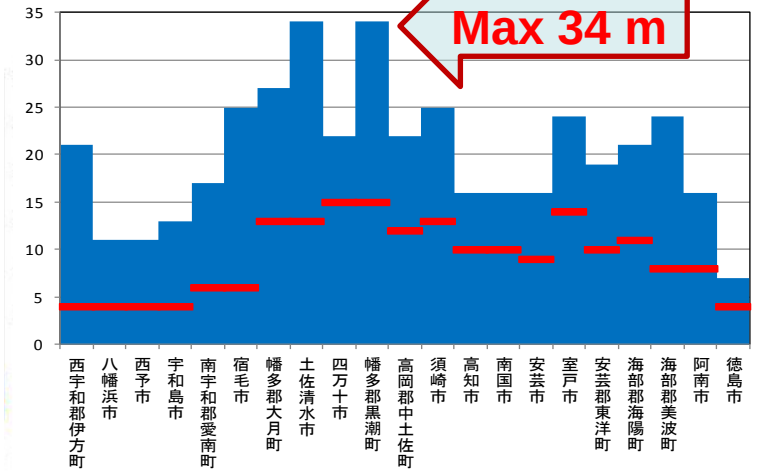
- Tsunami height estimated in2012
- Tsunami height estimated in 2003






(Source: Cabinet Office)

# 3. Countermeasures against Future Earthquake and Tsunami

## 1) Strengthening of Disaster Prevention Ability in Port

- Clarification of Disaster Prevention Target and Disaster Mitigation Target
- Strengthening of the information system for evacuation
- Introducing resilient structures
- Improvement of liquefaction evaluation method
- Disaster prevention base and earthquake resistant berths
- Necessity to strengthen cargo handling machineries against earthquake and tsunami

# Clarification of Disaster Prevention and Mitigation Target



- Necessity of preparation for the large-scale tsunami beyond estimation
- Limitation of feasibility to prevent such a large-scale tsunami only by constructing large structures
- Consideration of 2 levels of tsunami scale

Basic Concept of Tsunami Countermeasures

| Frequently occurring tsunami (Level 1 Tsunami) | Largest class of tsunami (Level 2 Tsunami) |
|---|---|
| Return period: Several decades - one hundred and several decades | Return period: Several hundreds of years - one thousand years |
| **Disaster Prevention Target** | **Disaster Mitigation Target** |
| Protect human lives | |
| Prevent tsunami from entering urban area by constructing structures | Allowing inundation into urban area, reduce damage mainly by evacuation countermeasures |

# Lessons Learned：Usefulness of GPS Wave Observation Buoys

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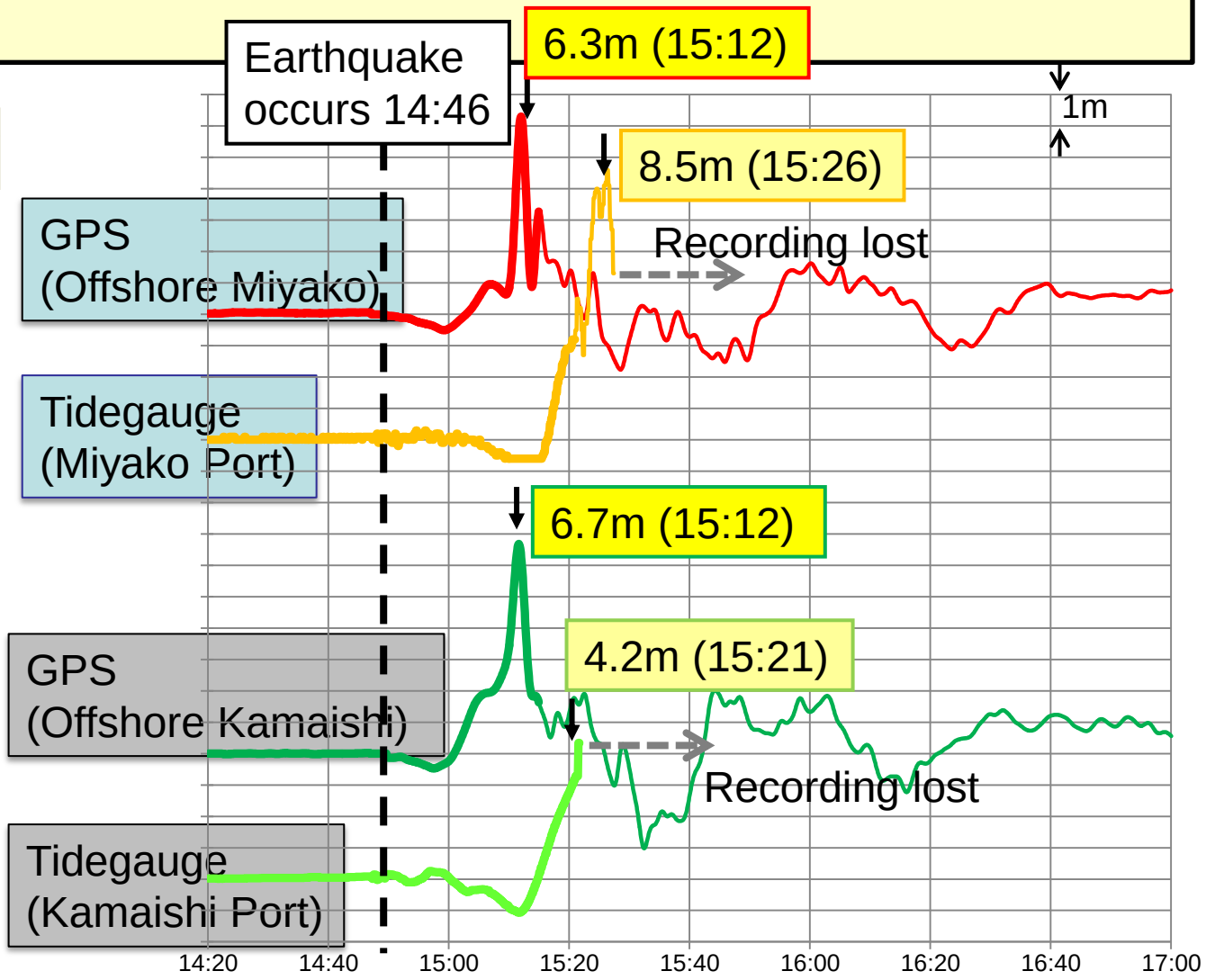
- GPS wave observation buoys observed the huge tsunami about 10 minutes before its arrival at the coast.
- Receiving this observation data, Japan Meteorological Agency raised the level of tsunami warnings.

**GPS Wave Observation Buoy**



# Strengthening of the information system for evacuation

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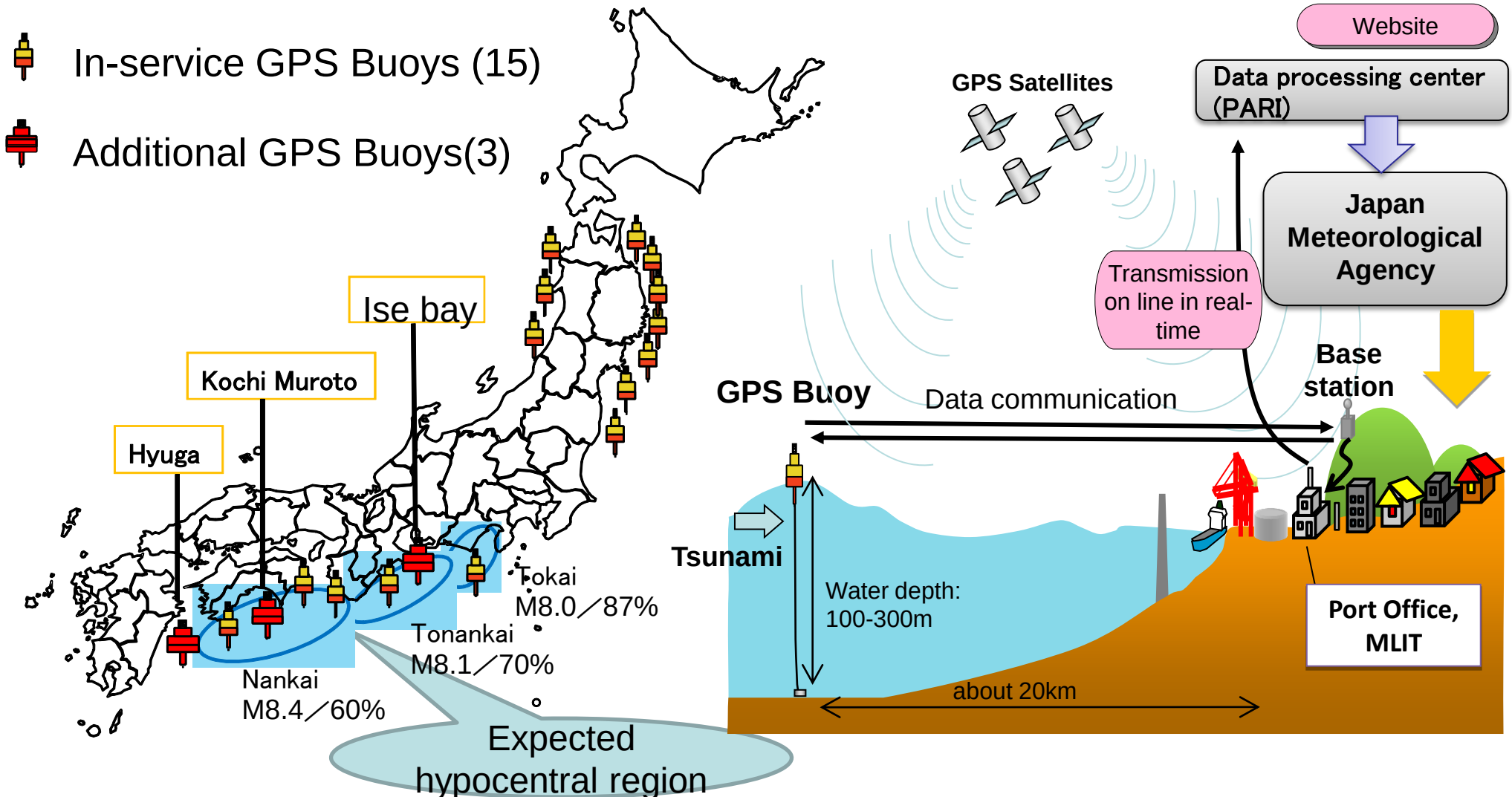
- To strengthen cooperation with Meteorological Agency, so on
- To multiplex communication system, and diversify information offering system
- To strengthen power-supply facilities



# Lessons learned：Tsunami Disaster Reduction by Breakwaters

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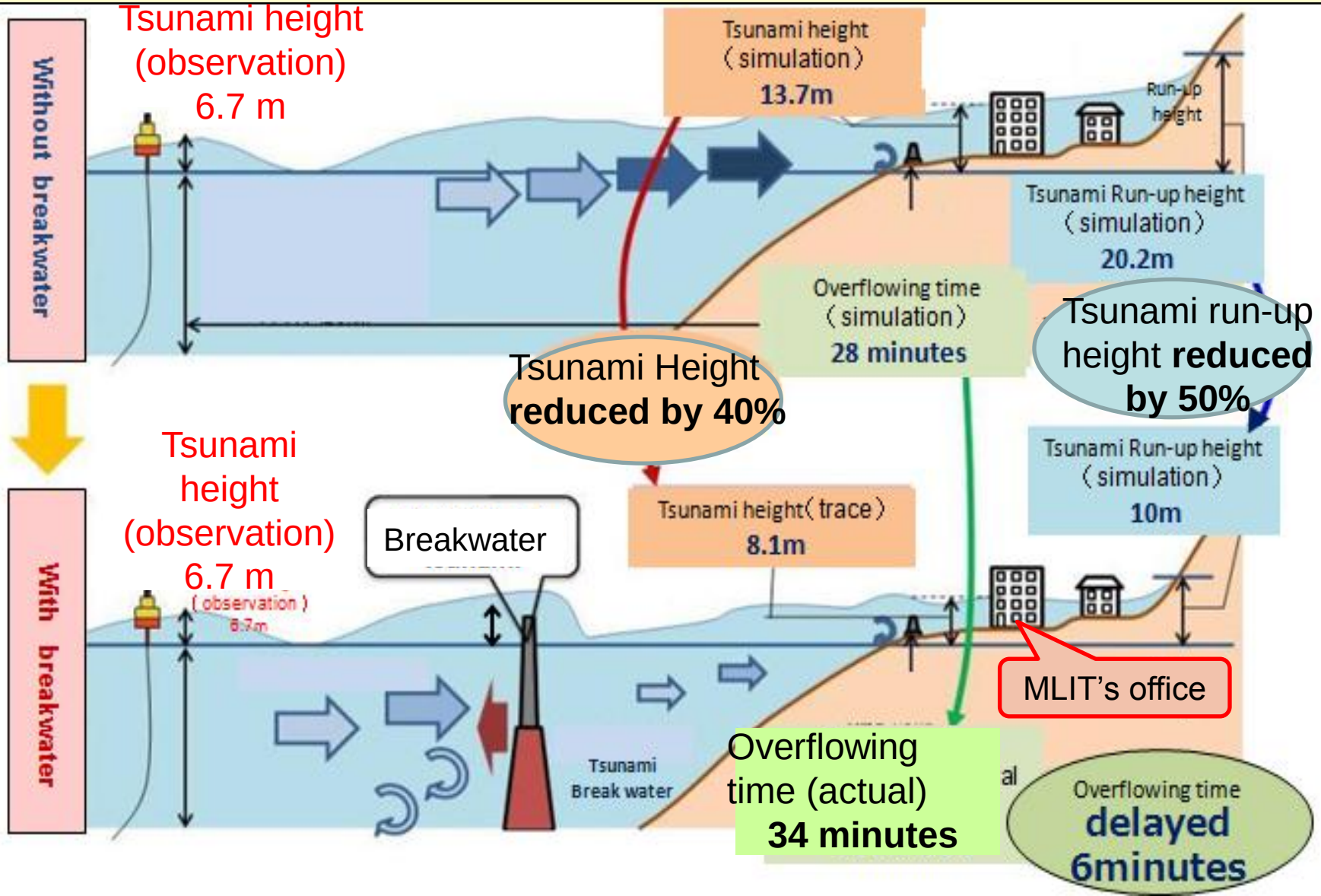
- Breakwater at Kamaishi port collapsed by tsunami, but it delayed tsunami overflowing time, and reduced tsunami height and inundation area.



# Introducing Resilient Structure

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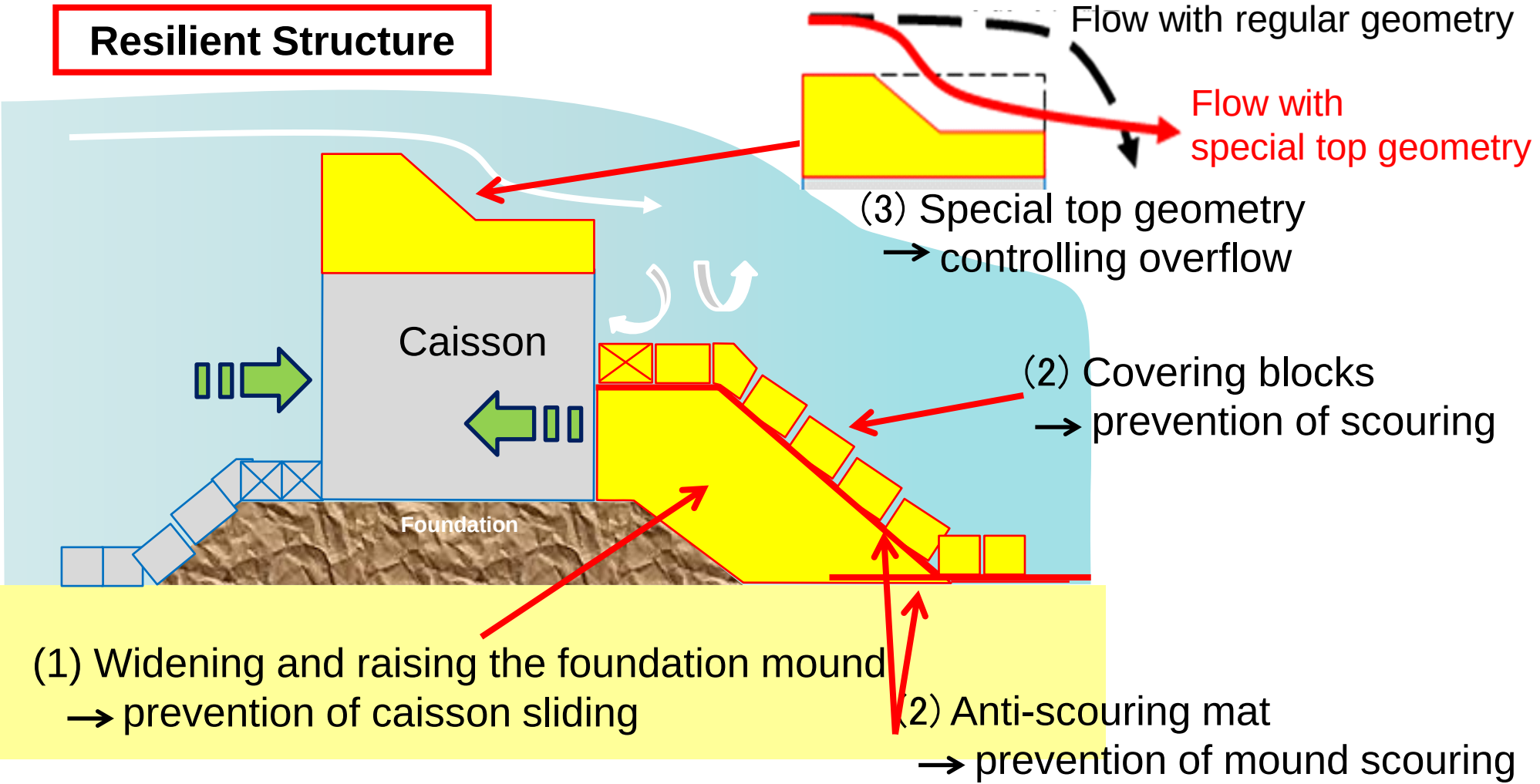
- Breakwater has effect to weaken tsunami energy.
- Once damaged, it needs a long time to recover.
- Consider to adopt a “resilient structure" so that it will keep its original function without being broken by an overtopping huge tsunami.



# Lessons learned: Liquefaction by Long-duration Earthquake

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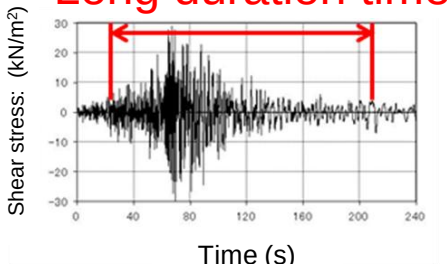
- Necessity to review the liquefaction evaluation method considering the earthquake duration time
- Realizing higher-accurate liquefaction modeling system

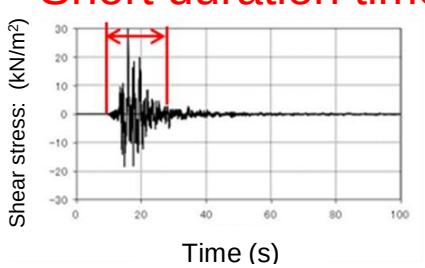
## Review of liquefaction evaluation method

Long duration time




Tohoku 2011

Short duration time




Hanshin 1995

**Revised liquefaction evaluation method taking into account the seismic duration time**
(Revision of Technical Standard, Aug. 2012)

## Building a liquefaction modeling system

**Realizing Higher-accuracy**

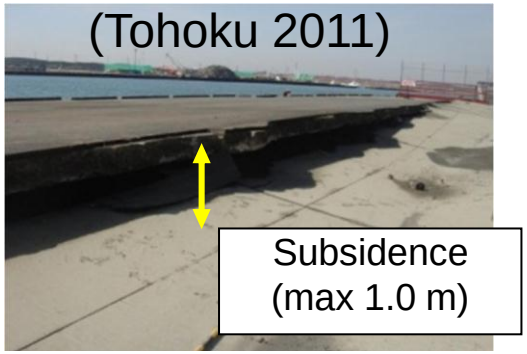
Modeling of numerical liquefaction analysis

Consistency

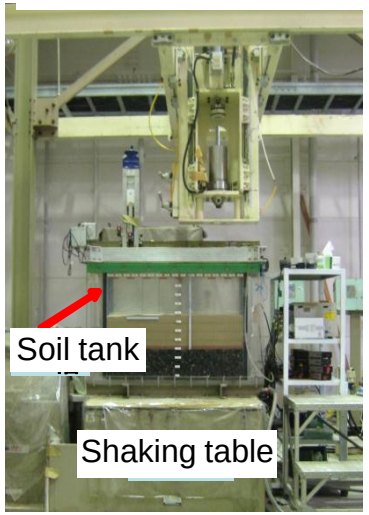
Consistency

Model experiment

Real case
(Tohoku 2011)



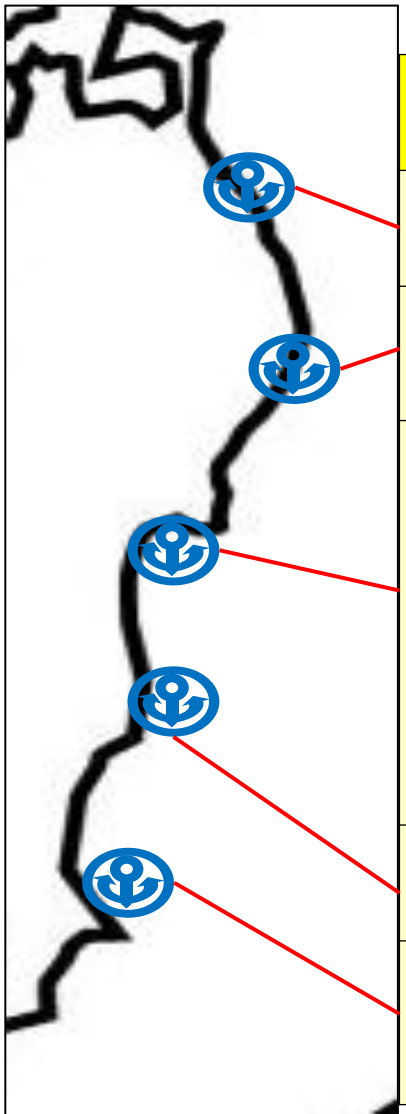

Example of liquefaction
(Ibaraki Port)




Shaking table test equipment

# Lessons learned: Effectiveness of earthquake resistant berths

- 6 earthquake resistant berths were available in the disaster area
- Accepting emergency commodities soon after reopening of waterways



Earthquake resistant berth：Specially reinforced berths against earthquake

| Name of Port | Facilities | First vessels after disaster | Variety of relief supplies |
|---|---|---|---|
| Hachinohe | Hachitaro Berth N | Feed (Private) | - |
| Kamaishi | Suga (-7.5m) | General Cargo (Private) | - |
| Sendai-Shiogama (Sendai) | Nakano Takamatsu Berth | Emergency Commodities (Kyushu RDB, MLIT) | Food (rice, boil-in-the-bag-food)<br>Heating oil |
| | Nakano Raijin Berth No.2 | Emergency Commodities (JCG) | Emergency food |
| Onahama | Warf No.5 Berth No.1 | Coal (Private) | — |
| Ibaraki (Hitachinaka) | Chuo Berth A | General Cargo (Private) | — |

# Disaster Prevention Base and Earthquake Resistant Berths

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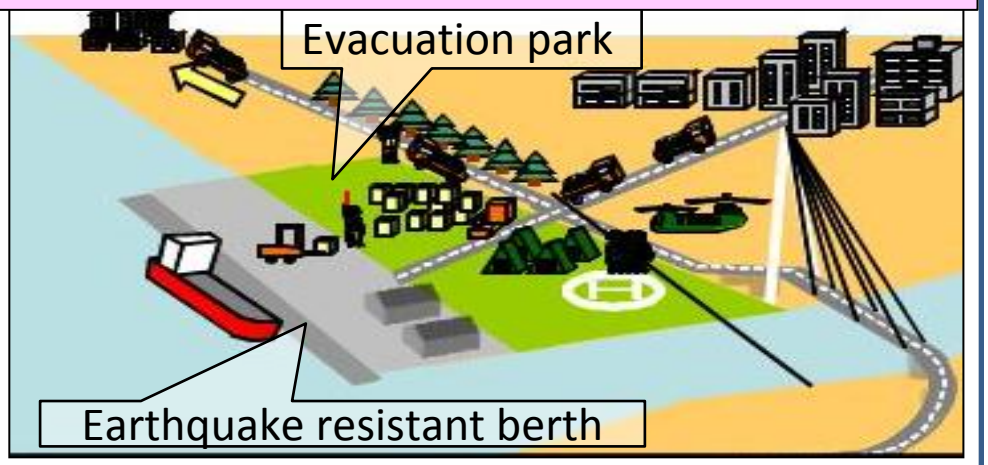
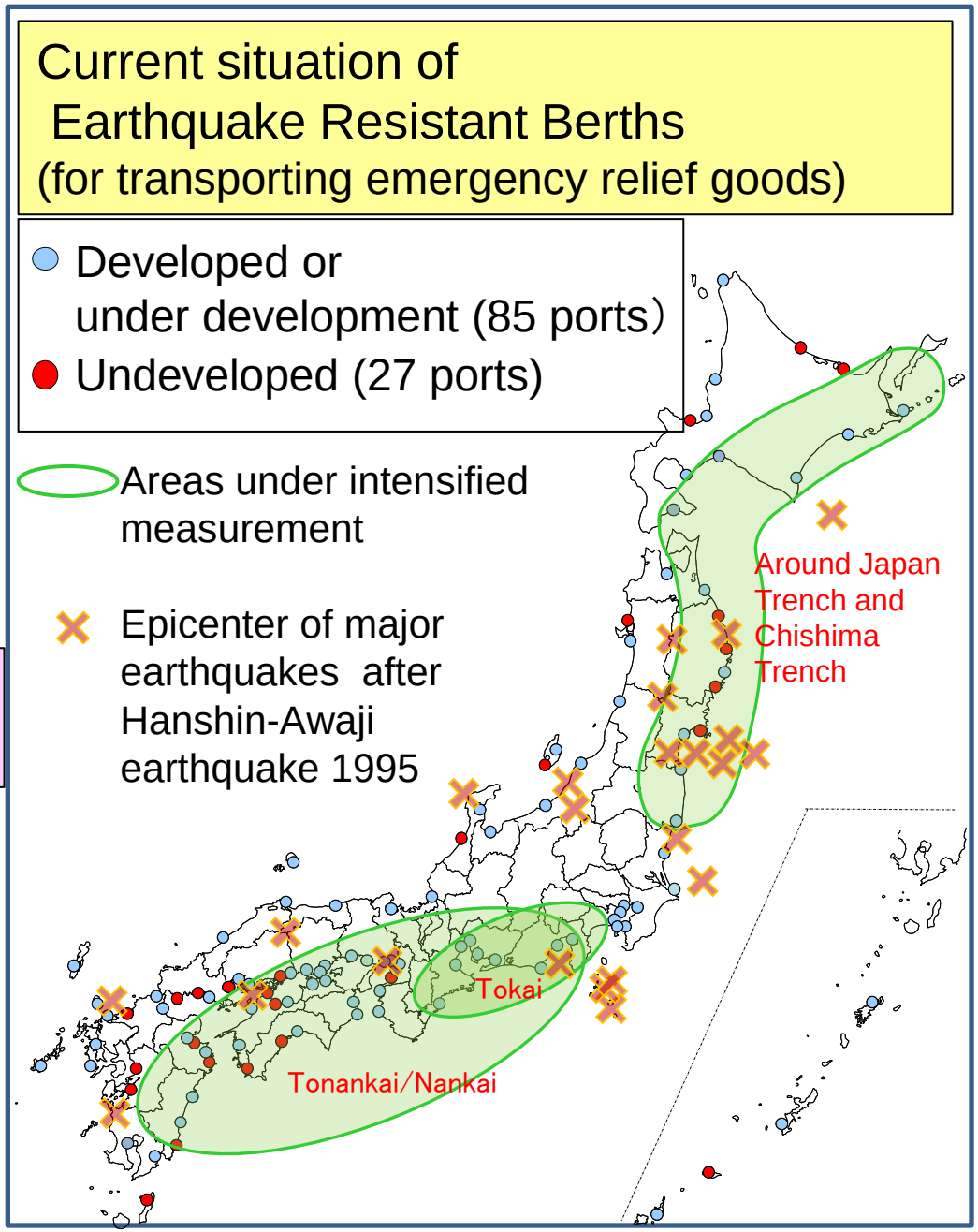
## Reconsideration of Earthquake Resistant Berths

- Ferry and RoRo vessels played important role to transport vehicles and personnel
- Necessity to utilize disaster prevention base as a basement of acceptance of wide-area relief and restoration and revitalization.

## Image of Disaster Prevention Base in ports




## Current situation of Earthquake Resistant Berths (for transporting emergency relief goods)



# Lessons learned: Necessity to strengthen cargo handling machineries against earthquake and tsunami

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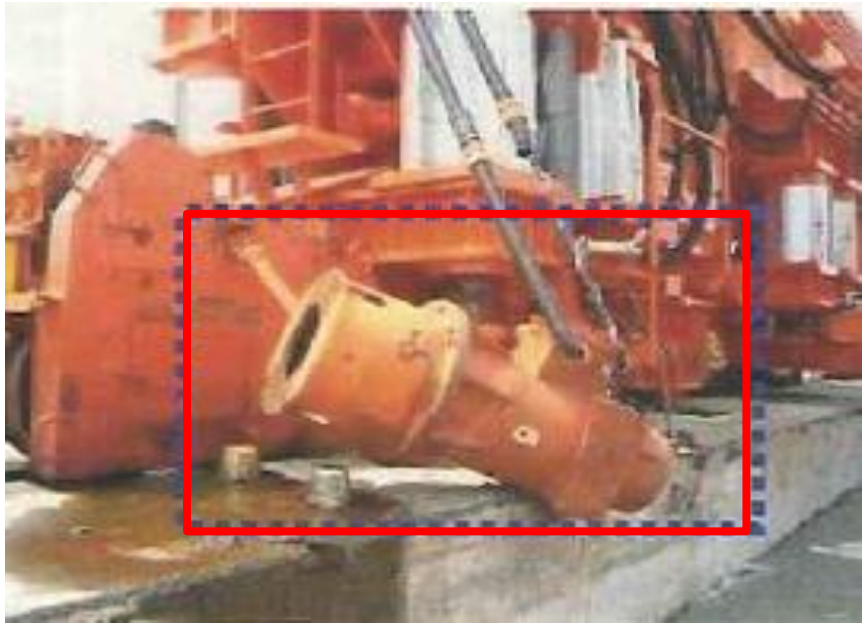
## Damages by Tsunami

About 3.0 m depth flooding above quay surface



Traveling motors were damaged by hitting of drifting objects.

Cable winding device was damaged by hitting of drifting objects.
Traveling section needs maintenance after 0.6m depth flooding.

Main causes observed
- Hitting of drifting objects such as containers
- Inundation of sea-water and sand into mechanical and electric devices
- Drag of vertical boom by drift of vessels under cargo-handling

# Necessity to strengthen Cargo Handling Machineries against earthquake and tsunami

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**Point of countermeasure for Cargo Handling Machines**

**→ To prevent Machineries from flooding**

- Raising elevation of the entire container yard
- Placing electronic facilities on higher places in the administration building
- Commoditizing and sharing components of crane materials and equipments

**Anti-earthquake measures**

Installation of seismic isolation device (Travelling section)

# 3. Countermeasures against Future Earthquake and Tsunami

## 2) Securing Maritime Transport Network and Wide-area Mutual Backup System

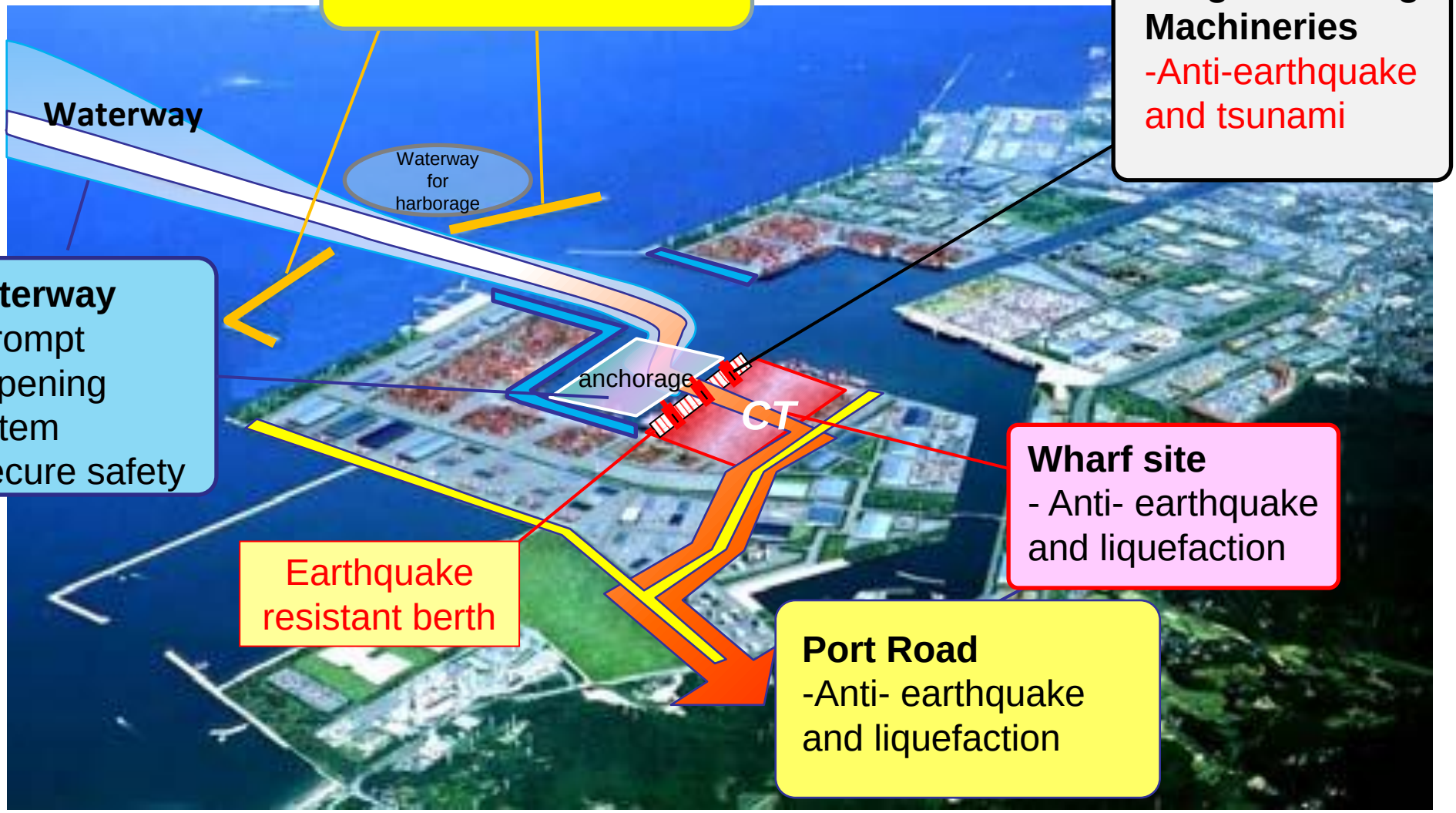
- Strengthening core port facilities against earthquake and tsunami

- Countermeasures to secure navigation safety in bay areas

- Establishment of wide-area mutual backup system among ports

# Strengthening core port facilities against earthquake and tsunami






**Breakwater**
- Resilient structure

**Cargo Handling Machineries**
-Anti-earthquake and tsunami

**Waterway**
- Prompt reopening system
- secure safety

**Wharf site**
- Anti- earthquake and liquefaction

Earthquake resistant berth

**Port Road**
-Anti- earthquake and liquefaction

# Lessons learned：Necessity of countermeasures to secure navigation safety in bay areas

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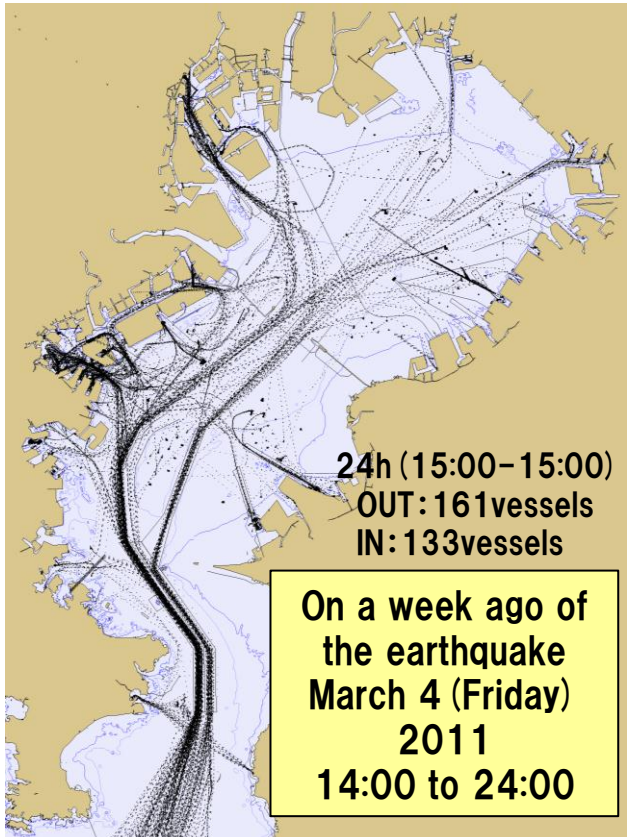
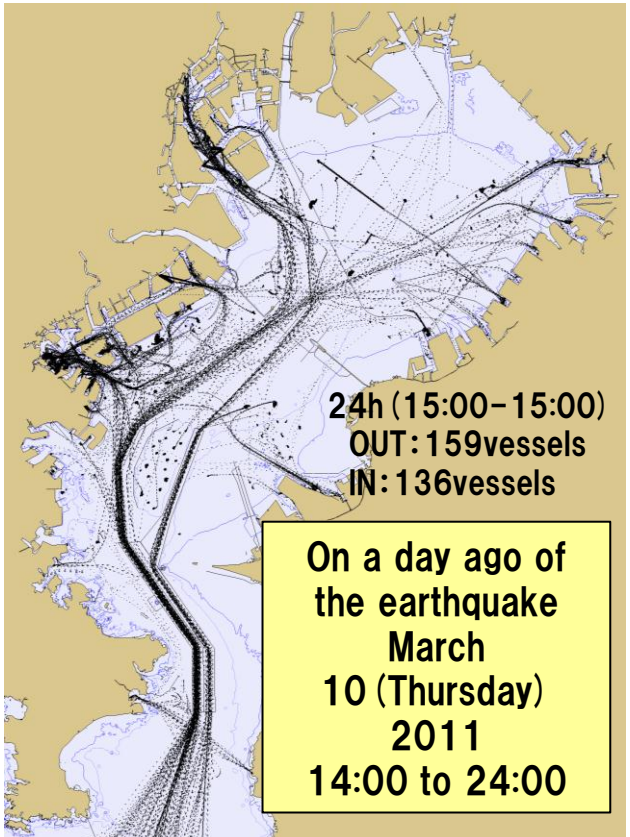
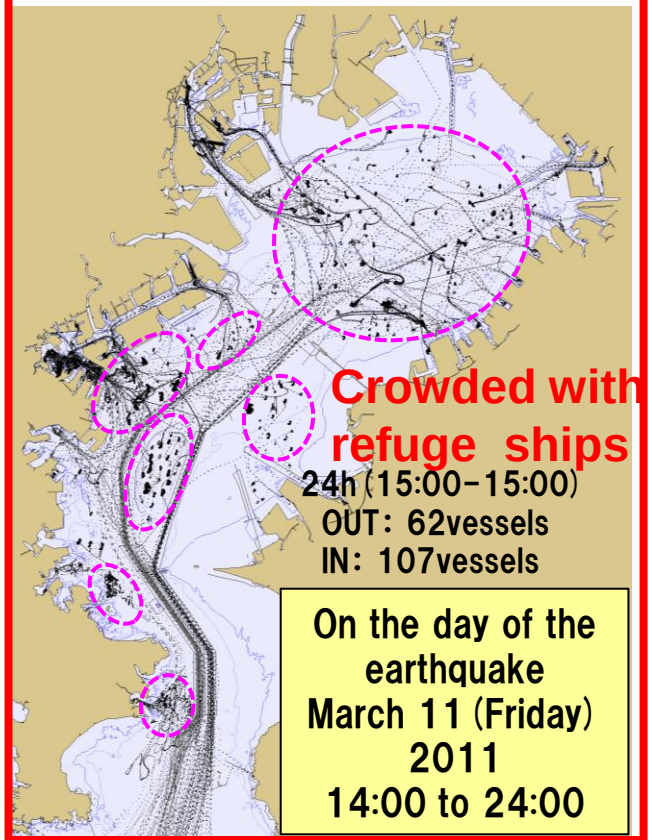
**Situation of Tokyo Bay (Tohoku Earthquake, 2011)**
- 400 vessels
- Tsunami Height: 2.5m (Funabashi), 1.6m (Yokohama)
- A lot of refuge ships stayed within Tokyo Bay
- Crowded with refuge ships until Mar. 15

**<Threat >**
Heavy congestion by refuge vessels in 3 major bays and Seto Inland Sea



# Maintain Waterway Function in Tokyo Bay in an Emergency

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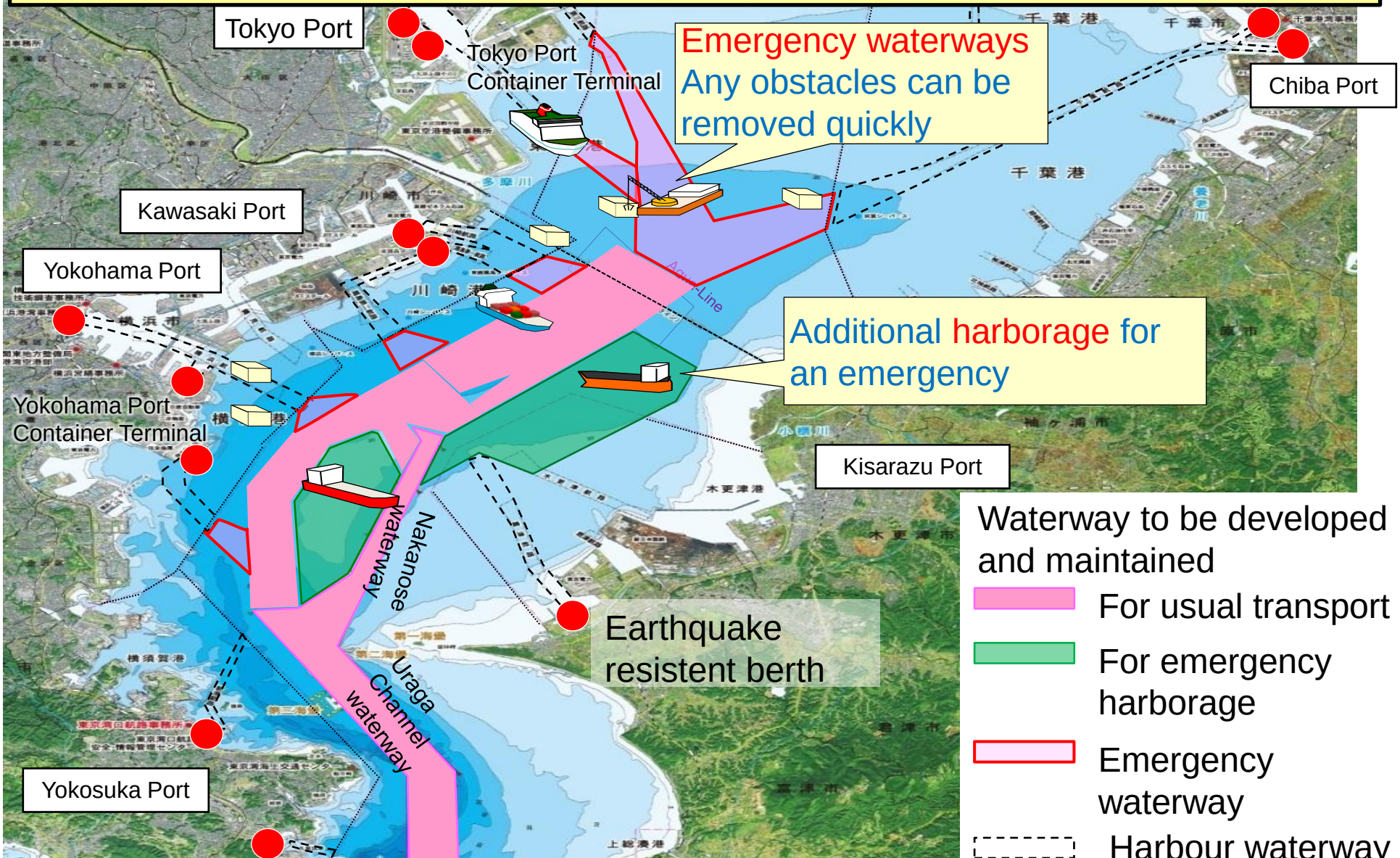
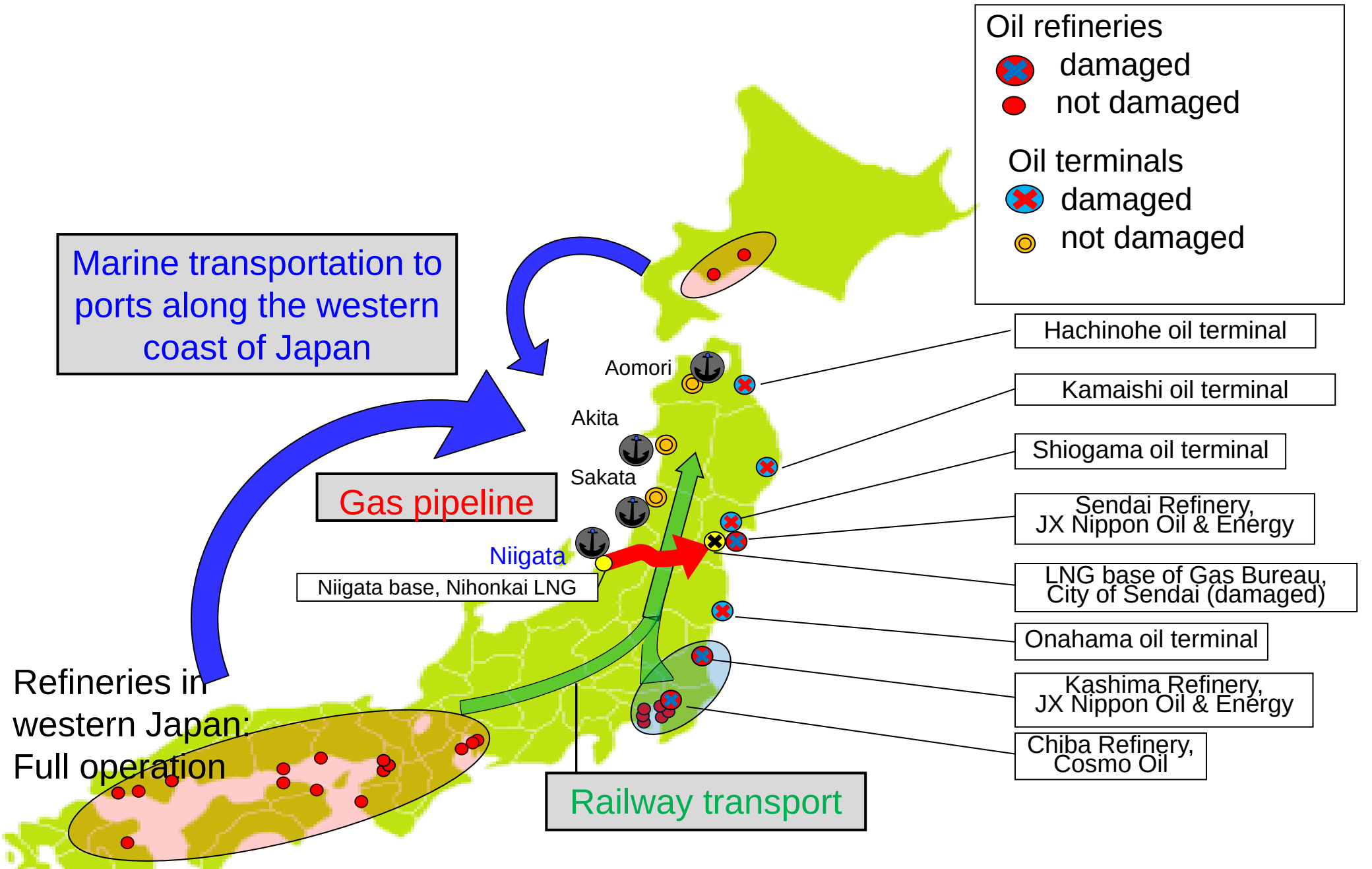
- Securement of refuge routes and harborage for large vessels
- Prompt reopening waterways after tsunami attack



# Lessons Learned: Backup Transport of Oil and Gas





# Establishment of Wide-Area Mutual Backup System

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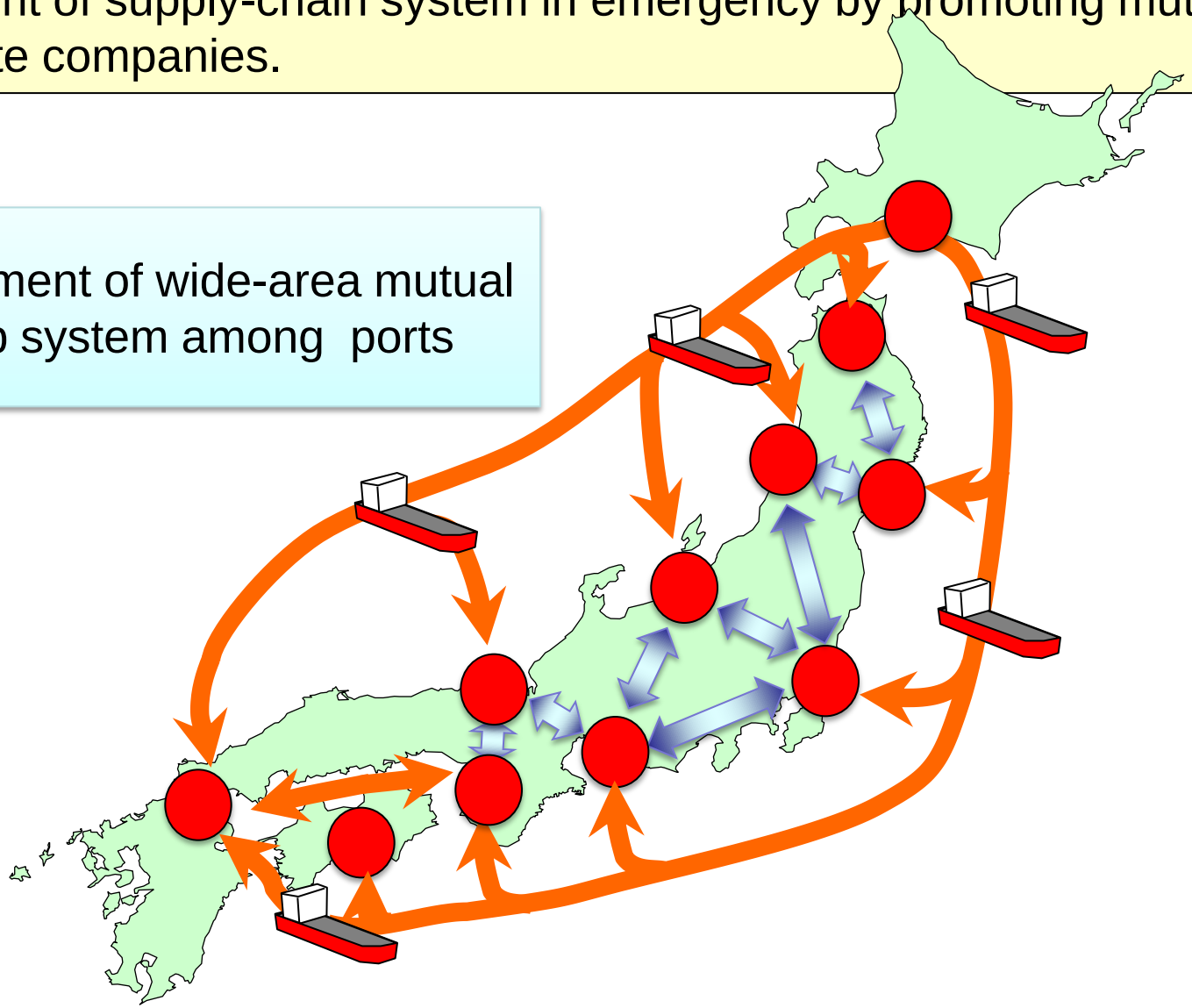
- Conclusion of cooperation agreement on disaster management
- Securement of disaster prevention base
- Securement of supply-chain system in emergency by promoting mutual cooperation with private companies.

Establishment of wide-area mutual backup system among ports



# 3. Countermeasures against Future Earthquake and Tsunami

## 3) Countermeasures for saving human lives and BCP

- Effective management of floodgate

- Improving the evacuation system

- Establishment of Business Continuity Plan (BCP) of Port

# Lessons Learned： Management of Floodgate

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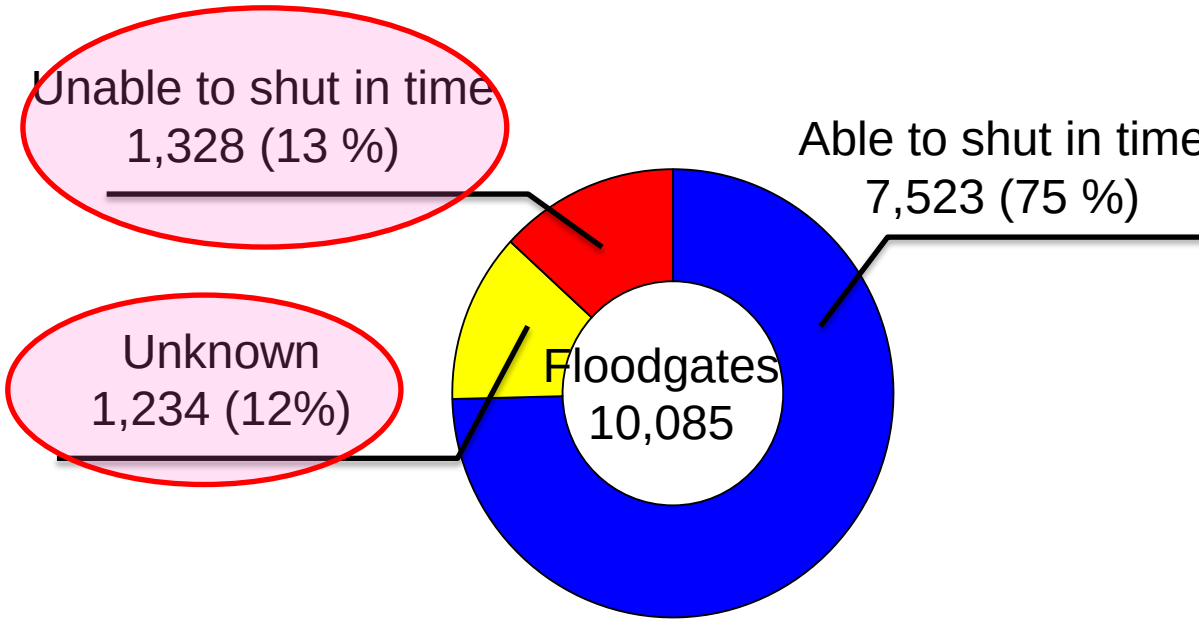
**Many people operating floodgates were killed or missed by tsunami.**

Current situation

Over 20% of all 10,085 floodgates cannot be shut before arrival of tsunami.



Rate of floodgates which can be shut by the arrival of tsunami




※Mar. 2012（MLIT, MAFF）
・Over the size of 2m(Width) × 1m(Height)
(Except for Iwate, Miyagi and Fukushima prefecture)

# Effective Management of Floodgates

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Proposal by “Committee for effective management of floodgates” (MLIT and MAFF)

- Necessity to make it a top priority to secure the safety of floodgate operators

Revising “Guideline for management of floodgates in the case of tsunami and high tide” , Apr.2013.

- Evacuation rule to make securing the safety of operators a top priority
  “Operator has to escape in an emergency”

- Establishment of management system to make sure safety of operators
  Elimination and consolidation of floodgates
  Introduction of automation or remote control system

- Information system for prompt evacuation of residents and operators

- Human resource development of operators

- Flexible management system keeping clarification of responsibility

- Technological development and its reflection to the technical standards

# Promotion of Evacuation Countermeasures in Port Area

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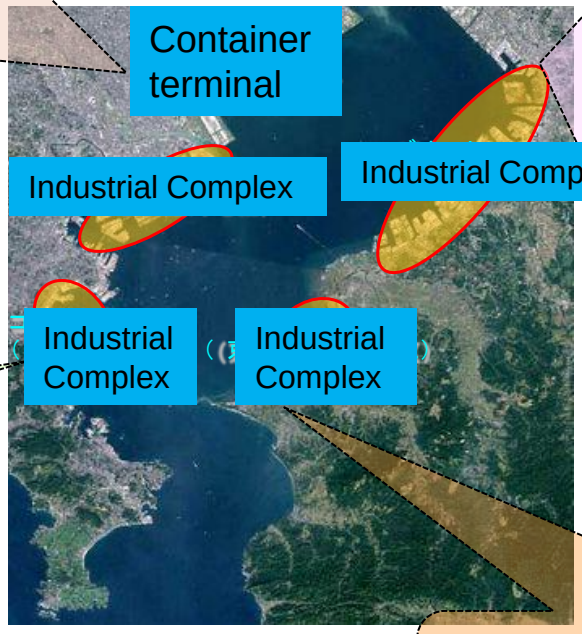
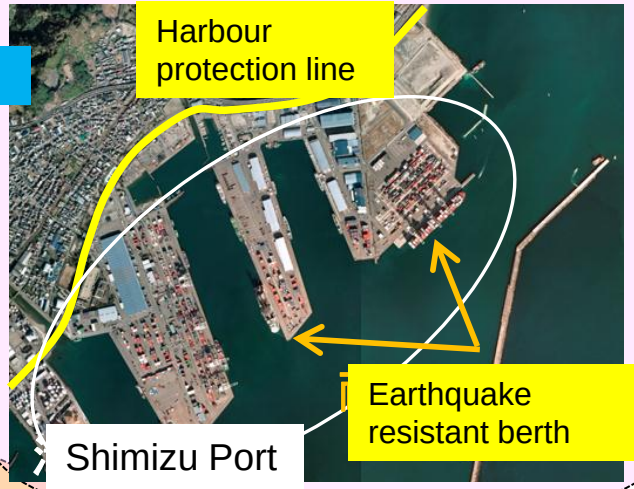
## Particularity of port area

**Variety of people**
-Workers, officers
- port visitors




**Variety of functions**
-logistic facilities
-wharves




**Severe land condition**
- Soft ground
- liquefaction
- high groundwater level

**Hazardous materials**
-power plant, LNG, chemical plants

- **Evacuation guideline in port area** (To be published in summer 2013)

- **Design guideline of refuge facilities** (WG started, Feb. 2013)

# Establishment of Business Continuity Plan (BCP) of Port

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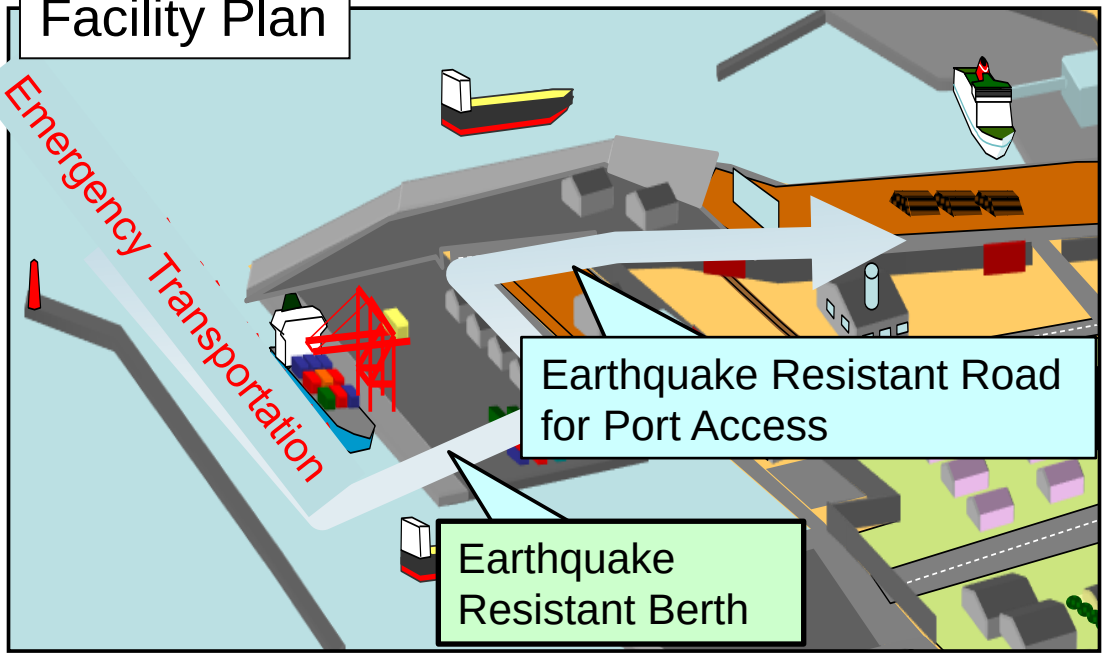
## Image of Business Continuity Plan (BCP) of port

### Action Plan

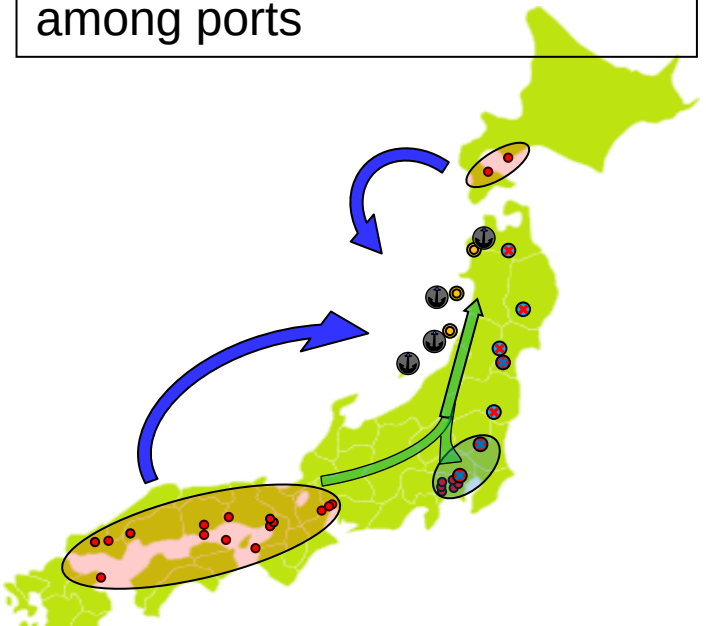
-Organization plan for emergency restoration
-Securing evacuation route
-Securing acceptability for emergency cargoes
-Harmonization with BCP of private sectors

### Facility Plan




### Transportation of Emergency Vehicles by Ferry

### Regional backup system among ports



## The Tohoku Earthquake 2011 –Damage and restoration

- Large scale of earthquake and tsunami
- Tremendous damage –human lives and properties
- Enormous damage to ports and harbours
- Under restoration - almost 80 % of public berths recovered –
- Brought many problems to be considered

## Imminent threat of Large-scale Earthquake and Tsunami

- Large Scale Earthquake and Tsunami predicted with high probability
- Necessary to prepare for the threat

## Countermeasures against Future Earthquake and Tsunami

### Strengthening of Disaster Prevention Ability in Port

- Clarification of disaster prevention target and disaster mitigation target
  Introduction of 2 level of Tsunami

- Evacuation information system utilizing GPS wave observation buoys

- Resilient structure for breakwaters

- Improvement of liquefaction evaluation method

- Necessity of disaster prevention base with earthquake resistant berths

- Strengthening cargo handling machines against earthquake and tsunami

## Securing Maritime Transport Network and Wide-area Mutual Backup System

- Strengthening core port facilities against earthquake and tsunami

- Securement of navigation safety in bay areas in an emergency
  Amendment of Ports and Harbours Law

- Establishment of wide-area mutual backup system among ports

## Countermeasures for saving human lives and BCP

-Effective management of floodgate – a top priority to lives of operators

- Improvement of the evacuation system
  Evacuation Guideline, Technical standard for evacuation facilities

-Establishment of Port's BCP

## 37th APEC Transportation Working Group Meeting

### To Carry Out the Role and the Practical Use of Port in Natural Disaster (Project completed by Japan)

-Compilation of best-practices among APEC countries focusing on ports in natural disaster

GPS Buoy (Japan)

Flood Protection wall (Thailand)

Aramir Project (Republic of Korea)

### Green Port Initiative

- Green port projects were presented by Canada, US, China, Japan and APSN (Asia Port Service Network).
- Examples presented by Japan contribute to work as emergency power supply system for port facilities in disaster, as well as to reduce environmental burden.

END

Thank you very much
for
your encouragement and support