3-Year Research Program
on

Risk and Crisis Management Strategy for Excessive and Multiple Actions of Natural Disasters

Research Center for Disaster Management
River Department
NILIM

国土交通省
国土技術政策総合研究所
National Institute for Land and Infrastructure Management

2011 Tohoku Earthquake

○Plate Boundary Type

○Large Fault Zone

(Fault Area: 500kmX200km)

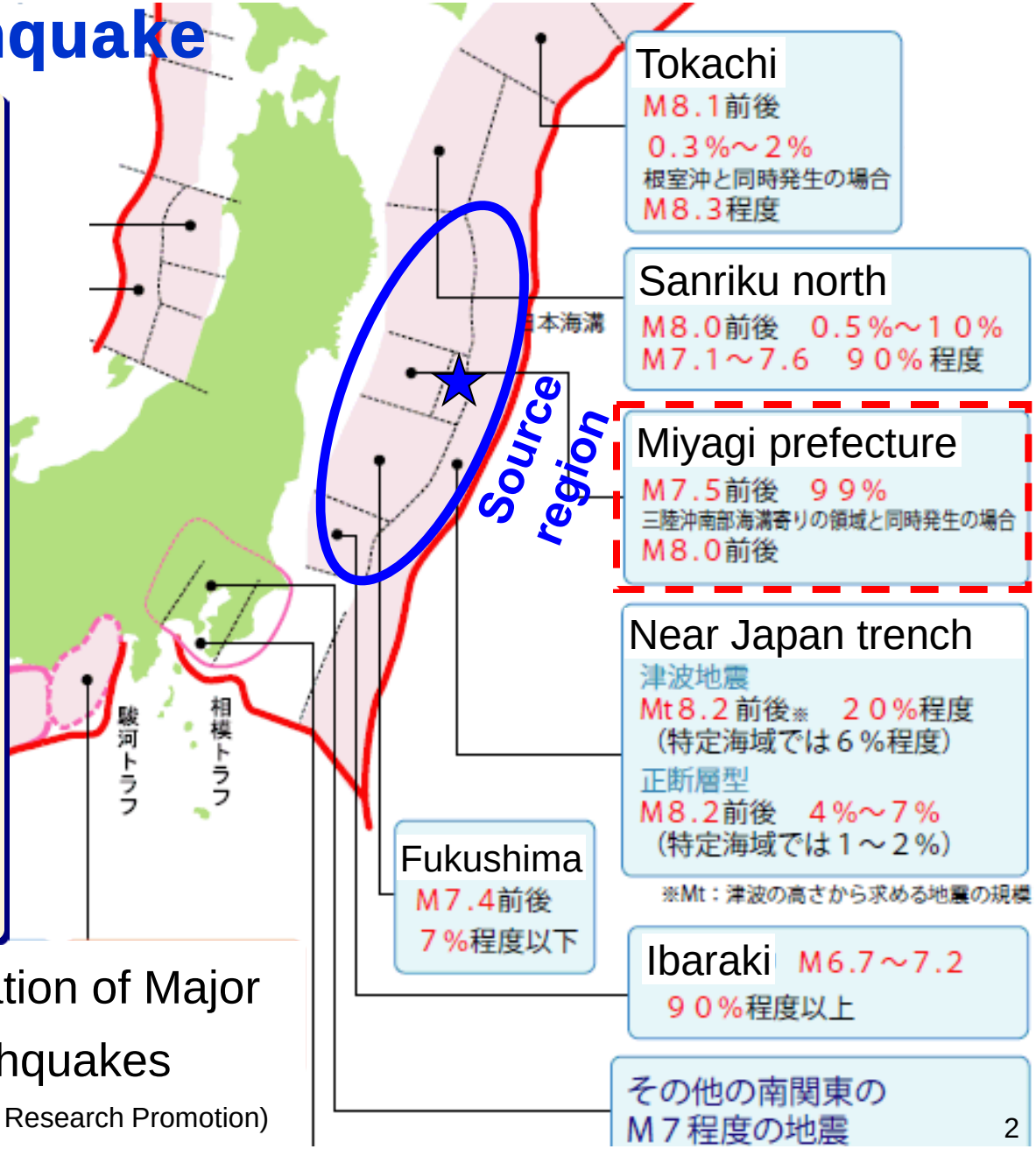
- Magnitude 9.0
- Long Duration Shaking
- Huge/Giant Tsunami

(Max. Inundation Height : 40m)

- Numerous and Large Aftershocks

○Extremely Larger Fault Zone exceeding Expected Miyagi Earthquake

(Sanriku ~ Miyagi ~ Ibaraki)



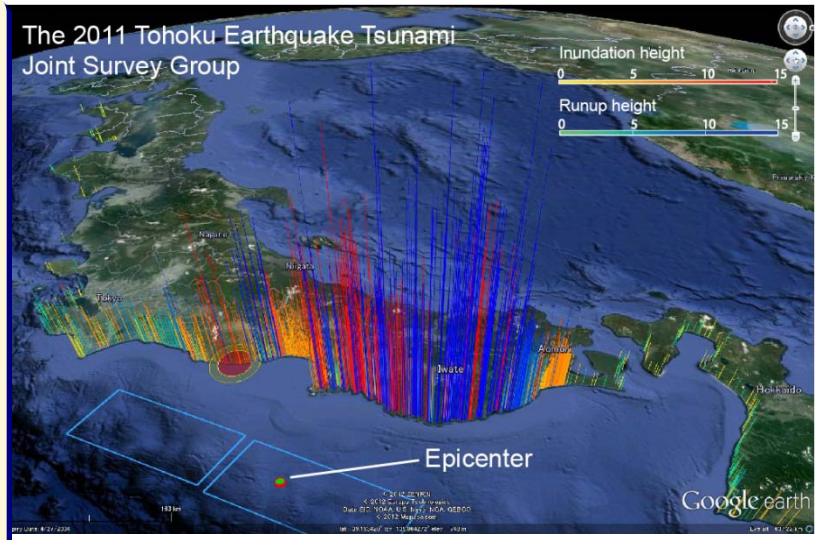
Long-term Evaluation of Major Oceanic Earthquakes

(Headquarters for Earthquake Research Promotion)

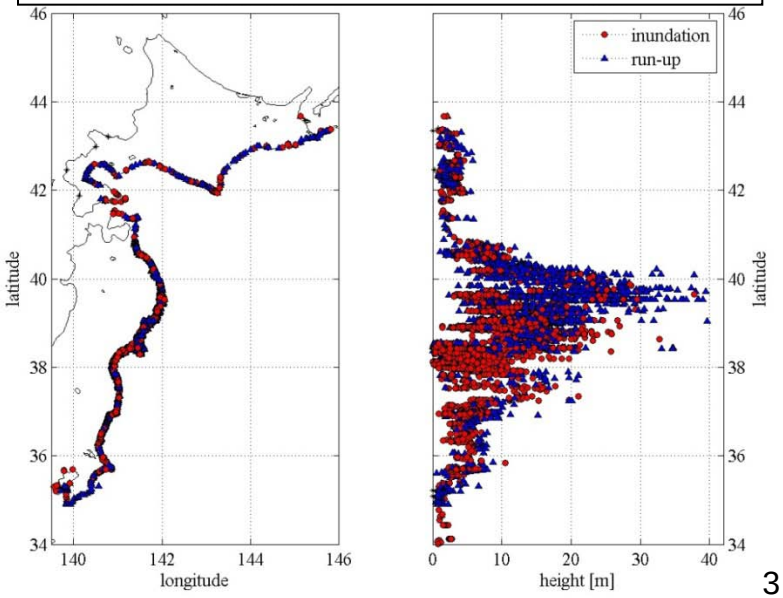
Destructive Damage and the Impacts

○**Destructive Damage by Huge Tsunami**

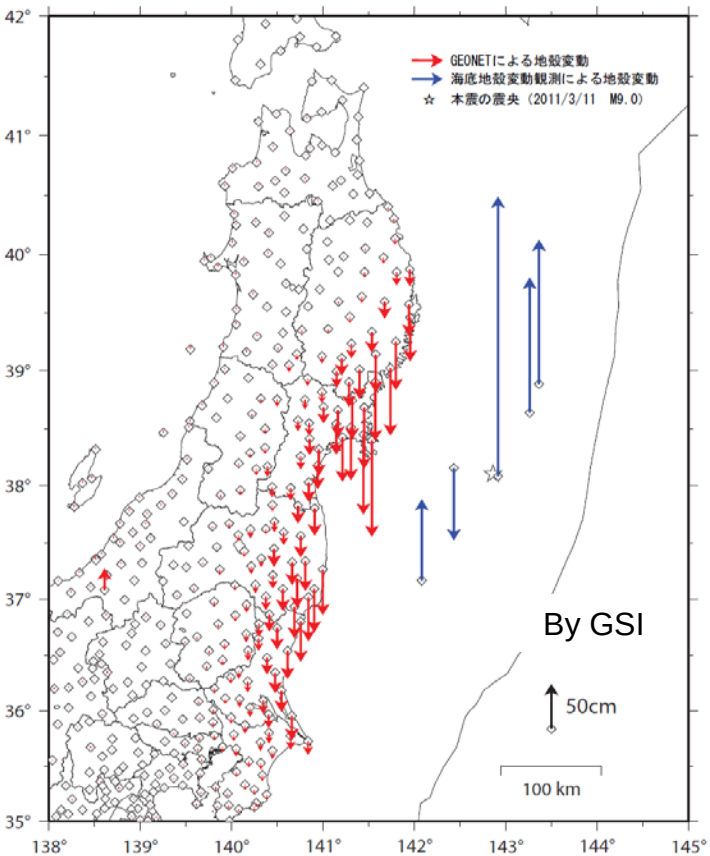
- Inundation Area exceeding the Estimation
- Casualty and Missing: About 20,000
- Destructive Damage to Houses (Complete Collapse 129,000), Lifelines and Base Infrastructures
- Damage Occurrence in Wide Area and Multiple Locations (Hokkaido-Tohoku-Kanto)
- Evacuee of 400,000 maximum
- Large Effects on Industries (Agriculture, Fishing, Supply Chain for Electrical Products, Automotive Industry, others)
- Liquefaction Damage in Wide Area
- Damage to Facilities with Hazardous Substances including Nuclear Power Plant

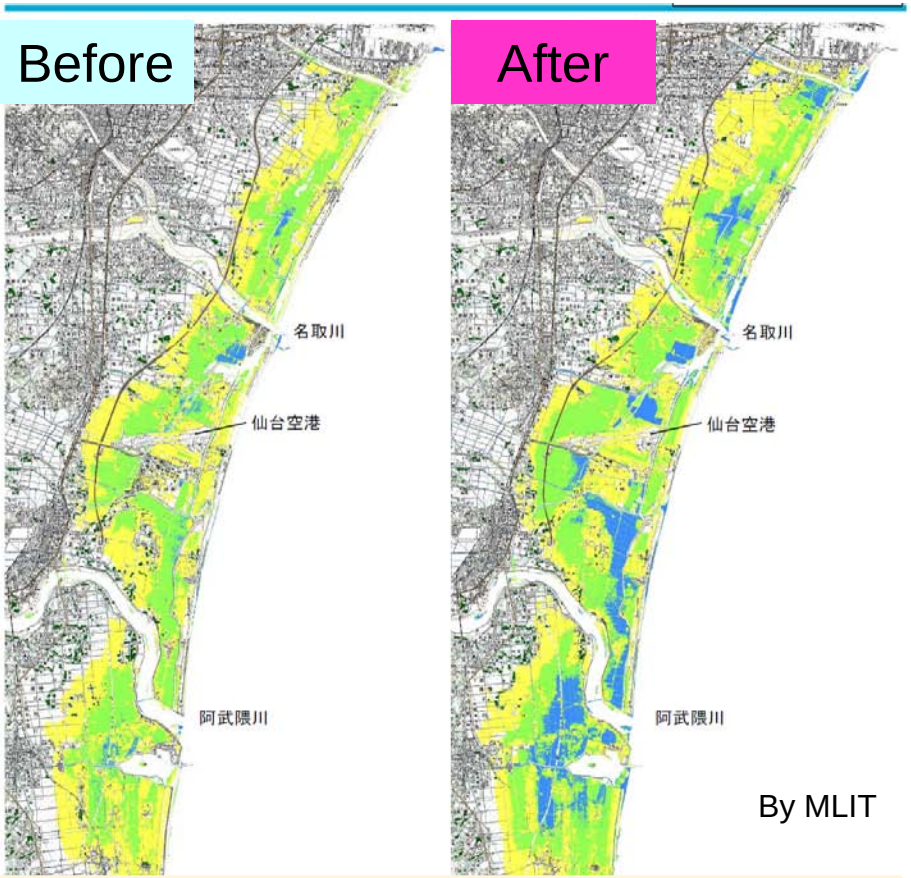


Max Inundation Height of about 40m



Complex Effects: Wide Crustal Movement and Ground Settlement





○One of Complex Effects

- Crustal Movement: Max. 530cm in horizontal to the Pacific, 120cm in Vertical Settlement
- Area below Sea-level: Increase from 3k㎡ to 16k㎡
- Significant Increase of Vulnerability by Storm Surge (Damage by Storm Surge)
- Increase of Flooding Risk by the Damage of Infrastructures including River Levee

Lessons Learned from the 3.11 Earthquake

- Devastating Damage in Wide Area by Giant Tsunami and Strong Shaking
- Damage Convolution: Flooding and Sediment Disasters followed on the Earthquake (Attacked by Typhoons after 5 months later)

Key Lessons

- Improvement of Preparedness to Natural Disasters which exceed **Past Experiences and the Estimation**
- Preparedness for Effects of **Multiple and Combined Actions of Natural Disasters** including Earthquake, Tsunami, Heavy Rain, Flood, Slope Failure and so on.

Disaster Management Concept after 3.11, 2011

◆Central Disaster Prevention Council, Gov. of Japan

1) Consider "Scientifically Possible Maximum Scale" of Earthquake and Tsunami
2) Recognition of Possibility of Uncertainty in the Estimation
3) Make Every Possible Effort for Disaster Mitigation to Expected Trench-type and Inland-type Earthquakes
4) For the Damage Assessment, Consider Combined Movement of Fault Zones and Occurrence time (day and night time), Combination with Typhoons

◆ Basic Policy of Rehabilitation from Tohoku Earthquake by Japanese Government

1) To Make Resilient and Disaster-Resistant Society, Put Every Possible Effort based on "Mitigation/Evacuation" concept rather than "Prevention"
2) Strengthen National Land to prepare Large Scale Disasters
3) Make Tough and Ductile Multiple Defense Concept

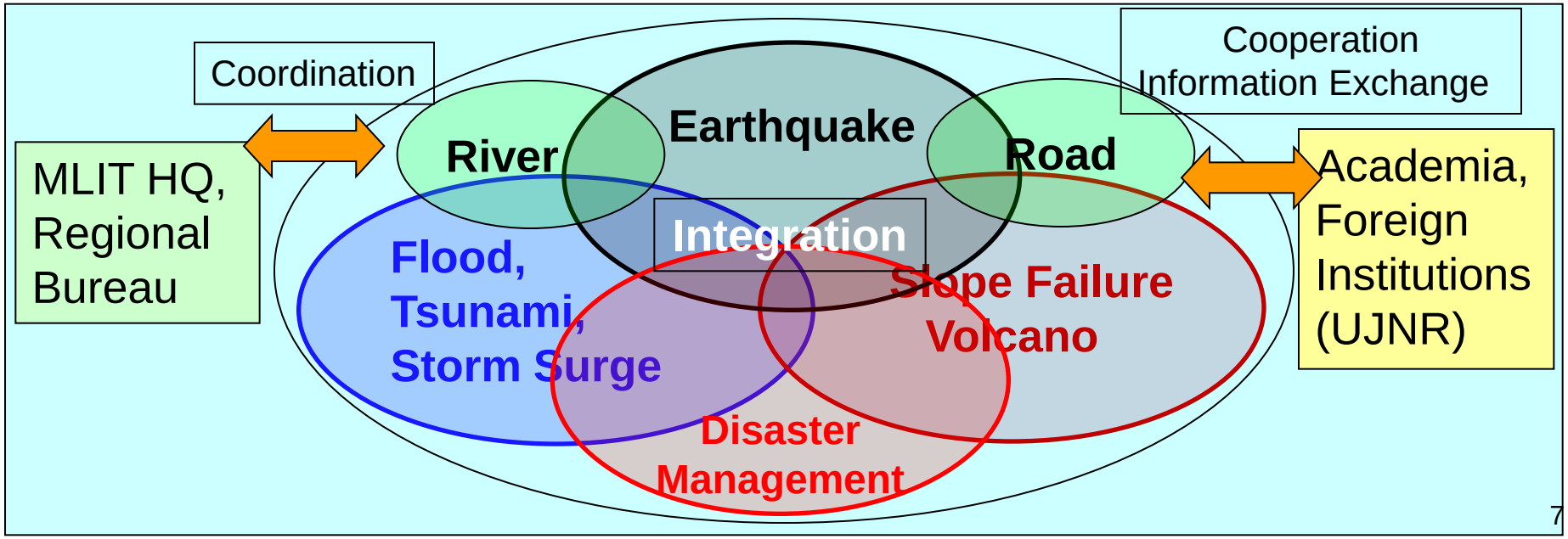
NILIM 3-Year Research Program (2012-2014 FY)

"Risk and Crisis Management Strategy for Excessive and Multiple Actions of Natural Disasters"

*) Excessive and Multiple Actions of Natural Disasters (EMAND)

All-out Mobilization Concept of Countermeasures

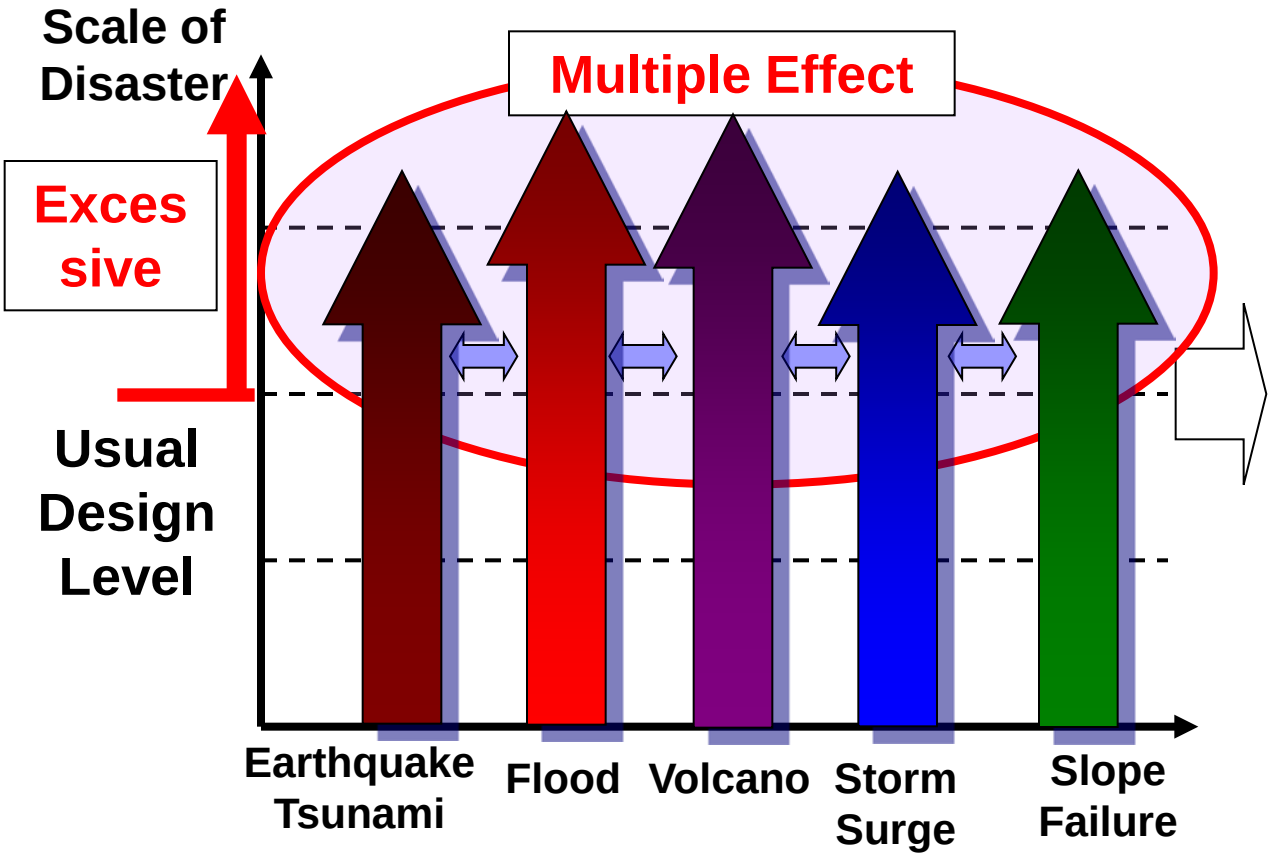
The project is included in the **MLIT's Master Plan for Technology Development** which was issued by the Panel on Infrastructure Development on Dec. 10, 2012.



Objectives

Review and Reconstruction of Disaster Mitigation Technology (Emergency Management) against Excessive and Multiple Actions of Natural Disasters

Keyword "Think outside the Box!!" "Beyond the Estimations!!"



●Exceeding Disasters

→Exceeding Actions

(Intensity, Scale, Area)

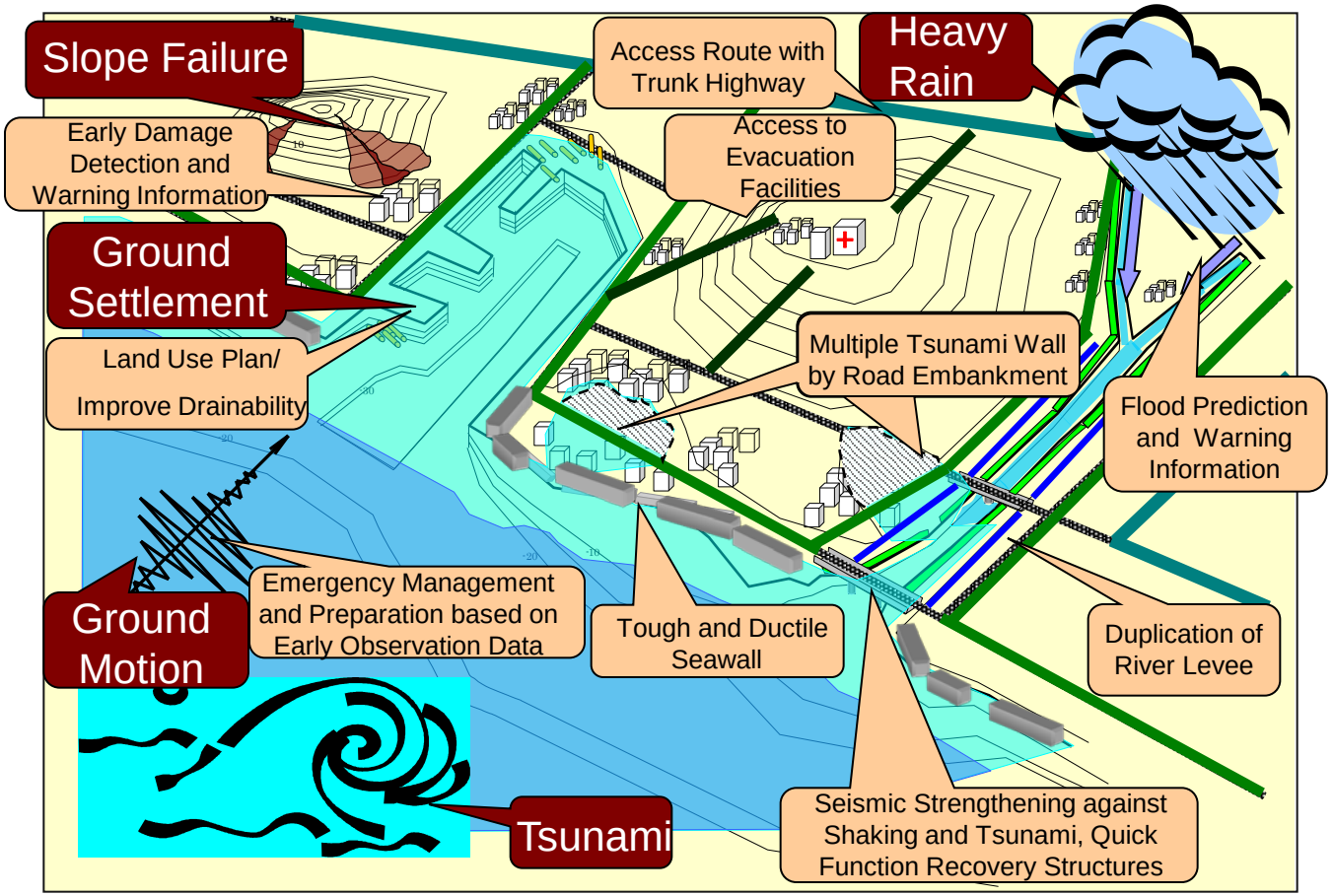
→Complex Effects

(Flood after Earthquake Heavy Rain after Volcano Eruption)

→ Respond to the Extreme Disasters with Low Frequency but High Impacts

NILIM 3-Year Research Program (2012-2014 FY)

All-out Mobilization Concept of Countermeasures
-Best Combination of Hard Measures and Soft Measures-



Research Topics

1. Re-Analysis of Past Damage Experiences by Excessive and Complex Disasters

   "Learn again what happened and Think what will happen"

2. Development of Scenario based Evaluation Methods of Disaster Occurrence and its Progress, and Risk Evaluation Methods

   "Understand how large the effect is and what we must protect"

3. Improvement of Emergency Management Technology and Provision of Disaster Prevention/Mitigation Infrastructures

   "What we have to prepare for next events "

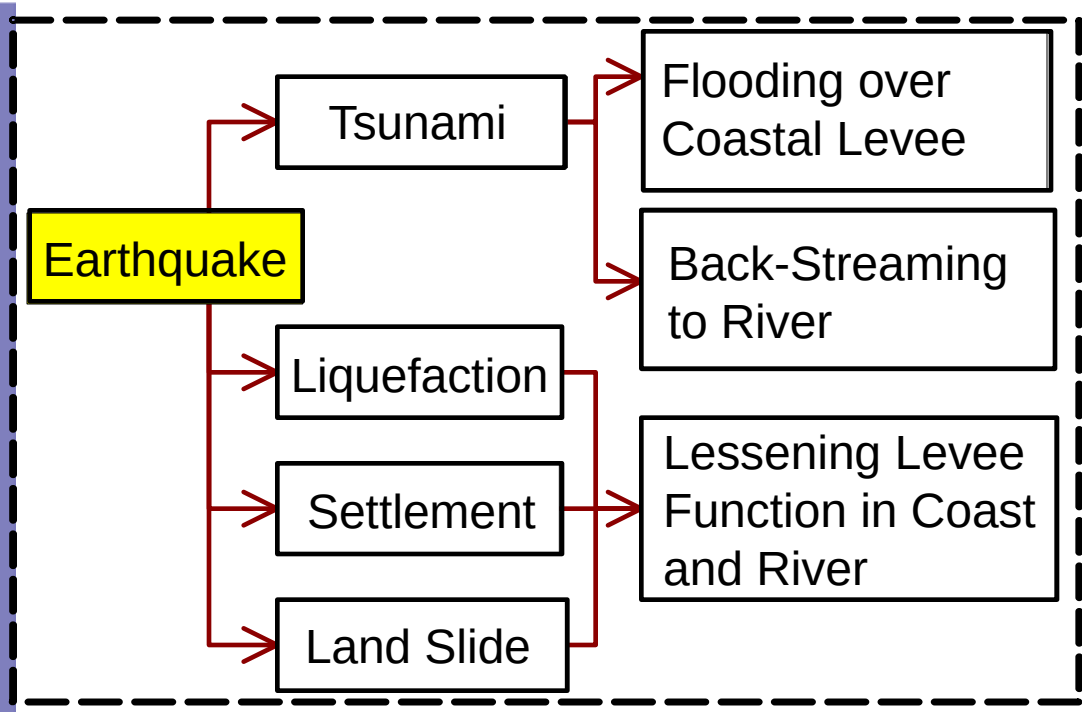
1.Re-Analysis of Past Damage Experiences by Excessive and Complex Disasters

- ◆ To know fully about EMAND
- ◆ Approach to consider both actual events and possible events with no experience is used for the analysis.

◆Chain Spreading of Disasters

The events of disaster and the chain spreading influences to the society are studied using tree diagram concept.

Clarify the disaster mechanism again to enhance the capability not to miss all possible important events and for flexible disaster management with well understanding of disaster.



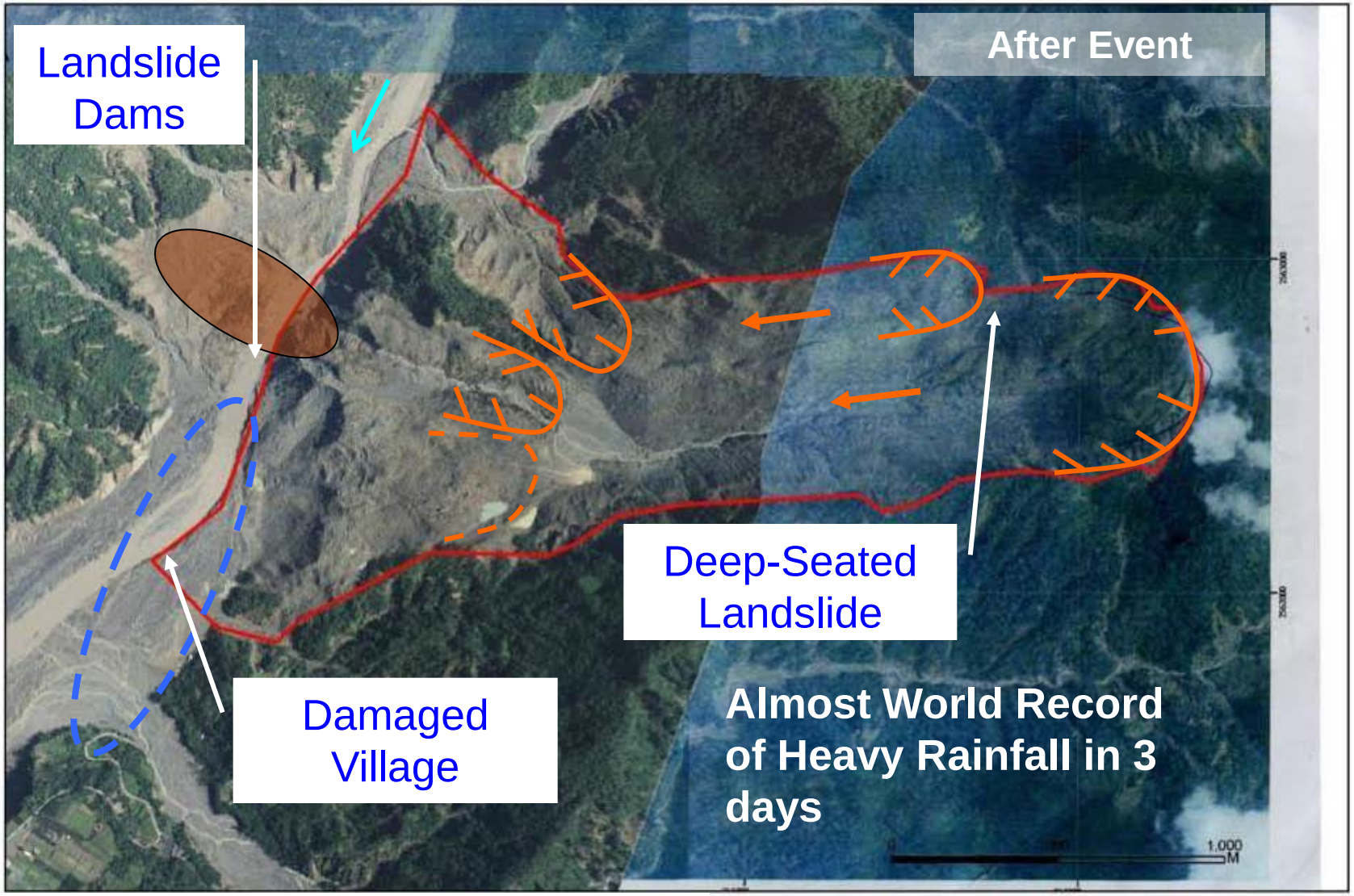
Excessive Disasters (Earthquakes)

1. Northridge Earthquake, USA (1994)
   Kobe, Japan (1995)
   → The strongest shaking with 1G
2. Kocaeli Earthquake, Turkey (1999)
   Chi-Chi Earthquake, Taiwan (1999)
   → The large ground fault displacement around 10m difference
3. Indian Ocean Earthquake (2004)
   → The largest Tsunami of 30m High
4. Iwate-Miyagi Earthquake, Japan (2008)
   → The large Slope Failure
5. China Earthquake (2008)
   Chile Earthquake (2010)
   → M8～9 Class Large Earthquake (Wide Affected Area)
6. Great East Japan Earthquake, Japan (2011)
   → M9, the largest Tsunami of 30m High

Great Nature says to Human Beings
What do you do for next?

Complex Disasters (Heavy Rain and Sediment Disasters)

(Aug. 9, 2009 Damage in South Taiwan by Typhoon MORAKOT)



Deep-Seated Landslide with Width: 800m, Length: 2.5km, Dams with 50m High

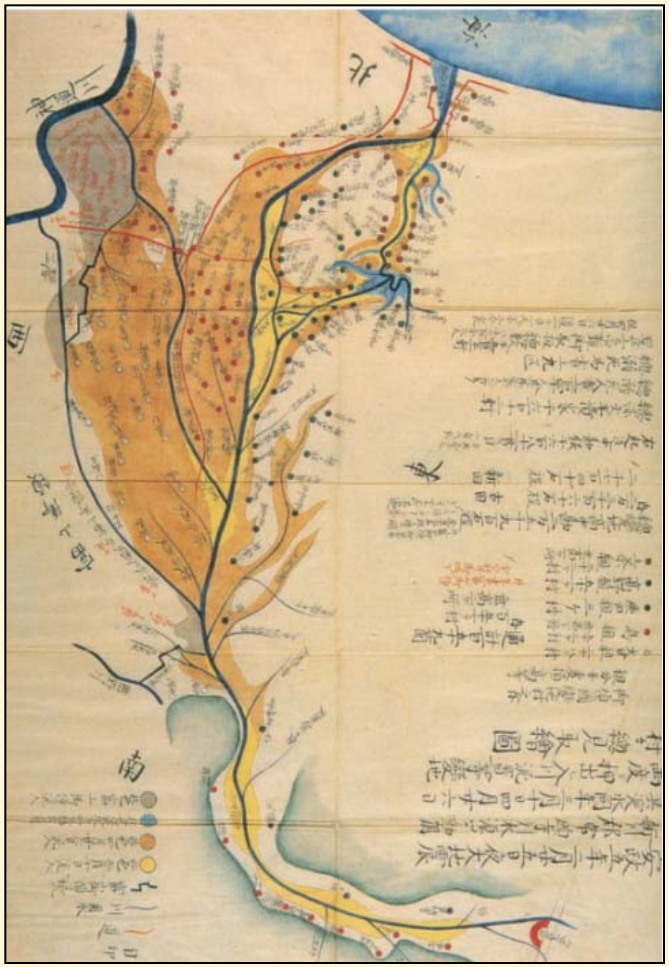
Casualty: over 500

Data Source: Gov. of Taiwan

0 100 200 400 600 800 Meters

Historical Complex Disasters in Japan

Earthquake and Flood



Data Source) 嶋本･高野･前田:安政大災害における加賀藩の災害情報と対応、立山カルデラ紀要、第9号、2008

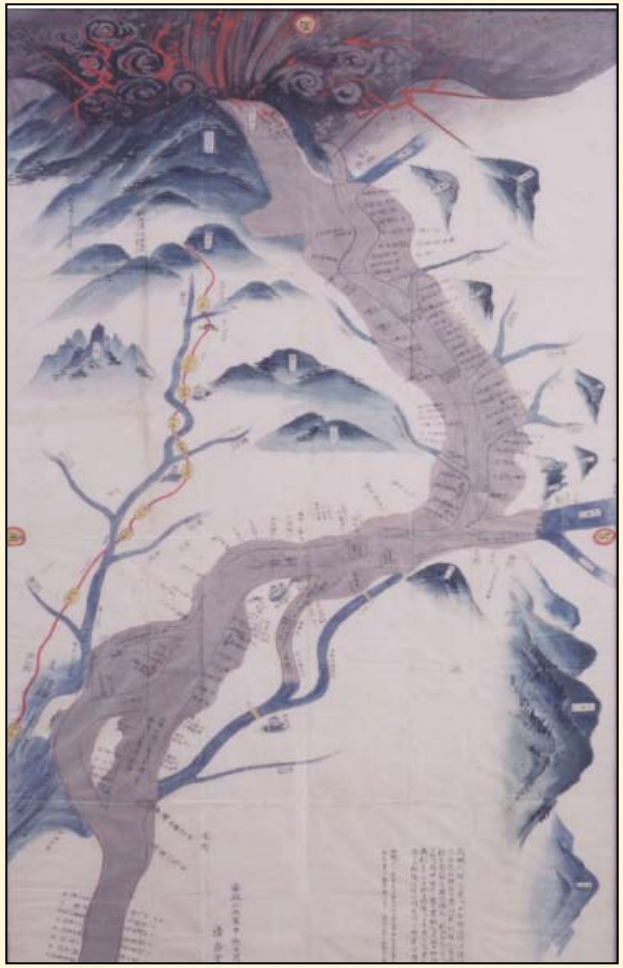
Ansei Earthquake (1858)

Large Landslides
→ Sediment Deposit of 400 million m^3
→ Landslide Dam
→ Dam failed by Aftershock
→ Flood

Tenmei Eruption (1783)

Pyroclastic Flow
→ Sediment Dam
→ Dam Failed
→ Volcanic Mud Flow
→ In 1786 Flood (Casualty of over 1000)

Volcano and Flood



Data Source)浅間焼吾妻川利根川泥押絵図

2. Development of Scenario based Disaster Evaluation and Risk Evaluation Methods

- To see through EMAND
- To understand how large the effect of the disaster and what must be protected and what is effective countermeasures to minimize the effects.

- **Scenario Structure of Events**

  The method to build scenario structure of events dependent on the social and economical conditions of the regions is being studied.

  // earthquake, heavy rain, volcano and others as well as the combinations

  // typical model regions: mountain, flat, coastal, and urban areas

- **Risk and Influence Analysis**

  The size of risk/influence is computed to evaluate the disaster quantitatively. The evaluation key index is assumed to be casualty and direct/indirect damage cost.

Select out of Impact Spreading to be considered in development of Disaster Scenarios

Example of Chain Spreading Effects of Infrastructures Damage

Damage of Roads	Lessing Function	1st Chain Damage	2nd Chain Damage
・Slope Failure ・Bridge Damage ・Damage of Traffic Signals ……	・Traffic Disfunction ・Traffic Control Disfunction ……	・Evacuation Interruption ・Traffic Interruption for Emergency Vehicle ……	・Delay of Recovery Action ・Lack of Emergency Goods/Equipments ・Lack of Foods, Living Necessities ・Industrial Mobilization Disfunction ……

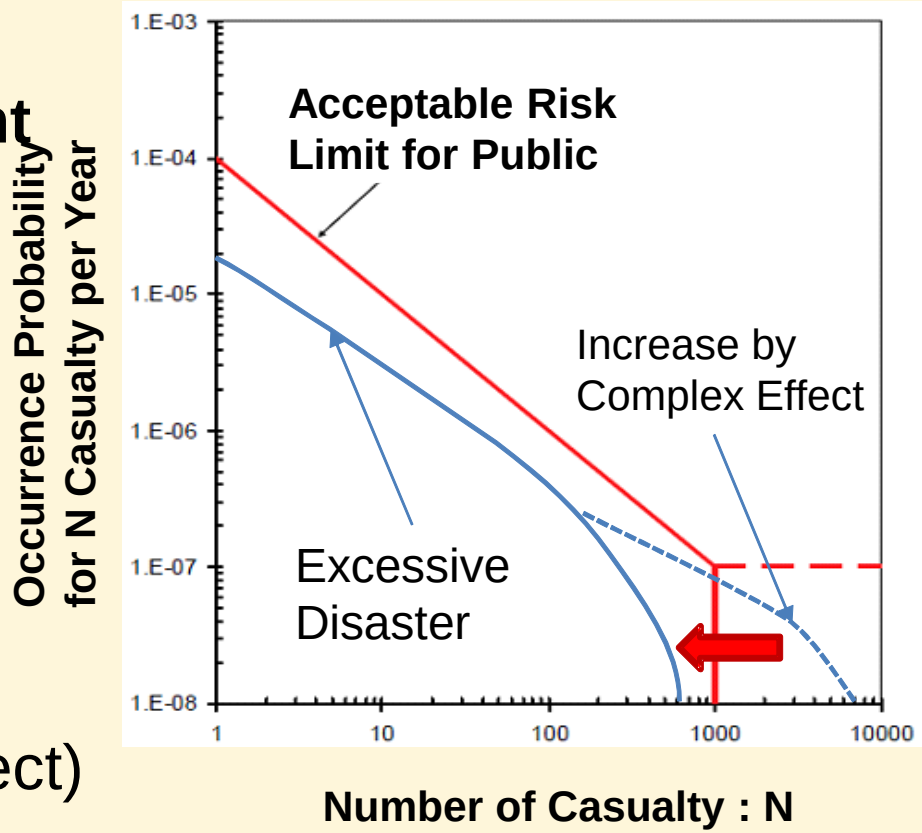
Spread to Regions

Spreading Effect by Flooding

- Inundation to Underground Space
- Failure to Escape
- Power down, Disfunction of Buildings

Evaluation of Risks and Influences of Disasters

The impact size by the index of casualty and/or damage costs is evaluated dependent on the level of the EMAND.



Source) Interim Tolerable Risk Guidelines for US Army Corps of Engineers Dams, USSD Conference, 2009

- **Number of Casualty**
- **Direct/Indirect Cost**
  - Index IE:

    IE= β_1(Construction)
    $+\beta_2$(Countermeasure)
    $+\beta_3$(Damage (Direct/Indirect)
    $+\beta_4$(Repair)
    $+\beta_5$(Other Impact)
  - Dependent on Provision of Facility and Countermeasures, and consider duration time for repair and rehabilitation

3. Improvement of Emergency Management Technology and Provision of Disaster Prevention/Mitigation Infrastructures

◆ To manage coolly EMAND

◆ All-out Mobilization Concept of Countermeasures

◆**Countermeasure Menu**

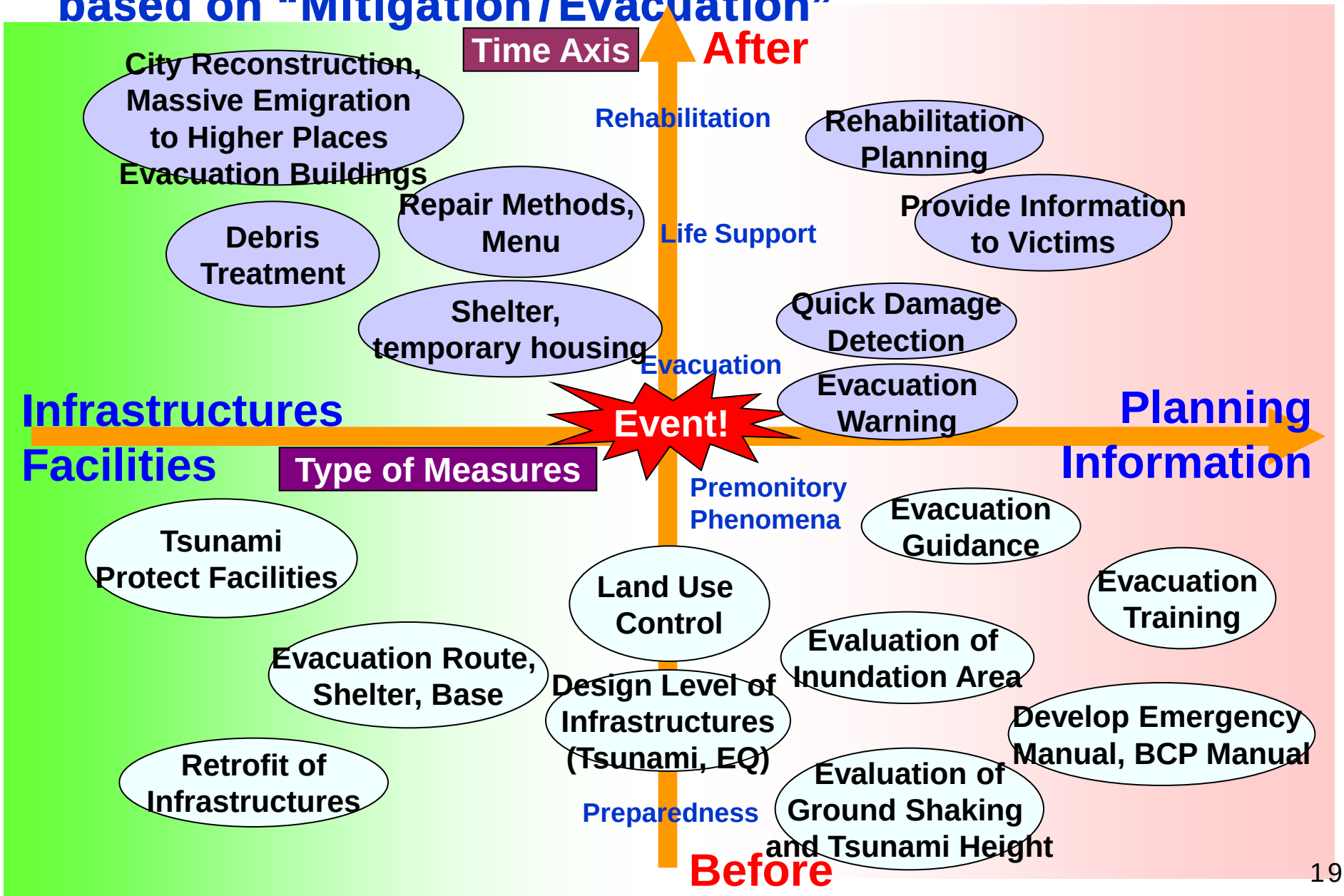
Effective and possible countermeasures to minimize the risk and impacts, and to hold back the chain spreading with large effects are studied.

◆**Multi-level Countermeasure Concept** (next move)

・Combination of the prevention, mitigation, and evacuation countermeasure concept and multi-level protection concept depending on the level of disasters

・Even when the disaster exceeded the expected level, it is essential to always provide the next move.

Example of Countermeasures: Every Possible Effort based on "Mitigation / Evacuation"



Multi-Level Countermeasure Concept

Well Preparation thinking "Outside the Box"

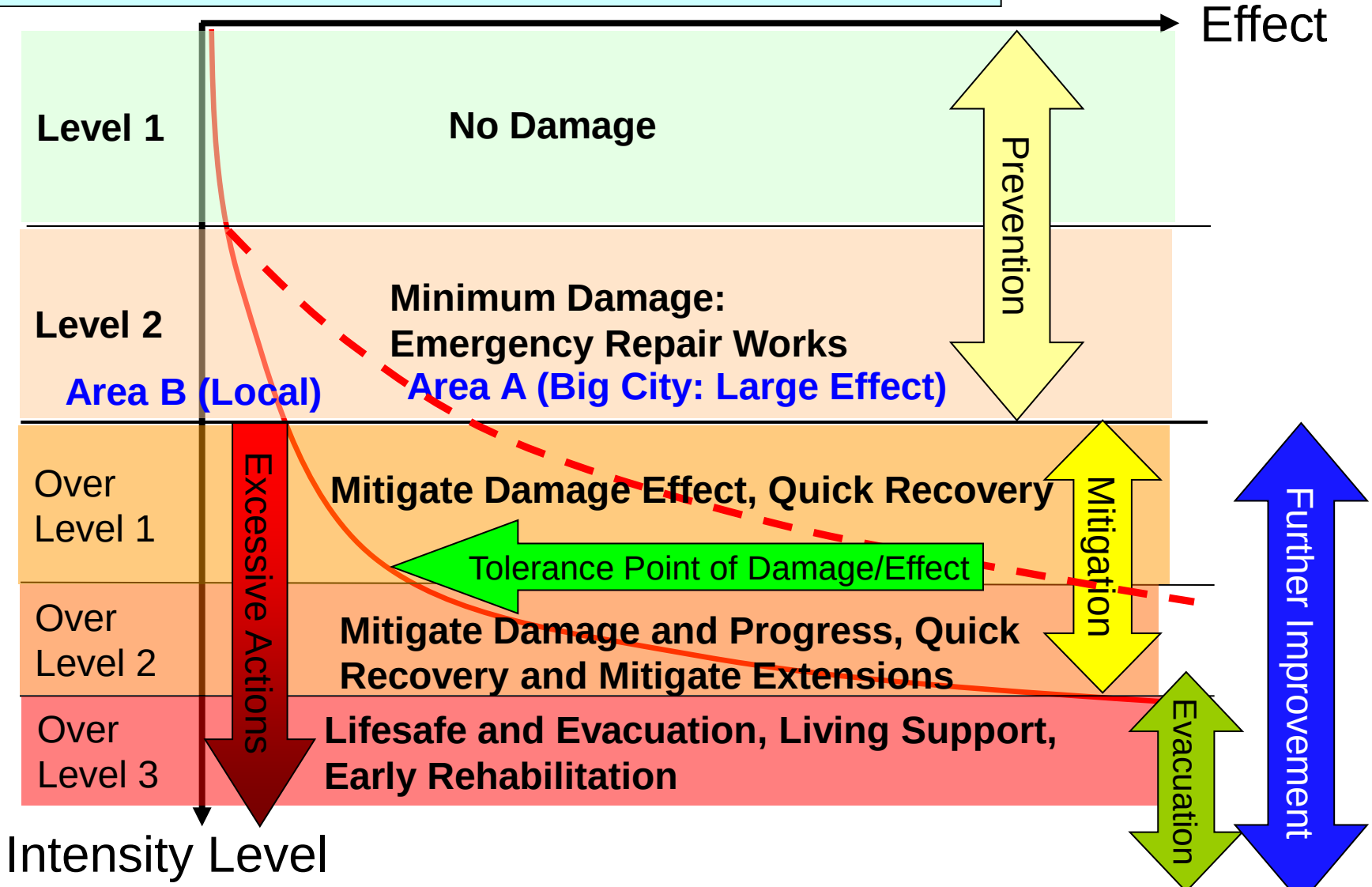
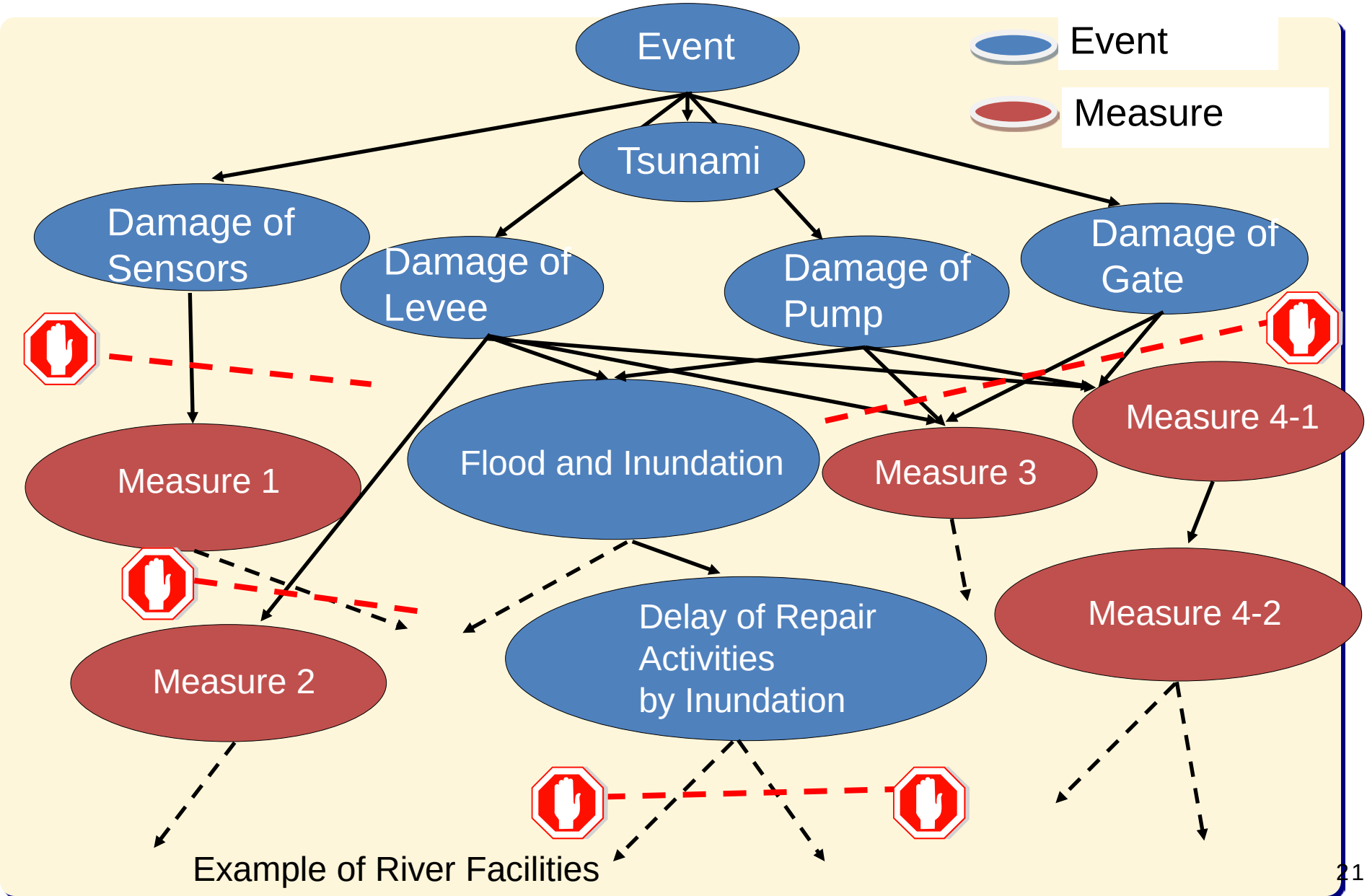


Illustration of Stop the Chain Spreading Influence



Final Target of Research

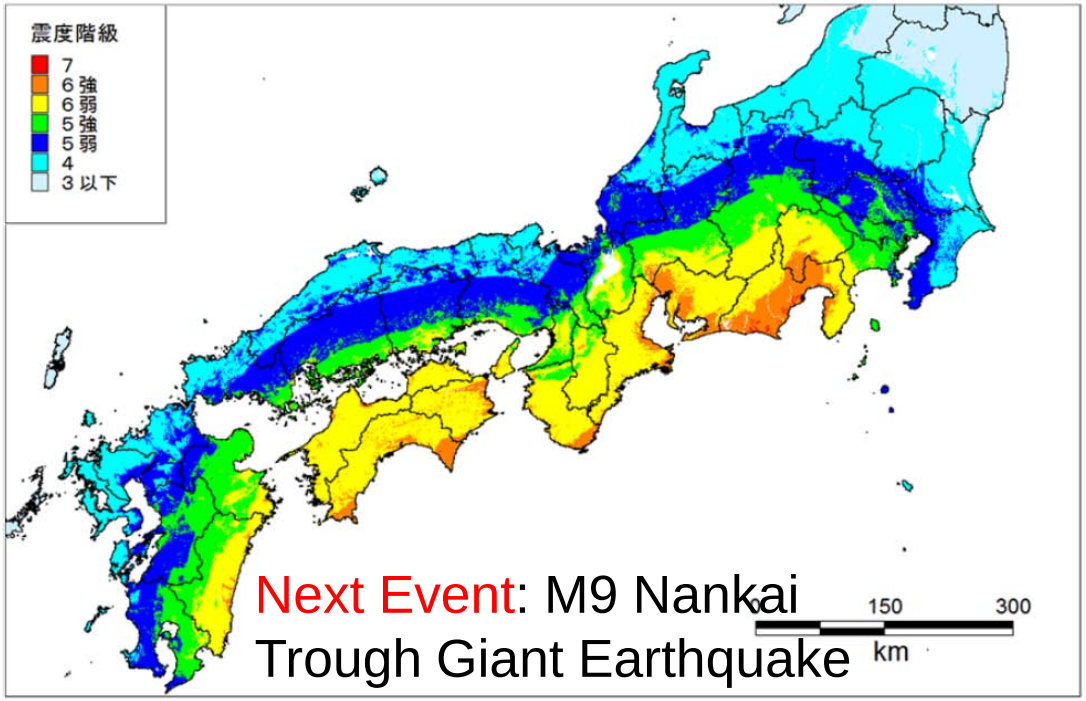
◆Outcomes

Development of Countermeasure Guidelines on Disaster Mitigation Technology

◆Application

1) Rehabilitation of Tohoku Earthquake
2) To prepare Next Events

Learn US Advanced Practices and Technology



ACKNOWLEDGEMENTS

◆Information Exchange

The authors visited US government agencies in Dec. 2-8 in 2012 to learn the US practices to manage natural disasters including the advanced technology.

Great appreciations to

Dr. W. Phillip Yen, Principal Bridge Engineer, FHWA/DOT for kind arrangement of all the visits to US federal agencies and Louisiana state agencies

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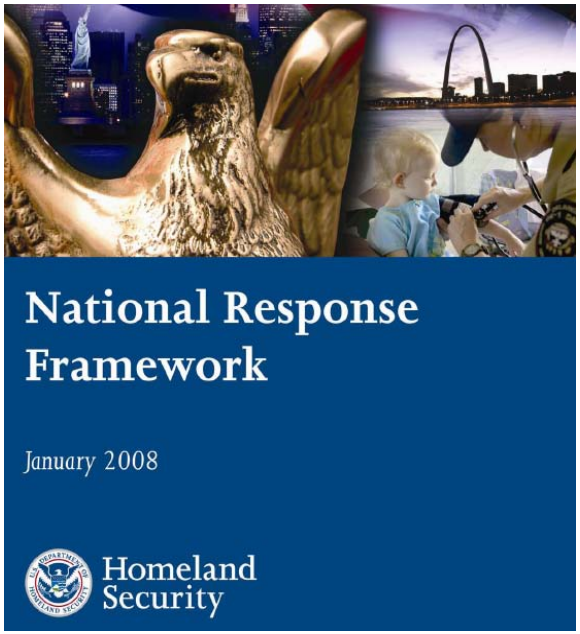
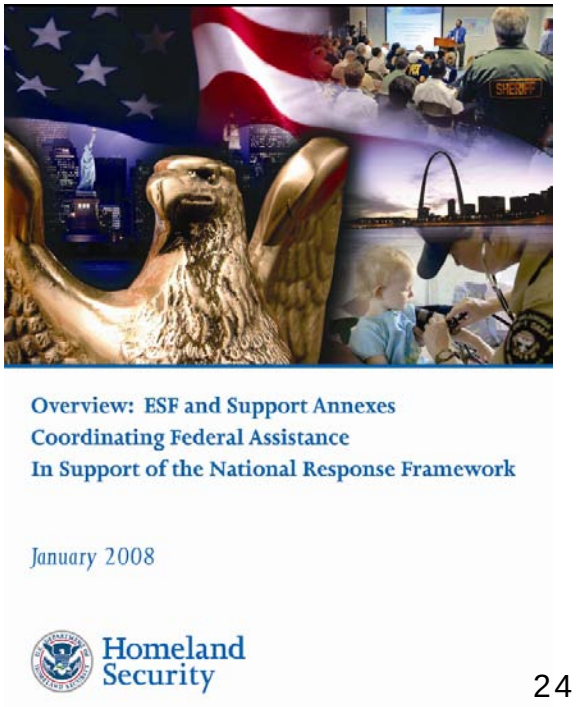
for providing us the useful information on the US practices during their busy time.

ACKNOWLEDGEMENTS

◆**Learning Lessons from Hurricane Sandy**

MLIT will send the survey team to DC and NY to learn the lessons from the damage caused by the hurricane Sandy from Dec. 25 to Mar.1. The damage to the big city, New York area, with a dense population, including power shut-down and flooding of underground spaces, caused so significant effects on the people and city functions.

We will learn about the experiences on the effective disaster responses conducted by US government. I believe that the US best practices and lessons learned from the Sandy will help us so much to improve Japan's emergency management capability (preparedness and responses) toward the development of resilient society.