

**Special Session for the Great East Japan Earthquake**  
15 WCEE, Lisboa, September 24, 2012



**Geotechnical Effects of  
the March 11, 2011, Tohoku,  
Japan earthquake**

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# **Major Geotechnical damage** due the 2011 earthquake in tsunami-unaaffected regions

- Soil Liquefaction
- Levee damage
- Ground deformation of recently developed land in hilly area
- Collapse of Fujinuma earth dam
- Land slide of natural slope

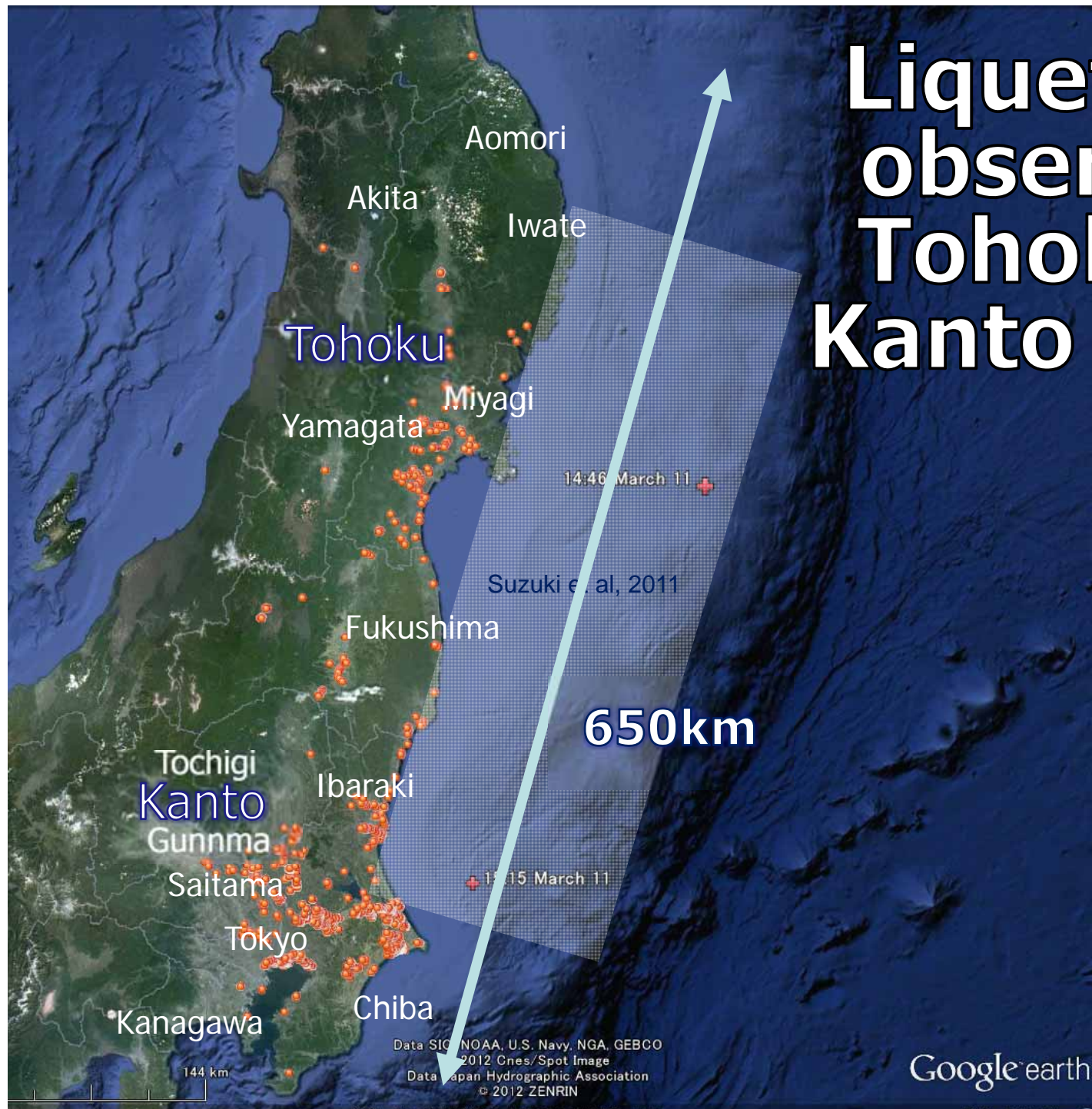
# Soil Liquefaction



Urayasu City

Yokoyama Tohru : [https://www.youtube.com/watch?v=qeA\\_rrv09Lo](https://www.youtube.com/watch?v=qeA_rrv09Lo)

# Liquefaction observed in Tohoku and Kanto regions





# Liquefaction Effects

- Residential houses
- Lifeline facilities
- Embankment
- Agricultural facilities
- Port facilities

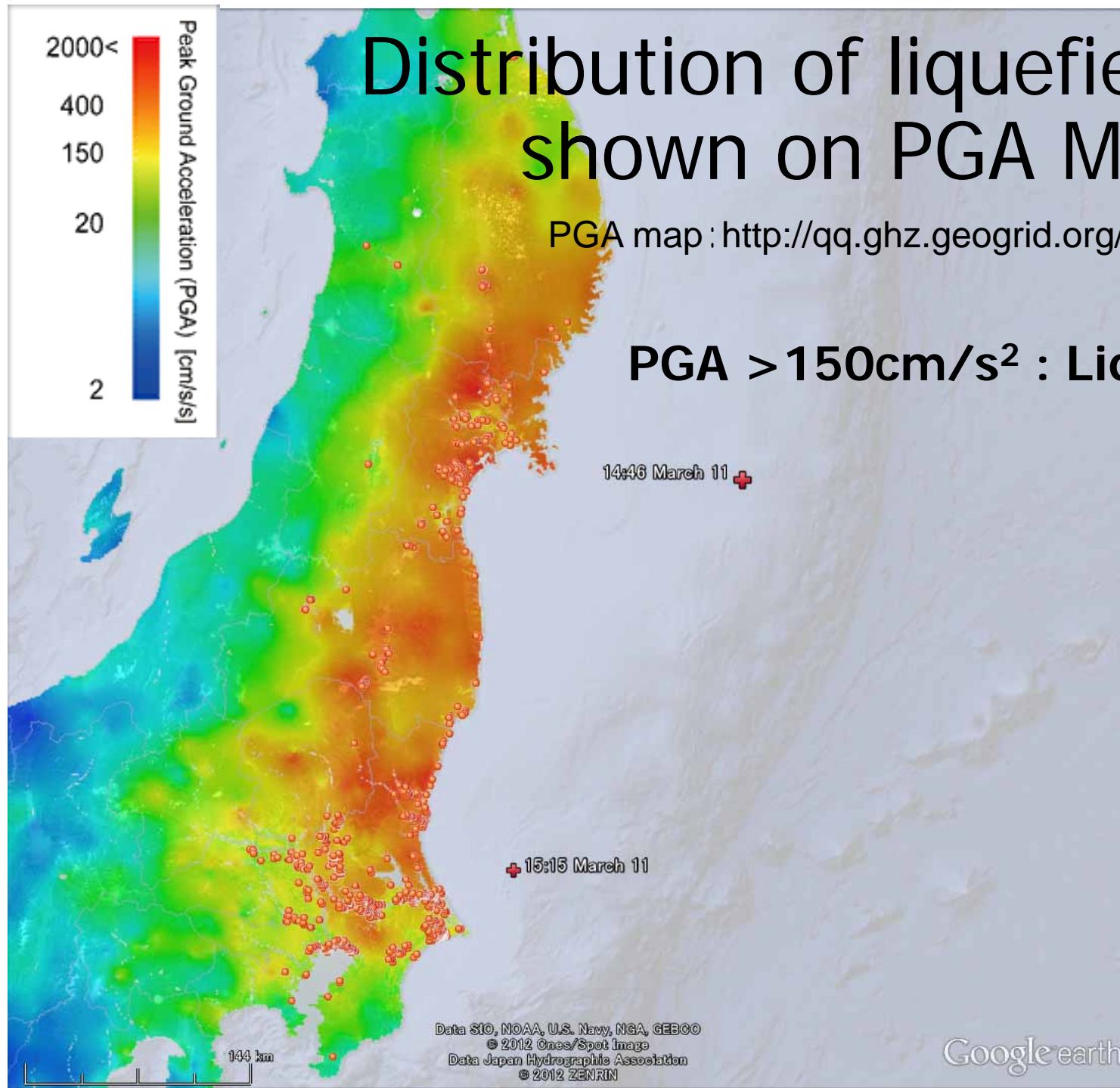




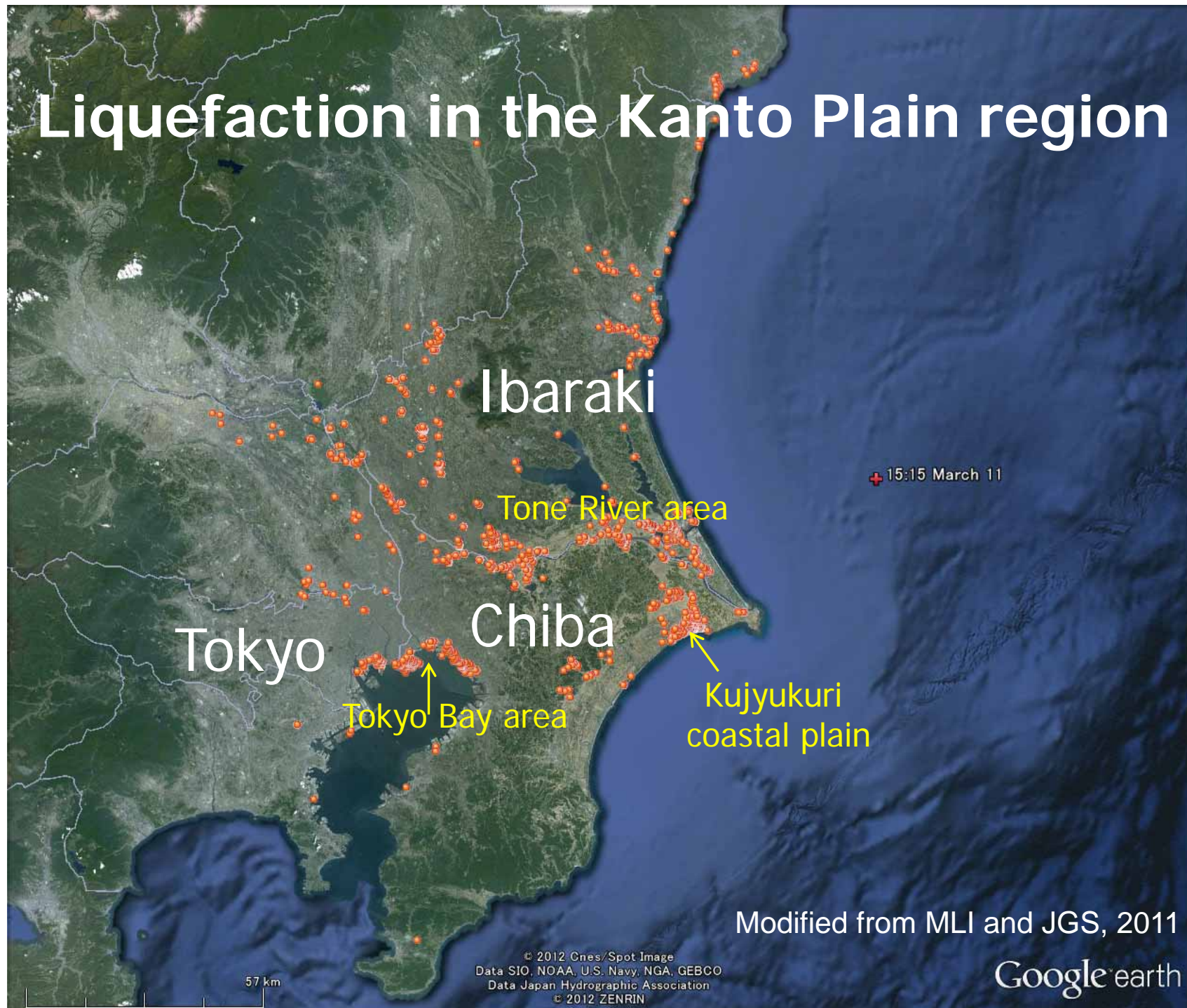
# Distribution of liquefied sites shown on PGA Map

PGA map : <http://qq.ghz.geogrid.org/QuakeMap/> (AIST)

**PGA > 150cm/s<sup>2</sup> : Liquefaction**



# Liquefaction in the Kanto Plain region





# Huge amount of sand erupted



Courtesy of Dr. Isoyama

Mihama and Mihama,  
Urayasu City



Courtesy of Urayasu City



# A house before and after the 2011 Earthquake in Urayasu



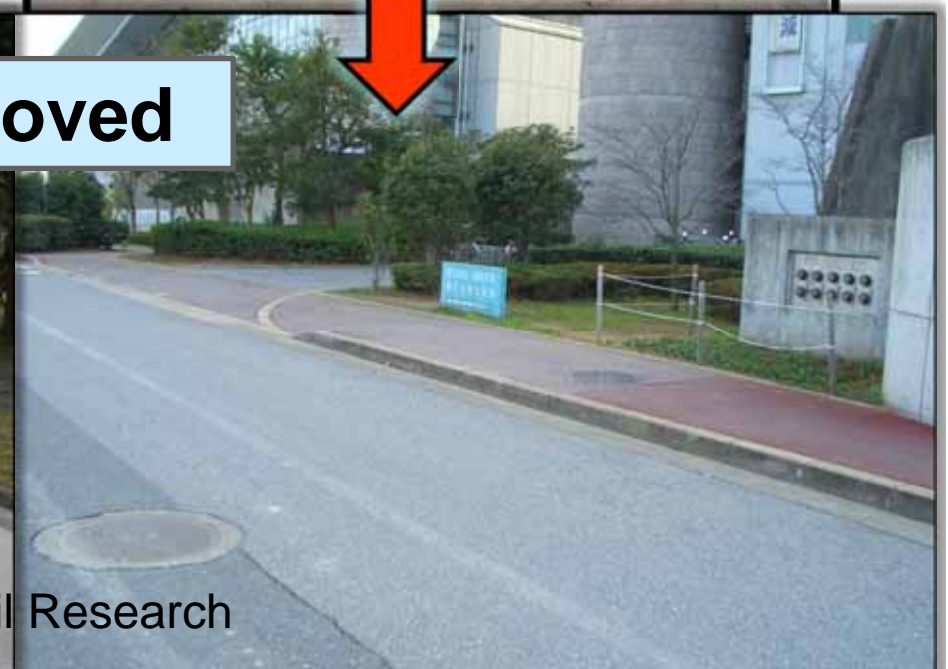
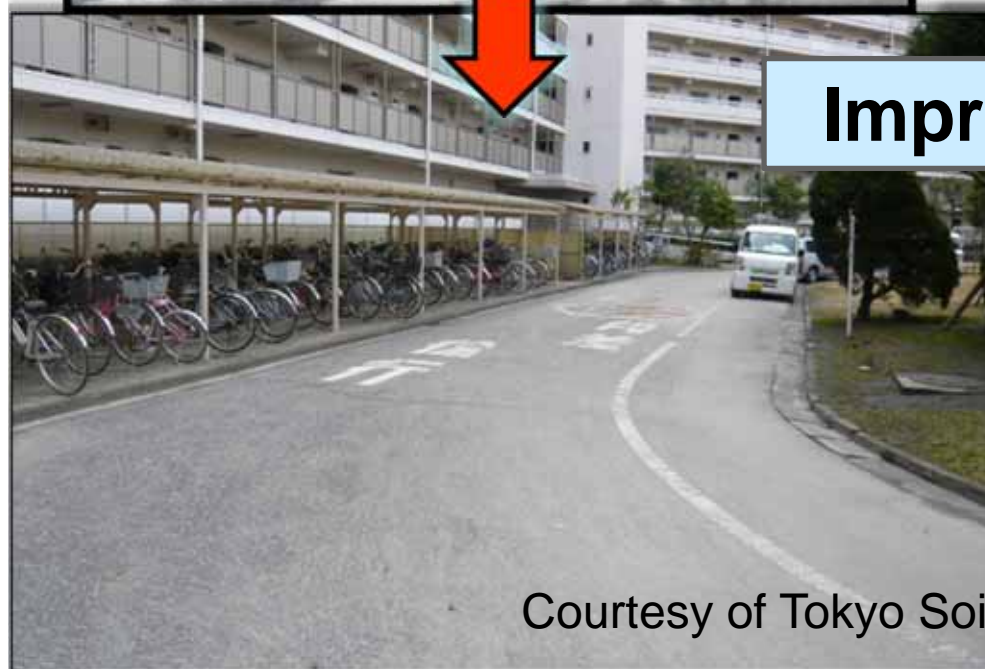
**Before earthquake**

Courtesy of Mr. Yamato

**After earthquake**



# Successful examples of soil improvement (Vibroflotation)





# Successful soil improvement in Urayasu residential area

Gravel drain

Sand compaction pile



Irifune-kita Area, Urayasu City

Towhata et al. (2011)

# Relative settlement between building with pile foundation and surrounding ground



from home page of Urayasu City



from home page of Urayasu City



from home page of Urayasu City



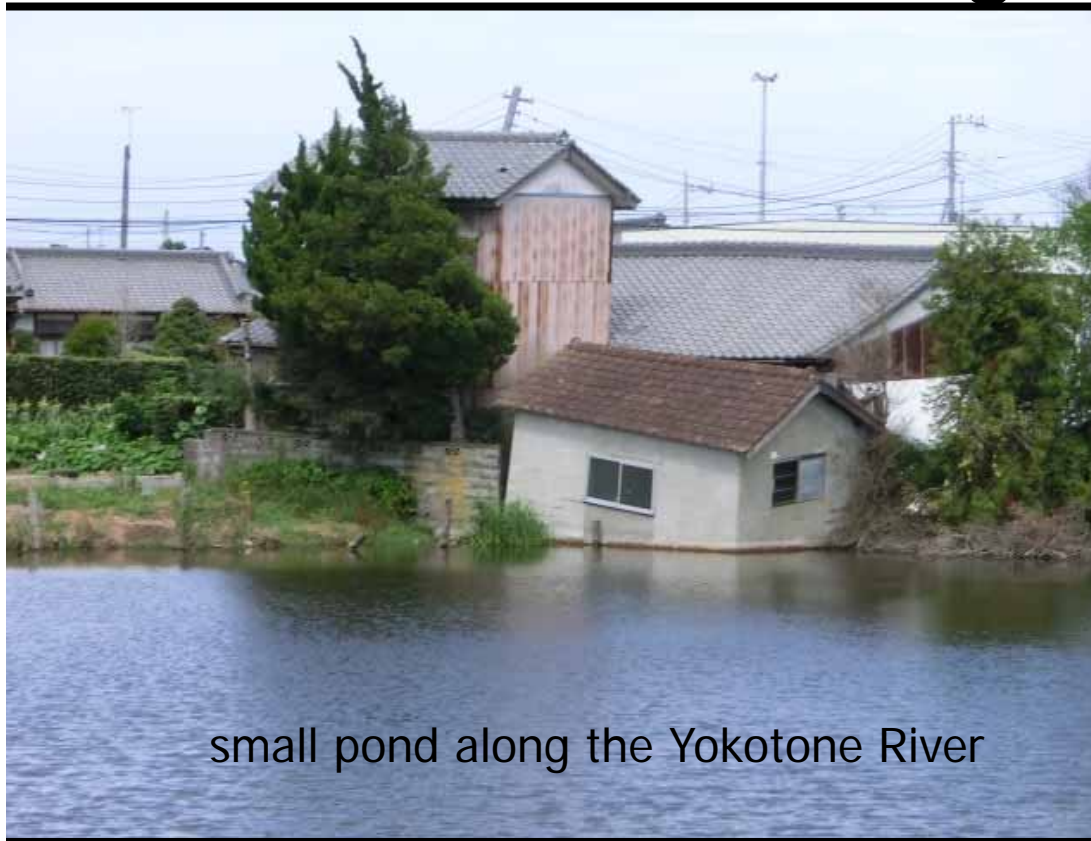
Katori city



# Large differential settlement (area along the Tone River)



# Lateral spreading occurred in the area along the Tone River



small pond along the Yokotone River



Courtesy of Inashiki City



Water Channel

from home page of Katori City



# Uplift of manholes observed wide area

Urayasu, Chiba Prefecture

Sukagawa, Fukushima Prefecture



Towhata et al. (2011)

# Water distribution plant in Kashima City

Maximum daily water supply:  
30,000m<sup>3</sup> for domestic water  
150,000m<sup>3</sup> for industrial water

←→  
underground conduit

Public Enterprise Bureau, Ibaraki Prefecture (2011)



# Inside of uplifted underground conduit



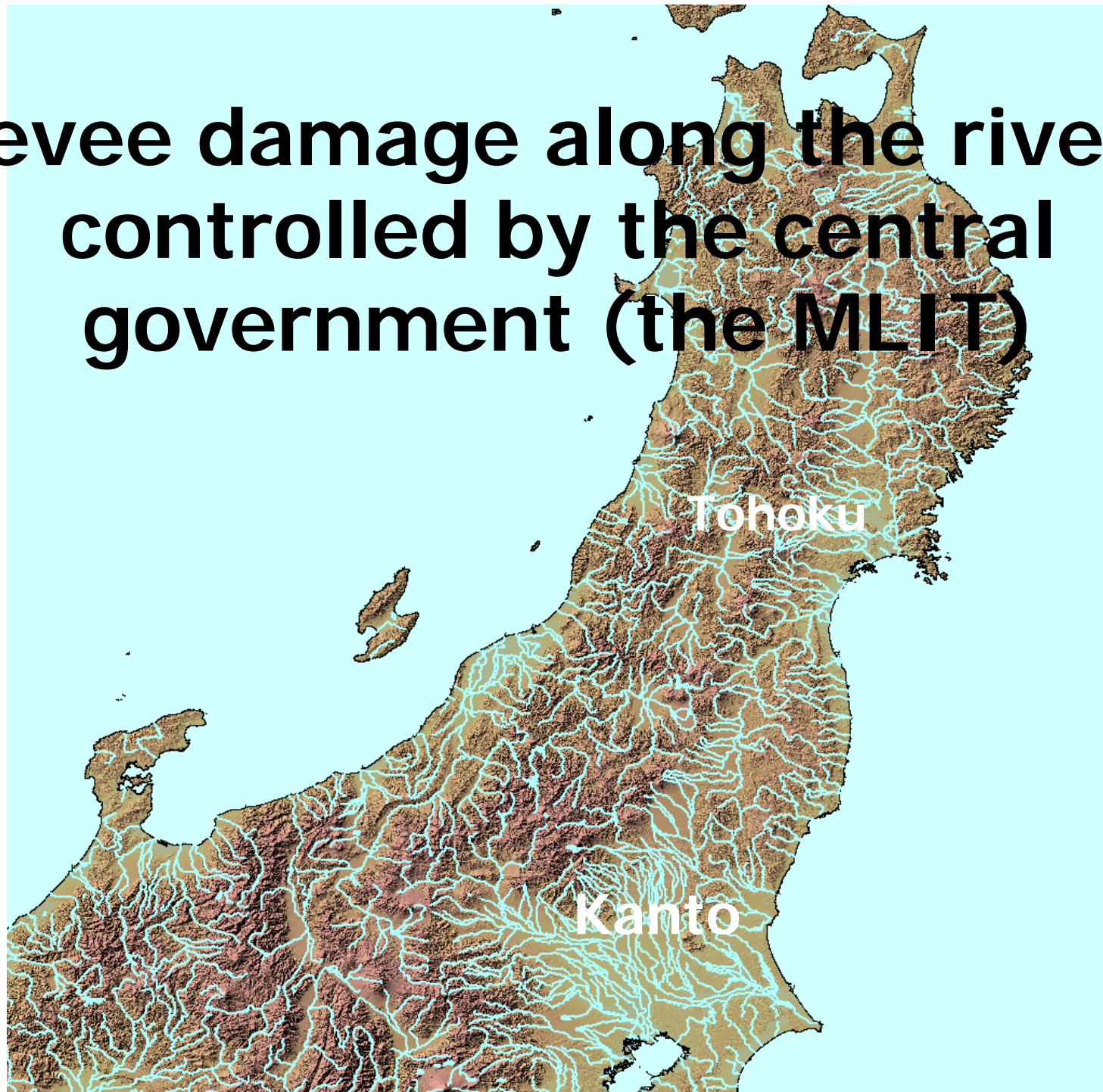
Courtesy of Nissuicon



Pipe break at flexible joint

Public Enterprise Bureau, Ibaraki Prefecture (2011)

# Levee damage along the rivers controlled by the central government (the MLIT)





# Type of Levee Damage Documented by the MLIT

	River System	Failure	Settlement	Slope Slumping	Levee Cracking	Liquefaction	Revetment/Wall Damage	Gate Damage	Other	Total
Tohoku region	Mabuchi	0	0	1	1	0	5	1	5	13
	Kitakami	14	62	46	278	0	121	67	58	646
	Naruse	9	27	25	183	1	56	26	37	364
	Natori	1	2	1	26	0	2	2	1	35
	Abukuma	2	26	16	77	0	2	11	3	137
Kanto region	Kuji	0	30	1	46	0	23	8	2	110
	Ara	0	0	0	5	12	0	3	2	22
	Naka	0	17	5	43	0	45	14	5	129
	Tone	0	106	37	291	22	106	55	42	659
	Total	26	270	132	950	35	360	187	155	2,115

# Damaged levee along the rivers controlled by the Central government

**TOHOKU REGION**

Kitakami River

Naruse River

Abukuma River

**KANTO REGION**

Tone River

- Major damage
- Moderate to minor damage

14:45 March 11

15:15 March 11

Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
© 2012 Cnes/Spot Image  
Data Japan Hydrographic Association  
© 2012 ZENRIN

Google™ earth

緯度 37.350147° 経度 141.804233° 標高 -452 m

高度 495.69 km



# Major slumping of landside slope of Naruse River right levee at river kilometer 29



Naruse River

## Major slumping of landside slope

Naruse River



Courtesy of PWRI

## Sand boils in the levee crack



Courtesy of PWRI



# Longitudinal Cracking and Slumping of the Kasumigaura Lake levee



Courtesy of Inashiki City





# Successful example of soil improvement of Naruse River right levee at river kilometer 14.7k+90~14.9k+70

No observable damage in the improved levee



Minor damage in unimproved levee





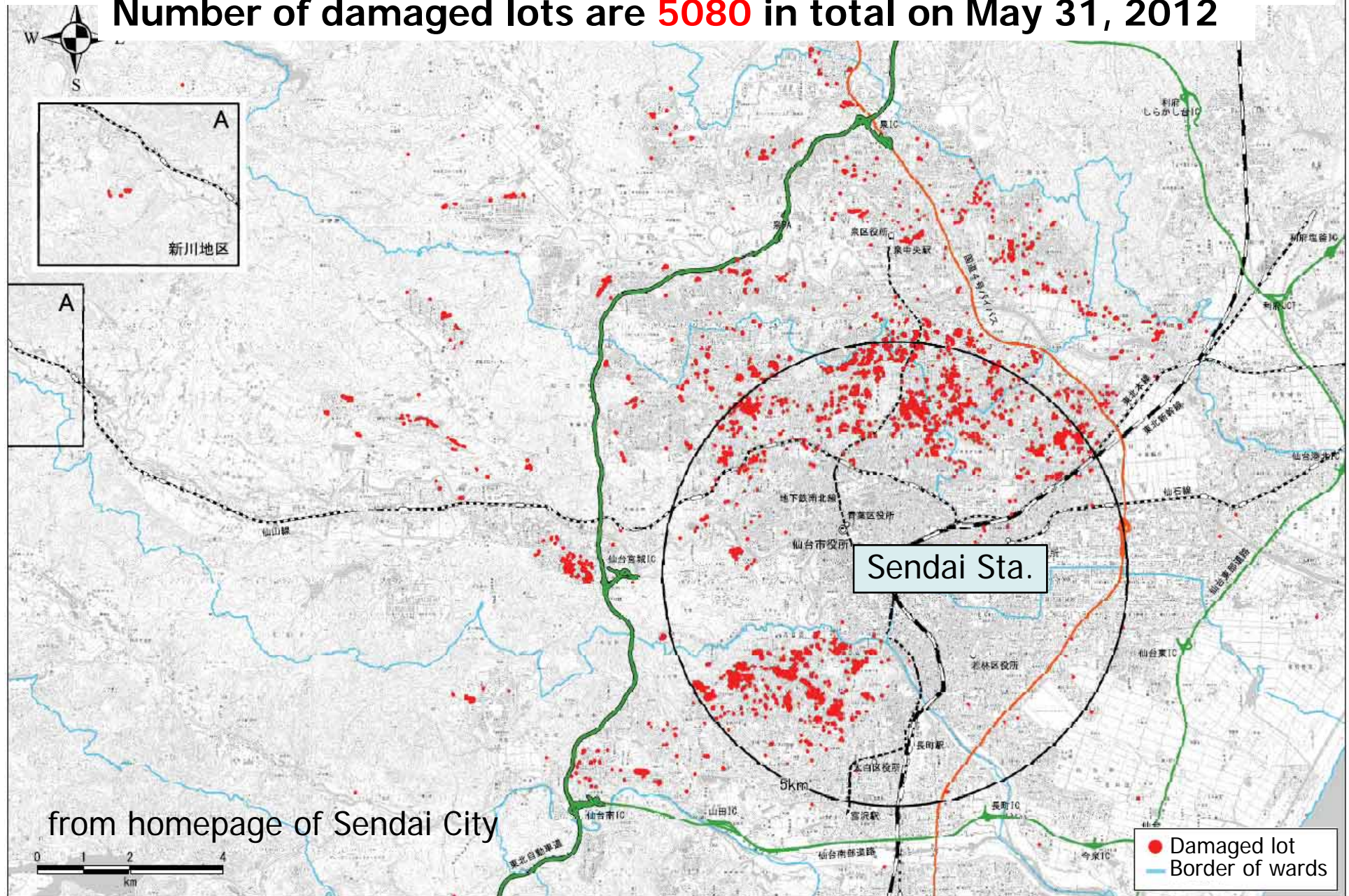
Ground deformation of recently developed land in hilly area





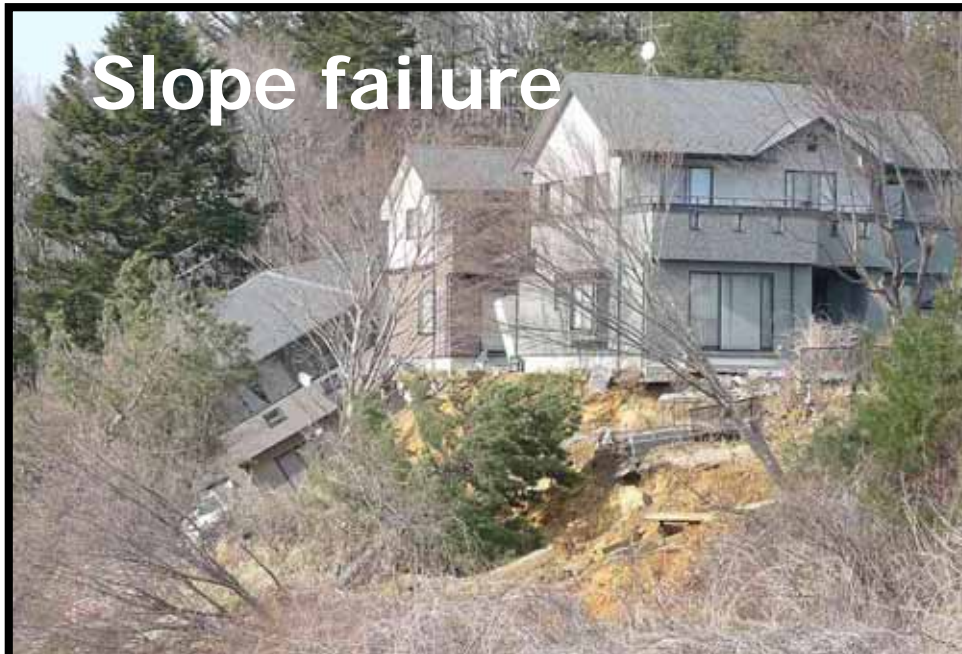
# Damaged housing land in Sendai City

Number of damaged lots are **5080** in total on May 31, 2012





# Damaged housing lots in Sendai City



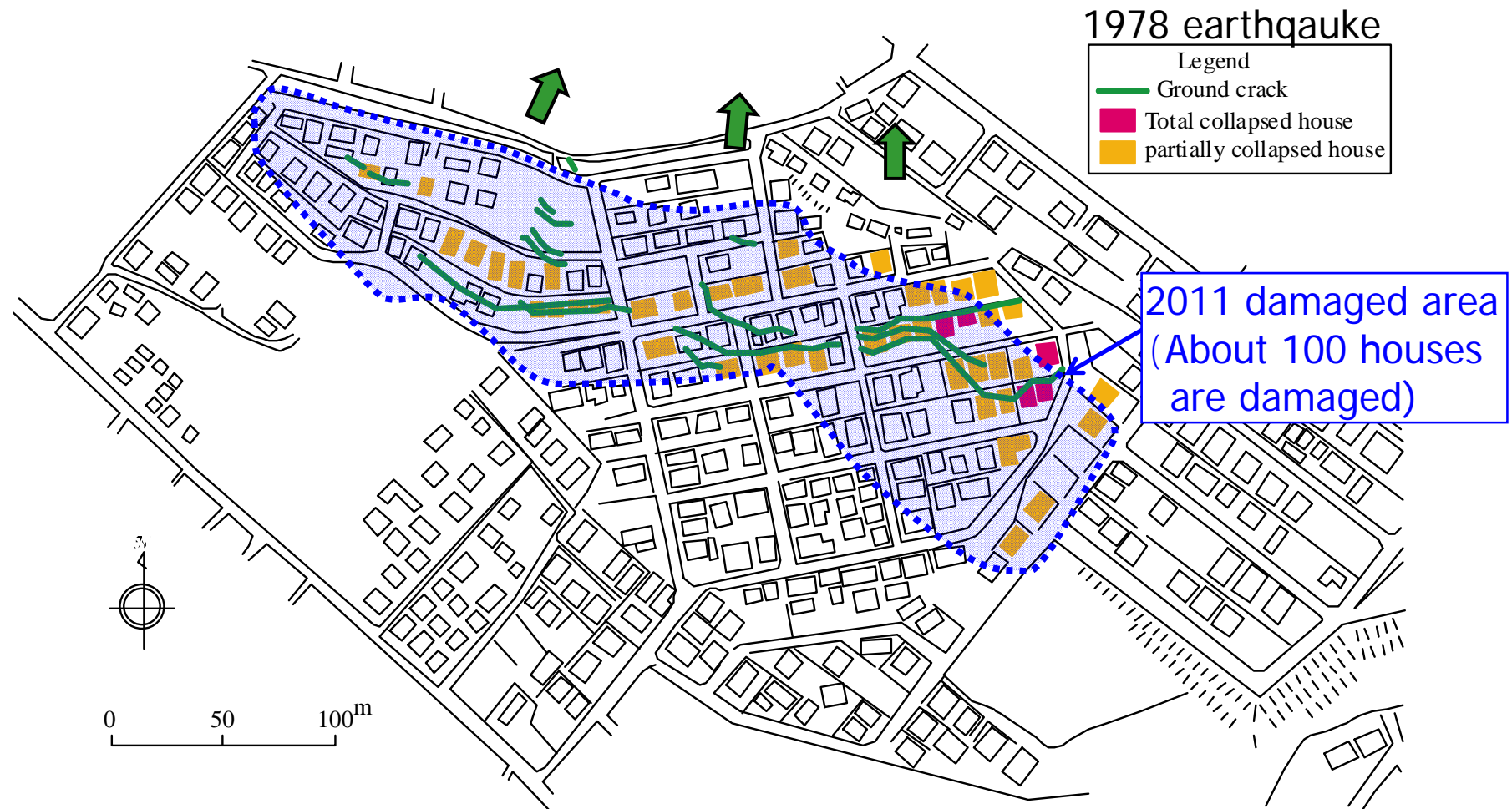
Courtesy of Prof. Yoshida



Courtesy of Mr. Sato



# Repeated damage in Midorigaoka 4-chome, Sendai



# 2011 damage in Midorigaoka 4-chome





# Midorigaoka 1-chome

1978 earthquake



Countermeasures

- Area has been converted to a green park
- Steel piles
- Retaining wall
- Drainage well

No observable damage

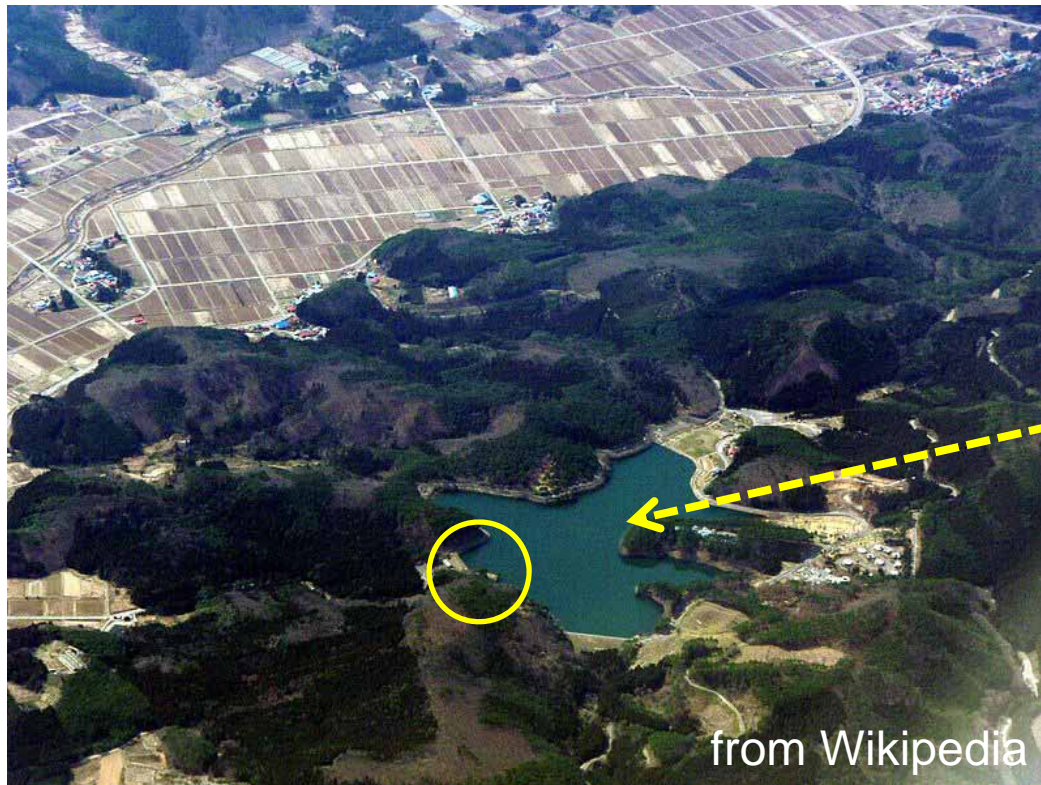
2011 earthquake





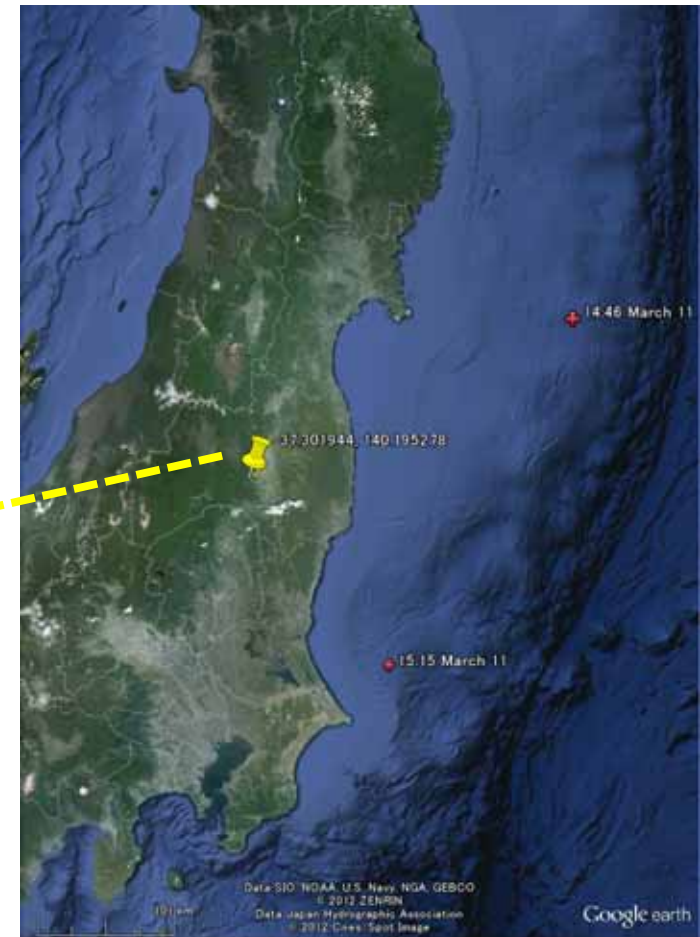
# Collapse of Fujinuma earth dam

## Southern Fukushima Prefecture



from Wikipedia

37.301944N, 140.195278E





# View of upstream slide



# Empty reservoir



Photo: [http://blog.goo.ne.jp/good\\_autoparts/e/8e7c5fa5df8265d55bfea0e36d84e6a4](http://blog.goo.ne.jp/good_autoparts/e/8e7c5fa5df8265d55bfea0e36d84e6a4)



# Valley after torrent



Photo: [http://blog.goo.ne.jp/good\\_autop](http://blog.goo.ne.jp/good_autop)

# Village attacked by flood



Towhata et al. (2011)



# Landslide of natural slope



Failure of natural slope at Hanokodaira  
Shirakawa City, Fukushima Prefecture



Rock fall at Ohgo, Ibaraki Prefecture

Towhata et al. (2011)

# Landslides in Iwaki City, Fukushima Pref.



Miyagi (2011)



# Concluding Remarks

- Geotechnical damage due to the 2011 earthquake was widespread and severe, which includes soil liquefaction, levee damage, dam collapse and landslides of fill and natural slope.
- Liquefaction had the most significant impact to structures and facilities.
- Countermeasures against liquefaction, landsliding and failure of embankment were demonstrated to be effective.