

# Lifelines, M 9.0 Tohoku Japan, March 2011

John Eidinger  
August 11, 2011

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More Information (free downloads): Lifeline Impacts, Japan and Christchurch Earthquakes:

[www.geEngineeringSystems.com](http://www.geEngineeringSystems.com)

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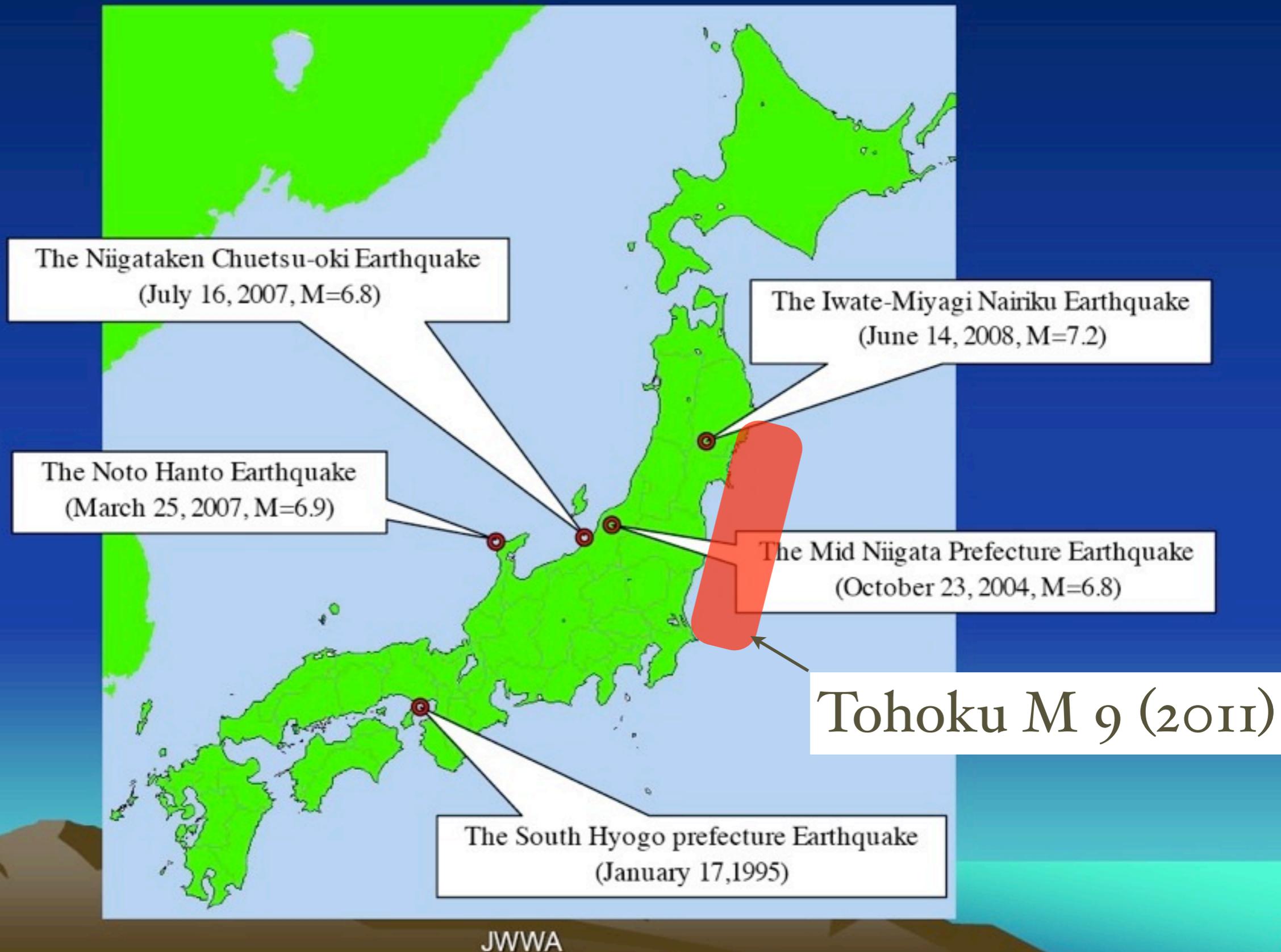
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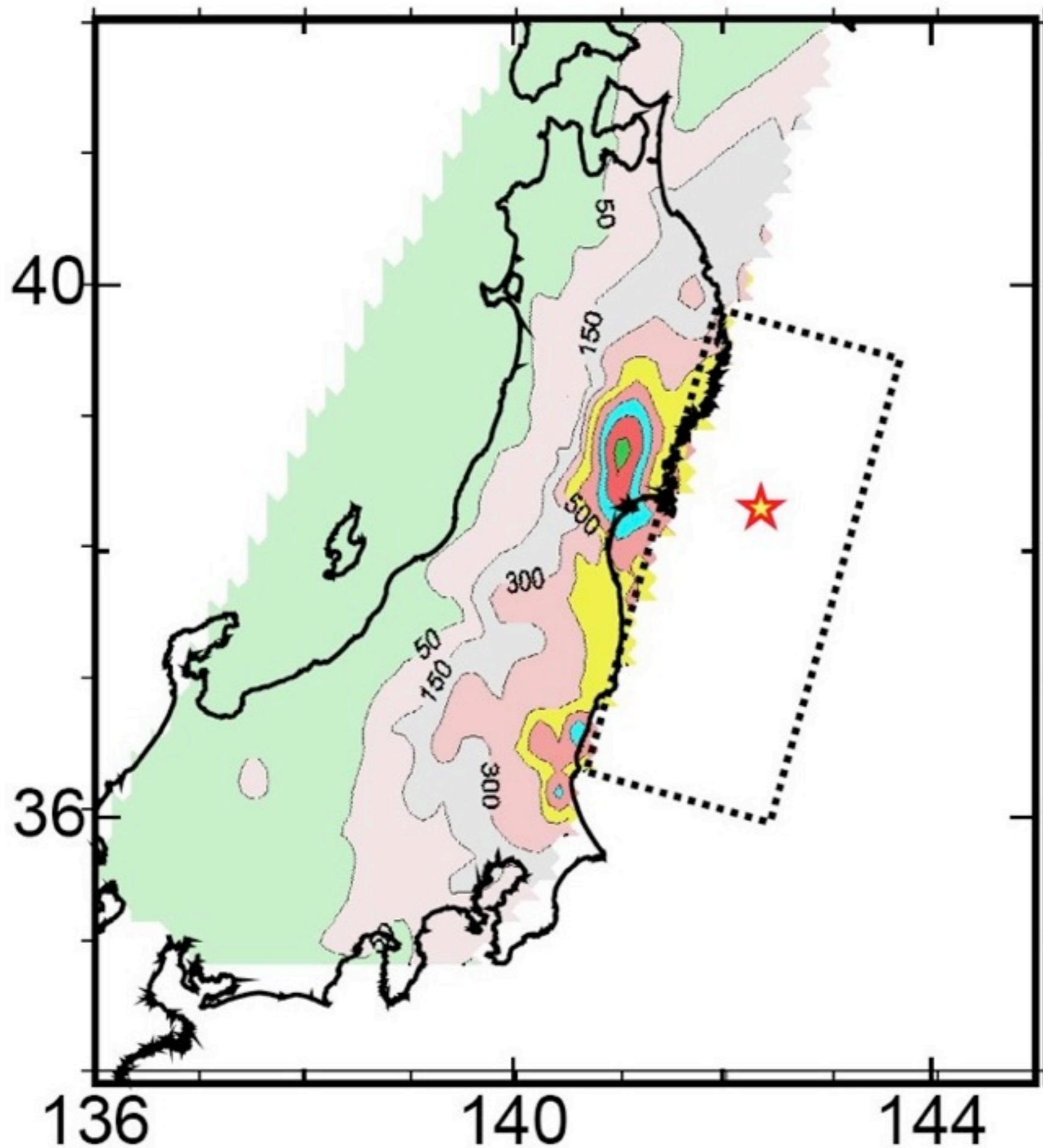
TCLEE web URL

<http://www.asce.org/Content.aspx?id=2147488653>

# 6 Major Earthquakes since the Great Hanshin Earthquake Kobe, 1995



# Maximum Ground Acceleration



**Unit: gals**

**Data from NIED**

Lifeline	Restoration Ratio	2011 M 9.0 Tohoku Chiba, Ibaraki, Fukushima Tokyo	2011 M 9.0 Tohoku Miyagi, Iwate	1995 M 6.9 Kobe
Electric	90%	4 days	6 days	2 days
	95%	7 days	10 days	3 days
	100%			7 days
Water	90%	36 days		38 days
	95%	41 days		43 days
	100%			81 days
City Gas	90%	35 days		64 days
	95%	36 days		71 days
	100%			84 days

Prefecture	Damaged Sewers (km)	Total Sewer Length (km)	Damaged manholes
Iwate (Note 1)	24	3,709	248
Miyagi (Note 1)	423	9,702	11,076
Fukushima (2)	181	5,073	3,397
Ibaraki (2)	208	9,679	4,727
Chiba (2)	81	9,260	1,805
Tokyo Met. Govt (2)	27	15,793	212

Note 1. Shake + Liquefaction + Tsunami

Note 2. Shake + Liquefaction

## Water Supply Disruption Conditions by Prefectures

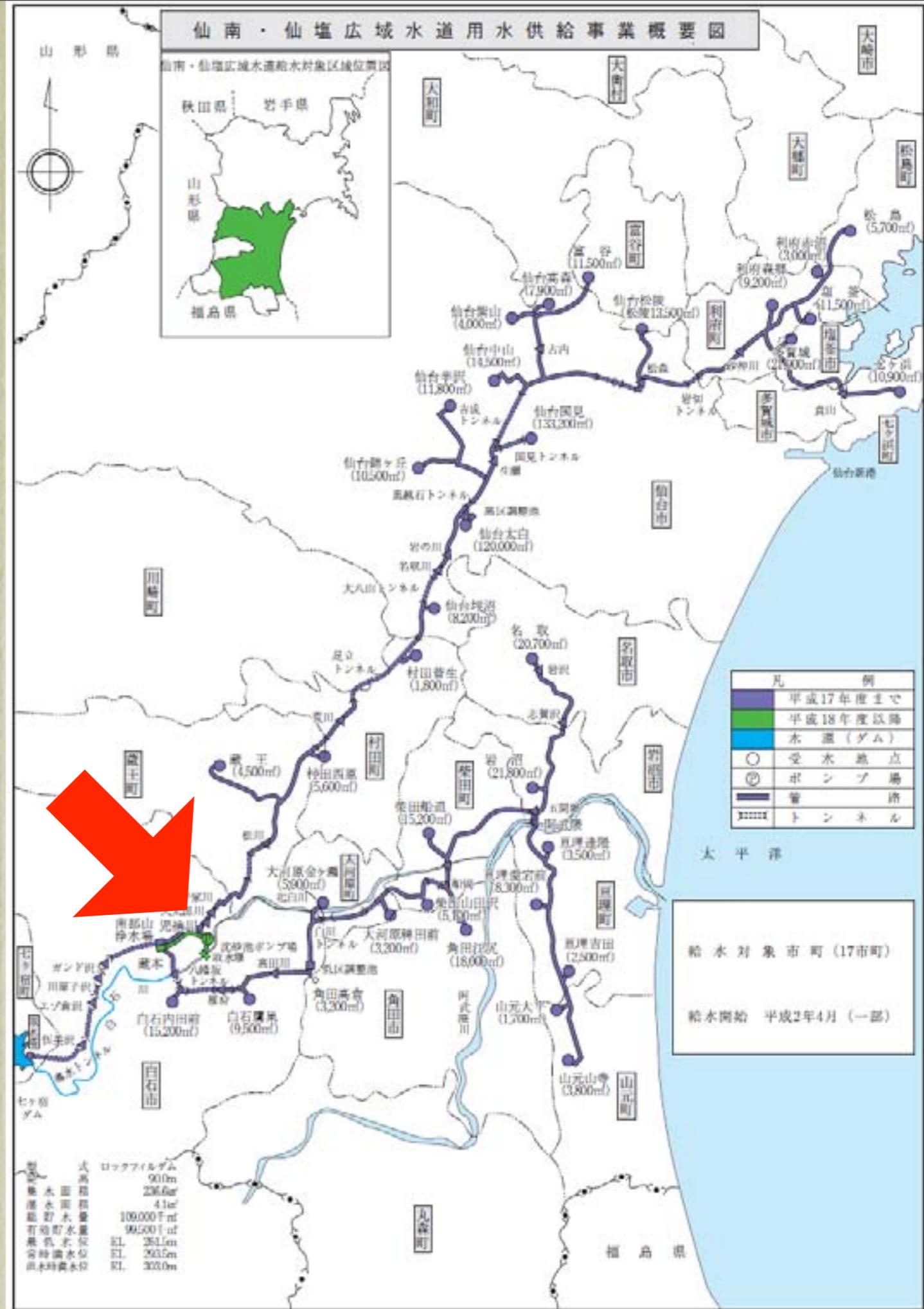
Name of Prefecture	Water Supply's Disruption Condition
Aomori	1,800 households
Iwate	80,000
Miyagi	310,000
Fukushima	190,000
Akita	1,700
Yamagata	6,000
Ibaragi	470,000
Tochigi	40,000
Gunma	2
Saitama	70
Chiba	300,000
Niigata	130
Nagano	1,000
Gifu	30
Hokkaido	0 (restore)
Tokyo	0(restore)
Kanagawa	0(restore)
Yamanashi	0(restore)
Shizuoka	0(restore)
Tokushima	0(restore)

Note: as of 18:00 JST of 13 Sunday March 2011

Why was there a long-term water outage to some cities in Miyagi Pref?

Wholesale water transmission system, constructed 1980.

96" diameter (largest)





March 11, 3:26 pm (t + 30 minutes)

48" (1.2m) steel pipe with pulled couplings

Concrete encasement

Concrete encasement

Route 4, near Shiroshi. This pipe is in the low zone, going to Natori

# Water - Sendai

- 800 km of damaged water pipe
- 2,800 people working
- 49 pump stations, all lost power
- No fuel to re-supply
- WTP: 3300000 m<sup>3</sup>, Prefecture supplies 1000000 m<sup>3</sup>/day (86 MGD)

# Sendai Hills Cut and Fill (Roadfill Slumps)

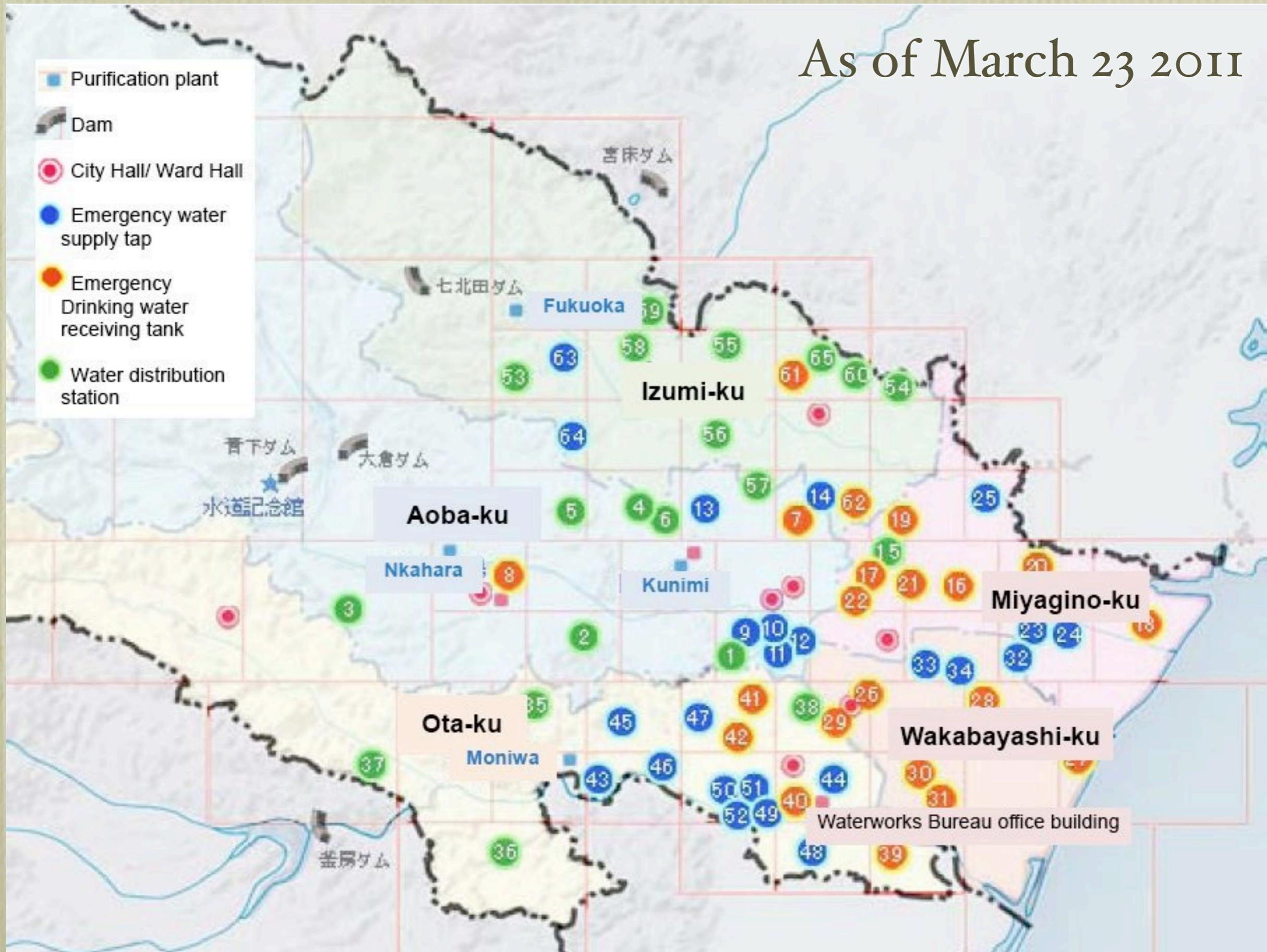


April 7 2011



# Emergency water supply stations in Sendai City

As of March 23 2011





Emergency water supply, Iwaki City, Fukushima



2000 ft  
500 m

# Urayasu City

Terms of Use



Asahi City - Uplifted Fire Cistern (40,000 liters)

Credit: Kuwata, 3/26/2011

# Seismic Storage Tank



March 28 2011 Urayasu



March 26 2011 Urayusa

# Damage due to Liquefaction at the Water Treatment Plant



496 ft

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©2010 Google

3/28/2011 2010

lat 35.932410° lon 140.628582° elev 5 ft

Eye alt 2145 ft

Thursday, August 11, 2011





鹿行広域水道用水供給事業の取水棟への取り付け部の伸縮可とう管  
φ600。周辺小口径管路が地盤と共に沈下したため、継手部で漏水



March 30, 2011



DIP 300  
mm. Joint  
Ring  
cracked.



# Fire at Tank Yard, Sendai Port (Inundation)



# Sendai Airport Fire



2011/06/16 16:24

# Yamada fire damaged cell base station



photo: A. Kwasinski, June 15 2011

# Fire at Tank Yard, Cosmos Refinery, Ichihara, Chiba Pref



# Iwaki



# Tokyo Office Building Fire



# Sendai Port, Refinery Fire 4/2011



4/6/2011  
2011

259 ft

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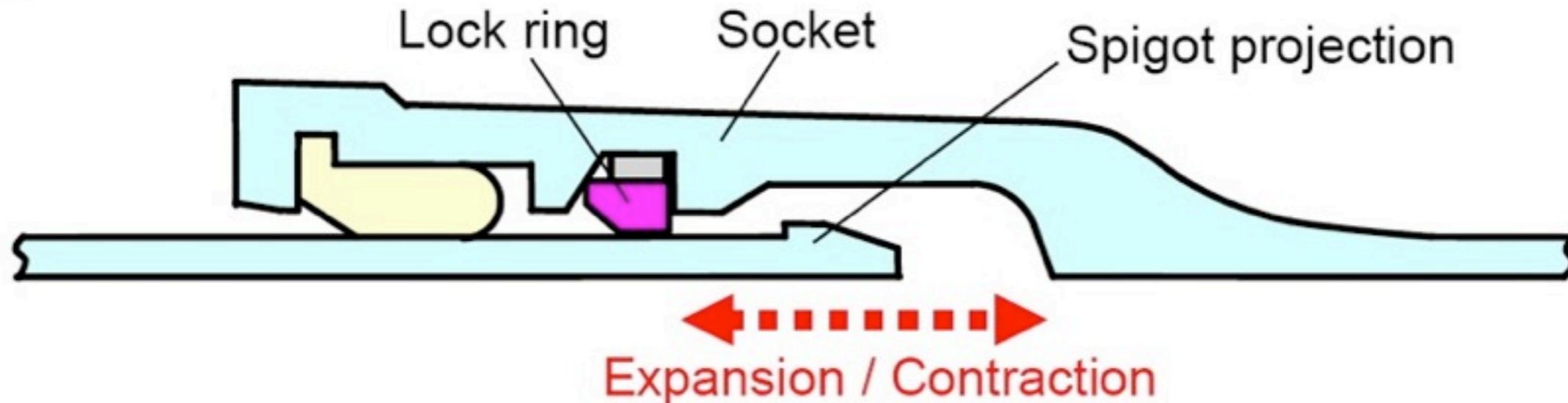
© 2010 Google

Date: 4/6/2011 2002

lat 38.283460° lon 141.032073° elev 8 ft

Eye alt 1143 ft

# Structure and performance of ER-Joint



Property	Performance	ISO 16134
Amount of expansion/contraction	$\pm 1\%$ of pipe length	Class S-1
Slip-out resistance	3D kN	Class A
Joint deflection angle	6–8° <sup>1)</sup>	—

Note) D : Nominal diameter of pipe (millimeters)

1) Joint deflection angles depend on pipe diameters.

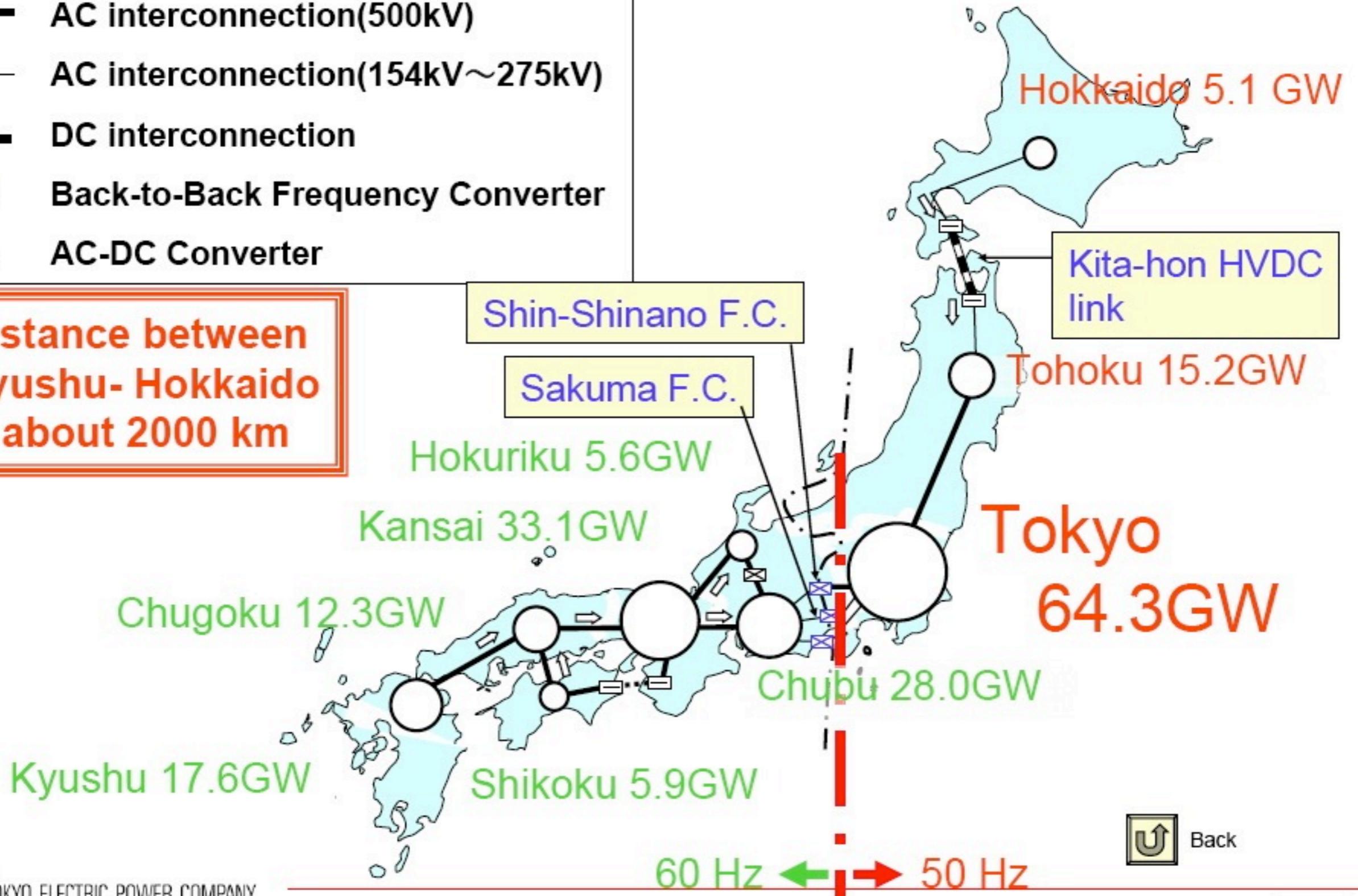


DIP with  
Restrained Push-  
on joint

# Power Systems in Japan

-  AC interconnection(500kV)
-  AC interconnection(154kV~275kV)
-  DC interconnection
-  Back-to-Back Frequency Converter
-  AC-DC Converter

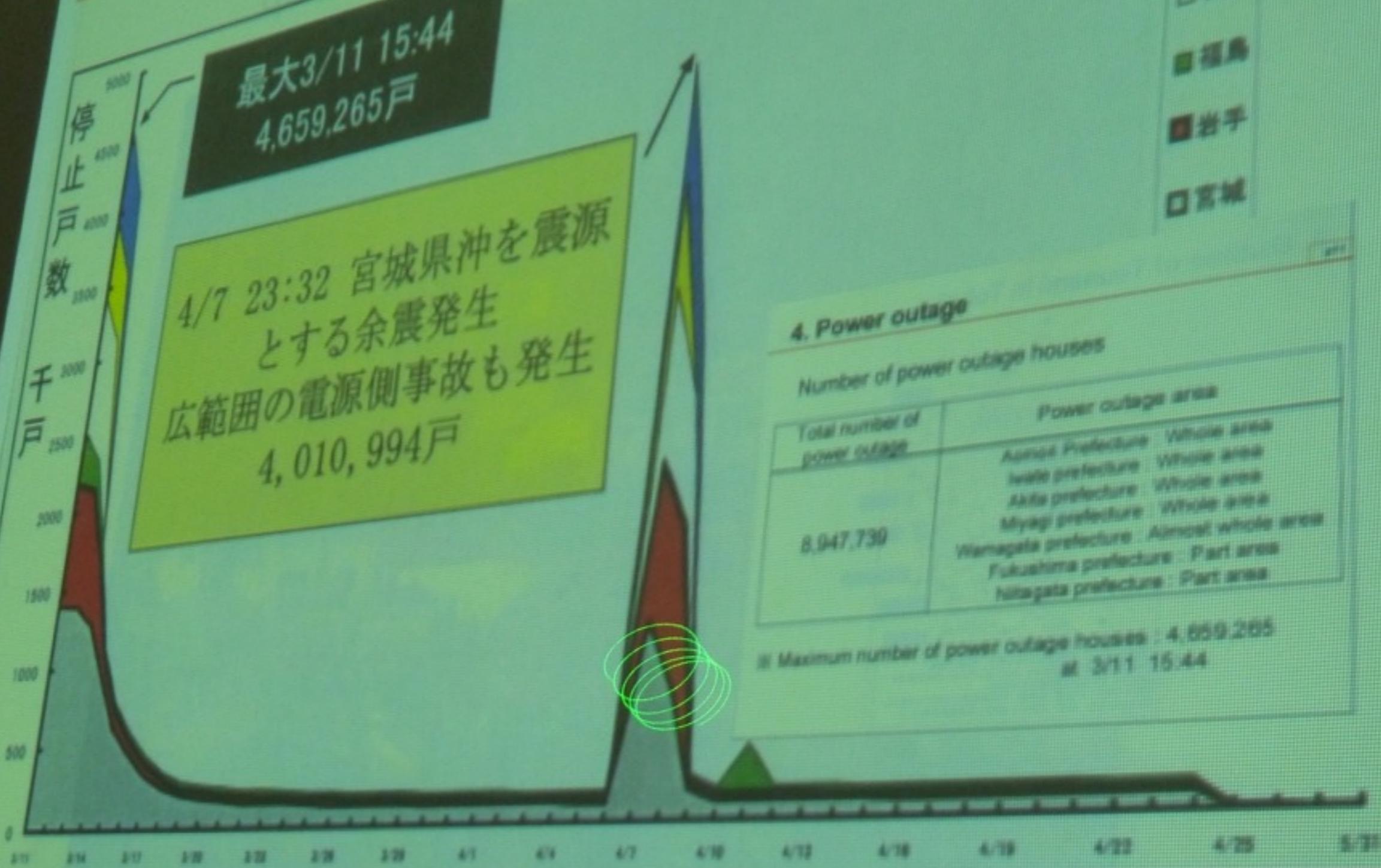
**-Distance between Kyushu- Hokkaido is about 2000 km**



Facility	Damaged Item	Main Shock M 9 3/11/2011	After Shock M 7.2 4/7/2011	After Shock M 7.0 4/11/2011 4/12/2011	Kobe M 6.9 1/15/1995
Thermal	Plants	4			10
Hydro	Plants	10	2	7	0
Substation	Transformer	70	15	1	52
154 kV - 500 kV	Circuit Breaker	197	15	1	10
	Disconnect Switch	179		2	41
Transmission	Steel Truss Tower	42			20
	Line / insulator	22	5	5	3/39
	underground cable	14	0	0	405
Distribution	Pole	23744	7831	572	11289
	Line	23550	13711	1085	7760
	Transformer, Switch	7112	2288	121	5346

Note: M 9 event includes damage due to tsunami, liquefaction, shaking

# 5. Number of power outage

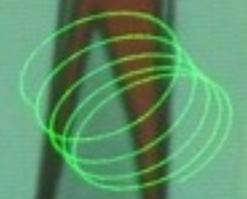


## 4. Power outage

Number of power outage houses

Total number of power outage	Power outage area
8,947,730	Aomori Prefecture: Whole area Iwate prefecture: Whole area Akita prefecture: Whole area Miyagi prefecture: Whole area Wanagata prefecture: Almost whole area Fukushima prefecture: Part area Iitagata prefecture: Part area

Maximum number of power outage houses: 4,659,265 at 3/11 15:44



4/6/2011  
2011



# Sendai Substation

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Google



Honda 本田

Shimizubata 清水端

Kashima 鹿島

Mizu 柳清水

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GOOGLE

Imagery Date: 4/6/2011 2001

lat 38.318686 lon 140.908474 elev 125ft

Eye alt 23

Thursday, August 11, 2011

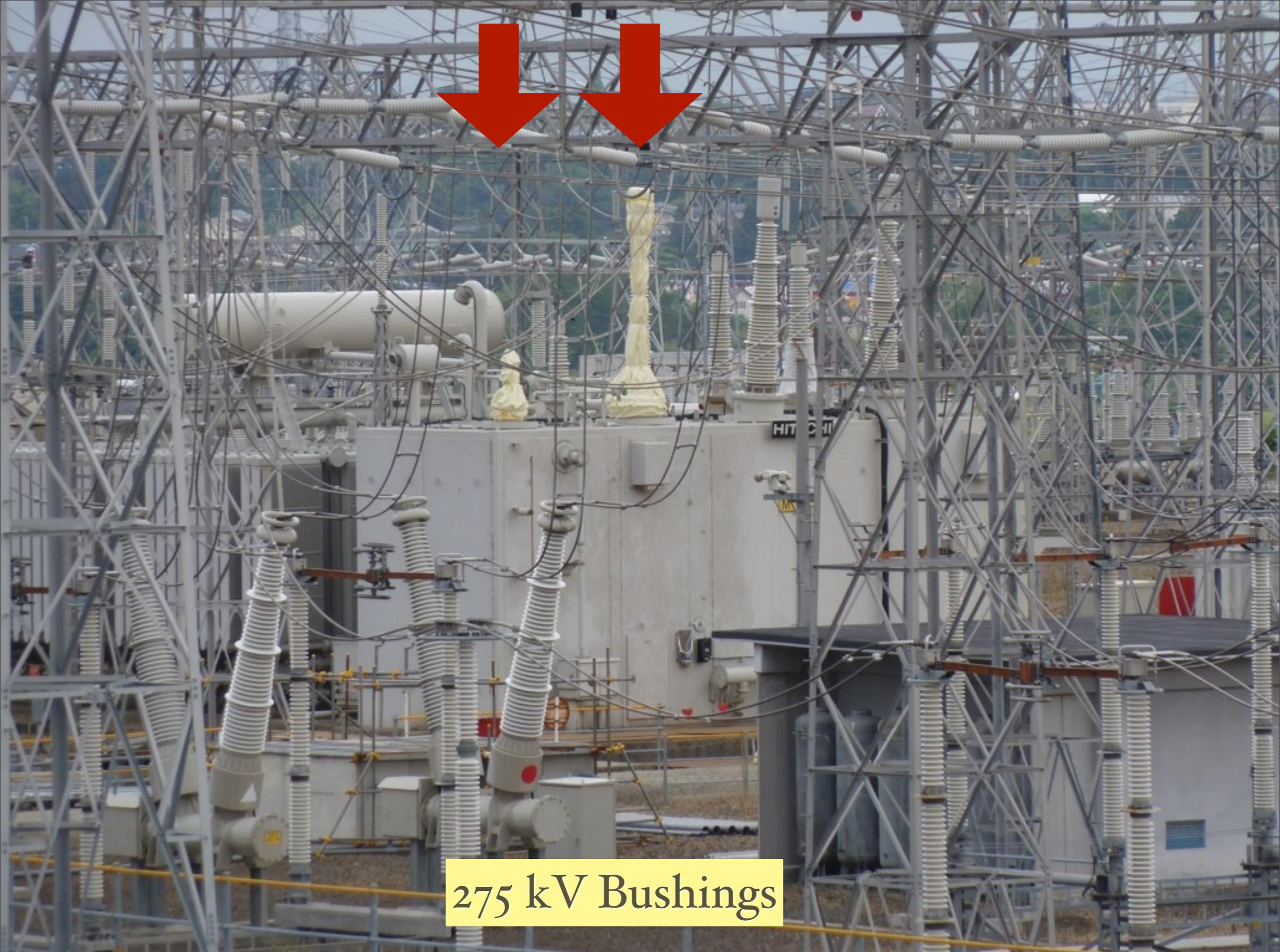
38





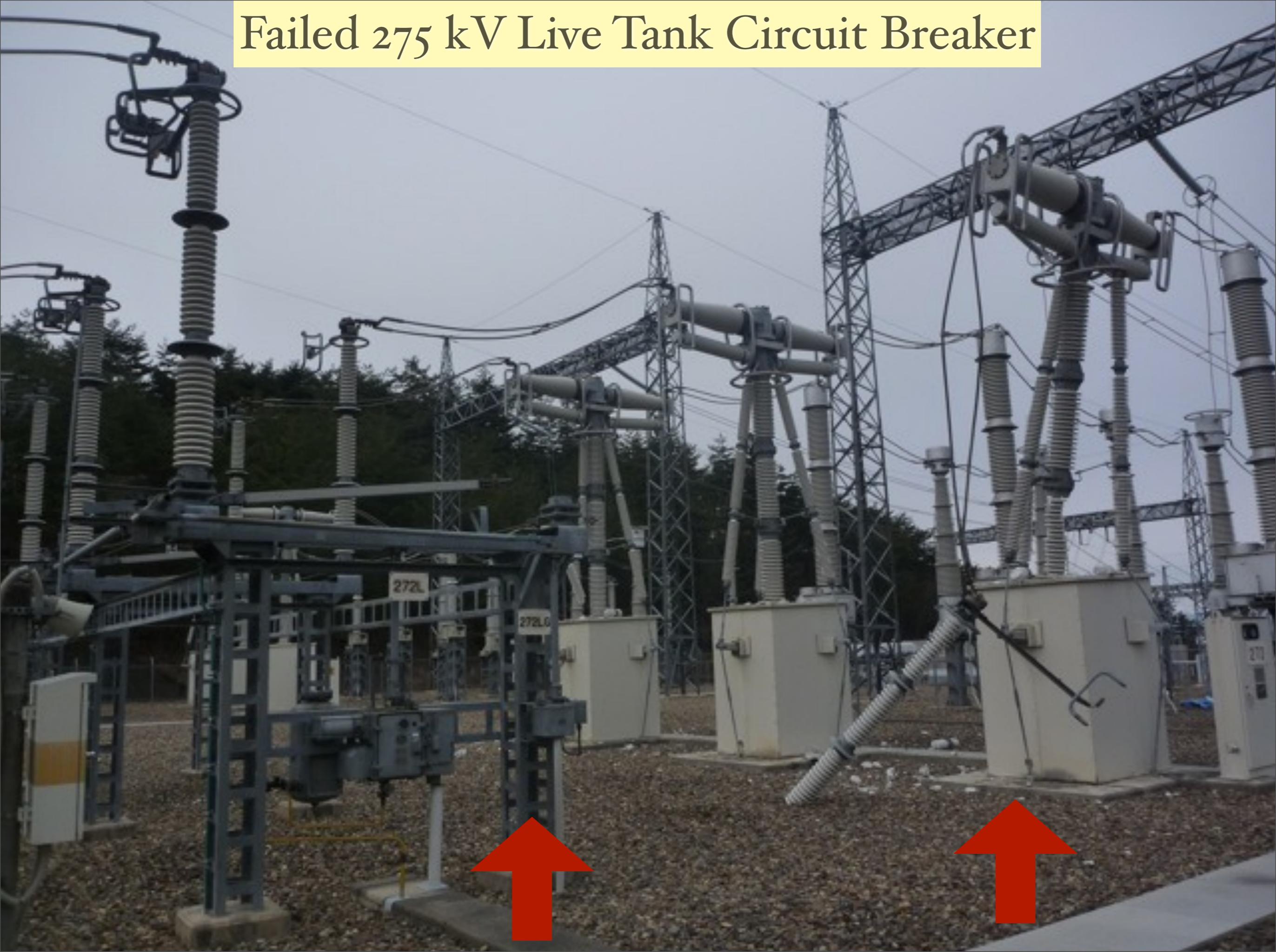
# Disconnect Switches





275 kV Bushings

# Failed 275 kV Live Tank Circuit Breaker

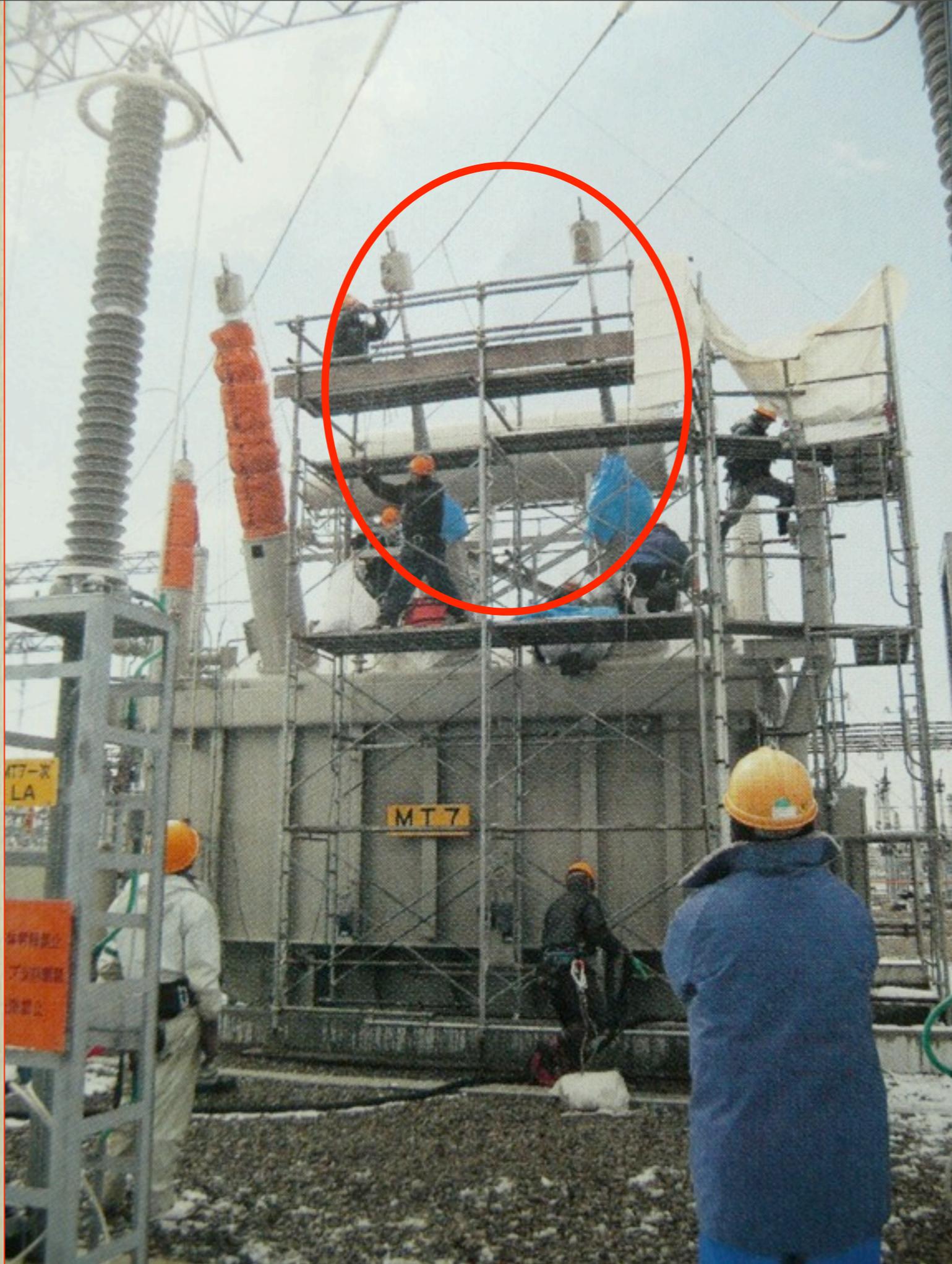


# Failed 275 kV Surge Arrestor



# Oil Leak at Radiator





# Failures, 161 kV - 500 kV

M 9.0 3/11/11. 47 Shaking, 23 Tsunami

M 7.2 4/7/11. 15 Shaking

M 7.1 4/11/12; M 6.3 4/12/11 M 6.3. 1 Shaking



# Debris impact / Tsunami Knocks over tower



# Tower Foundation (after tower removal)



Leon Kempner, BPA

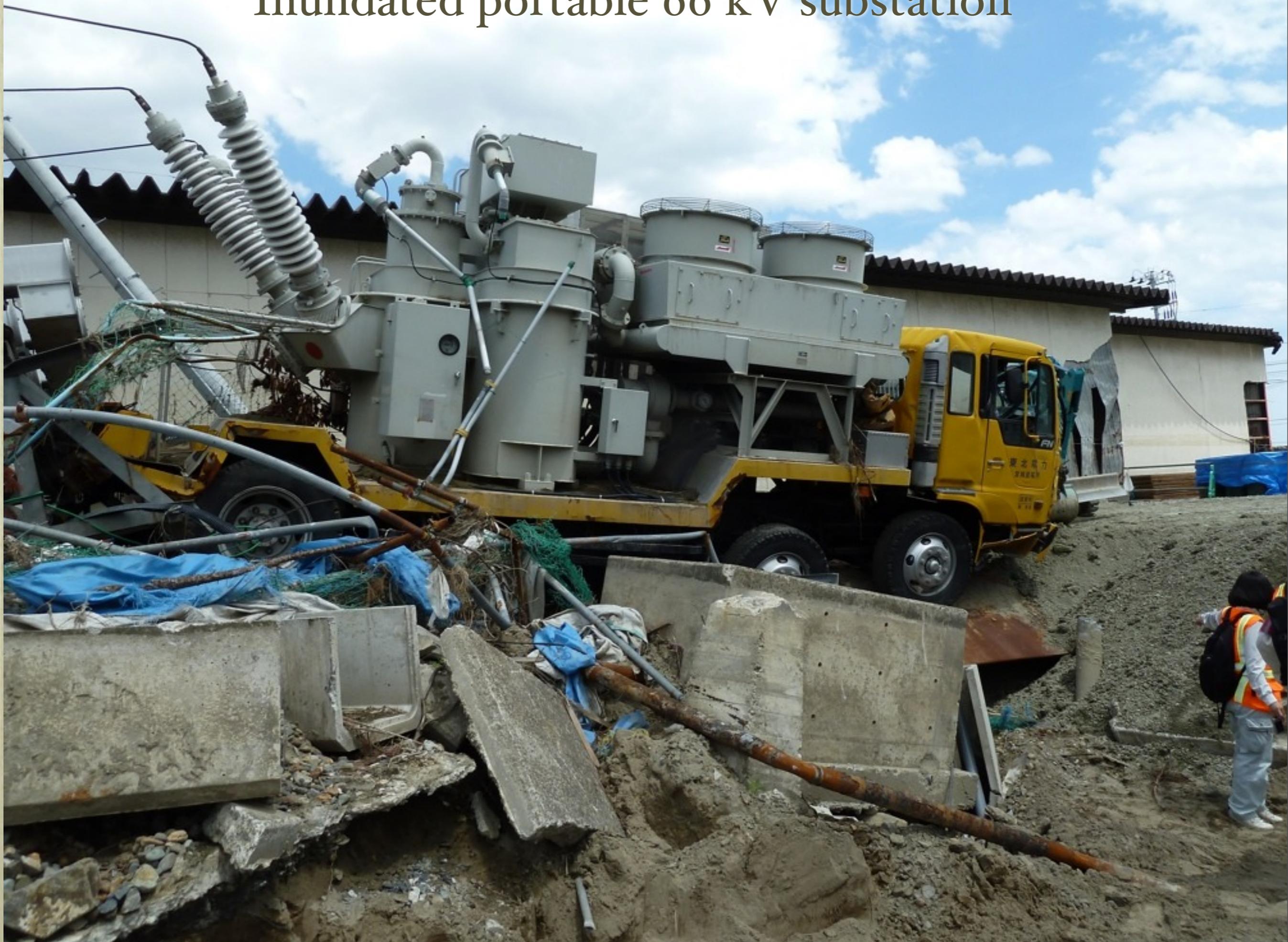


66 kV tsunami  
inundation, with  
scour



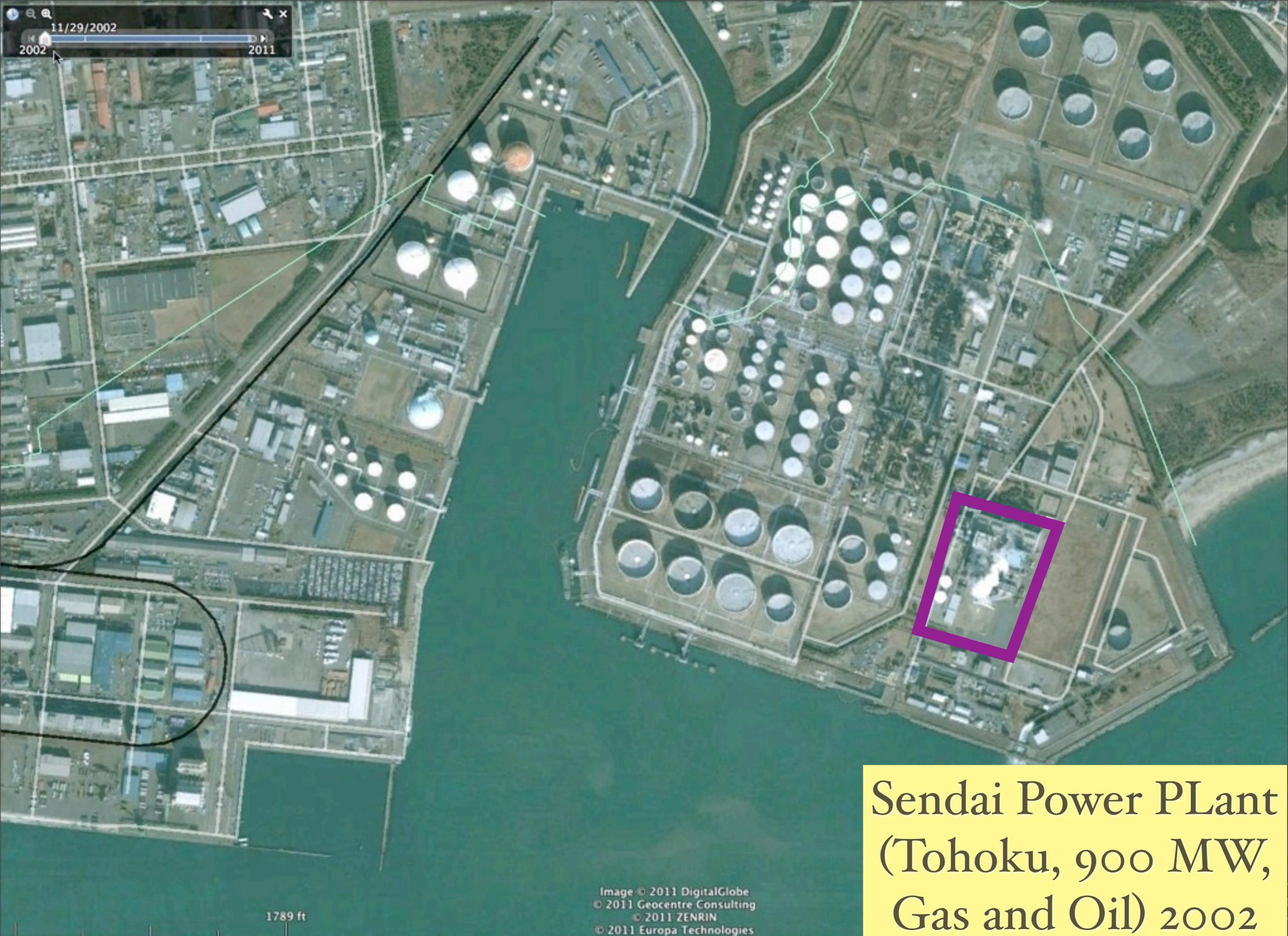


# Inundated portable 66 kV substation



# Truck-mounted Portable 66 kV Substations (destroyed by Tsunami Inundation)





Sendai Power PLant  
(Tohoku, 900 MW,  
Gas and Oil) 2002

Image © 2011 DigitalGlobe  
© 2011 Geocentre Consulting  
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Imagery Date: 11/29/2002 2002

lat 38.285603° lon 141.017246° elev 7 ft

Eye alt 77







# Ishinomaki







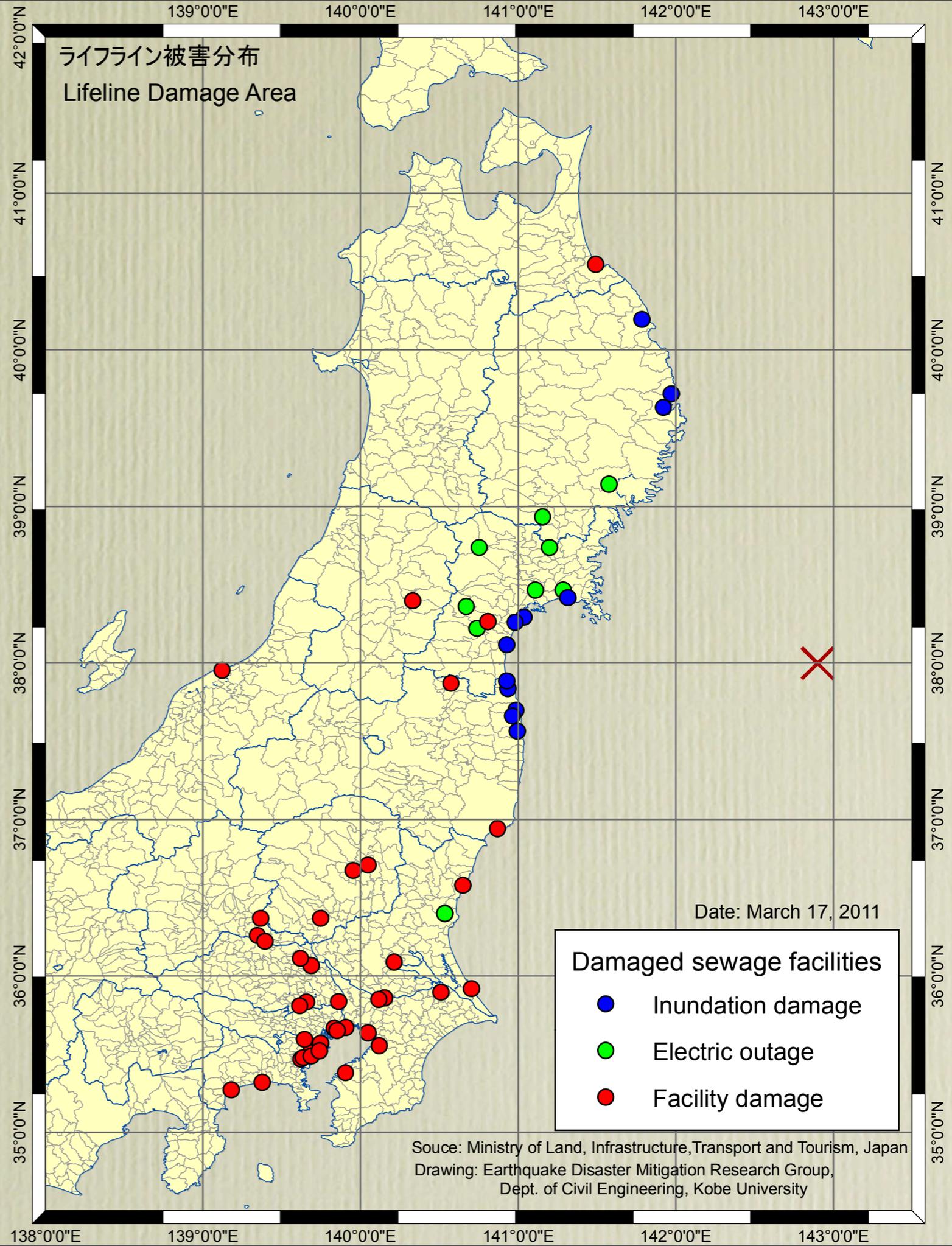








# WWTP - Sewer Damage



# Minami Gamo WWTP



# Tsunami Inundation Paths

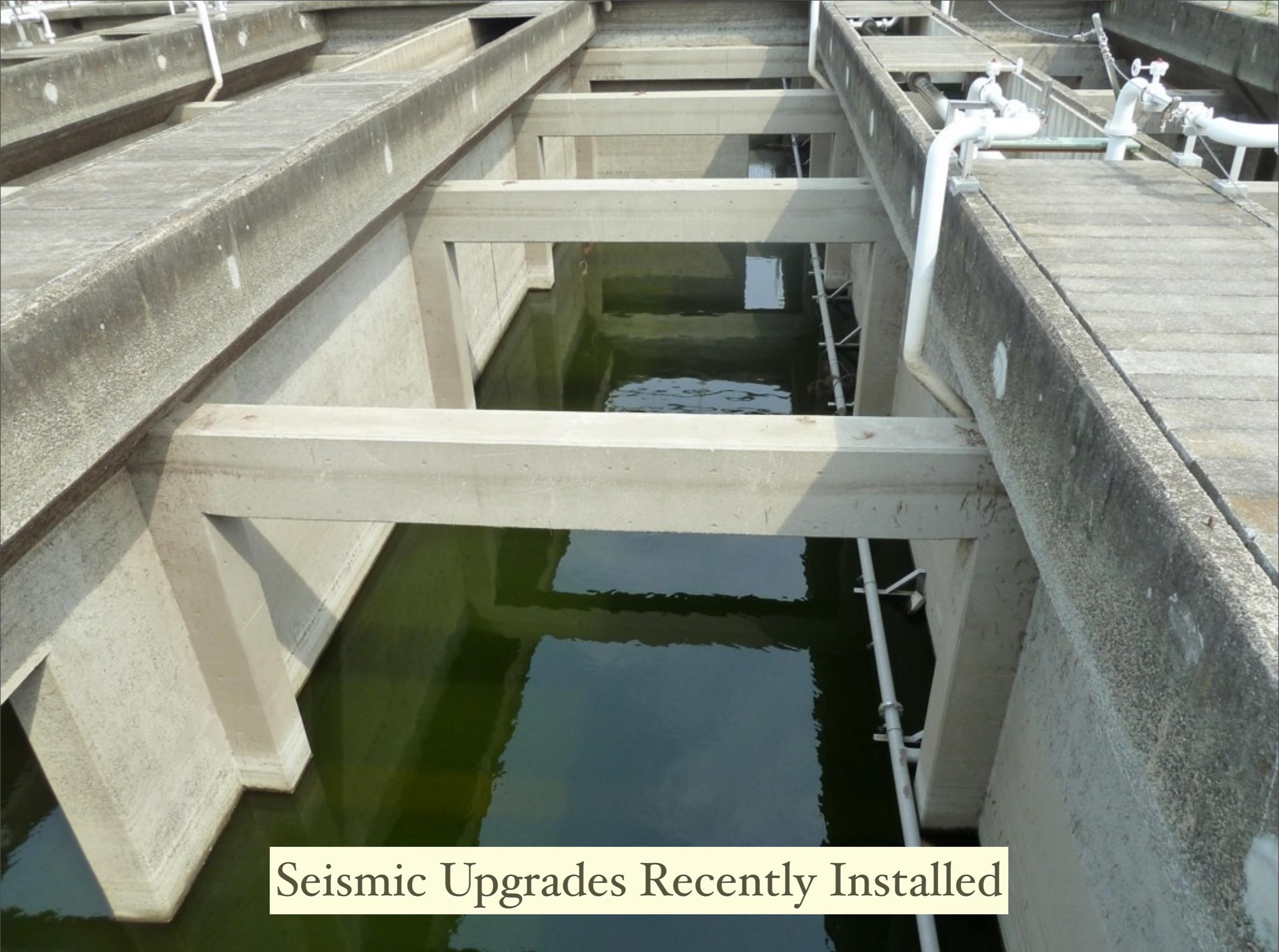


# Electric Switchgear Building



# Diesel Generator Building - OK





Seismic Upgrades Recently Installed













# Foundation bearing failure due to tsunami

John Eiding





4/6/2011

2011

03

534 ft

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lat 38.113127 lon 140.935651 elev 0 ft

Eye alt 2331 ft

Query Date: 4/6/2011 2003

Thursday, August 11, 2011

# Miyagi Pref WWTP



# Sendai WWTP

















11 4:02PM











沈砂池ポンプ棟





Broken Pipe and Flange

























Mei Mei Wang

# Onegawa





Two failed oil tanks, the higher one was OK





No. 1

No. 3  
783.8 KL



