The Great East Japan Earthquake and Current Status of Nuclear Power Stations

April 18, 2011

Tokyo Electric Power Company

東京電力 TEPCO

1. Overview

- **The earthquake occurred at 2:46 pm on March 11, 2011 (Friday).**

- **Fukushima Daiichi Nuclear Power Station**
  - Units 1-3 shut down automatically (Units 4-6 had been cold shutdown due to annual outage).
  - Although emergency diesel generators had started after the loss of offsite power due to the earthquake, they were lost by the ensuing tsunami.

    ->Currently offsite power has been restored and lights in the main control room (all units) and some area in turbine building (Units 1-4) have been energized.
  - Core cooling functions were insufficient. Initially fresh water were used for cooling and then sea water (boric acid partially contained) were injected.

    ->Currently fresh water has been injected into the reactor core by the temporary motor driven pump (Units 1-3).
  - Implemented ventilation to reduce the pressure of Primary Containment Vessel (PCV) in Units 1-3 to prevent over pressurization of the PCV.
  - Reactor buildings were damaged due to possible hydrogen explosion (Units 1&3).
  - Abnormal sound was heard near the suppression chamber followed by a decrease in the suppression chamber pressure (Unit 2).
  - Large sound was heard, and the reactor building of Unit 4 was confirmed to be damaged.
  - Contaminated water with high radioactive materials have been found in large quantity in turbine buildings of Units 1-3, leakage of the water into the ocean was found via Unit 2 trench, sealing of the leakage was implemented on April 6. Pumping out the contaminated water is on progress. In order to transfer and store the contaminated water with extremely high radioactive dose in Unit 2 in Centralized Radioactive Waste Disposal Facility, approximately 10,000 tons of low level radioactive water stored therein was discharged into the ocean.
  - Units 5 and 6 are under cold shutdown.

- **Fukushima Daini Nuclear Power Station**
  - Units 1-4 shut down automatically.
  - All Units are under cold shutdown, and water level of the reactors are stable and controlled. Offsite power has been available.

2. Tohoku Pacific Ocean Earthquake

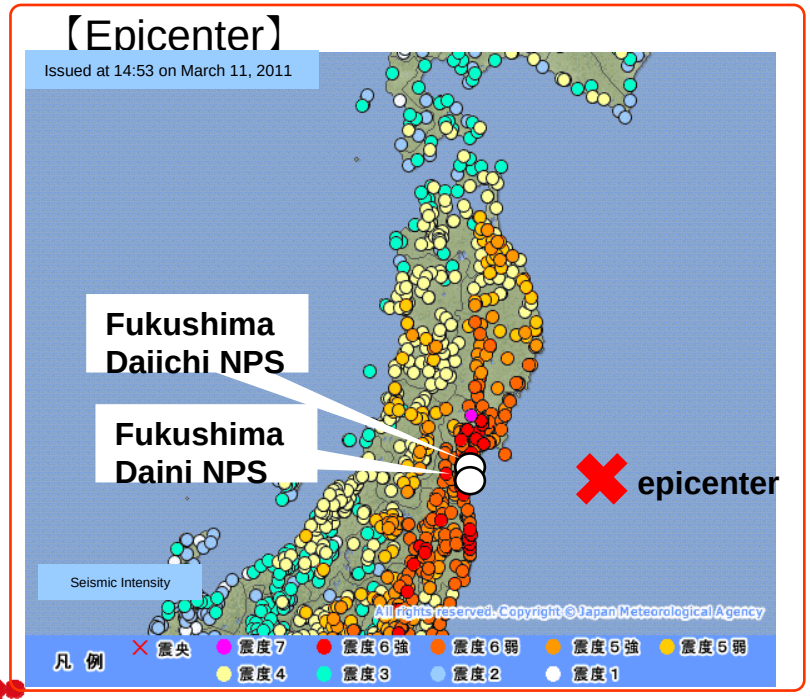
- **Time:** 2:46 pm on Fri, March 11, 2011.
- **Place:** Offshore Sanriku coast (northern latitude of 38 degrees, east longitude of 142.9), 24km in depth, Magnitude 9.0
- **Intensity:** **Level 7** at Kurihara in Miyagi Miyagi prefecture

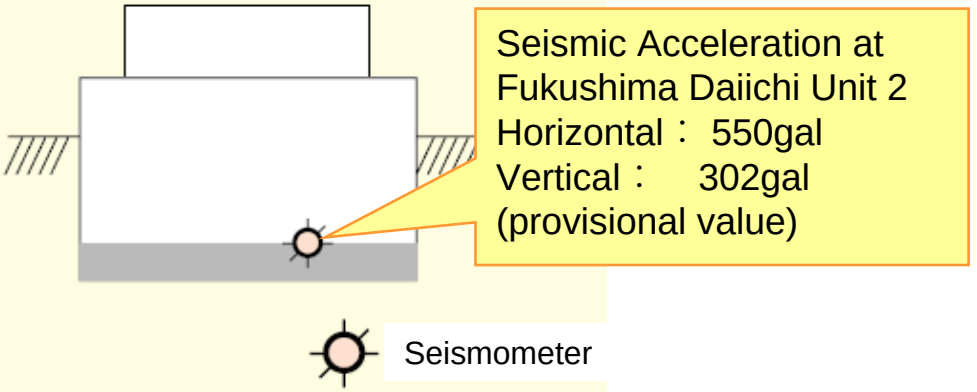
  Upper 6 at Naraha, Tomioka, Okuma, and Futaba in Fukushima pref.

  Lower 6 at Ishinomaki and Onagawa in Miyagi pref., Tokai in Ibaraki pref.

  Lower 5 at Kariwa in Niigata pref.

  Level 4 at Rokkasho, Higashidori, Mutsu and Ohma in Aomori pref., Kashiwazaki in Niigata pref.

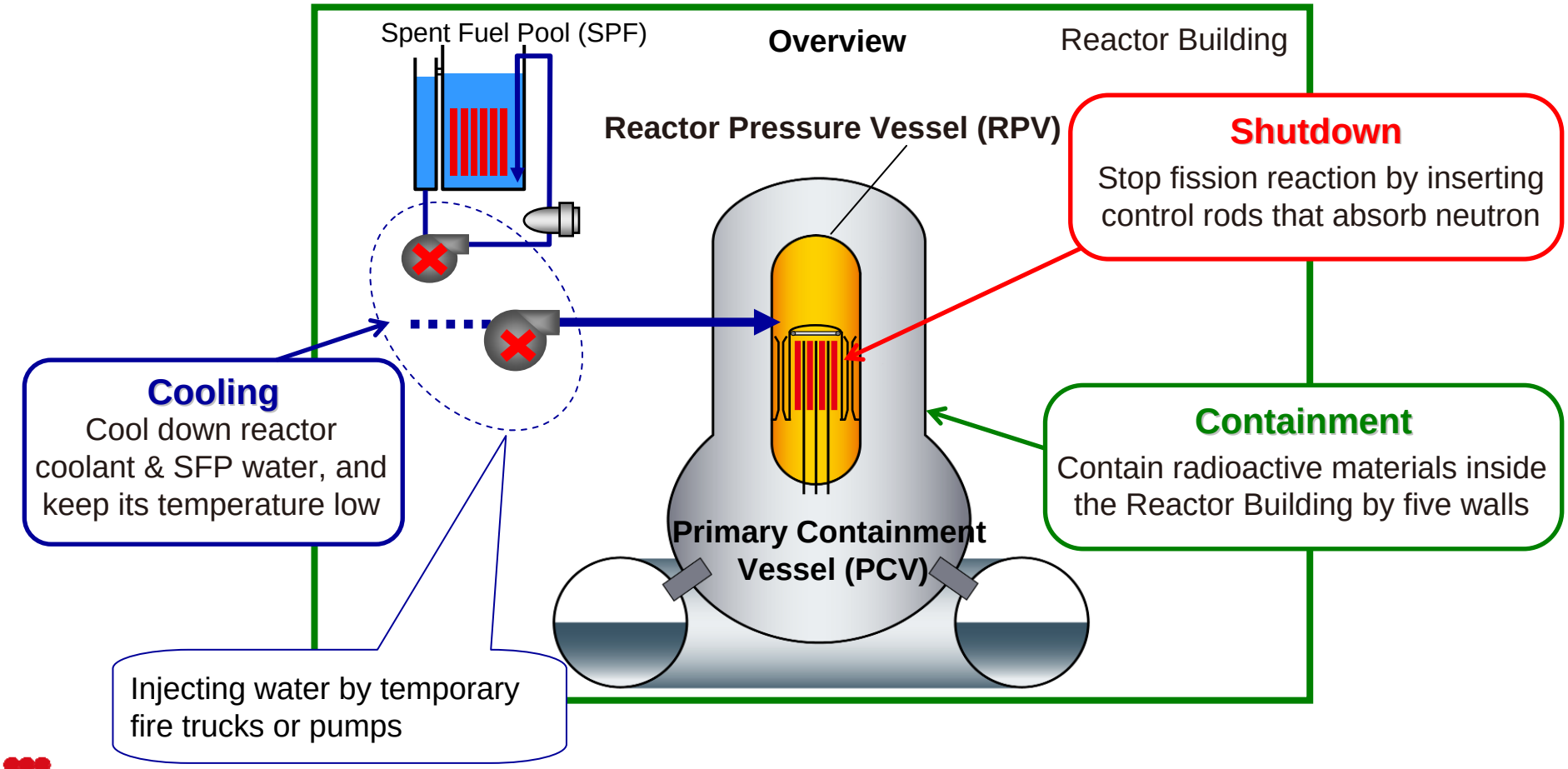




* gal: a unit of acceleration defined as cm/s².

3. Impacts for Safety Function

- Offsite Power Supply lost by the quake; diesel generators started but subsequently were lost due to the Tsunami.
- "Shutdown" was secured by automatic shutdown of all control rods inserted at the same time of the earthquake
- "Cooling" of reactor and spent fuel pool was insufficient due to the loss of power supply
  ->Currently freshwater is injected by temporary motor pumps.
- "Containment" is possibly impaired because high level contaminated water has been found in turbine buildings.
  ->Preventative measures of expanding contaminations are in full force.



4. Plant Status: Fukushima Daiichi

- Units 1-3: Injecting fresh water by temporary motor-driven pumps in order to cool the fuels in reactors.
- Units 1-4: Injecting fresh water from the top or via Fuel Pool Cooling System intermittently in order to cool the fuels in spent fuel pool.
- Units 1-3: Found contaminated water with high radioactive materials in turbine buildings. Pumping out of the water into the condensers, etc. is in progress.
- Unit 1: Injecting N_2 into PCV to lower the possibility of hydrogen explosion. Also scheduled for Units 2&3.
- Units 5&6: Under cold shutdown.

			#1 460MW	#2 784MW	#3 784MW	#4 784MW	#5 784MW	#6 1,100MW
Pre-Earthquake Status			Operating			Shutdown for Outage		
After Earthquake	Shutdown		○ Automatic Shutdown			—	—	—
	Cooling	Reactor	△ Offsite Power Freshwater	△ Offsite Power Freshwater	△ Offsite Power Freshwater	– Fuels have been removed	○ Cold Shutdown	○ Cold Shutdown
		Pool	△	△	△	△	○	○
	*Containment		X Highly contaminated water	X Highly contaminated water	X Highly contaminated water	△	○	○

○ :functioning △: non-functioning (work in progress) X:non-functioning (not working)

***There are damages on upper part of the Reactor buildings of Unit 1,3 and 4. There is a possibility of malfunction of containment in suppression chamber of Unit2. Holes are drilled on the roof of reactor buildings of Units 5 and 6 to prevent hydrogen accumulation.**

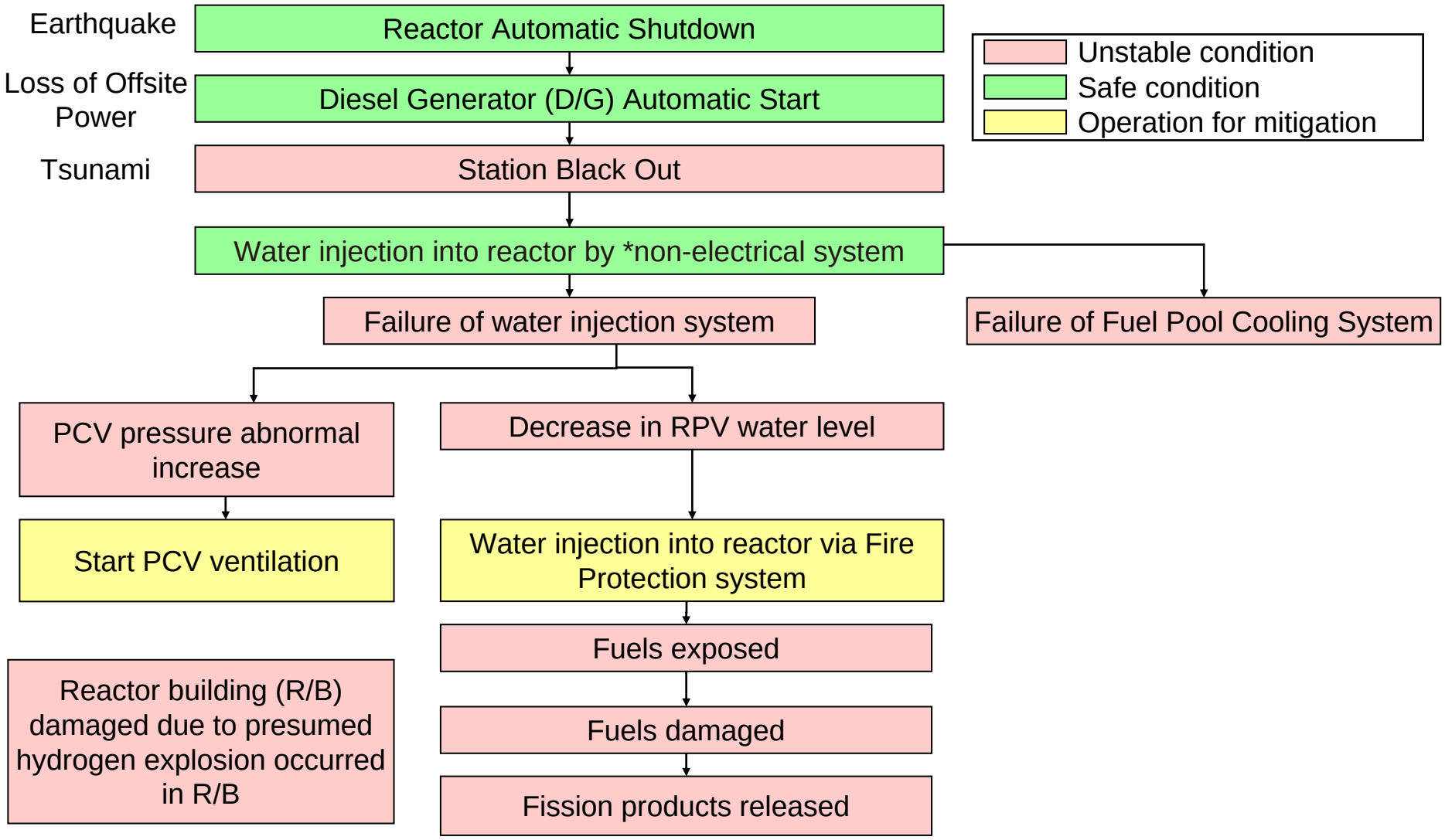
4. Plant Status: Fukushima Daini

- Unit1-4: Automatic Shutdown
- Unit1,2 & 4: Offsite power maintained. Heat removal functions for reactors were lost in Units 1, 2 and 4. Later the functions were restored and cold shutdown has been secured for those units.
- Unit 3: Cold Shut down in 22hrs after the quake

		Fukushima Daini Nuclear Power Station			
		# 1 1,100MW	# 2 1,100MW	# 3 1,100MW	# 4 1,100MW
Pre-Earthquake Status		Operating			
After Earthquake	Shutdown	○			
	Cooling	○ (Cold Shutdown)			
	Containment	○			

○ :functioning △: non-functioning (work in progress) X:non-functioning (not working)

5. Course of Events（Fukushima Daiichi Unit 3）



*High Pressure Coolant Injection System (HPCI), Reactor Core Isolation Cooling System (RCIC)

6. Chronology of Fuel Cooling (Fukushima Daiichi)

SF Pool | Reactor | Power Supply

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5-6	Common SF Pool
March 11, 14:46	**Earthquake**					
	11 Cooling by injecting fresh water				One D/G survived	
12th	12 Start injecting sea water		13 Start injecting sea water			
13th						
14th		14 Start injecting sea water				
17th			17 Start watering (sea water, fresh water)	20 Start watering (sea water, fresh water)	20 Reactor cooling shutdown	
20th		20 Start injecting sea water				
21th				22 Power Center (P/C) energized from Offsite Power	20～21 Switched from D/G to offsite power	21 Fresh water injection
22th			23 Recover Main Control Room lighting			
23th	24 Recover Main Control Room lighting					24 Received electricity from offsite
24th		26 Recover Main Control Room lighting				
25th	25 Switch from sea water to fresh water		25 Switch from seawater to fresh water			24 Start cooling by existing system
26th		26 Switch from sea water to fresh water		29 Recover Main Control Room lighting		
27th			29 Switch from seawater to fresh water			
31st	31 Start watering fresh water	29 Switch from sea water to fresh water		30 Switch from sea water to fresh water		

[Reference] Recovery Status (Main Control Room)

- Main Control Room Power recovered as the first symbolic step of restoration
  - March 22 at 22:45 Unit 3 Main Control Room lights turned on
  - March 24 at 11:30 Unit 1 Main Control Room lights turned on
  - March 26 at 16:46 Unit 2 Main Control Room lights turned on
  - March 29 at 11:50 Unit 4 Main Control Room lights turned on

Unit 1 Main Control Room lights turned on
（The light covers come off by the earthquake）

Unit 4 Main Control lights turned on

7. Plant Parameters (Fukushima Daiichi) as of April 17 at 14:00

RPV Pressure [MPa-g]

Unit 1	Unit 2	Unit 3
0.973	-0.023	-0.030

RPV Temp [℃]

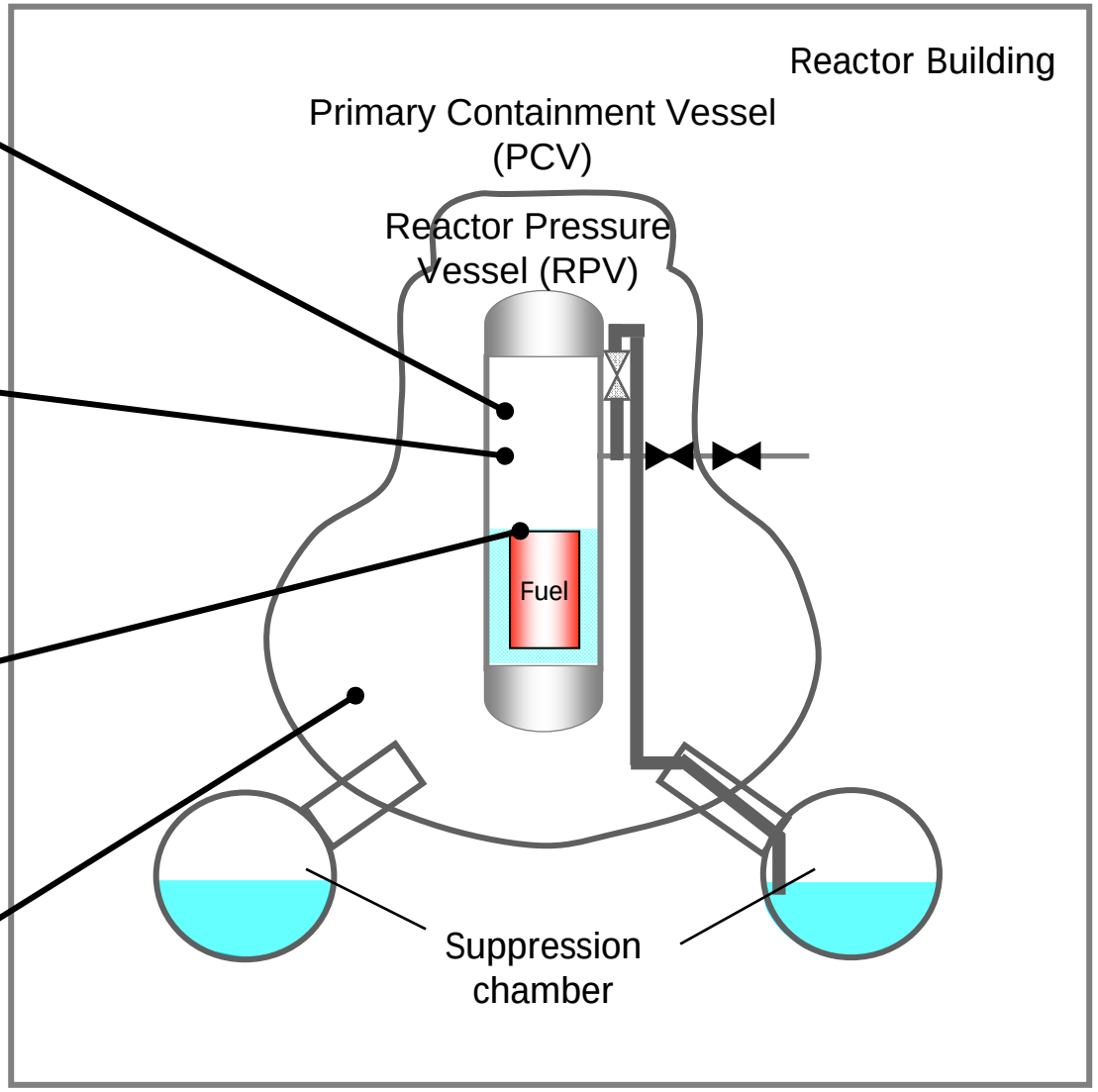
Unit 1	Unit 2	Unit 3
180.4 (Feedwater Nozzle)	141.1 (Feedwater Nozzle)	121.7 (bottom of RPV)

Reactor water level [mm]

Unit 1	Unit 2	Unit 3
-1,650	-2,100	-2,250

Drywell pressure [MPa-abs]

Unit 1	Unit 2	Unit 3
0.175	0.085	0.1047



Pressure conversion: Gauge pressure (MPa-g)=absolute pressure (MPa-abs)-atmospheric pressure(0.1013Mpa)

*Posted in one gauging

8. Water Removal Process from Turbine Building (Fukushima Daiichi)

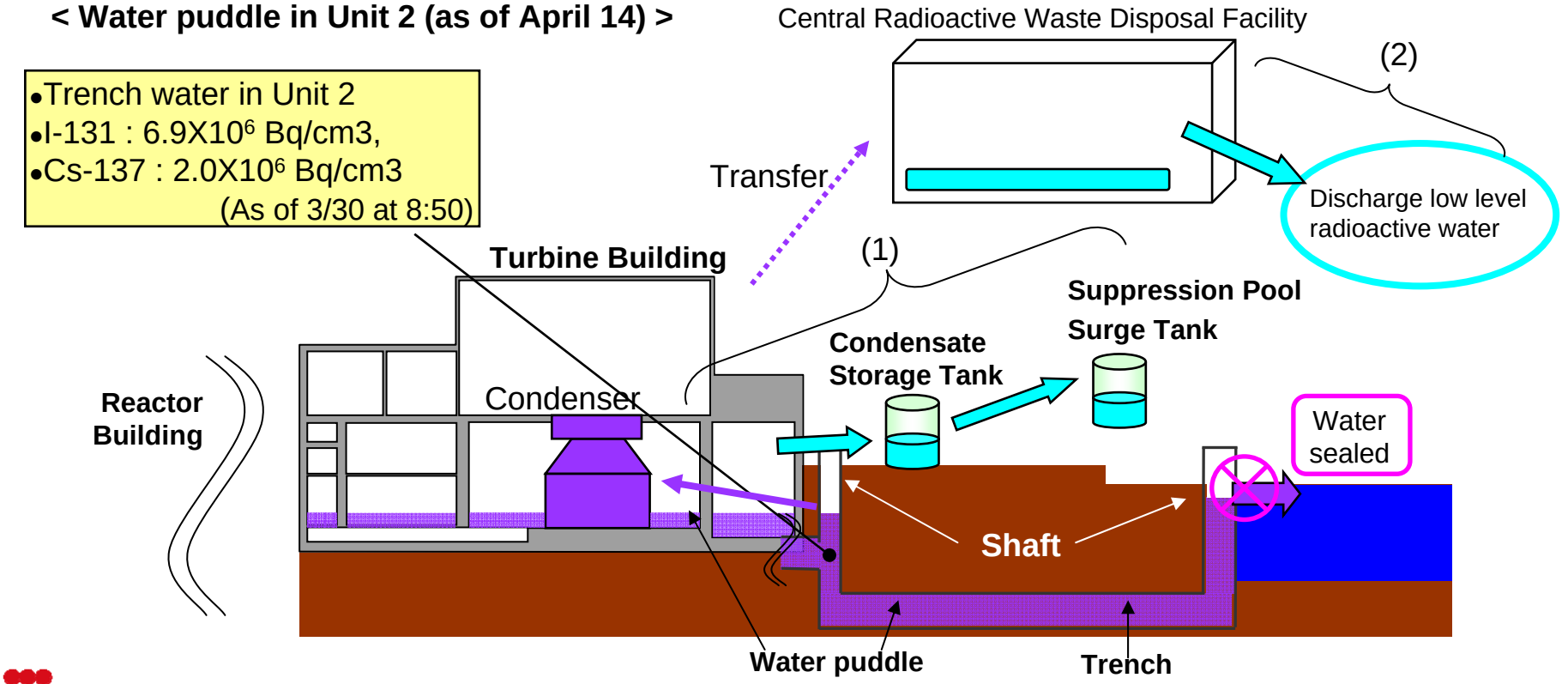
- Contaminated water with high radioactive materials have been found in large quantity in Turbine buildings of Units 1-3 etc. Following measures will be taken to store them safely.
  - ✓ Transfer the low level radioactive wastewater stored in Condenser to the tanks outside in order to store the water puddle therein (1).
  - ✓ Discharged approximately 10,000 tons of low level radioactive water stored in Centralized Radioactive Waste Disposal Facility in order to store the contaminated water with extremely high radioactive dose in Unit 2 therein (2).

  (Assessed low impact to the public as the radioactivity in 10,000 tons of the low level water is equivalent to 10 litter of high level water in Unit 2.)

< Water puddle in Unit 2 (as of April 14) >

- Trench water in Unit 2
- I-131 : 6.9×10^6 Bq/cm3,
- Cs-137 : 2.0×10^6 Bq/cm3

(As of 3/30 at 8:50)



9. Countermeasures to Prevent Diffusion of Radioactive Materials

- Sprayed dust inhibitor agents on trial basis to reduce spreading of powder dust containing radioactive materials on the ground. (Have been spraying intermittently since April 1st)
- Took following measures in order to prevent radioactive contaminated water from running off into the sea.
  - ✓ Injected coagulants from the holes near the shaft. Have confirmed the outflow from the crack on the concrete wall of the pit stopped. (at 5:38 am, April 6)
  - ✓ Installed a rubber plate and jig to enhance water sealing.
  - ✓ Monitoring continuously for any existence of leakage.
- Took following measures in order to prevent contaminated water from running off from a plant's port at southern part of the site.
  - ✓ Launched construction of installing large sandbags around the breakwater.
  - ✓ Installed 120 meter-wide double silt fences around the breakwater.

Spraying dust inhibitor agents

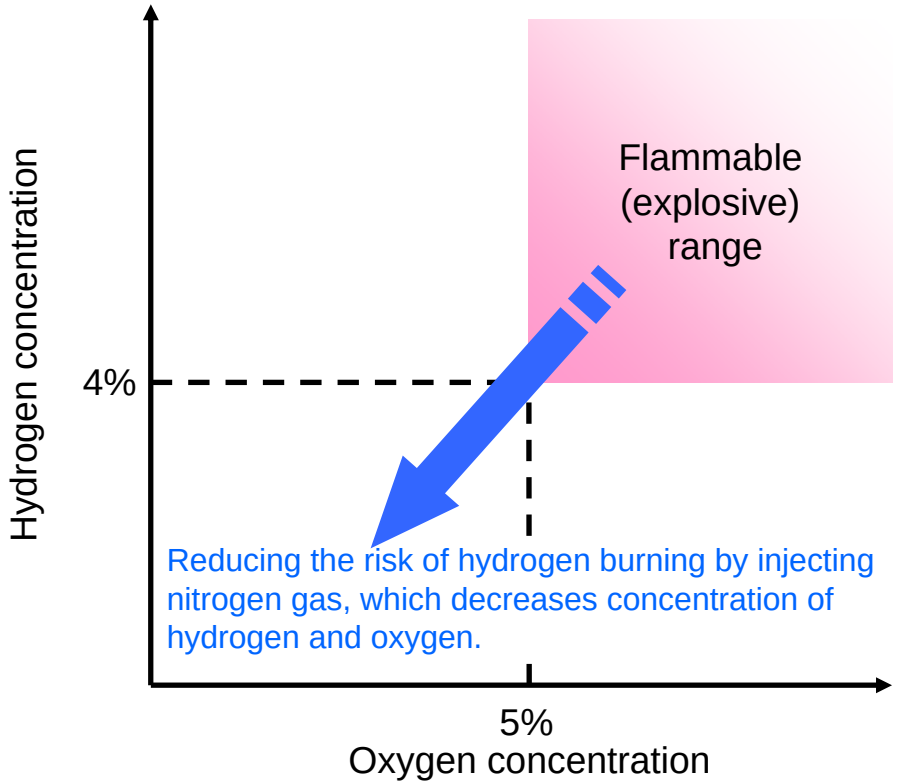
Coagulant injection to stop outflow

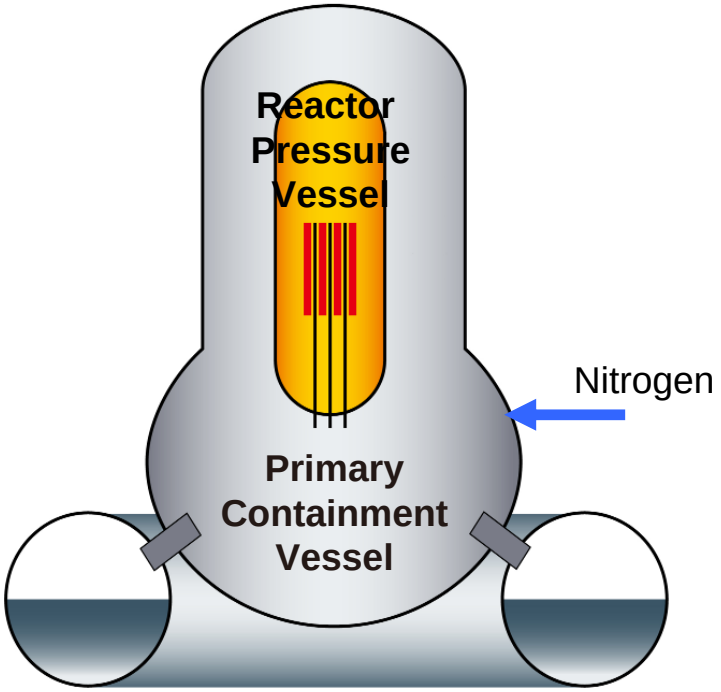
10. Injection of Nitrogen Gas into the Primary Containment Vessel (PCV)

- Injecting nitrogen gas into PCV since April 6th to mitigate the risk of hydrogen gas accumulation in the PCV (Fukushima Daiichi Unit 1).
- Same measures are scheduled to be take for Units 2 and 3.

As of April 13

Flammability limit of hydrogen gas





11. Evacuation

Fri, 11 March

14:46 Automatic Shutdown by the earthquake (Daiichi Units 1-3, Daini Units 1-4)
19:03 Emergency Declaration by the Gov't (Daiichi)
21:23 3 km radius evacuation directed by the Prime Minister (PM) (Daiichi)
10 km radius taking shelter directed by the PM (Daiichi)

Sat, 12 March

5:44 10 km radius evacuation directed by the PM (Daiichi)
6:50 The Gov't ordered to control the internal pressure of PCV (Daiichi Units 1&2, Nuclear Regulation)
7:45 Emergency Declaration by the Gov't (Daini)
3 km radius evacuation and 10 km radius taking shelter directed by the PM (Daini)
17:39 10 km radius evacuation directed by the PM (Daini)
18:25 20 km radius evacuation directed by the PM (Daiichi)

Tue, 15 March

11:00 20-30 km radius taking shelter directed by the PM (Daiichi)

Fri, 25 March

A.M. 20-30 km radius evacuation announced by the Chief Cabinet Secretary

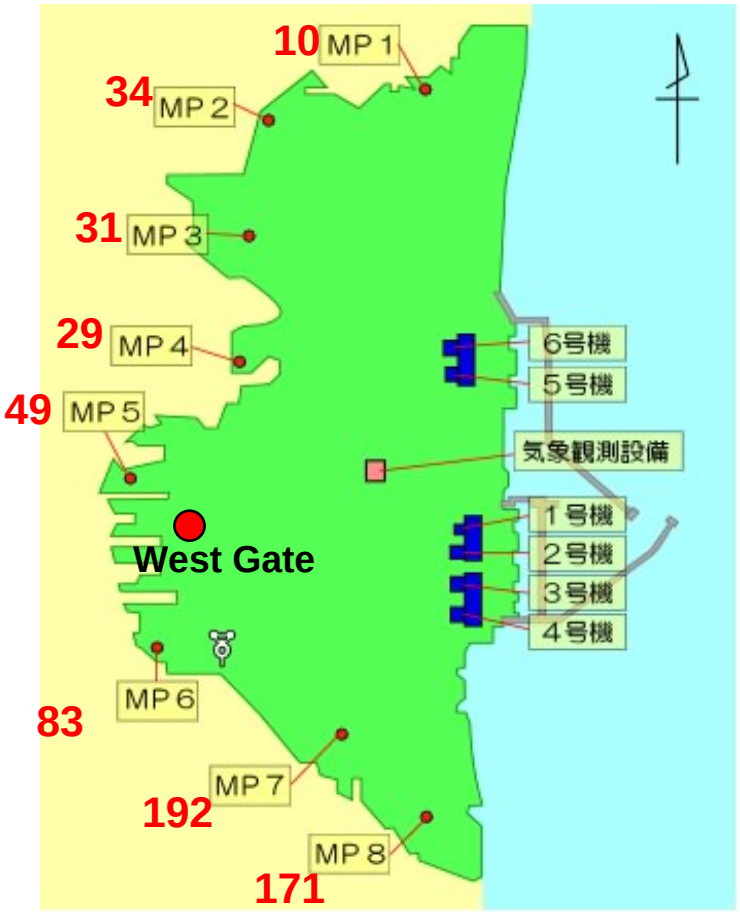
Mon, 11 April

P.M. Government declared two new regions "Planned evacuation area" where the accumulated dose of radiation to the public might exceed 20 millisieverts/yr. The second area overlapping with "Shelter in Place", is "emergency preparation evacuation area".

12. Monitoring Data (at Site Boundary of Fukushima Daiichi)

- Monitoring data at the site boundary of Fukushima Daiichi
- Continue to monitor the surrounding environment

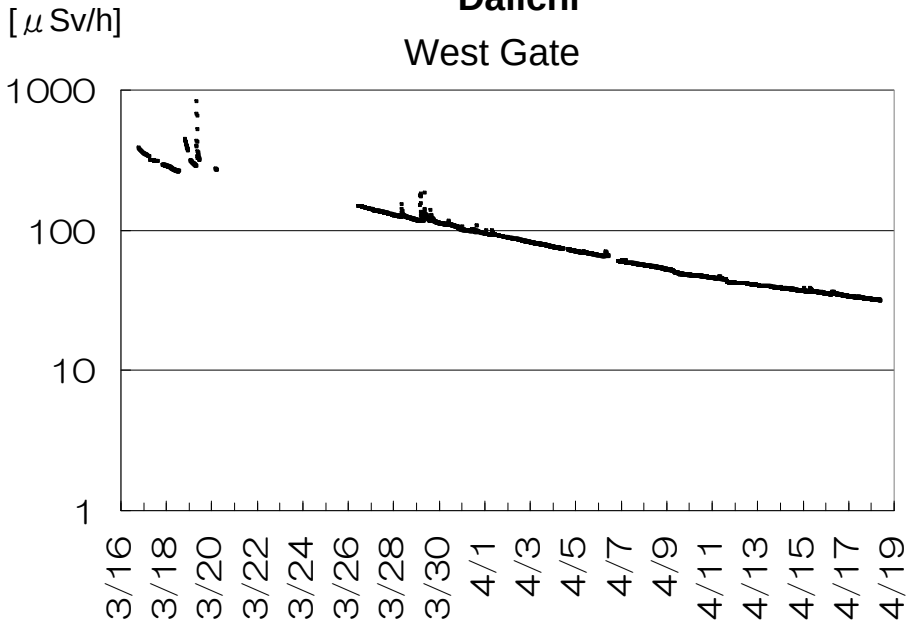
Monitoring post air dose rate
: μSv/h as of 17. April 2011 21:00



Dose rate at the surrounding area of Nuclear Power Station

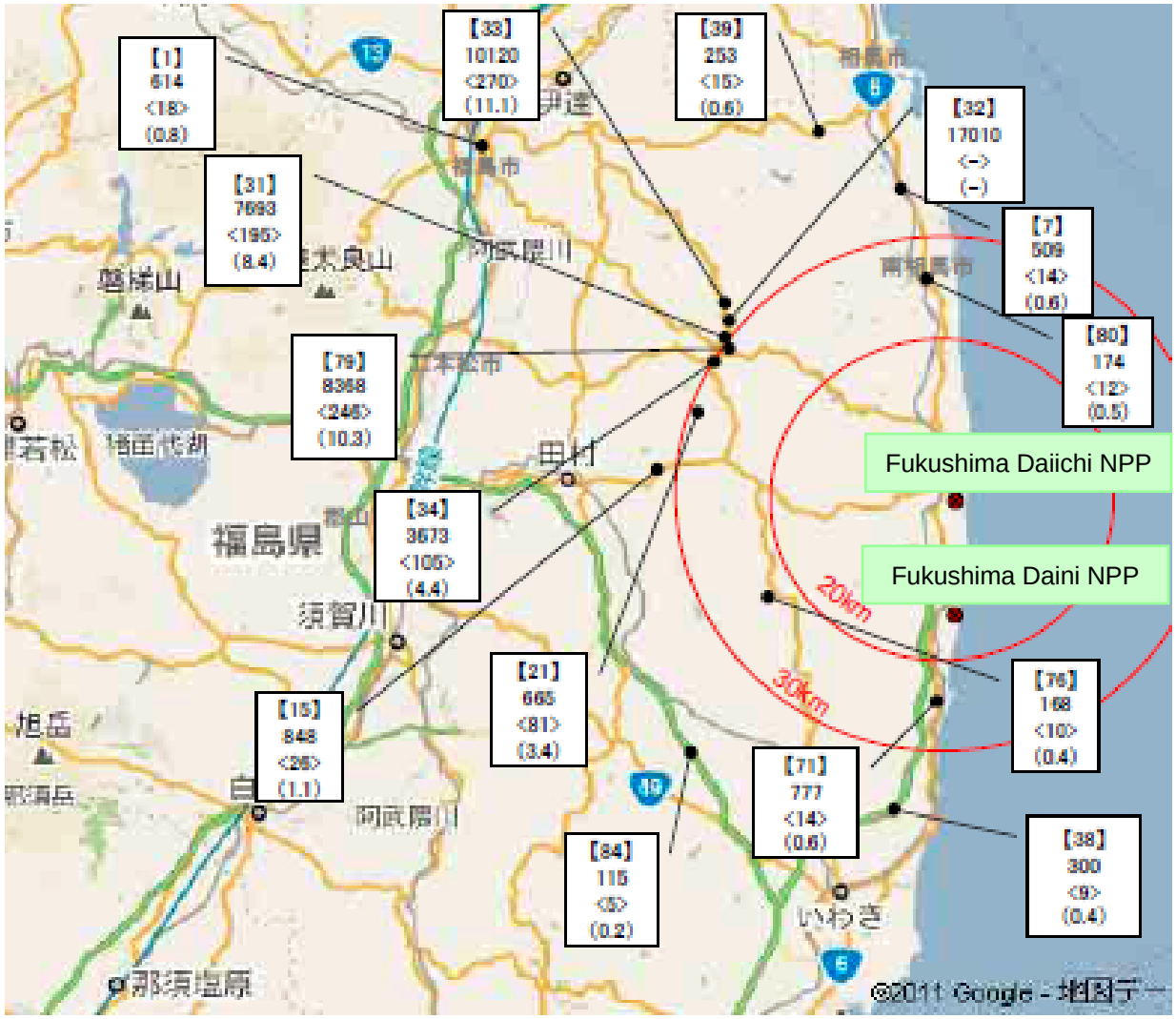
Daiichi (maximum):
Area around Unit 3: 400mSv/h (3/15 10:00)
Site boundary:12mSv/h (3/15 9:00)
Daini: 0.03-183 μSv/h

Dose Rate Trend at the Site Boundary of Fukushima Daiichi



12. Monitoring Data (Surroundings of Fukushima Daiichi)

- Accumulated Dose 30km radius from 23 March to 13 April maximum 16.0 mSv



【Location Number】 Accumulative Dose (Dose per hour)
Unit : μ Sv (μ Sv/h)

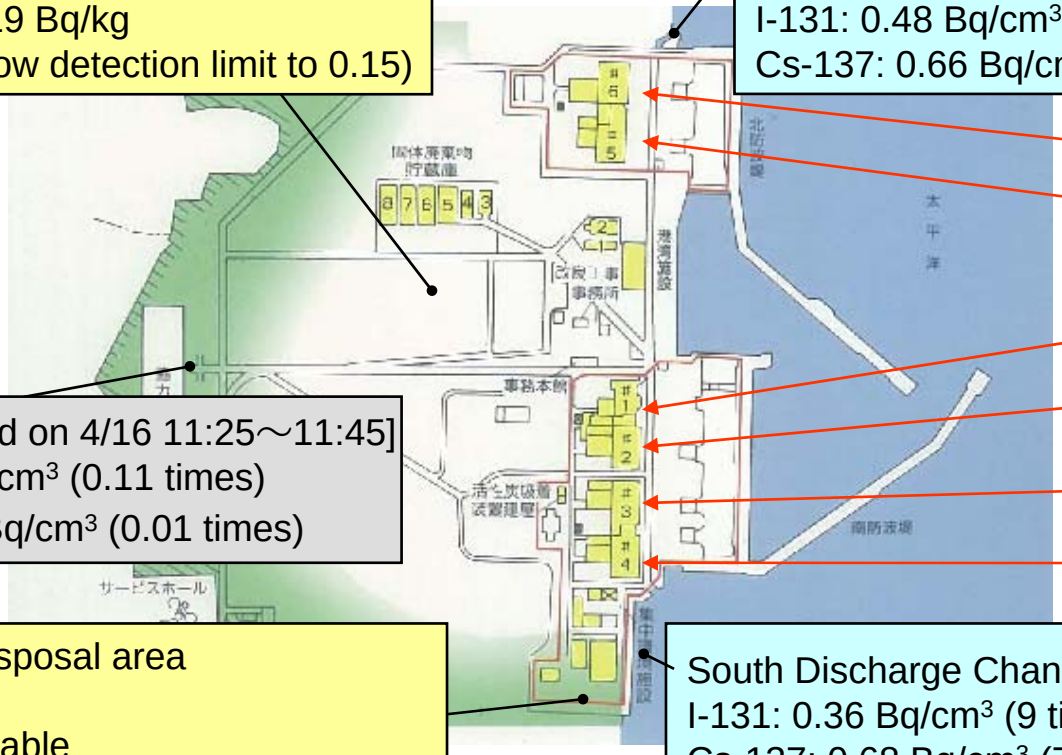
Source: Ministry of Education, Culture, Sports, Science and Technology

12. Nuclide Analysis Data Sampled in and Near the Site

- Plutonium was detected from the soil at the site sampled after March 21.
- Concentration of Plutonium detected was as same level as that under usual environment and it is considered not to be harmful to human health. Environmental monitoring at the site and surroundings were strengthened just in case.

Ground [sampled on 4/4]
Pu-238: 0.21±0.019 Bq/kg
(normal level is below detection limit to 0.15)

North Discharge Channel of Units 5~6
[sampled on 4/16 14:15]
I-131: 0.48 Bq/cm^3 (12 times)
Cs-137: 0.66 Bq/cm^3 (7.3 times)



West gate [sampled on 4/16 11:25～11:45]
I-131: 1.1X10^{-4} Bq/cm^3 (0.11 times)
Cs-137: 1.6X10^{-5} Bq/cm^3 (0.01 times)

Industrial waste disposal area
[sampled at 4/4]
Pu-238: not detectable
(normal level is below detection limit to 0.15)

South Discharge Channel [sampled on 4/16 14:00]
I-131: 0.36 Bq/cm^3 (9 times)
Cs-137: 0.68 Bq/cm^3 (7.6 times)

*Representative nuclides concentration described out of detected nuclides
(times in the bracket is the ratio of concentration limit by law)

: sea water : air : soil
I : Iodine, Cs : Cesium, Pu : Plutonium

[Reference] Impacts to Food and Water (Restriction as of April 17, 2011)

- Since March 21, radioactive materials that exceed provisional standard set by the Ministry of Health, Labour and Welfare have been detected from vegetables, milk and tap water, which leads to the restriction of food distribution etc.

Vegetables, Milk		Fukushima pref.	Ibaraki pref.	Tochigi pref.	Gunma pref.	Chiba pref.		
						Asahi city	Katori city	Tako town
Non-head leaf vegetables	spinach	D.R. C.R.	*** D.R.	D.R.	—	D.R.	D.R.	D.R.
	Kakina	D.R. C.R.	—	—	—	—	—	—
	Shungiku Bok choy sangchu	D.R. C.R.	—	—	—	D.R.	—	—
	Other Non-head leaf vegetables	D.R. C.R.	—	—	—	—	—	—
head leaf vegetables		D.R. C.R.	—	—	—	—	—	—
Brassica oleracea		D.R. C.R.	—	—	—	—	—	—
turnip		D.R. C.R.	—	—	—	—	—	—
parsley		—	—	—	—	D.R.	—	—
celery		—	—	—	—	D.R.	—	—
raw milk		D.R. *partly lifted	—	—	—	—	—	—

	Iidate Village, Fukushima pref.	**15 municipalities, Fukushima pref.
Tap water	C.R. for infant	—
Fresh Shiitake	D.R. C.R.	D.R.

D.R.: Distribution Restricted, C.R.: Consumption Restricted

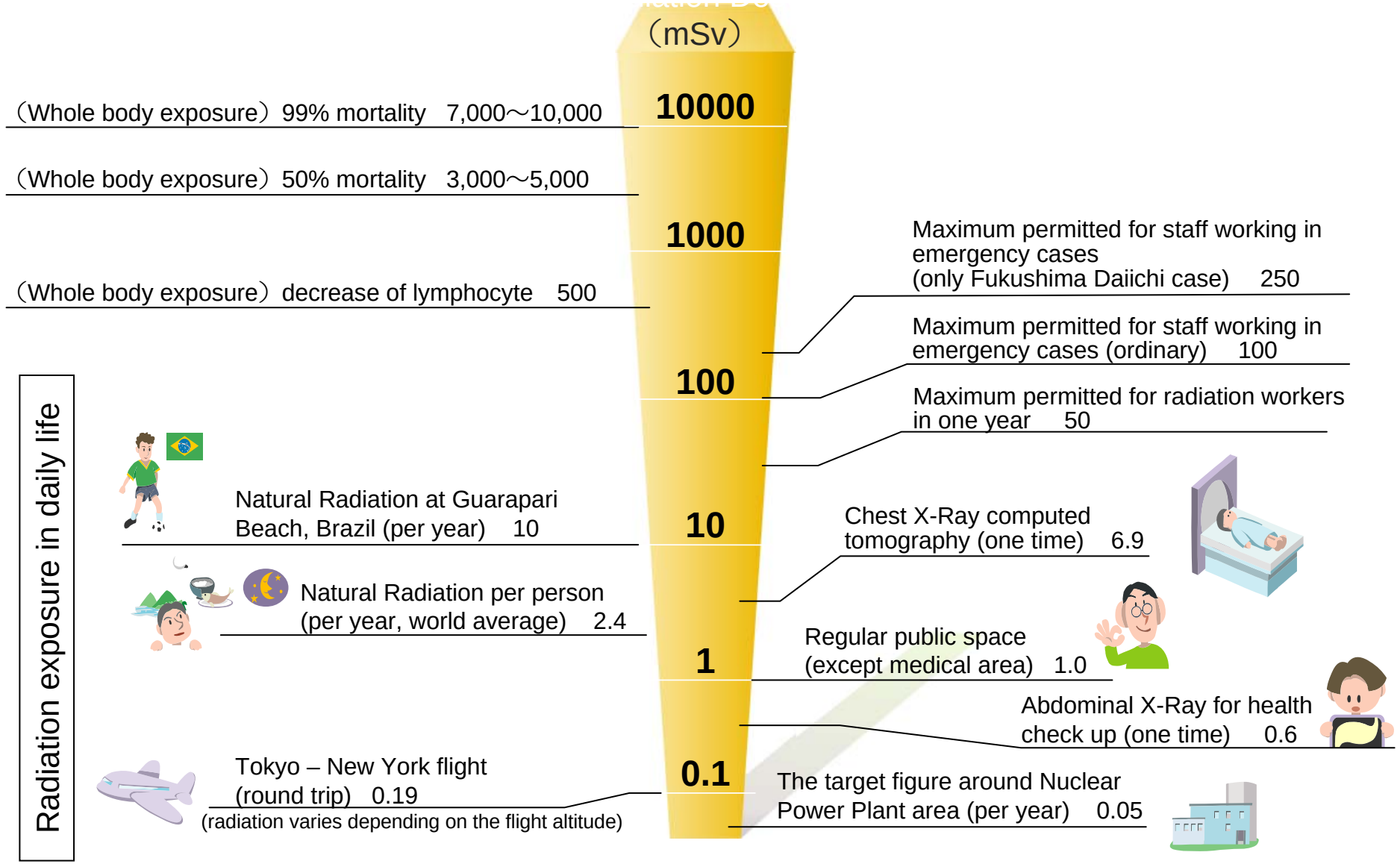
*Kitakata, Bandai, Inawashiro, Mishima, Aizumisato, Simogo, Minamiaizu were lifted

**Date, Souma, Minamisouma, Tamura, Iwaki, Shinchi, Kawamata, Namie, Futaba, Ohkuma, Tomioka, Naraha, Hirono, Katsurao, and Kawauchi

***Kitaibaraki and Takahagi

Source : web site by the Ministry of Health, Labour and Welfare

[Reference] Relationship between Health and Radiation Dose



(Note) The amount of natural radiation is including the effect of inhalation of Radon.
(source) UNSCEAR 2000 Report, "Sources and Effects of Ionizing Radiation" etc.

13.INES (International Nuclear Event Scale) Evaluation

- On April 12, Nuclear and Industrial Safety Agency released as below;
  - Tentatively assigned Level 7 on INES for the accident at Fukushima Daiichi Nuclear Power Station.
  - In this regard however, the amount of released radioactive materials is one-tenth as much as the accident at Chernobyl.
- We are wrestling with hurdles such as cooling the reactors or reducing the diffusion of radioactive materials in order to resolve the situation as soon as possible. We will commit in full force to resolve this situation along with the close coordination and cooperation with the national and local governments.

	Estimated release from Fukushima Daiichi		(Reference) Release from Chernobyl
	by NISA	by Nuclear Safety Commission	
Iodine 131 (a)	130 thousands T Bq ($1.3X10^{17}$Bq)	150 thousands T Bq ($1.5X10^{17}$Bq)	1,800 thousands T Bq ($1.5X10^{17}$Bq)
Cesium 137	6 thousands T Bq ($6.0X10^{15}$Bq)	12 thousands T Bq ($1.2X10^{16}$Bq)	85 thousands T Bq ($8.5X10^{16}$Bq)
Iodine value conversion (b)	240 thousands T Bq ($2.4X10^{17}$Bq)	480 thousands T Bq ($4.8X10^{17}$Bq)	3,400 thousands T Bq ($3.4X10^{18}$Bq)
(a) + (b)	370 thousands T Bq ($3.7X10^{17}$Bq)	630 thousands T Bq ($6.3X10^{17}$Bq)	5,200 thousands T Bq ($5.2X10^{18}$Bq)

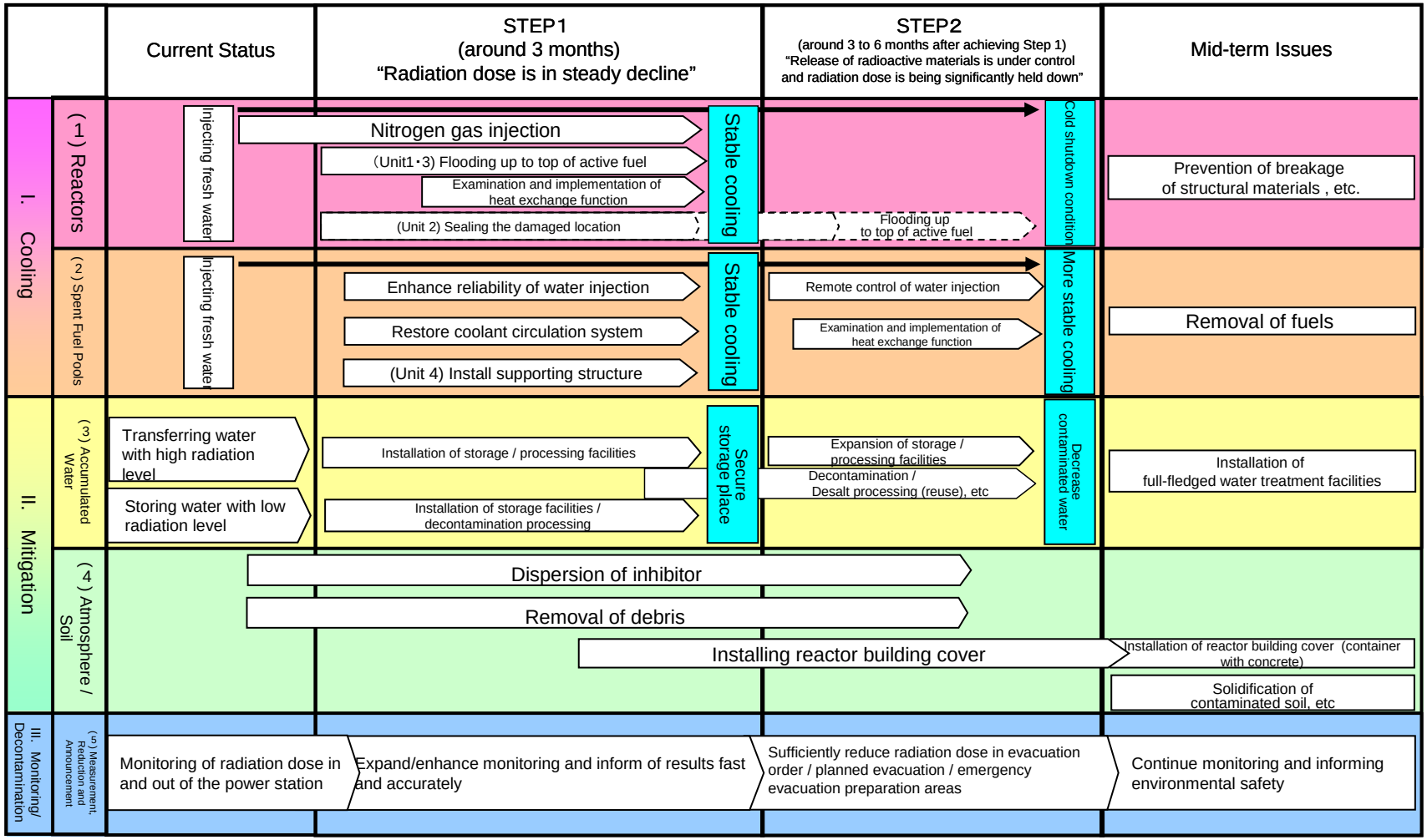
INES level 7 equivalent : over 10 thousands Tera Becquerel (T Bq) (over 10^{16}Bq)

Source: Nuclear and Industrial Safety Agency

14. Roadmap towards Restoration from the Accident

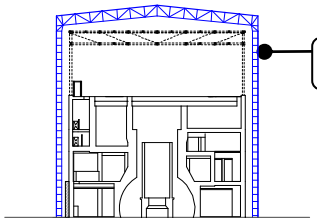
- By bringing the reactors and spent fuel pools to a stable cooling condition and mitigating the release of radioactive materials, we will make every effort to enable evacuees to return to their homes and for all citizens to be able to secure a sound life.

< Roadmap for Immediate Actions (Issues / Targets / Major Countermeasures) >



14. Roadmap towards Restoration from the Accident

< Overview of Major Countermeasures in the Power Station >



Reactor building cover

Cooling of spent fuel pool by external water injection

Sampling of steam/pool water and measurement of radioactive materials

Storage of low radiation-level water

Reactor Building

Circulation cooling of spent fuel pool

Nitrogen gas injection

Tank

Processing high radiation-level water

Water processing facility (Decontamination and desalt processing)

Tanks, Megafloats, Barges, Reservoir

PCV venting (with filtration)

Primary Containment Vessel (PCV)

Tank Lorry

Reuse of processed water

Storage of high radiation-level water

Flooding up to top of active fuel

Reactor Pressure Vessel (RPV)

Turbine Building

Steam Turbine

Heat Exchanger

Additionally-installed Tank

Centralized Waste Treatment Building

Installation of heat exchangers

Condenser

Injection of fresh water with pumps

Suppression Chamber

Dispersion of inhibitor
Removal of debris
Consideration of countermeasures for contaminated soil

Preventive measures against leakage of high radiation-level water

(Unit 2) Sealing the damaged location

Treatment of sub-drainage water after being pumped up

Seismic assessment,
Continued monitoring,
(Unit 4) Installation of supporting structure under the bottom of spent fuel pool

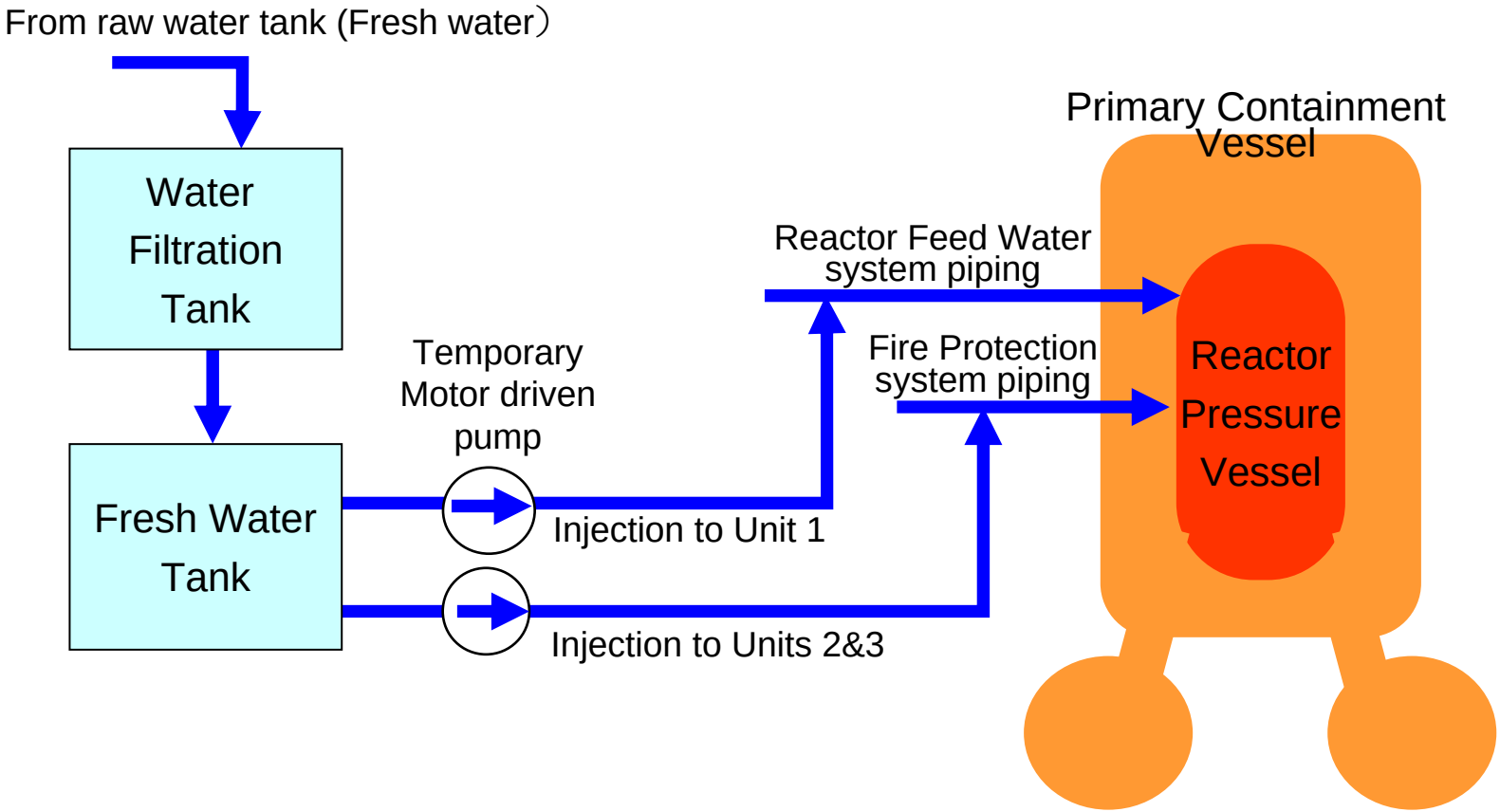
piping

pumps

heat exchangers, water processing facilities

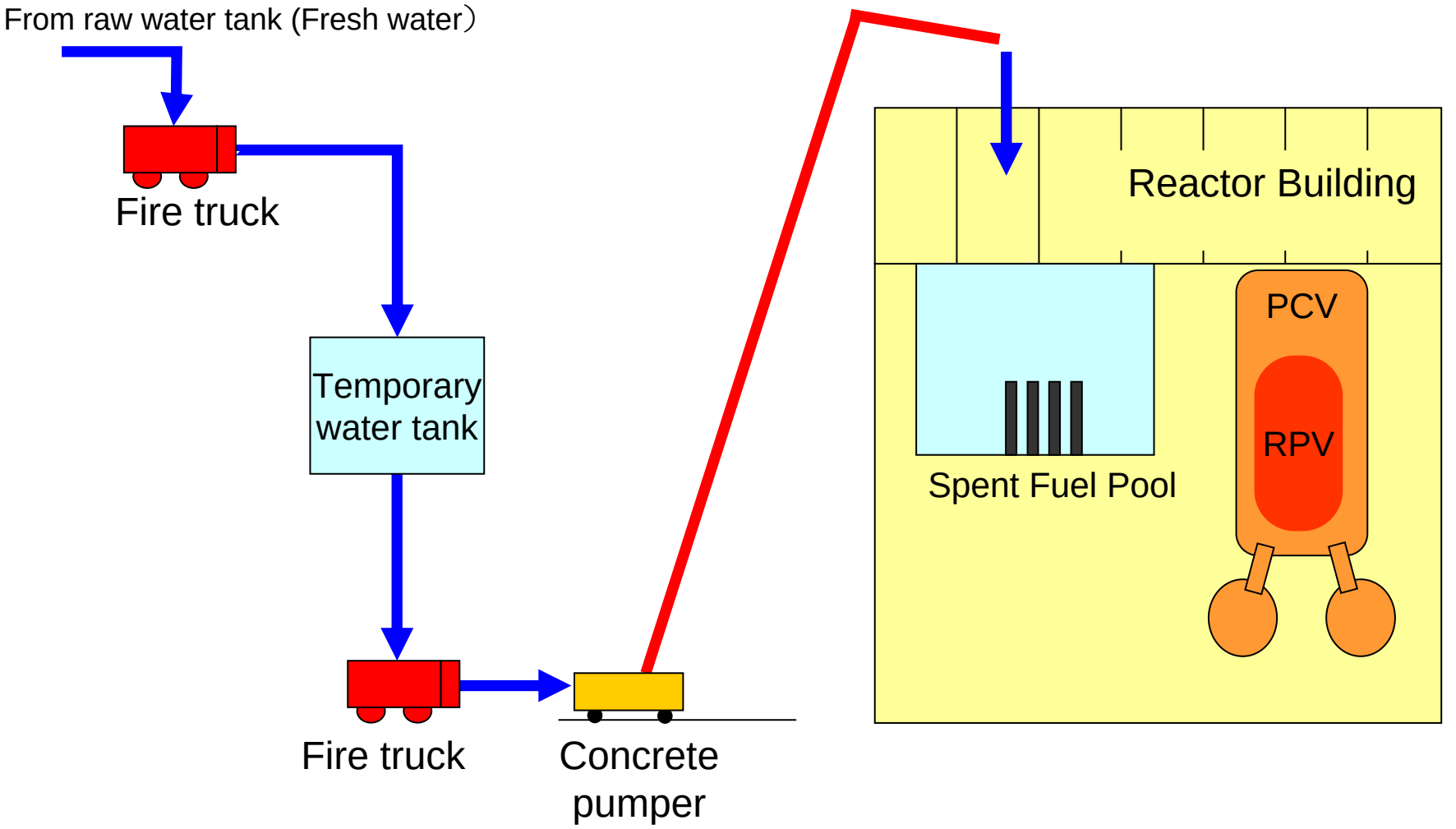
[Reference] Reactor Feed Water System

- Injected fresh water to cool the reactor just after the earth quake, changed over from fresh water to sea water (boric acid contained) after that , and then changed over again from sea water to fresh water for the injection.



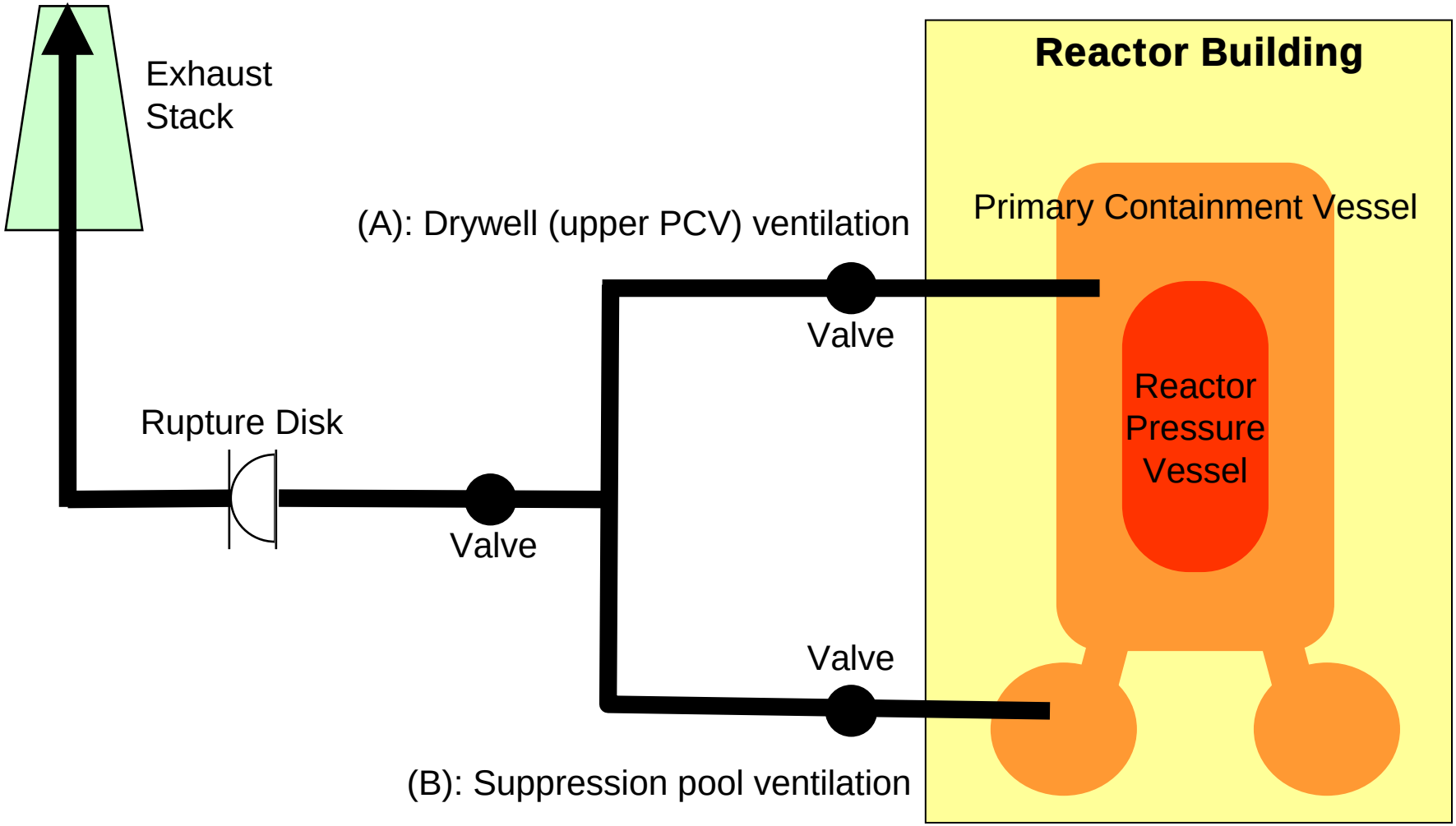
[Reference] Water Spray into Spent Fuel Pool

- Injecting freshwater although injected seawater just after the earth quake.
- Monitoring continuously the status of spent fuel pools, and will spray/inject fresh water into the pools if it is necessary.



[Reference] Measure to Decrease Pressure of PCV (Ventilation)

- Implemented ventilation to reduce the pressure of Primary Containment Vessel (PCV) in Units 1-3 to prevent PCV from getting over pressured.



Reference : Seismic Observed Data

- Will endeavor to keep collecting as much data as possible and analyze these in more detail

Comparison between Basic Earthquake Ground Motion and the record of intensity

Observation Point (The lowest basement of reactor buildings)		Observed data (*interim) Maximum Response Acceleration (gal)			Maximum Response Acceleration against Basic Earthquake Ground Motion (Gal)		
		Horizontal (N-S)	Horizontal (E-W)	Vertical	Horizontal (N-S)	Horizontal (E-W)	Vertical
Fukushima Daiichi	Unit 1	460*2	447*2	258*2	487	489	412
	Unit 2	348*2	550*2	302*2	441	438	420
	Unit 3	322*2	507*2	231*2	449	441	429
	Unit 4	281*2	319*2	200*2	447	445	422
	Unit 5	311*2	548*2	256*2	452	452	427
	Unit 6	298*2	444*2	244	445	448	415
Fukushima Daini	Unit 1	254	230*2	305	434	434	512
	Unit 2	243	196*2	232*2	428	429	504
	Unit 3	277*2	216*2	208*2	428	430	504
	Unit 4	210*2	205*2	288*2	415	415	504

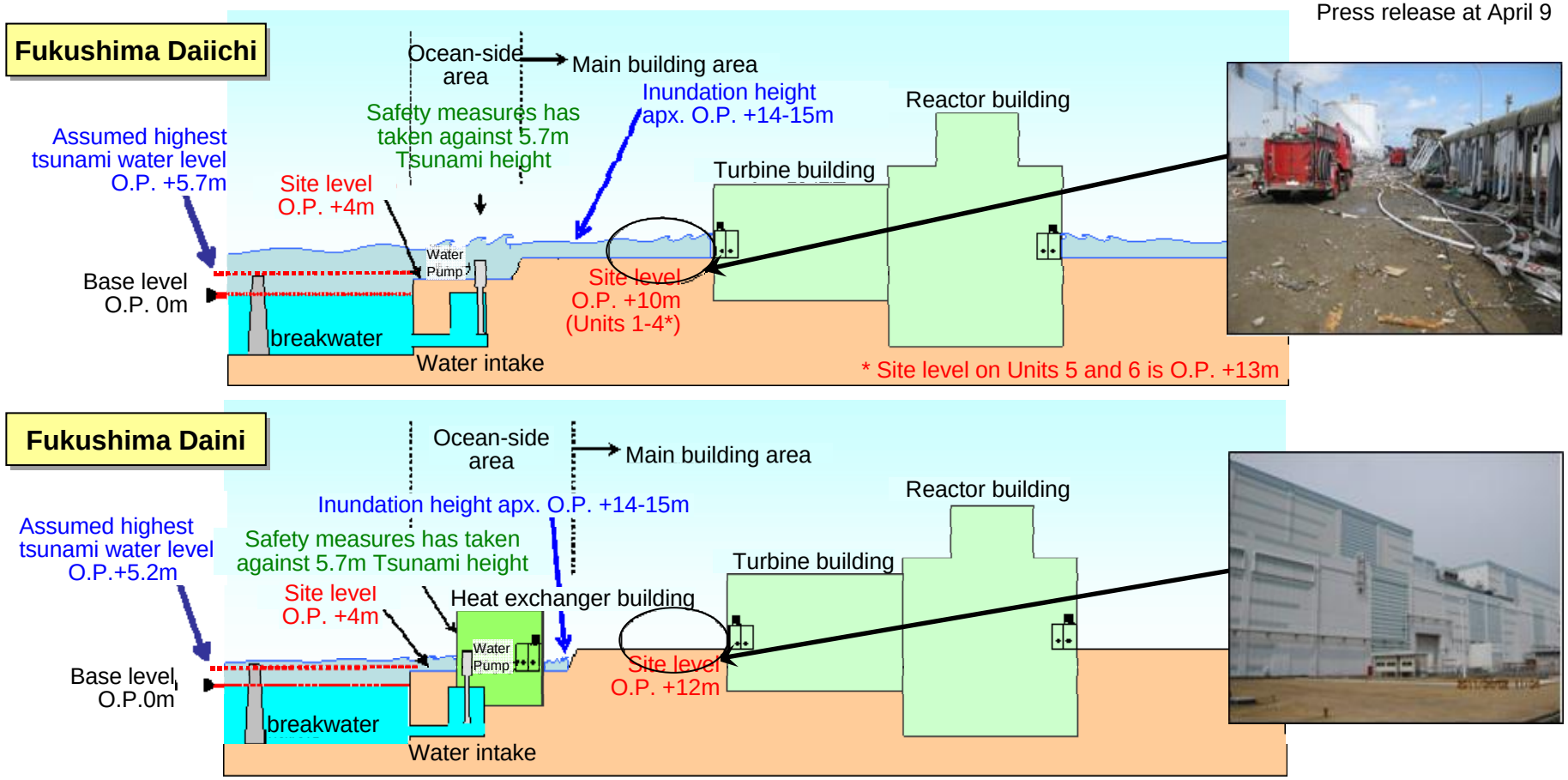
*1: The data above is interim and is subject to change.

*2: The recording time was about 130-150 seconds

[Reference] Height of Tsunami

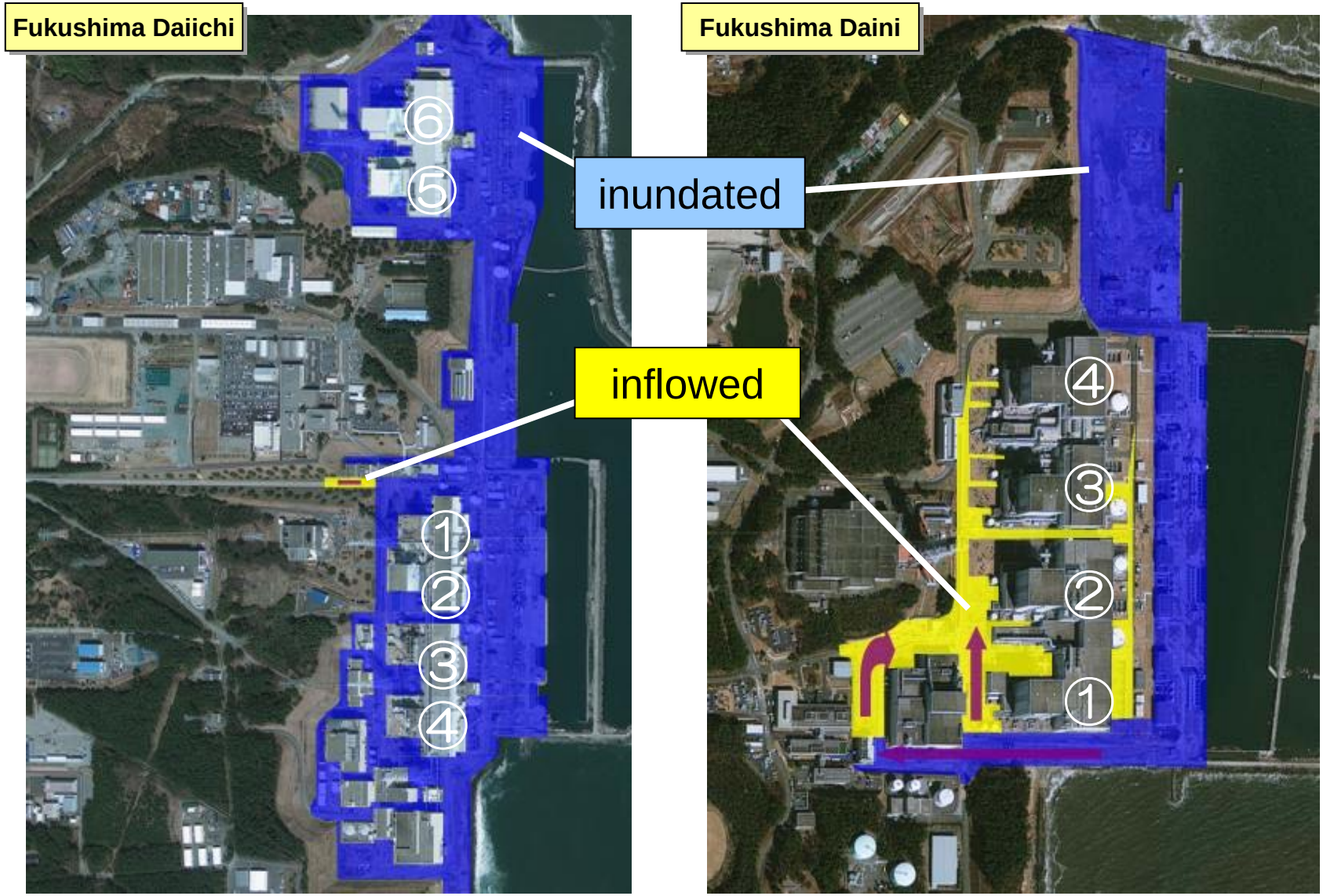
- Based on the evaluation method by the Japan Society Civil Engineers revised on 2002, we conducted an assessment regarding Tsunami of O.P. 5.1～5.7m, and based on this evaluation, we have taken safety measures.
- At Fukushima Daiichi Nuclear Power Station, inundation with inundation height of approximately O.P. + 14 to 15 meters and inundation depth approximately 4 to 5 meters occurred in most of the area.
- At Fukushima Daini Nuclear Power Station, inundation with inundation height of approximately O.P. + 6.5 to 7 meters occurred in the ocean-side areas, however, only surrounding areas of Unit 1 and 2 buildings and the south side of Unit 3 building was inundated within the main building area.
- **Accordingly, we have confirmed that the impact of tsunami was relatively larger in Fukushima Daiichi Nuclear Power Station than Fukushima Daini Nuclear Power Station.**

Press release at April 9



O.P.：Onahama bay construction base level

[Reference] Inundated and Inflowed Area at Fukushima Daiichi and Daini Site



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