U.S. National Academy of Sciences
Washington D.C.

Overview of the Accident in Fukushima Daiichi Nuclear Power Plants

May 26, 2011

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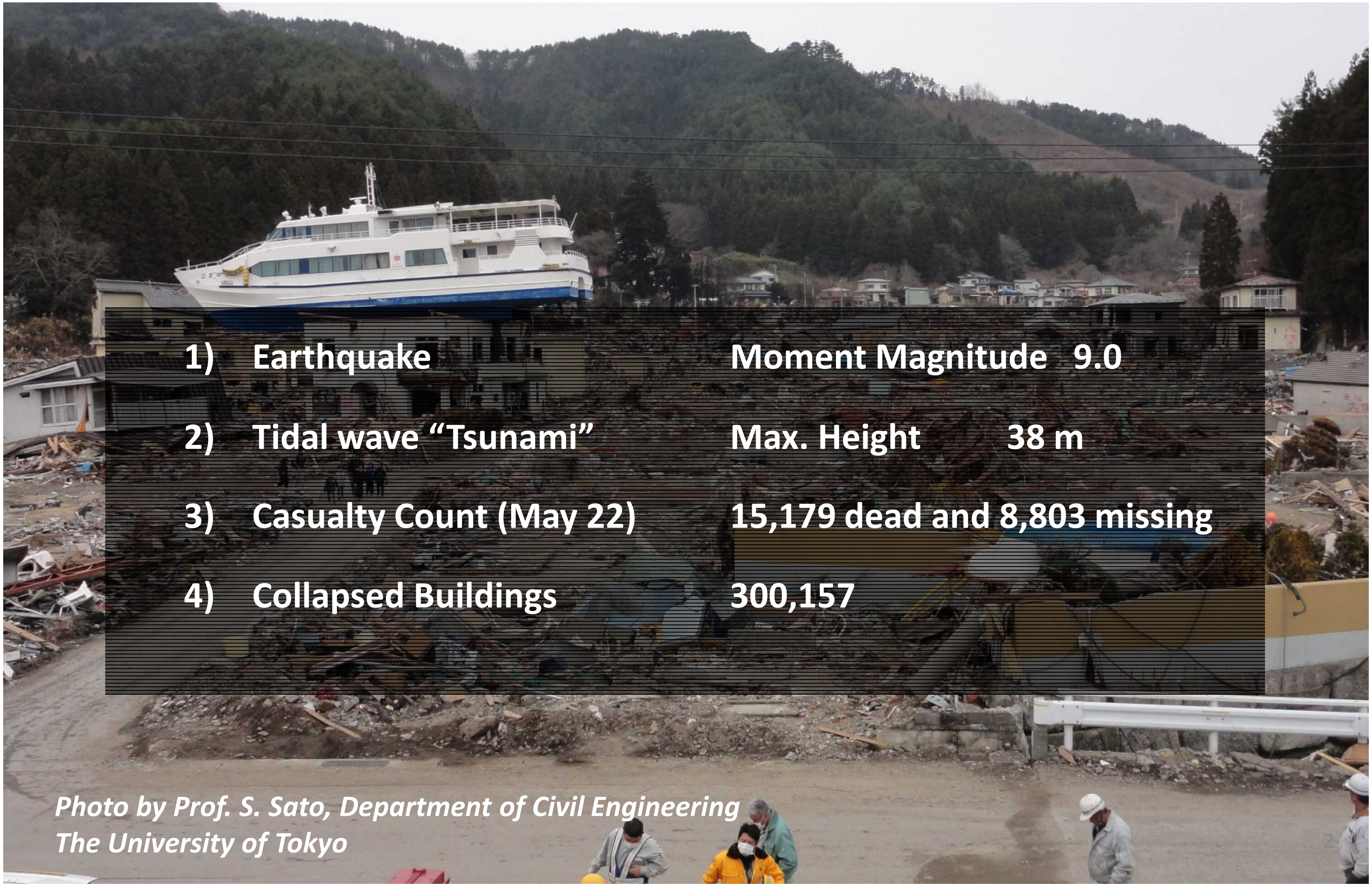
Associate Member of Science Council of Japan

Contents

The information is preliminary and needs to be confirmed later.

2011.3.11 Earthquake and Tsunami



1)	Earthquake	Moment Magnitude 9.0
2)	Tidal wave “Tsunami”	Max. Height 38 m
3)	Casualty Count (May 22)	15,179 dead and 8,803 missing
4)	Collapsed Buildings	300,157

Photo by Prof. S. Sato, Department of Civil Engineering
The University of Tokyo

震災の科学技術に対するインパクト
Impact of the Disaster upon Science and Technology

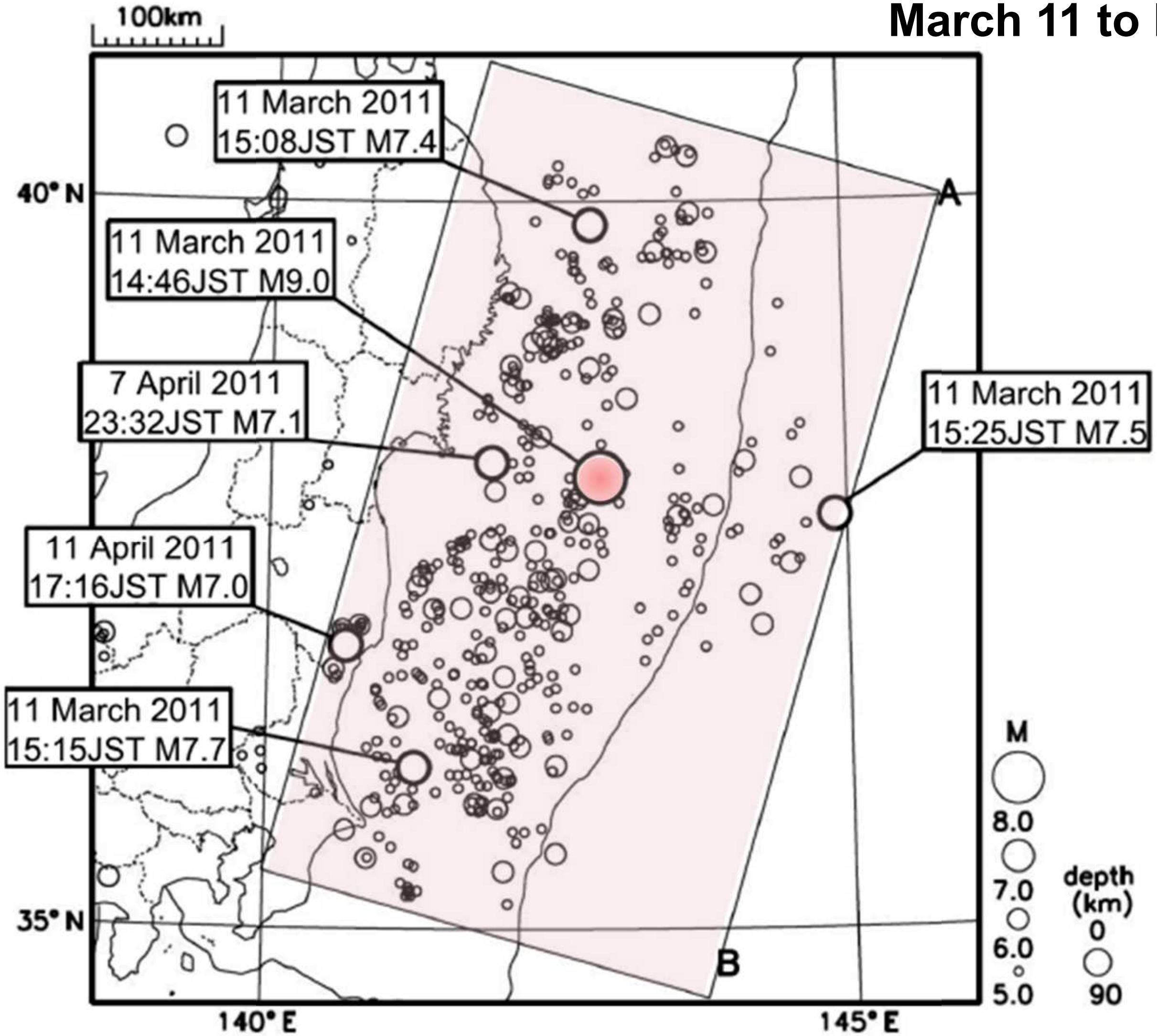
1)	原子力発電所の事故 Accident of nuclear power plant	4基同時，レベル7 4 plants, Level 7
2)	電力供給不足 Shortage of electric power supply	3950×10^4 kW/h，計画停電 Rolling blackouts
3)	工業生産の低下 Diminishing industrial production	サプライチェーンの断裂 Supply-chain disruption
4)	通信網の断裂 Disruption of communication network	1週間 1 week

科学技術への信頼低下
Loss of credibility of science and technology ?
工学者・学生の自信喪失
Loss of confidence in engineering scholars and students ?

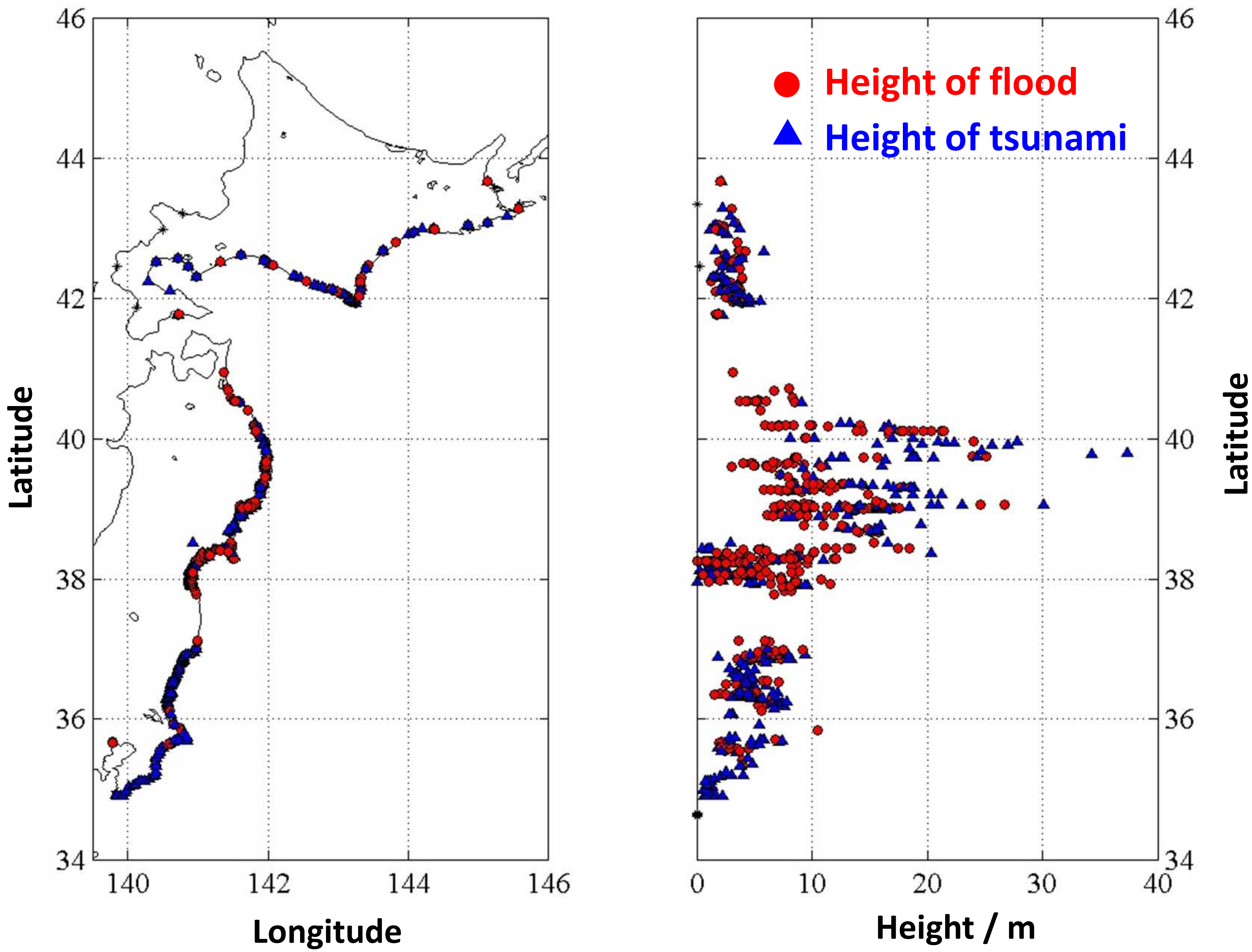
Prof. T. Kitamori, Dean of School of Engineering, The University of Tokyo

The Main Shock and Aftershock of the Earthquake on 2011.3.11

March 11 to May 13, 2011



Tsunami after the Earthquake on 2011.3.11



Compiled by 80 members from 33 organization including The University of Tokyo
http://www.coastal.jp/ttjt/

Automatic Shut-down of Nuclear Reactors by the Earthquake on 2011. 3. 11

11 reactors were automatically shut-down

- Onagawa Unit 1,2,3
- Fukushima Daiichi Unit 1,2,3
- Fukushima-Daini Unit 1,2,3,4
- Tokai-2

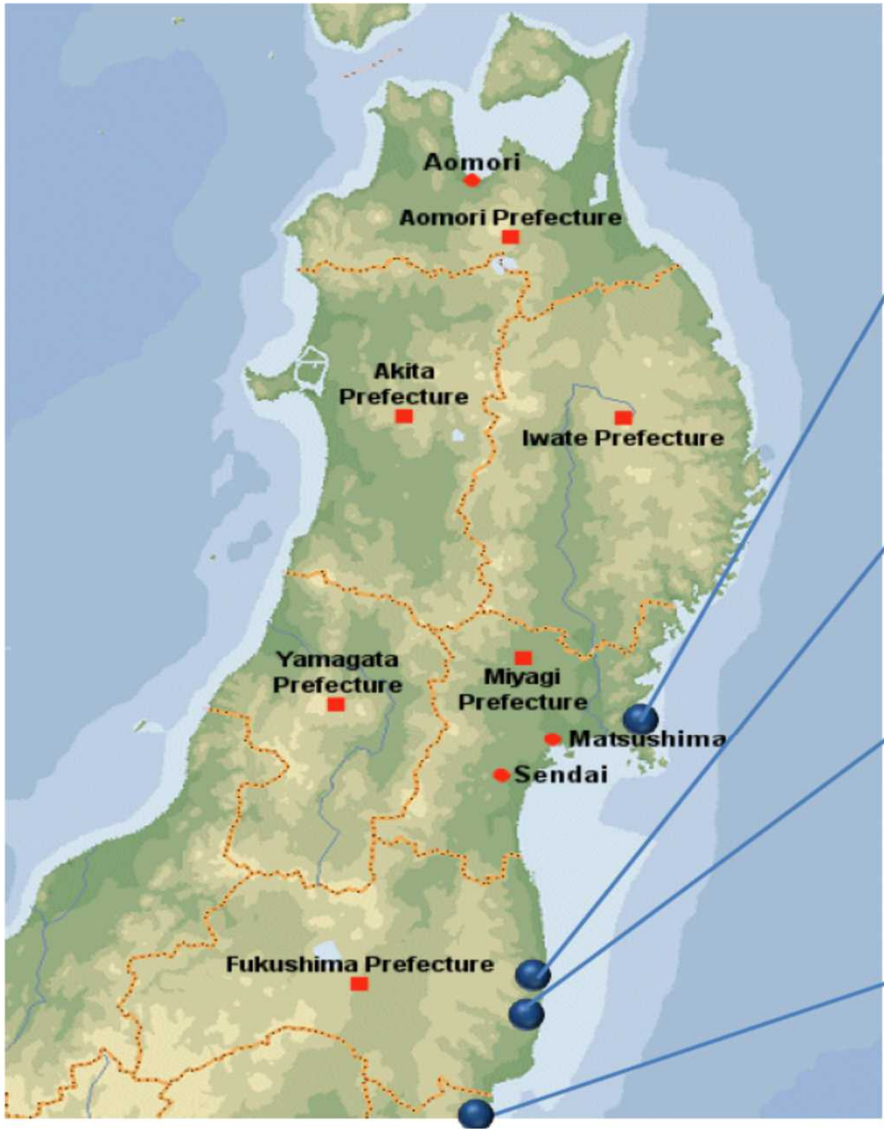
3 reactors were under periodic inspection

- Fukushima Daiichi Unit 4,5,6

- **After the automatic shut-down, the Units 1-3 at Onagawa Nuclear Power Station, the Unit 3 at Fukushima Daini Nuclear Power Station, and the Tokai-2 Nuclear Power Station have been cold shut down safely.**

- **As for the unit 1,2,4 at Fukushima Daini Nuclear Power Station, the operator of the station reported NISA nuclear emergency situation because the temperature of the suppression pools became more than 100 ℃, but afterward the three units have been cold shut down.**

Nuclear Power Plants in Eastern Coast of Japan



Onagawa (Tohoku)

Unit1: 524 MW, 1984-
Unit2: 825 MW, 1995-
Unit3: 825 MW, 2002-

Fukushima Daiichi * (TEPCO)

Unit1: 460 MW, 1971-
Unit2: 784 MW, 1974-
Unit3: 784 MW, 1976-
Unit4: 784 MW, 1978-
Unit5: 784 MW, 1978-
Unit6: 1,100 MW, 1979-

Fukushima Daini (TEPCO)

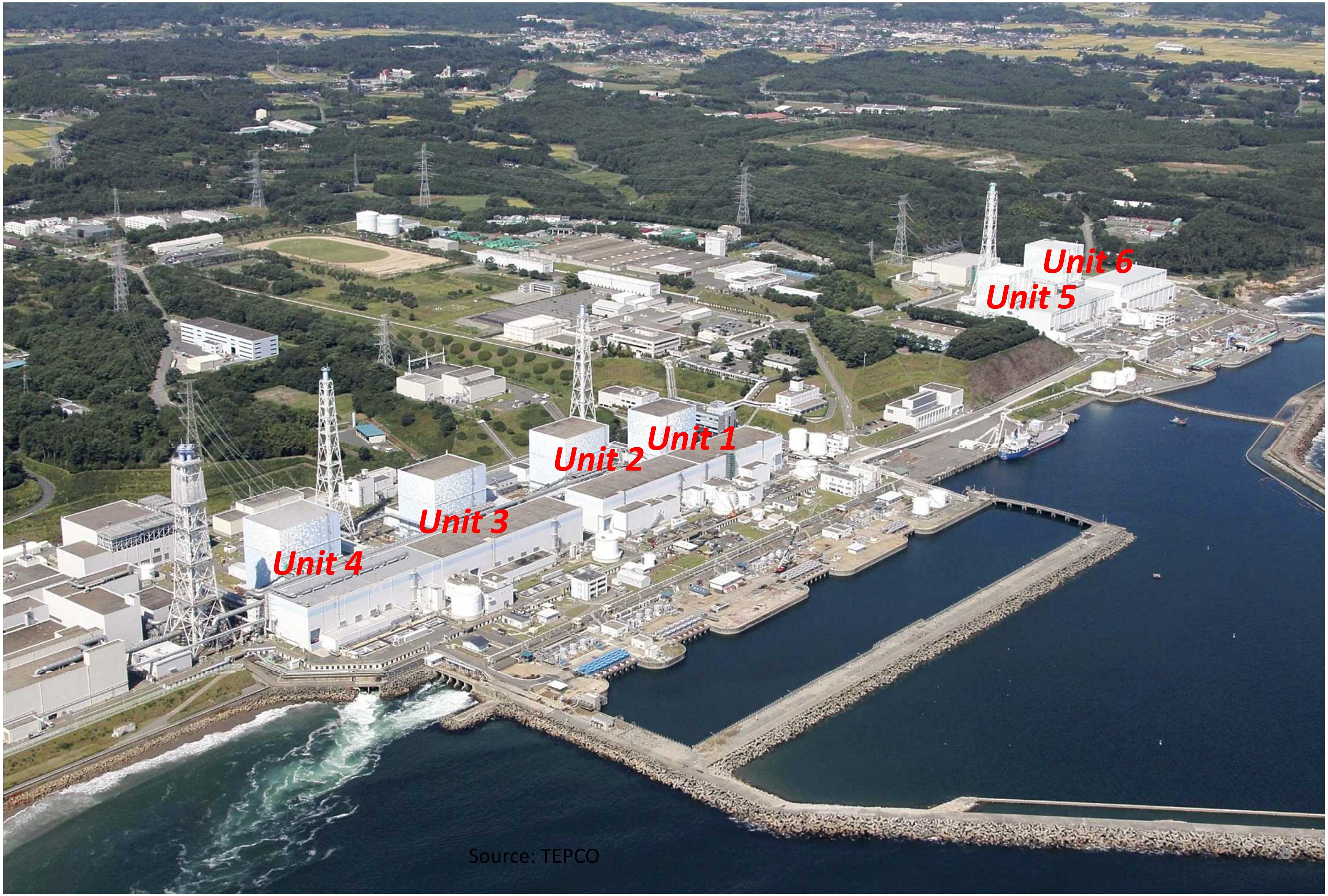
Unit1: 1,100 MW, 1982-
Unit2: 1,100 MW, 1984-
Unit3: 1,100 MW, 1985-
Unit4: 1,100 MW, 1987-

Tokai-2 (JAPCO)

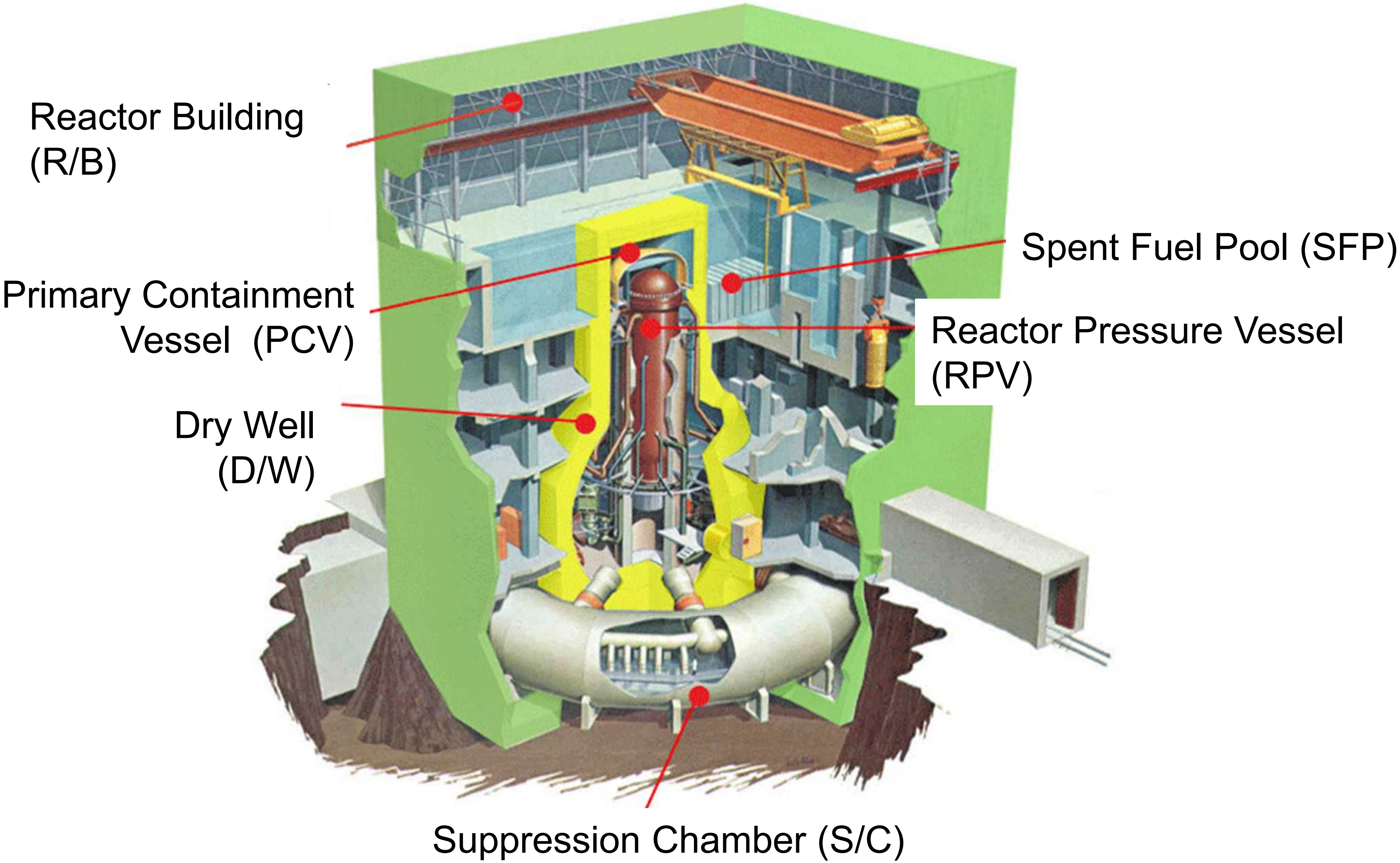
(1,100 MW, 1978-)

****** Fukushima Daiichi locates approximately 230 km north of Tokyo***

Fukushima Daiichi Nuclear Power Plants operated by TEPCO



Overview of Mark-I Type BWR (Units 1,2,3,4 and 5)



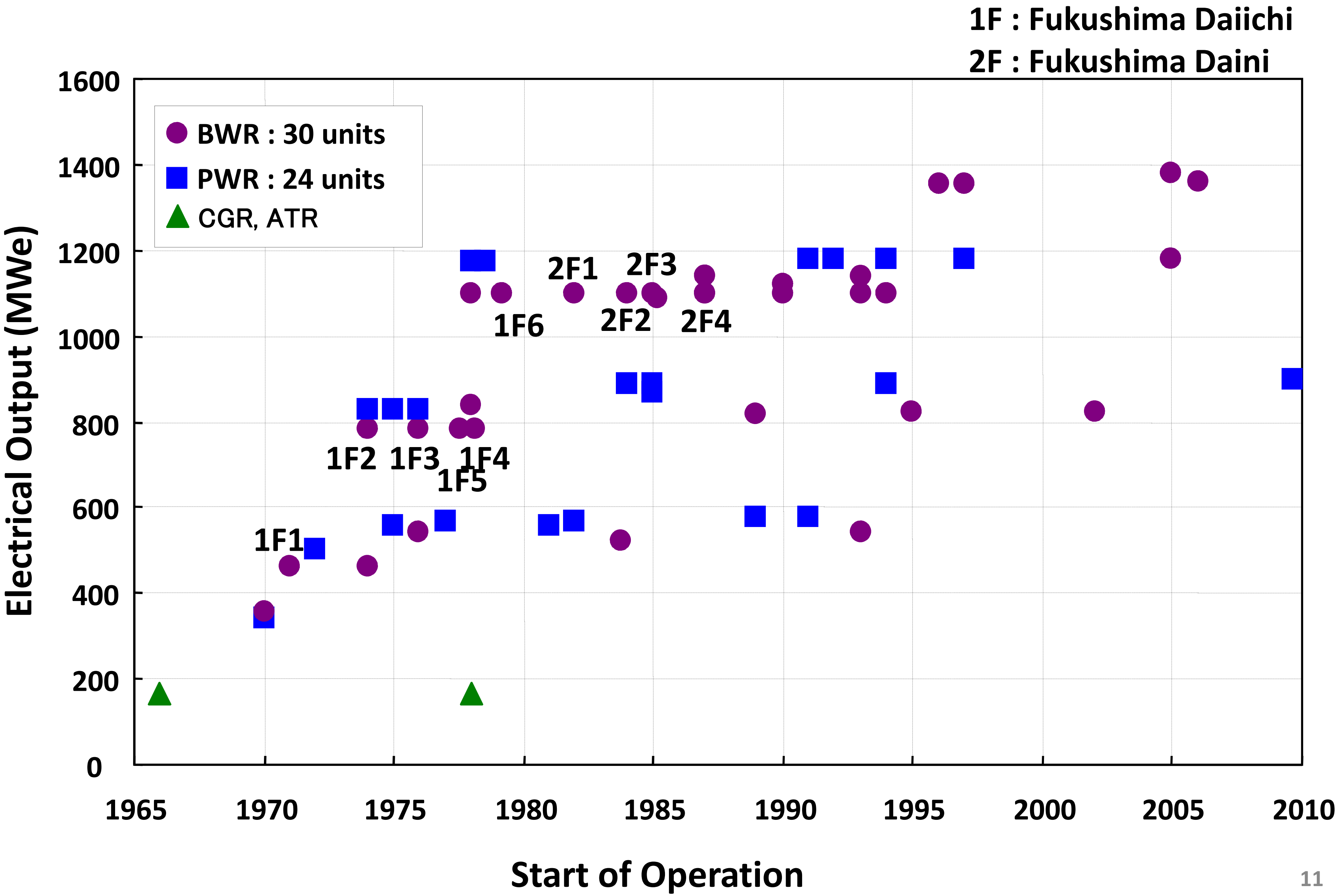
Summary of Fukushima Daiichi NPP

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
PCV Model	Mark-I	Mark-I	Mark-I	Mark-I	Mark-I	Mark-II
Electric Output	460MWe	784MWe	784MWe	784MWe	784MWe	1100MWe
RPV Operation Pressure	6.89MPa	6.93MPa	6.93MPa	6.93MPa	6.93MPa	6.93MPa
RPV Max. Design Pressure	8.24MPa	8.24MPa	8.24MPa	8.24MPa	8. 62MPa	8.62MPa
RPV Max. Operation Temp.	300℃	300℃	300℃	300℃	302℃	302℃
PCV Max. Design Pressure	384kPa	384kPa	384kPa	384kPa	384kPa	279kPa
PCV Max. Pressure *	427kPa	427kPa	427kPa	427kPa	427kPa	310kPa
PCV Max. Temp	140℃	140℃	140℃	140℃	138℃	171℃:D/W 105℃:S/C
Commercial Operation	1971.3.26	1974.7.18	1976.3.27	1978.10.12	1978.4.18	1979.10.24
Emergency DG	2	2 **	2	2 **	2	3 **
Electric Grid	275kV×4				500kV×2	
Plant Status on Mar. 11	In Operation	In Operation	In Operation	Long Outage for Shroud Replacement	Refueling Outage	Refueling Outage

* Typical operating pressure of PCV is about 5 kPa.

** One Emergency DG is Air-Cooled

Nuclear Power Plants in Japan



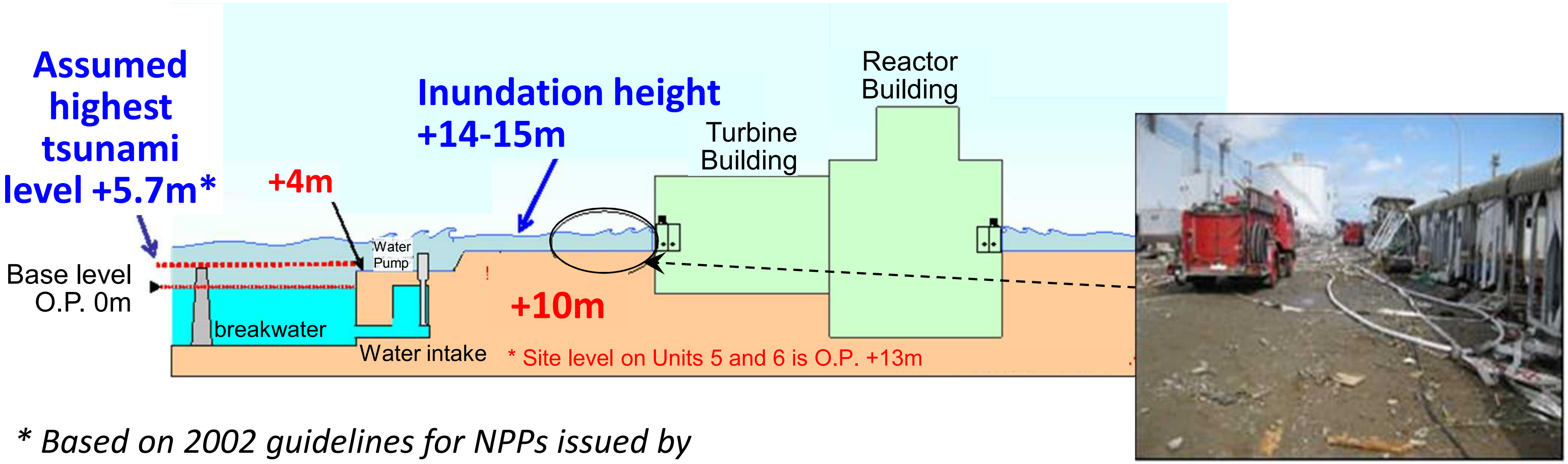
Recorded Intensity of Ground Motion and Basic Earthquake Ground Motion

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

* At the lowest basement of reactor building

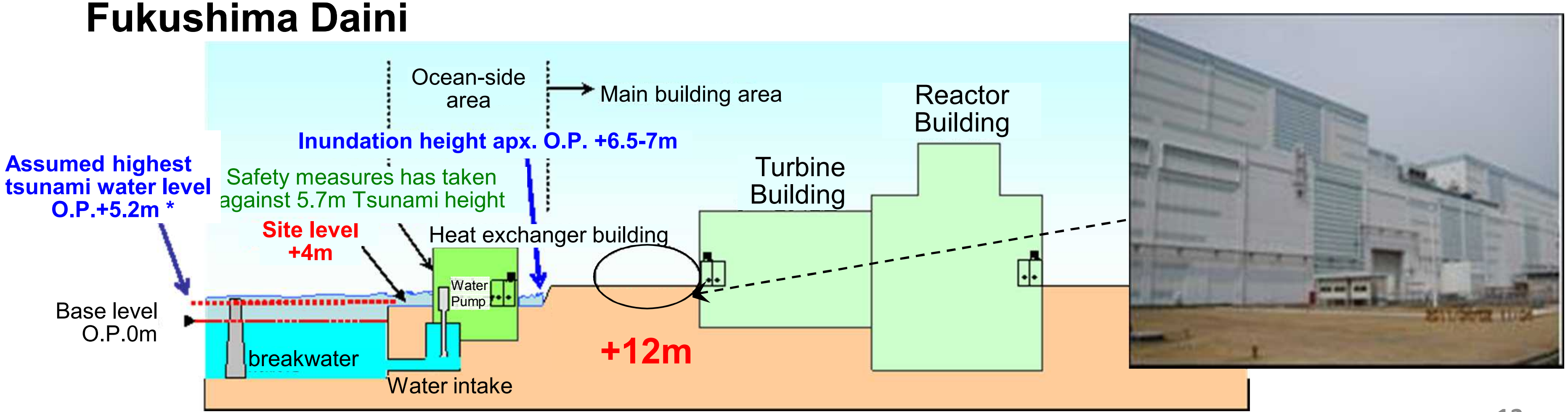
Tsunami

Fukushima Daiichi

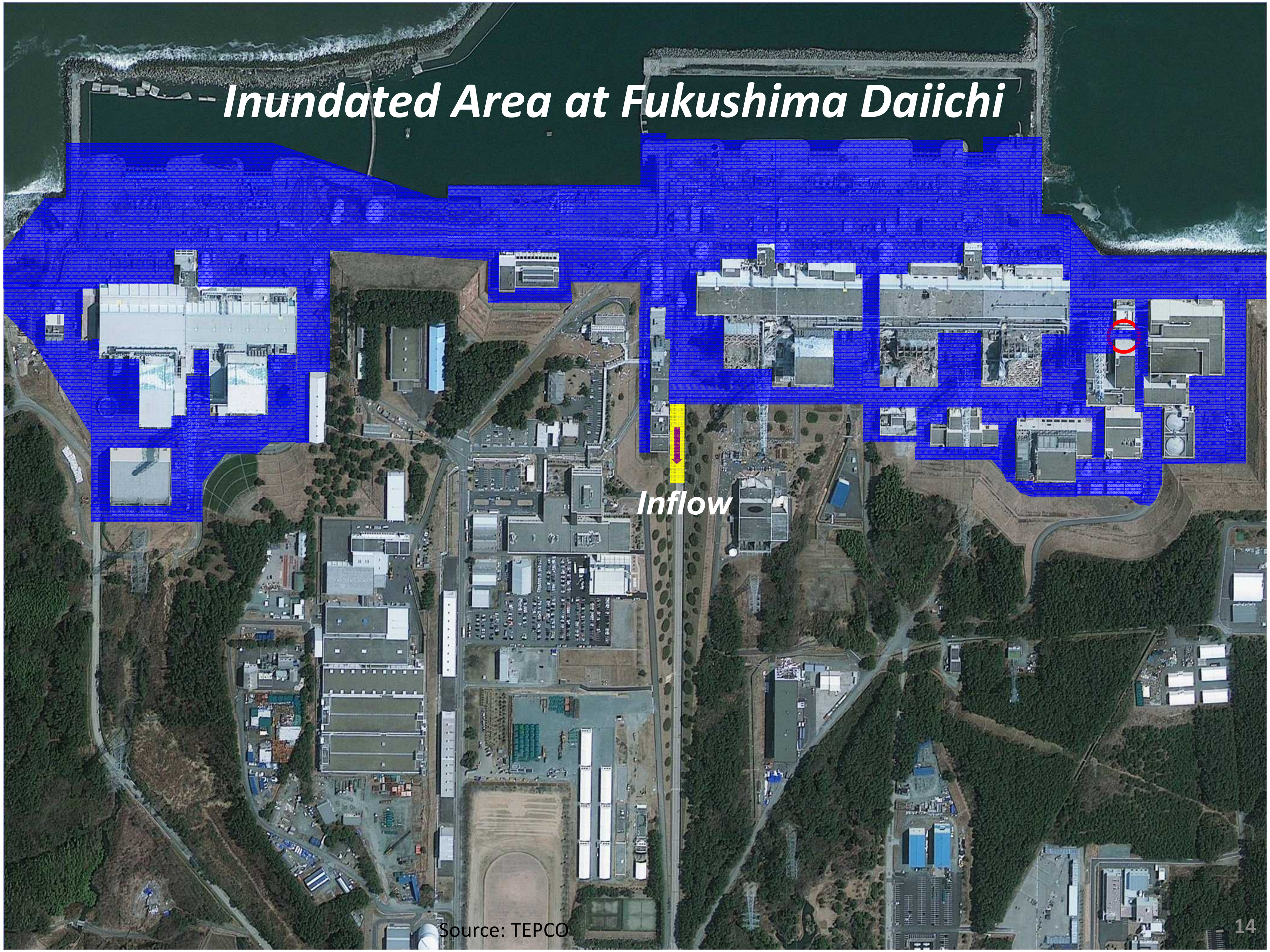


** Based on 2002 guidelines for NPPs issued by the Nuclear Civil Engineering Committee of JSCE*

Fukushima Daini



O.P.: Onahama bay construction base level


Inundated Area at Fukushima Daiichi
Inflow
Source: TEPCO
14

Tsunami, March 11, 2011

15:42:40

15:42:46

15:43:26

15:43:36

15:43:54

15:44:18

15:44:44

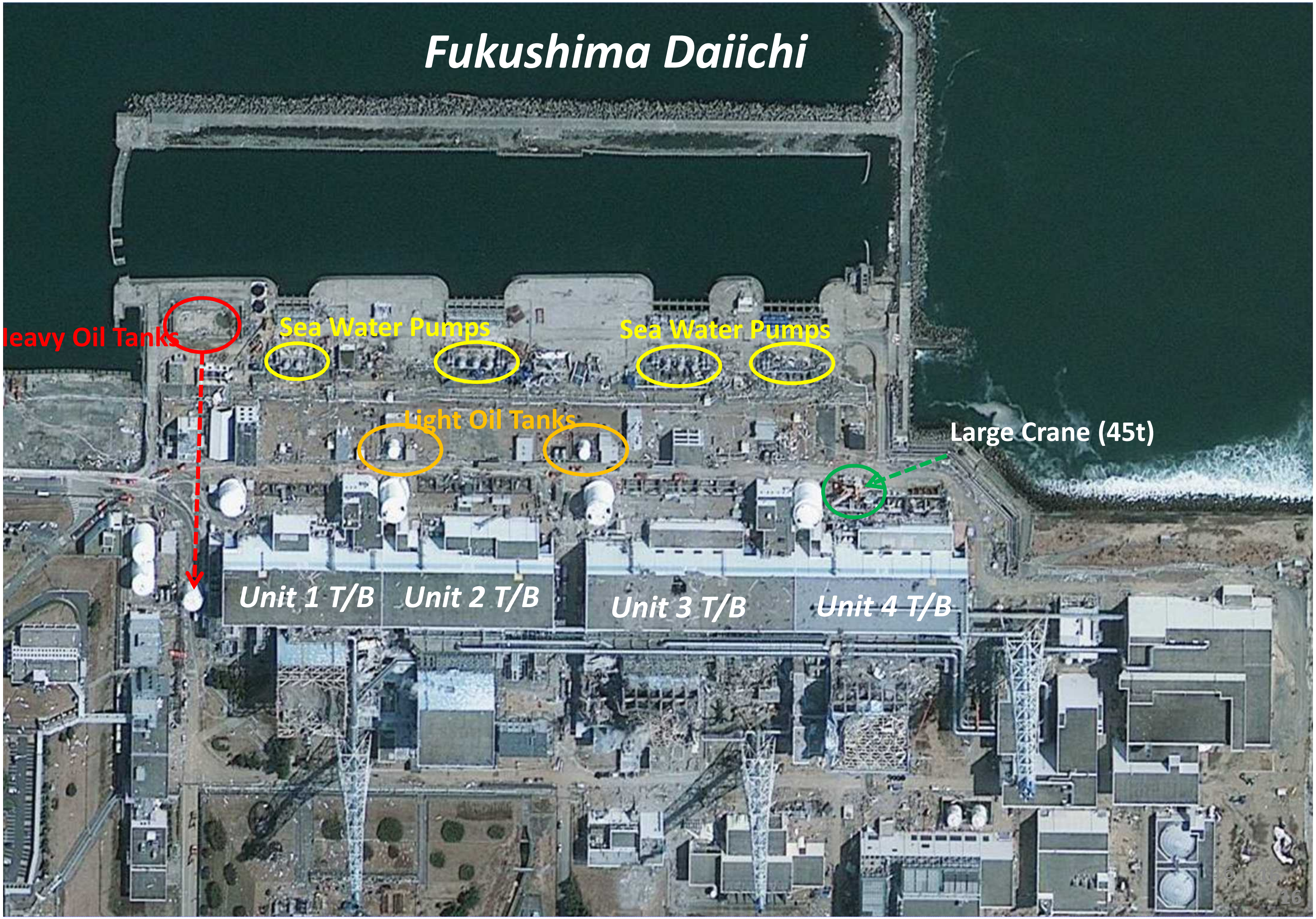
15:44:58

15:46:10

Tsunami height in Fukushima Daiichi was about 15 m.

Source: TEPCO

Tsunami, March 11, 2011



Station Black-Out in Units 1-4
- Loss of Off-Site Power Supply and EDG -

Station Black-Out

All the motor operated pumps including ECCS pumps became inoperable

① Loss of Off-Site Power due to the Earthquake and Tsunami

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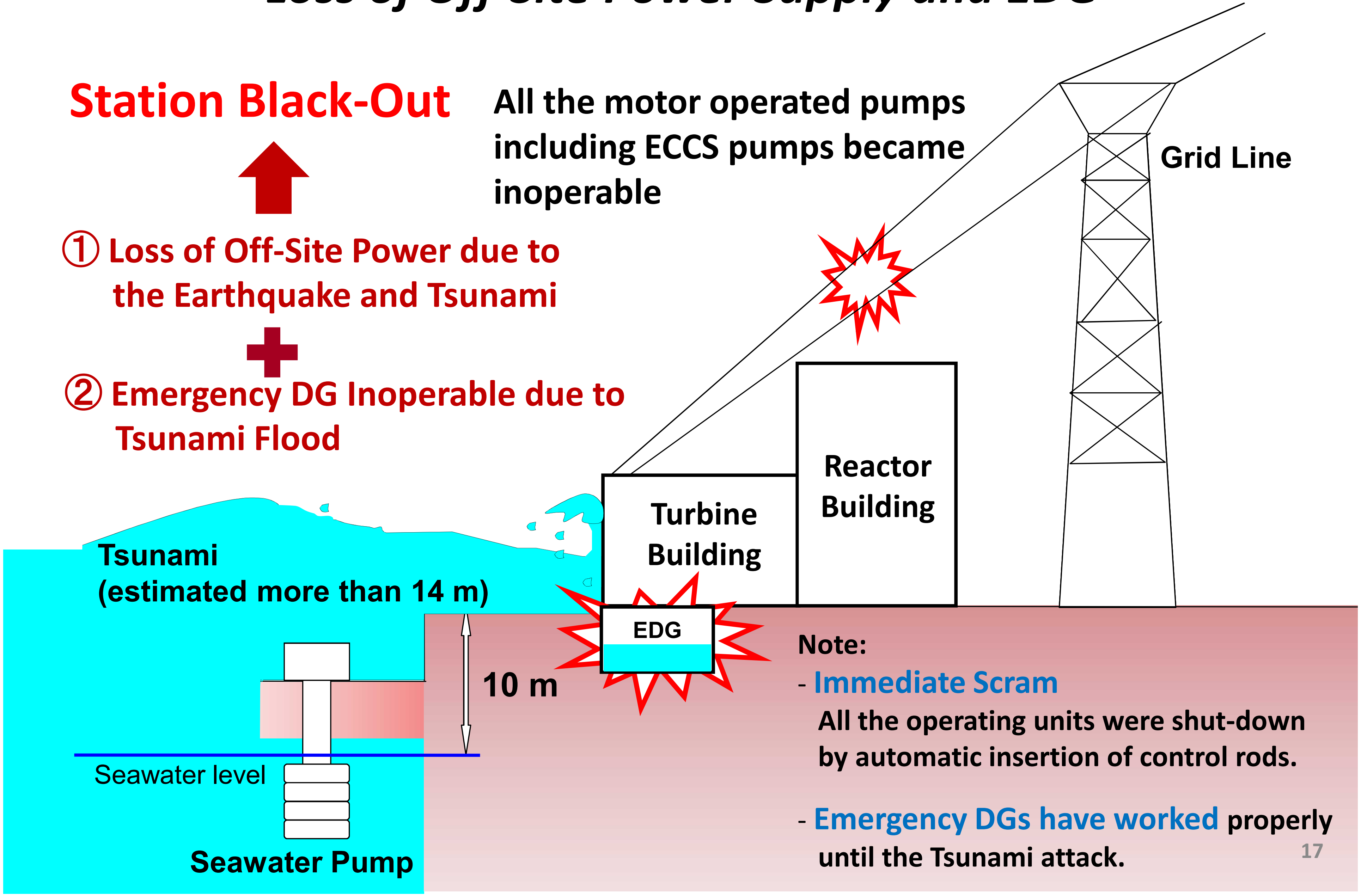
② Emergency DG Inoperable due to Tsunami Flood



Note:

- **Immediate Scram**
  All the operating units were shut-down by automatic insertion of control rods.

- **Emergency DGs have worked properly until the Tsunami attack.**

Loss of Off-site Power Supply and EDG in Units 1-4

Loss of the external power supply

Okuma 1L,2L : Breakers were broken due to the earthquake

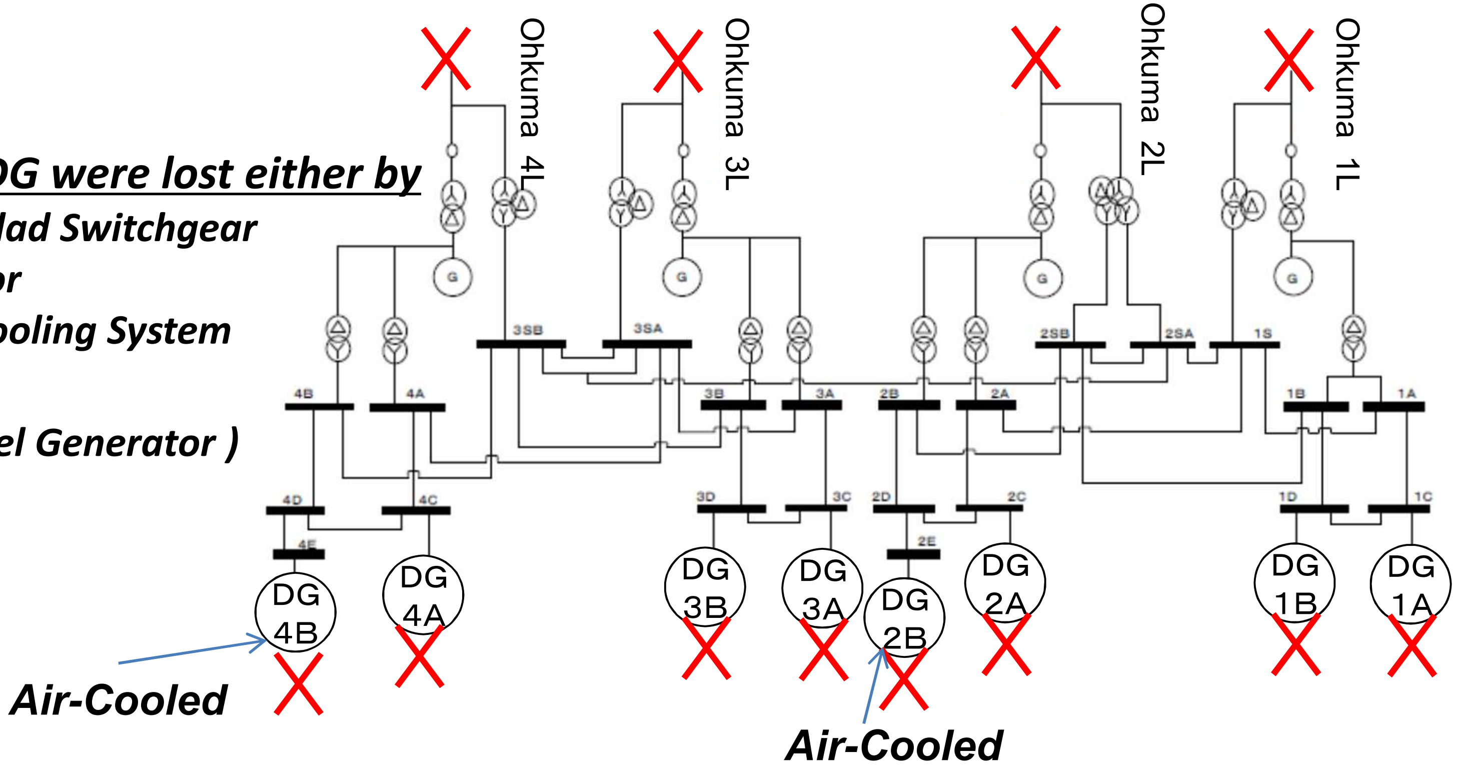
Okuma 3L : Under modification

Okuma 4L : The failure cause is being investigated

Functions of all the EDG were lost either by

1) *Damage at Metal-Clad Switchgear*
2) *Damage in Generator*
3) *Loss of Sea-Water Cooling System*

(EDG : Emergency Diesel Generator)

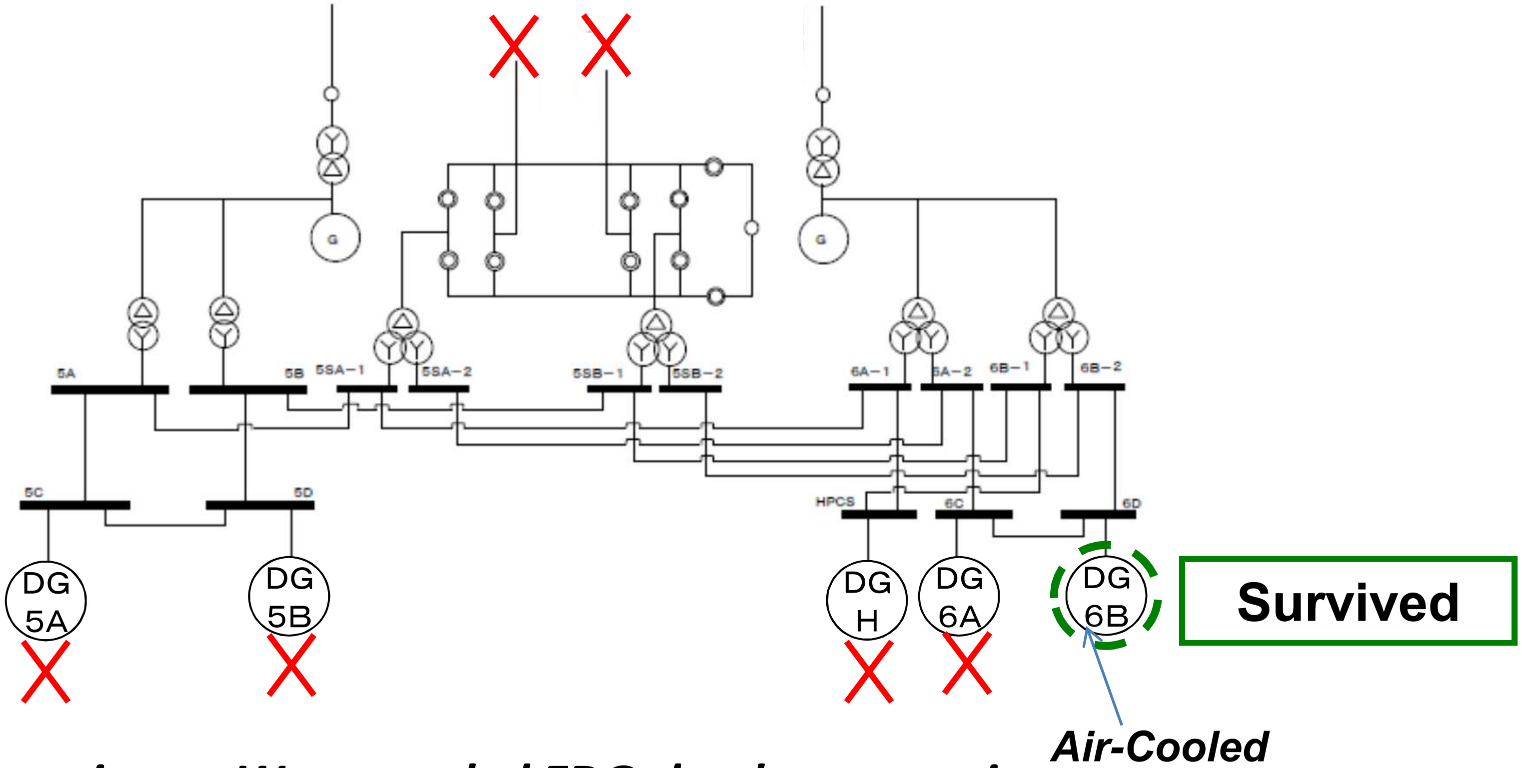


Recovery of Off-site Power Supply

Unit 2 on March 20, Unit 1,3,4 on March 22

One Air-Cooled DG (DG6B) survived in Units 5 & 6

Pylons damage by the earthquake caused loss of off-site power supply



Damage in sea-Water cooled EDGs by the tsunami

Recovery of Off-site Power Supply on March 20-21

Photographs from One of the Fukushima 50

Source: TEPCO

Summary : Differences of Units 1-4, Fukushima Dai-ichi

- ***Fukushima Daiichi Units 5 & 6***
  - **Elevation of the ground is 13 m. (Units 1 - 4 : 10m)**
  - **One air cooled EDG of Unit 6 which is located on the ground level was survived.**
  - **Metal Clad Switchgears were not lost.**
  - **Temporary sea water pump installed after the earthquake was operable, making use of power from survived EDG.**

- ***Fukushima Daini NPPs***
  - **External power was not lost.**
  - **RHR function of Unit 3 was survived.**
  - **Motors of sea water pumps for Unit 1,2 and 4 were replaced by March 14, followed by re-activation of core cooling function.**

- ***Onagawa NPPs***
  - **Elevation of the plants was 14.8m which is higher than Tsunami height.**

- ***Tokai-2***
  - **Although off-site power was lost until May 13, 2 out of 3 EDGs were not lost thanks to the recently installed barrage to one of 2 seawater pump area to protect pumps from tsunami.**

Radioactive Materials and Decay Power in Units 1, 2 and 3

Source Term just after the Shutdown

Unit 1 Fuel

I-131 : 1.9 x 10^{18} Bq

Cs-137 : 2.0 x 10^{17} Bq

Unit 2

I-131 : 2.7 x 10^{18} Bq

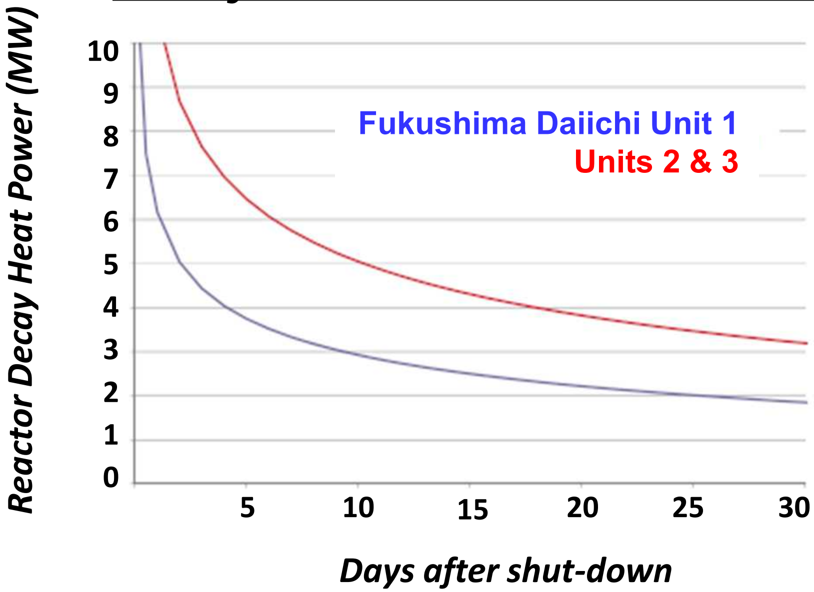
Cs-137 : 2.4 x 10^{17} Bq

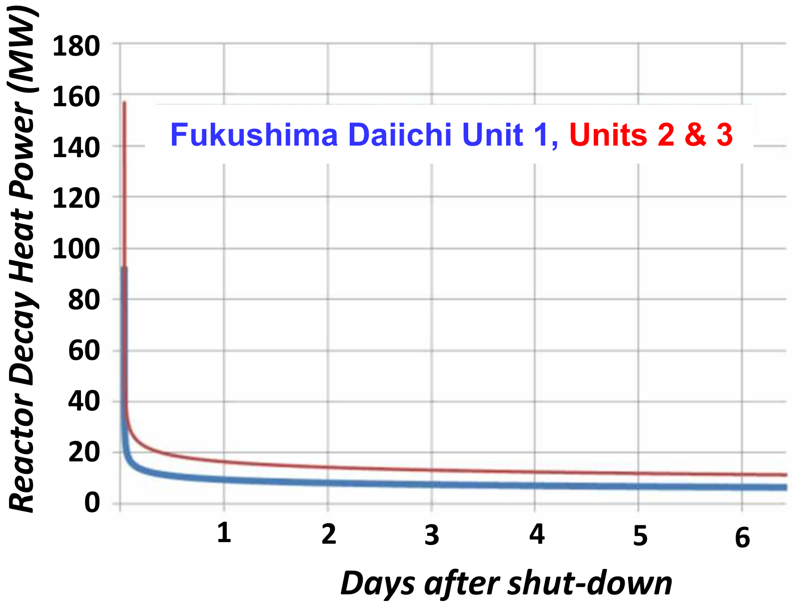
Unit 3

I-131 : 2.7 x 10^{18} Bq

Cs-137 : 2.4 x 10^{17} Bq

Decay Heat after the Shutdown



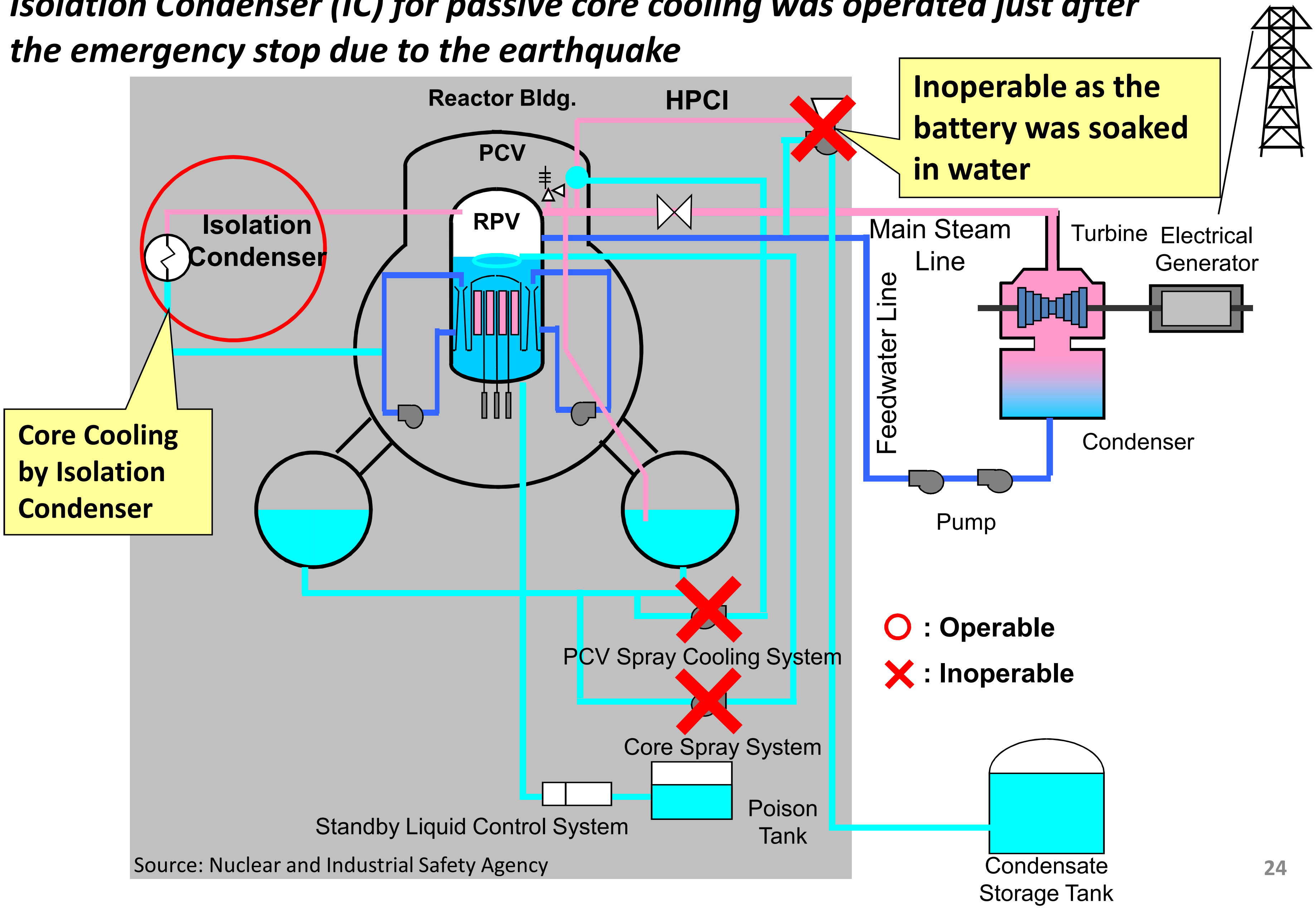


Short-term Actions for Termination of Accident and Emergency

- **Stable Cooling to Cold Shut-down**
  - Flooding (?) the containment to a certain level & installation of heat exchanger to remove heat
  - SFP cooling system
- **Minimize Airborne and Liquid Effluent**
  - Recycling of water, storage of contaminated water, …
  - Cover for reactor building, site soil, ground water, …
- **Dose and Contamination Maps**

Unit 1 : Cooling by Isolation Condenser

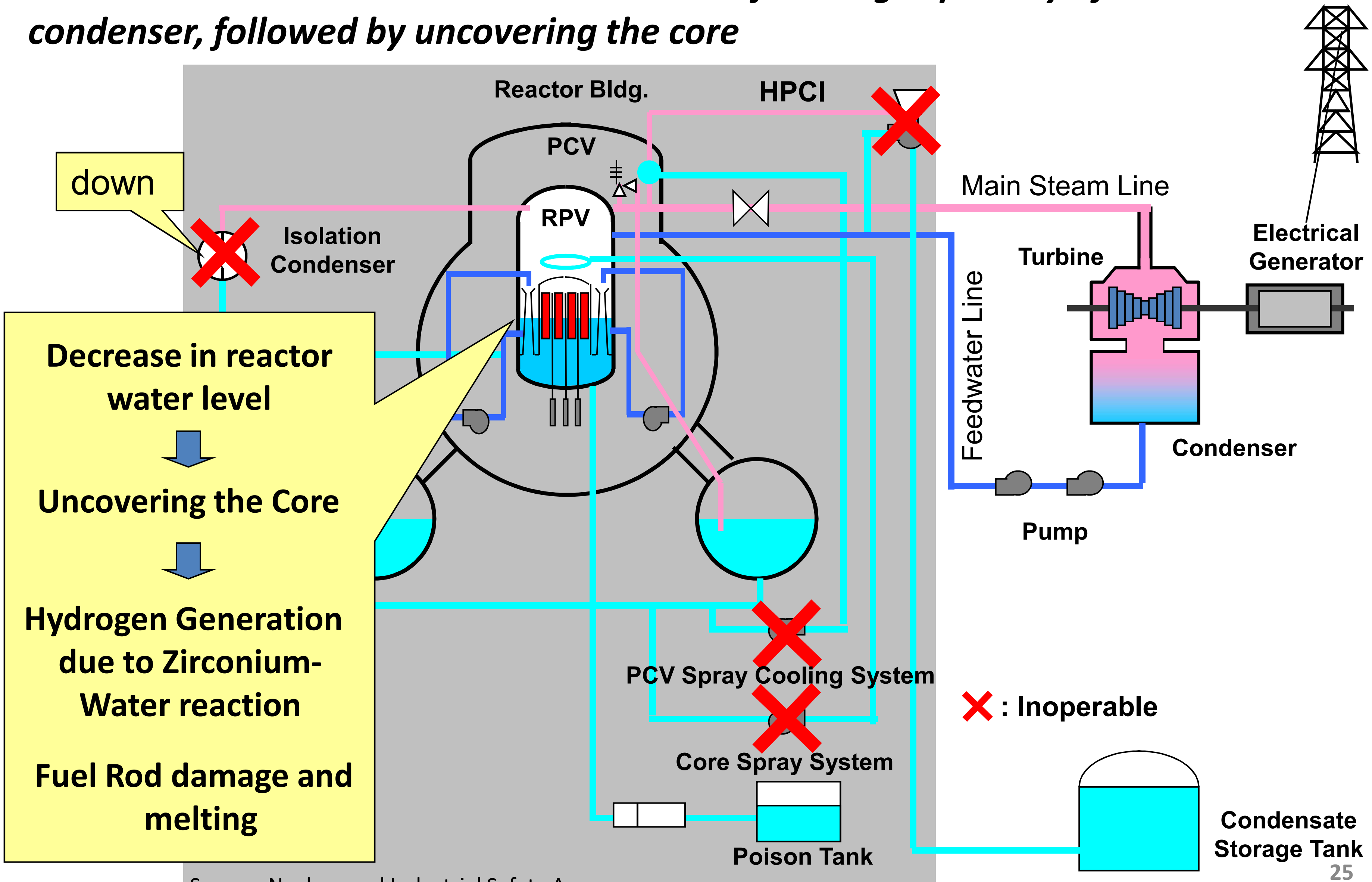
Isolation Condenser (IC) for passive core cooling was operated just after the emergency stop due to the earthquake



Source: Nuclear and Industrial Safety Agency

Unit 1 : Loss of Cooling

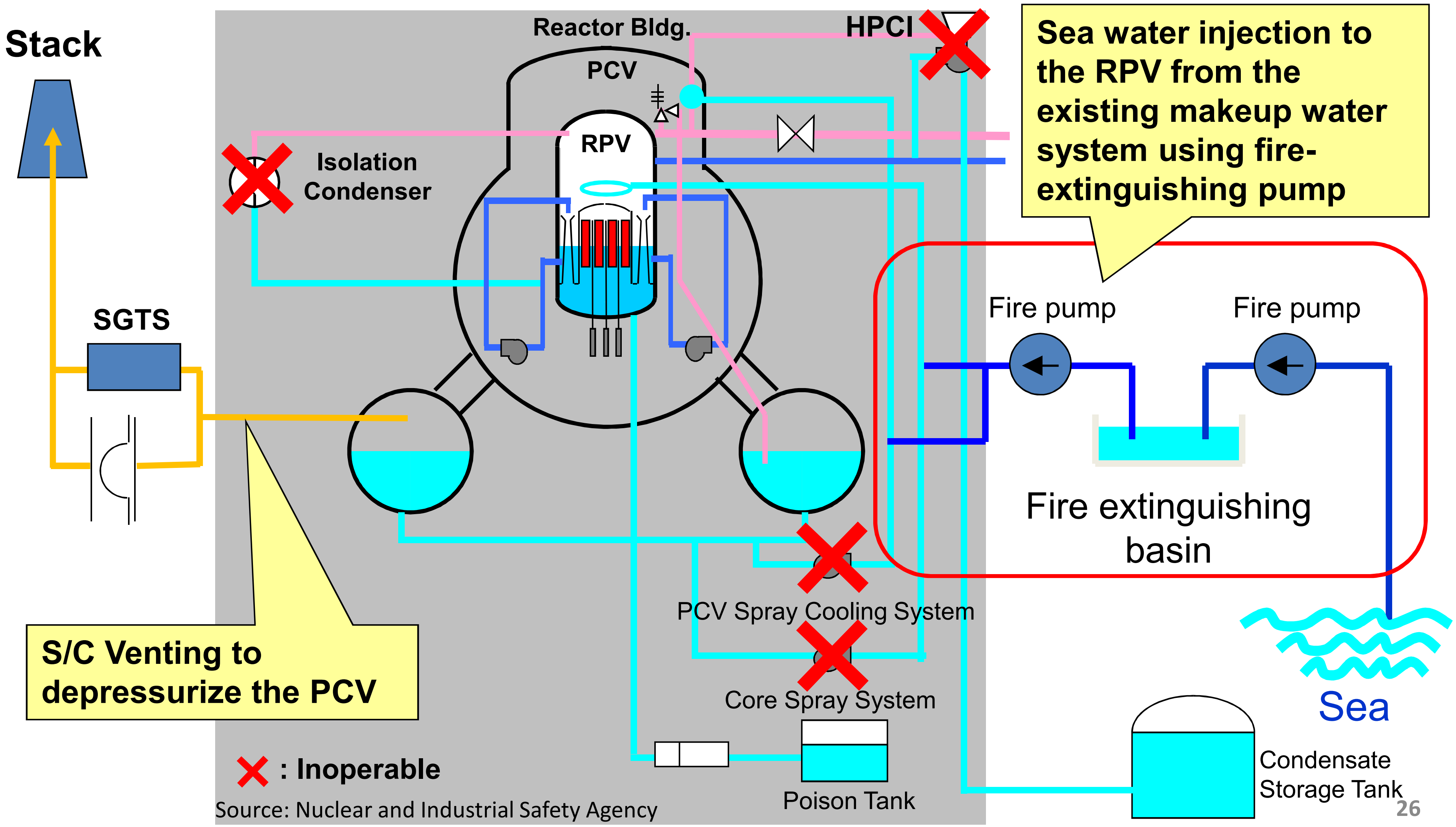
Decrease in reactor water level due to loss of cooling capability of Isolation condenser, followed by uncovering the core



Source: Nuclear and Industrial Safety Agency

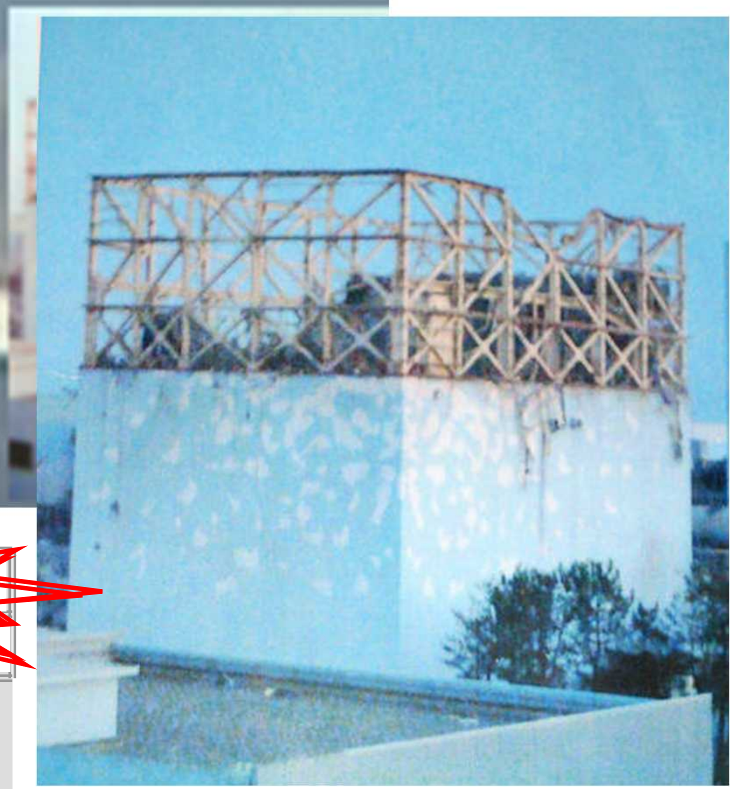
Unit 1 : PCV Venting and Cooling by Sea Water Injection

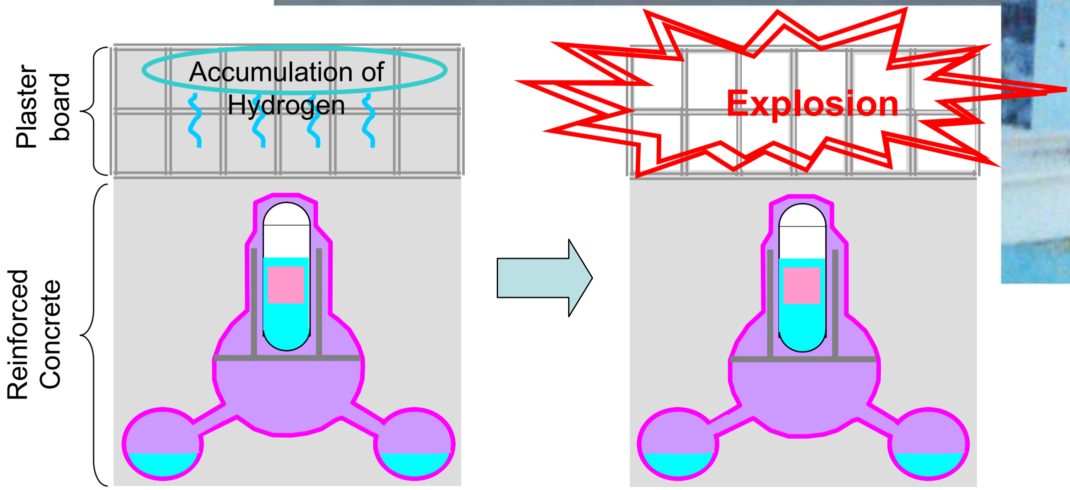
- ***S/C Venting to depressurize the PCV***
- ***Sea water injection using fire water pump***



Source: Nuclear and Industrial Safety Agency

Hydrogen Explosion in the Operation Floor in Unit 1
- March 12, 15:36 -

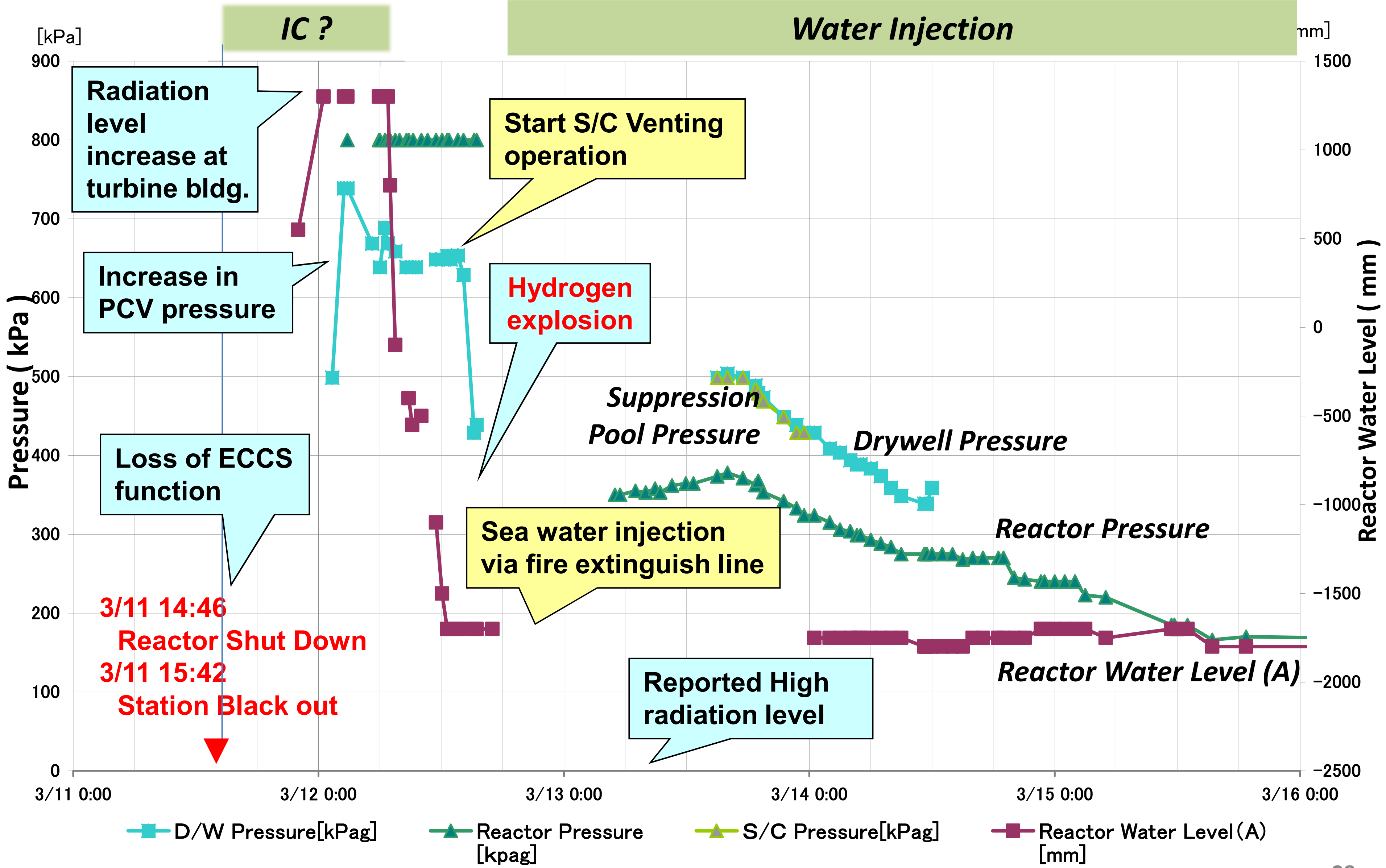




Reactor building　　Reactor building

Water Level in RPV, Pressure in RPV and PCV (D/W & S/C)

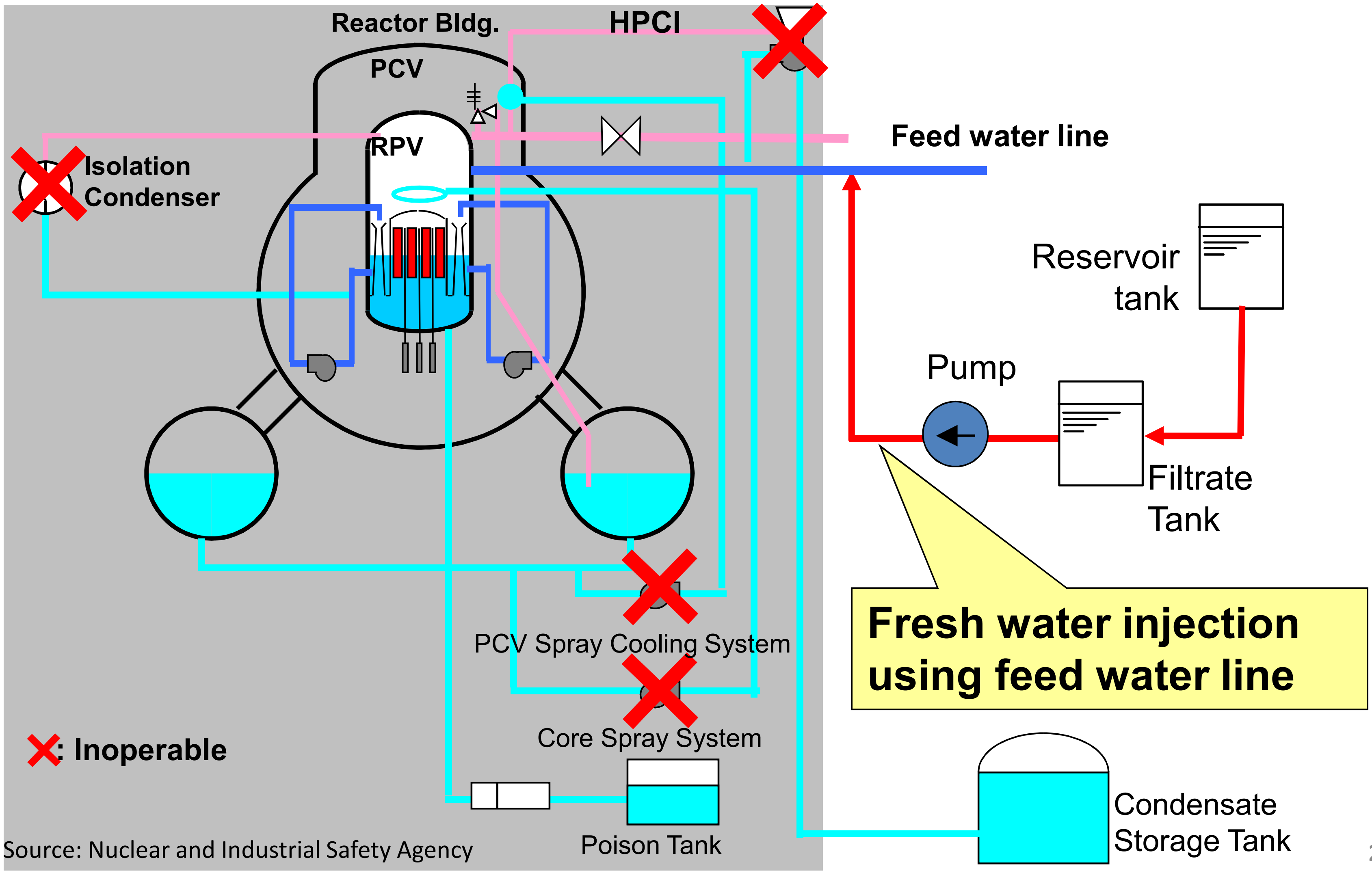
From March 11 to 16 in Unit 1



Source: Side event material on the “Fukushima Daiichi Accident and Initial Safety Measures Worldwide” in IAEA.

Unit 1 : Cooling

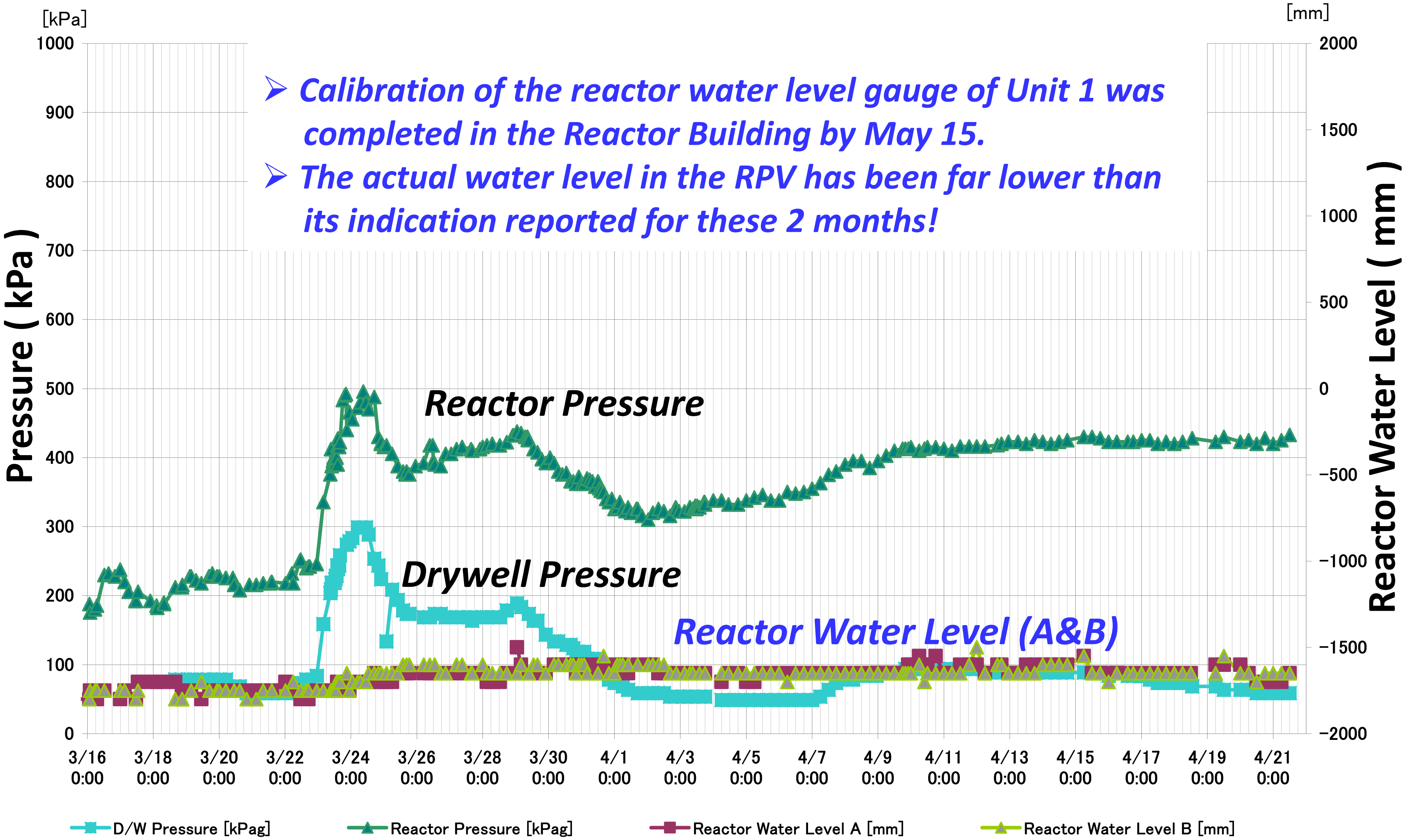
Switched to fresh water injection on March 25th



Source: Nuclear and Industrial Safety Agency

Reported Water Level in RPV, Pressure in RPV and PCV (D/W)

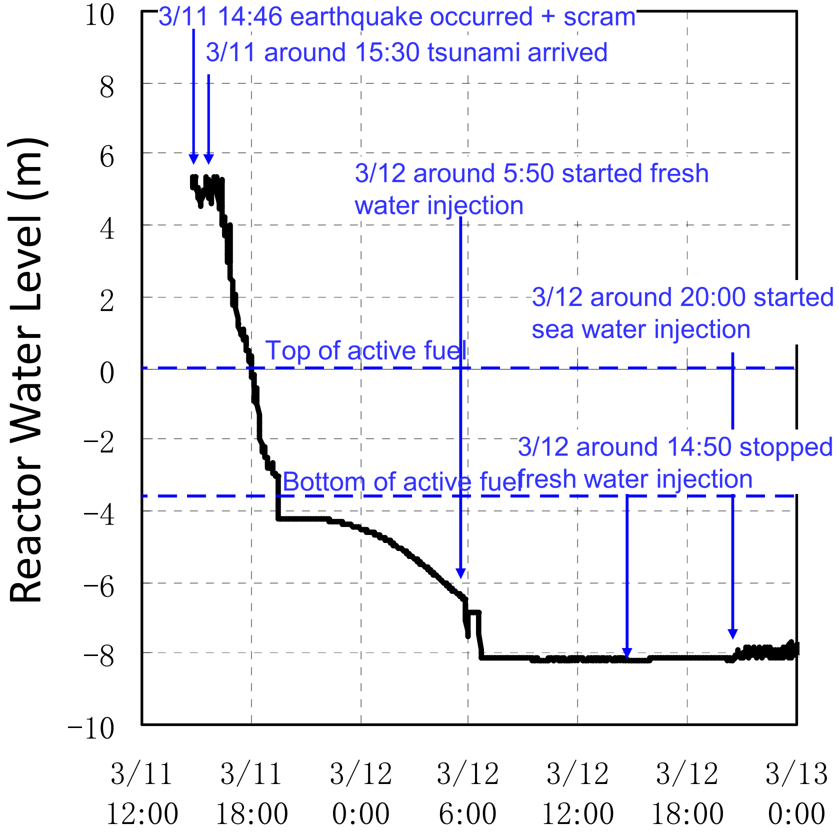
From March 16 to Apr. 21 in Unit 1

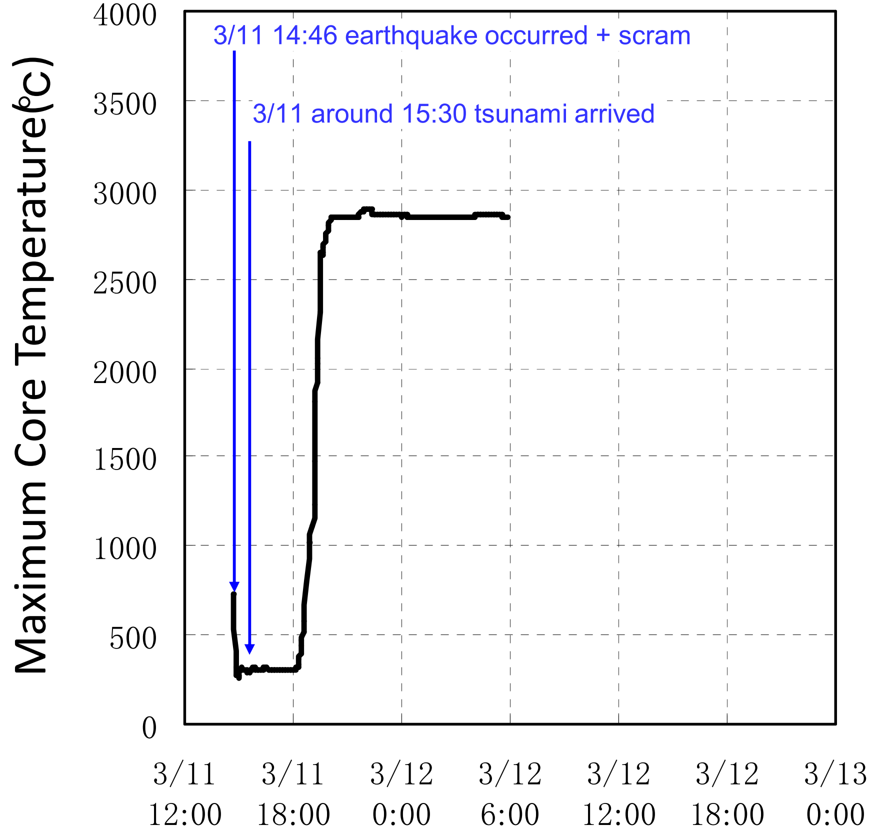


Source: NISA & TEPCO's press release.
※As TEPCO is currently reviewing all relevant plant parameter, above parameter in this chart may not be correct

Reactor Water Level and Core Temperature in Unit 1 - Simulation Trial by the MAAP code -

<u>*Assuming that IC lost its function by the Tsunami*</u>





- reached top of active fuel in 3 hours (around 18:00) after the scram
- reached bottom of active fuel in 4 and a half hours (around 19:30) after the scram

The core temperature started increasing when the reactor water level became lower than top of active fuel, then reached the core melting temperature.

Source: TEPCO

Transition of Core Status in Unit 1
- Simulation Trial Results by the MAAP code -

<u>Degree of fuel damage</u>

:Normal fuel

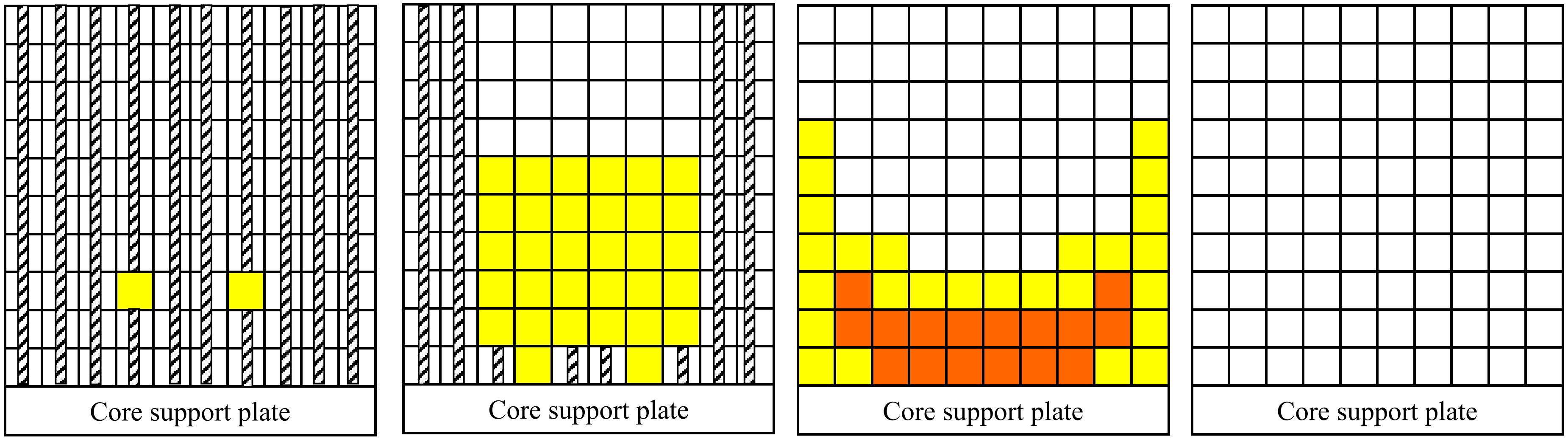
:Damaged fuel

:Fuel pellet melted

:Void (fuel melted down)

- ***Melting starts from the central part of the core.***
- ***In 16 hours after scram, most part of the core fell down to the RPV bottom.***
- ***Although RPV is damaged in this provisional analysis, the actual damage of RPV is considered to be limited according to the temperatures presently measured around the RPV.***

Source: TEPCO



4.8 hours after scram (around March 11th 19:30)

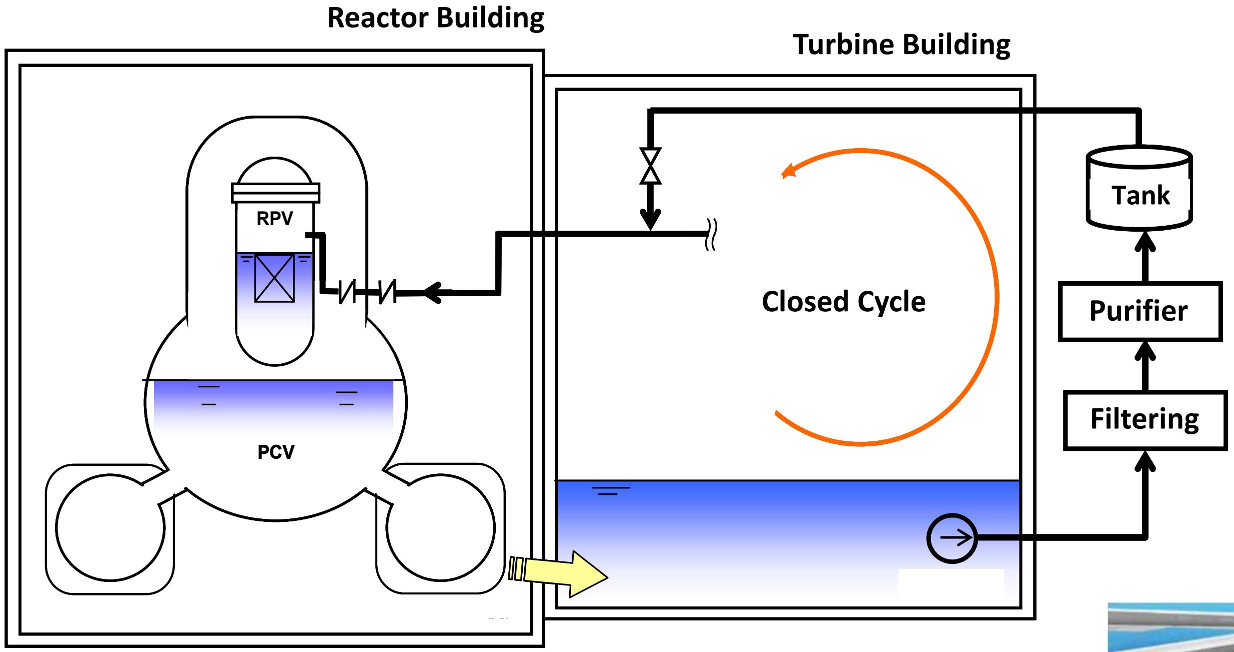
5.1 hours after scram (around March 11th 19:50)

15.1 hours after scram (around March 12th 6:00)

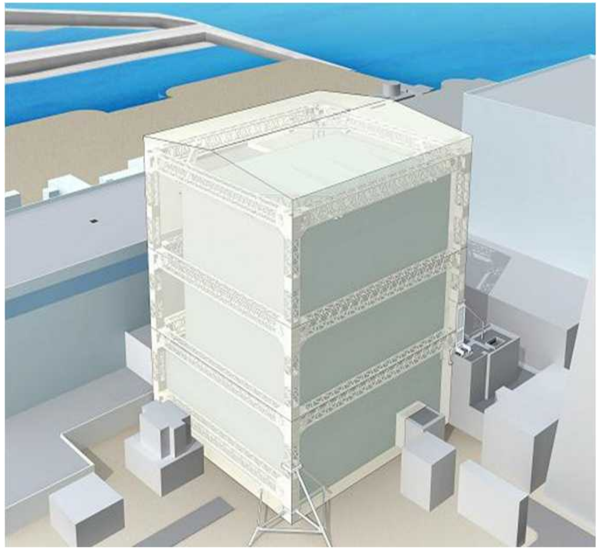
16.0 hours after scram (around March 12th 6:50)

Comparison of simulation results and their sensitivity on input parameters from other severe accident analysis codes like MELCOR and THALES should also be made.

System outline of water reuse as reactor coolant by processing accumulated water



Reactor Building Cover for Unit 1

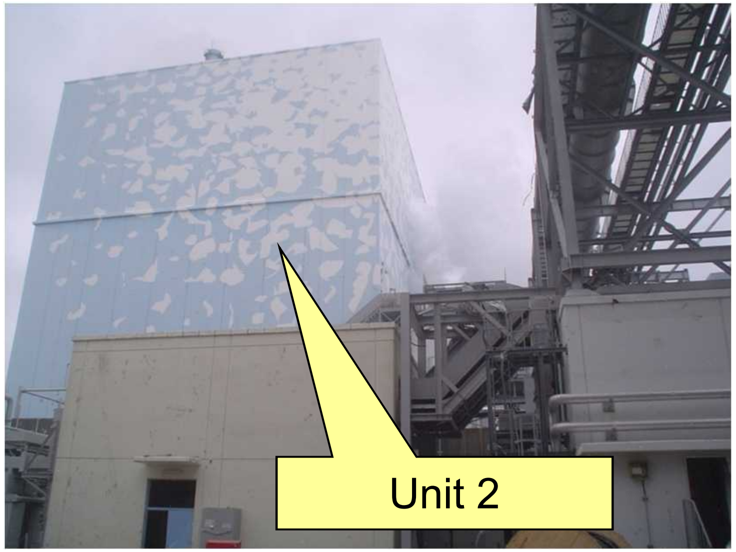


Source: TEPCO

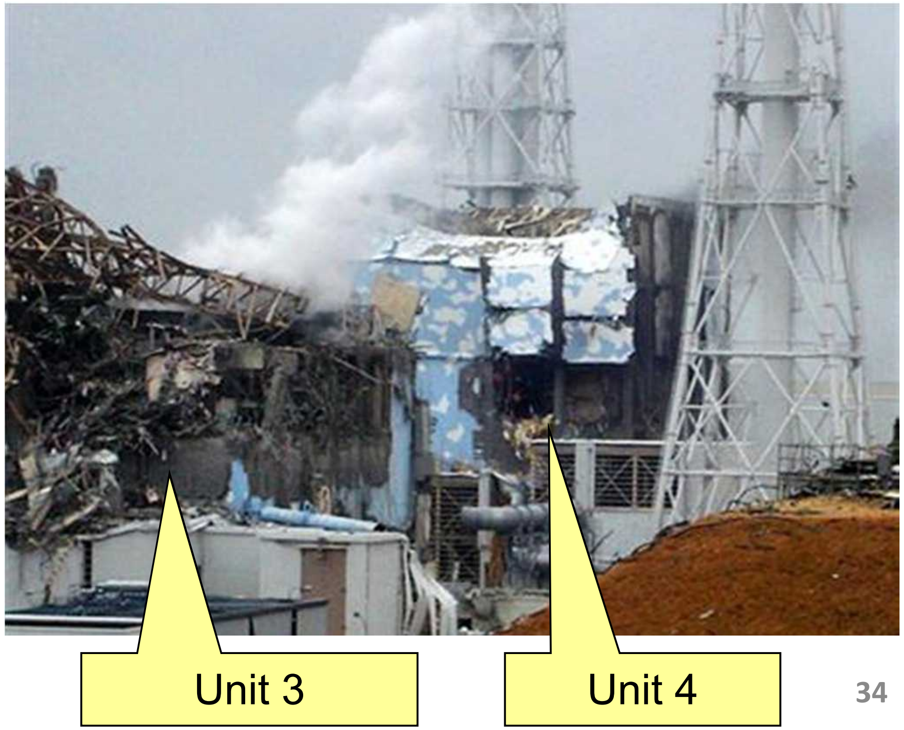
Unit 3

Unit 2

Hydrogen explosion at Unit 3 on March 14



Explosion sound at Unit 2 on March 15



Source: TEPCO

Highly Radioactive Debris near Unit 3

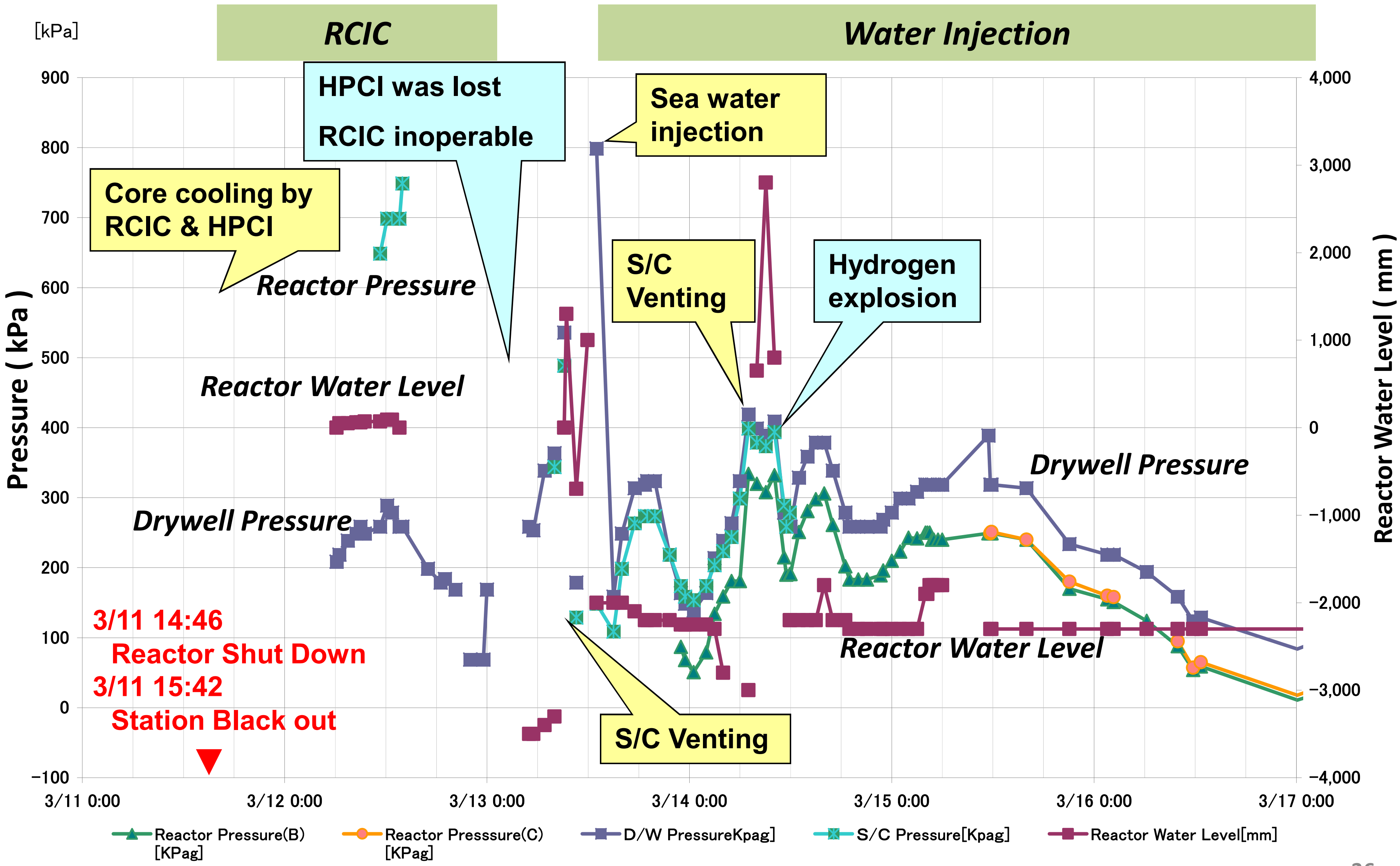
> 1000 mSv/hr

Source: TEPCO

Unit 3

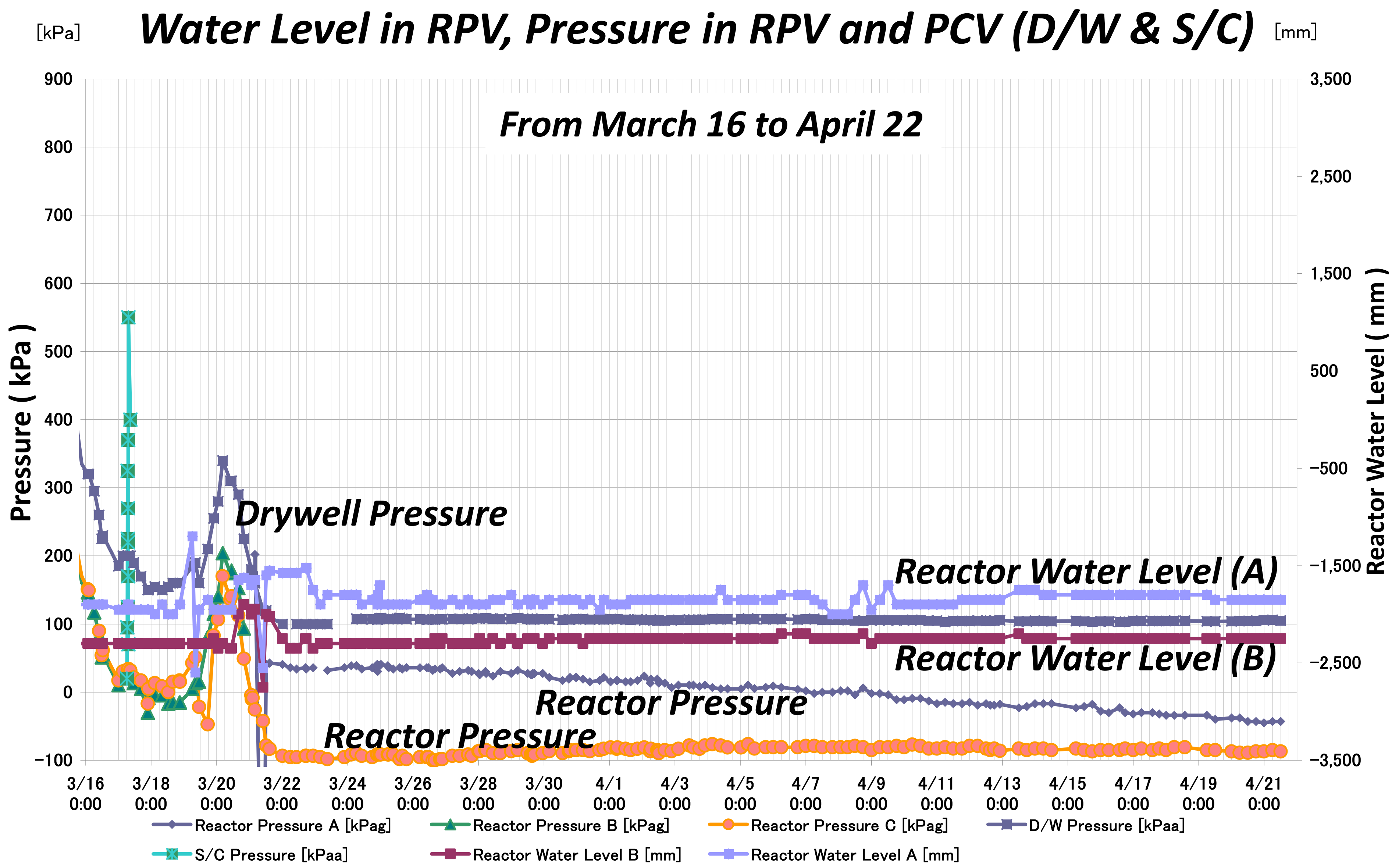
Water Level in RPV, Pressure in RPV and PCV

From March 11 to 17



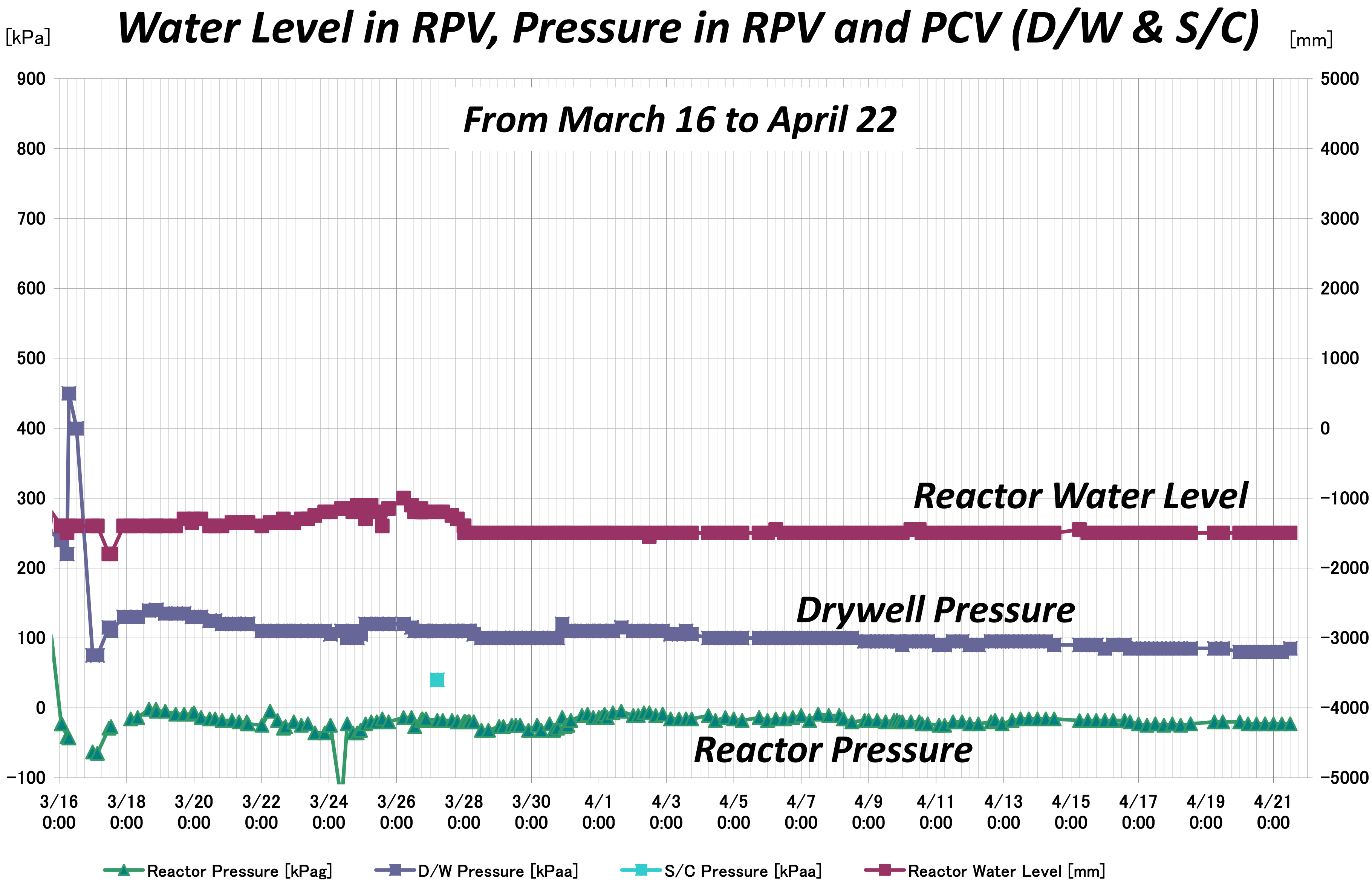
Source: Side event material on the “Fukushima Daiichi Accident and Initial Safety Measures Worldwide” in IAEA.

Unit 3



Source: NISA & TEPCO's press release

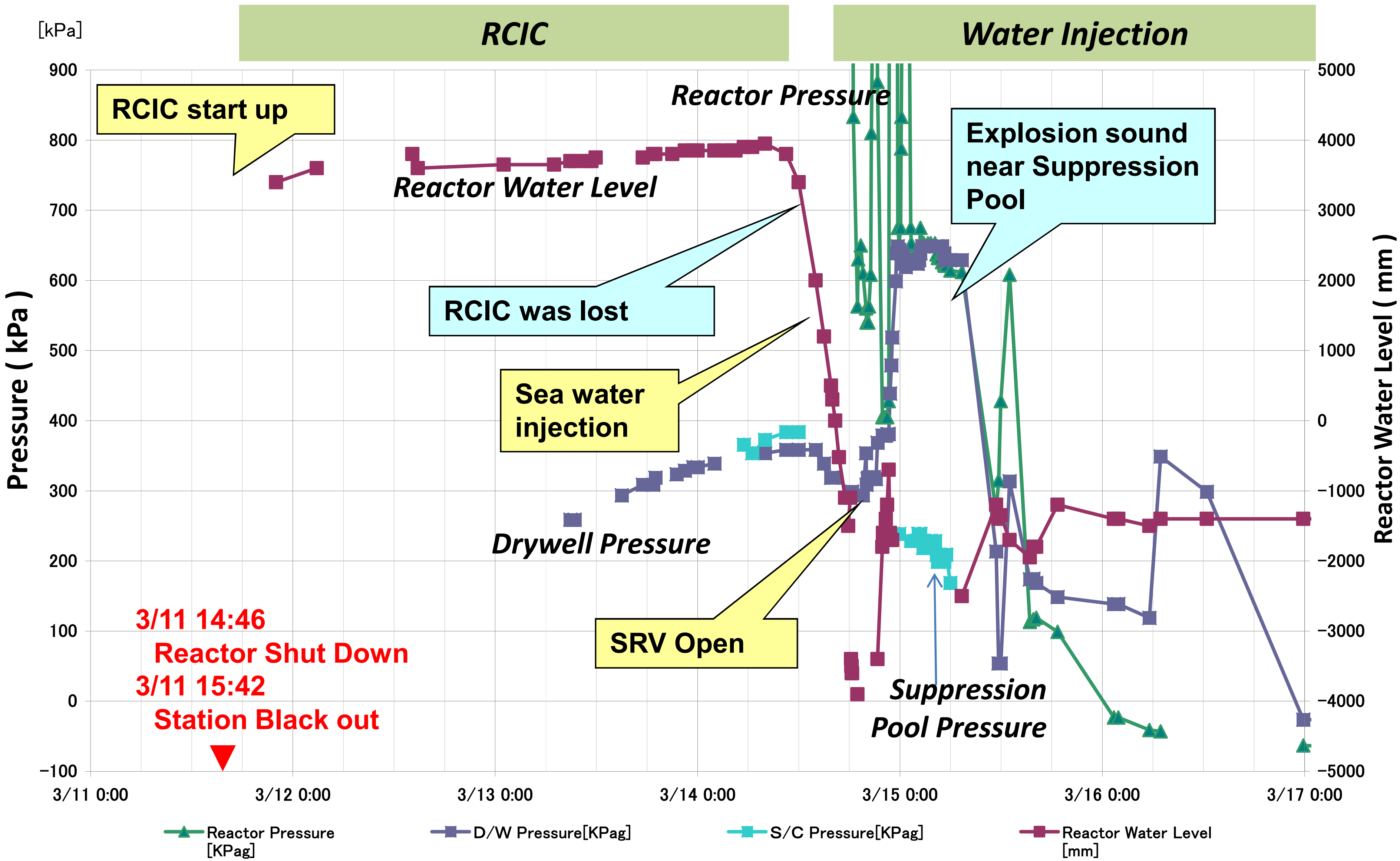
Unit 2



Source: NISA & TEPCO's press release.

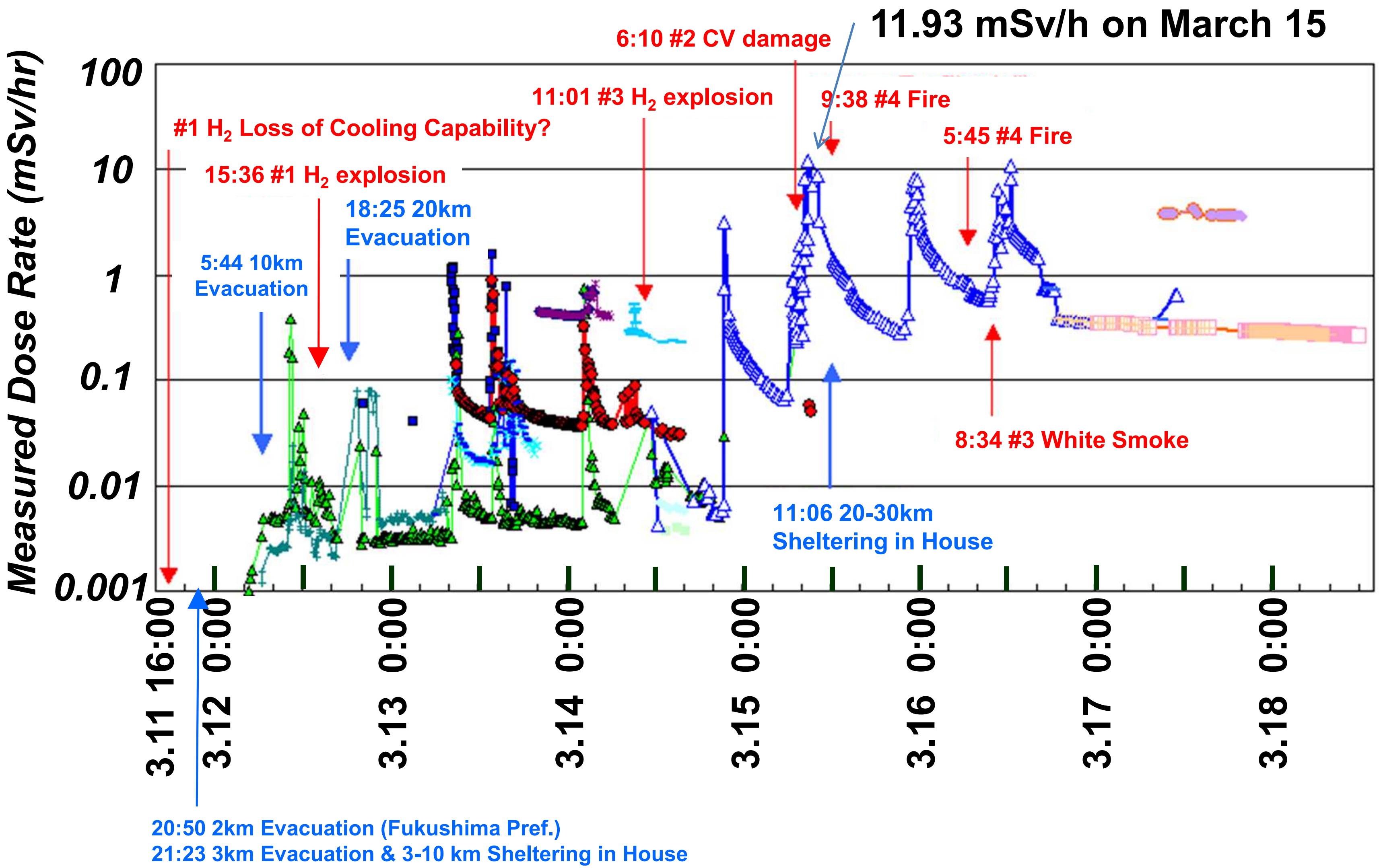
Unit 2 Water Level in RPV, Pressure in RPV and PCV (D/W & S/C)

From March 11 to 17

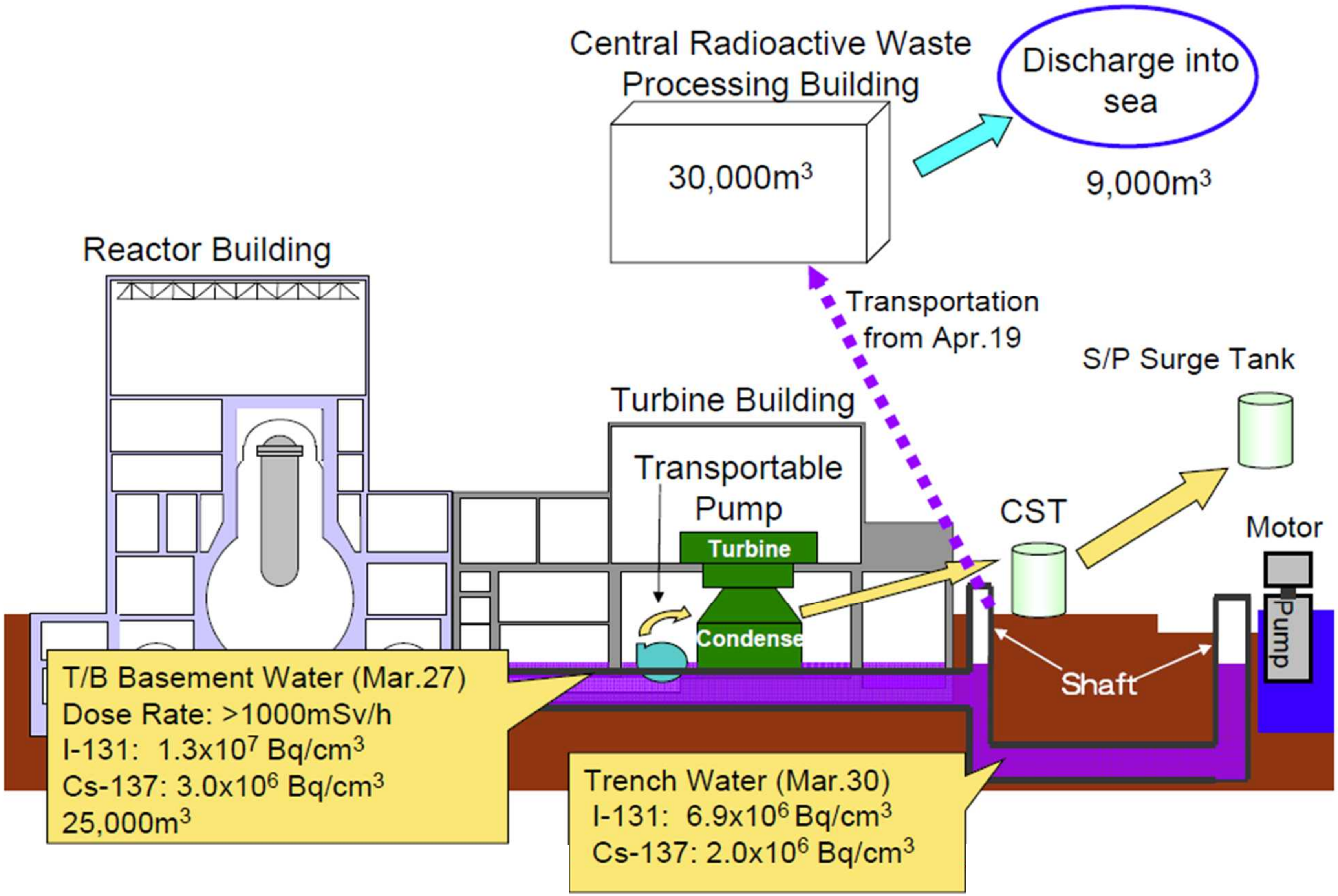


Source: Side event material on the "Fukushima Daiichi Accident and Initial Safety Measures Worldwide" in IAEA.

On-site Radiation Monitoring in Fukushima Daiichi Site From March 11 to 18



Measures against Water Puddles at Fukushima Daiichi



Source: TEPCO

Leakage of Highly Radioactive Water from Unit 2

Leakage of radioactive water to the ocean between Apr. 1 to 6 from the pit of Unit 2

Amount of Released Water : 520 m^3

Concentration of Radioactive Materials

I-131 : 5.4×10^4 Bq/cm^3
Cs-134 : 1.8×10^4 Bq/cm^3
Cs-137 : 1.8×10^4 Bq/cm^3

Total Released Radioactivity

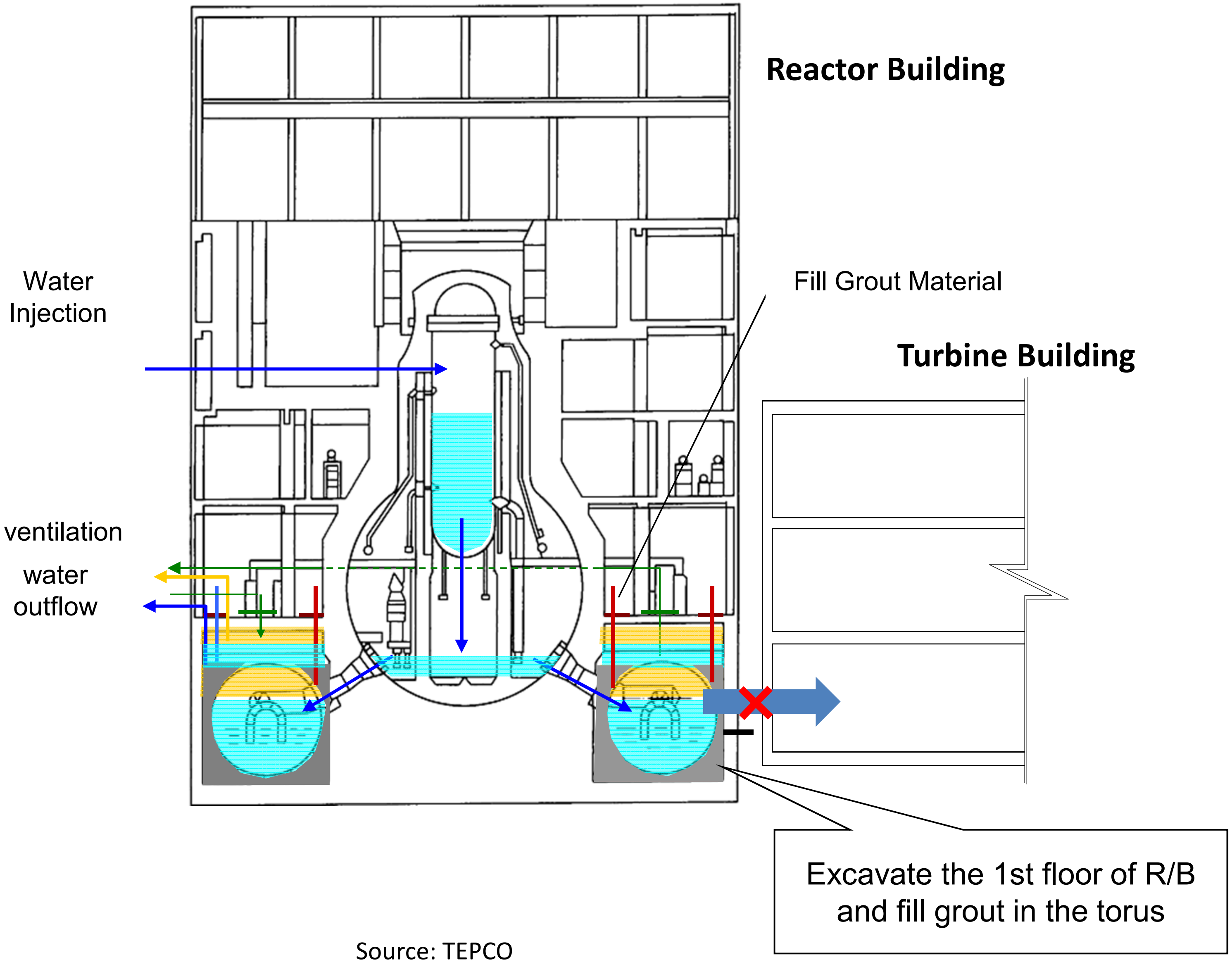
I-131 : 2.8×10^{15} Bq
Cs-134 : 9.4×10^{14} Bq
Cs-137 : 9.4×10^{14} Bq

Source: TEPCO

Countermeasures

-Drilled a hole into the pit and injected water glass (sodium silicate) into the pit.
-By April 6, the outflow was confirmed to stop.

Countermeasure to Seal the Damaged Location in the PCV of the Unit 2



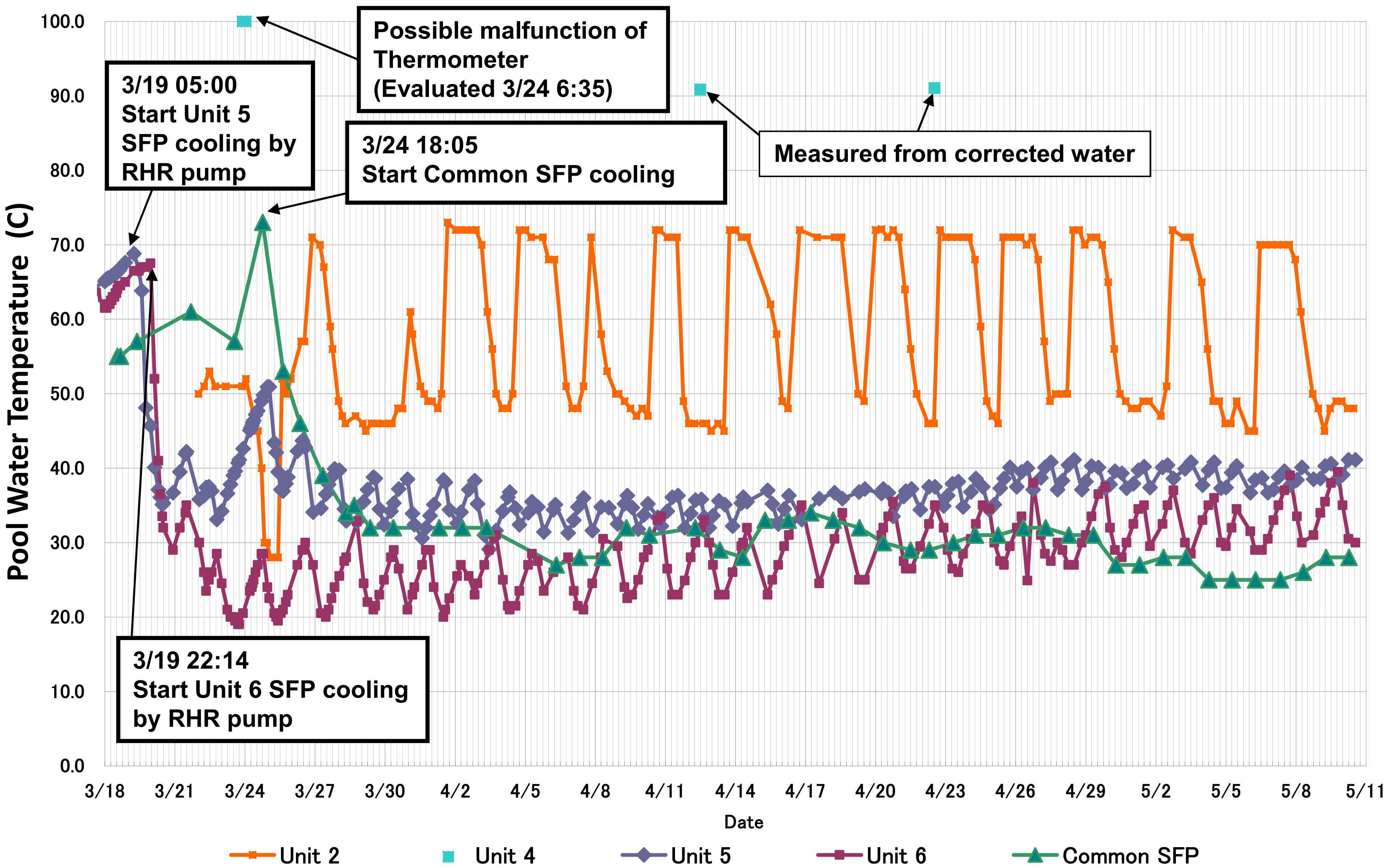
Source: TEPCO

Fuel Assemblies in Core and Spent Fuel Pool

Unit	*1*	*2*	*3*	*4*	*5*	*6*
Number of Fuel Assembly in the Core	400	548	548*	-	548	764
Number of Spent Fuel Assembly in the SFP	292	587	514	1,331	946	876
Number of New Fuel Assembly in the SFP	100	28	52	204	48	64
Water Volume (m^3)	1,020	1,425	1,425	1,425	1,425	1,497
Heat Generation in Spent Fuel Pool (MW)	0.07	0.47	0.23	2.3	0.08	0.07

** including 32 MOX Fuel Assembly*

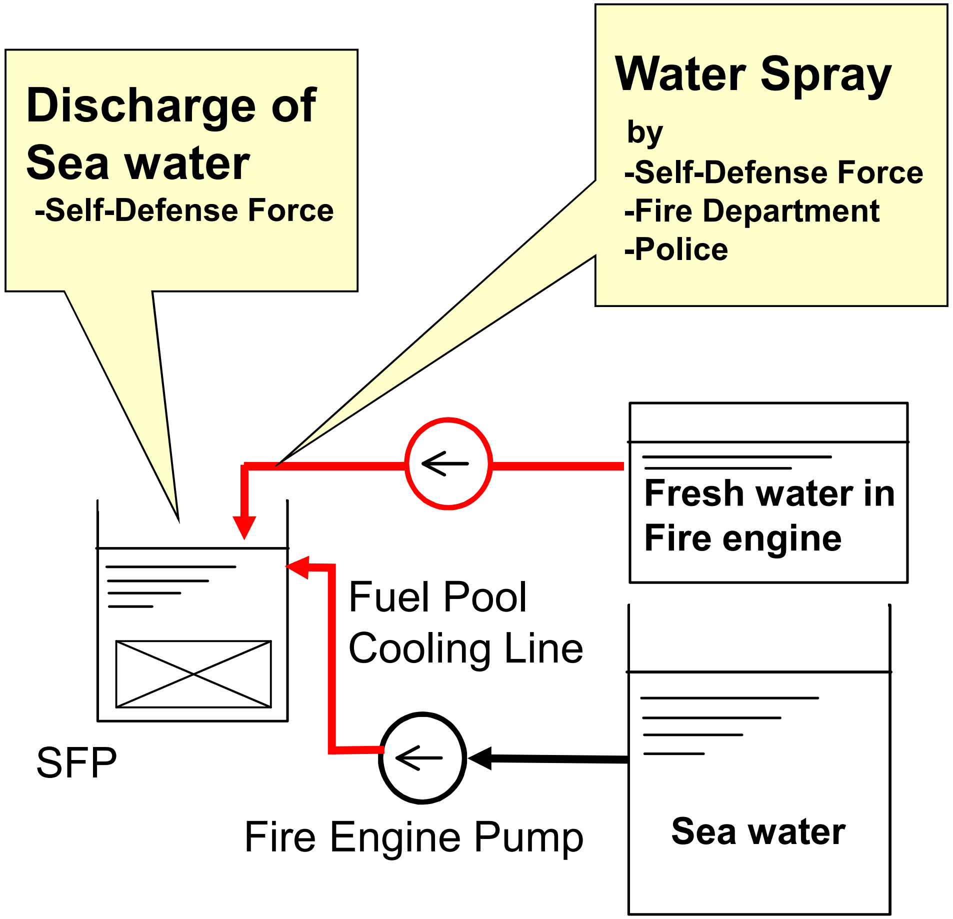
Temperature History of Spent Fuel Pools



Source: NISA & TEPCO's press release

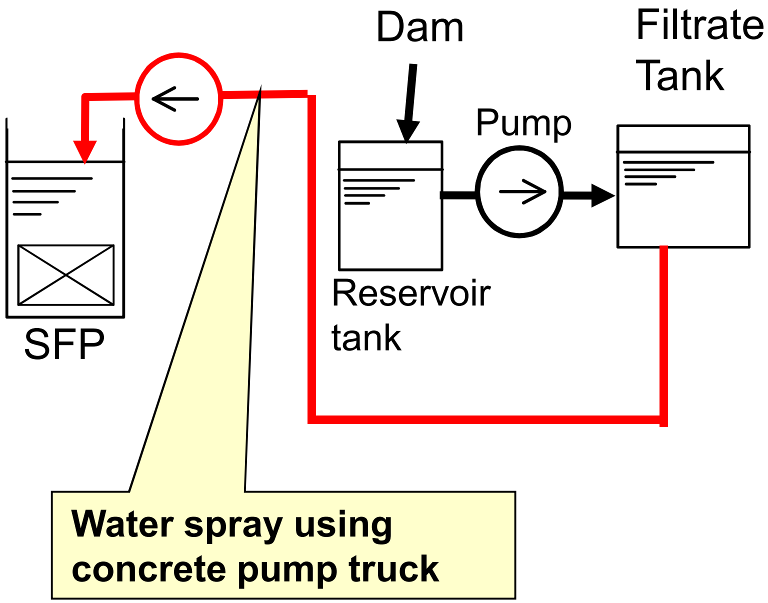
Unit 3 : Spent Fuel Pool Cooling

【1st Stage】Sea water injection



asahi.com

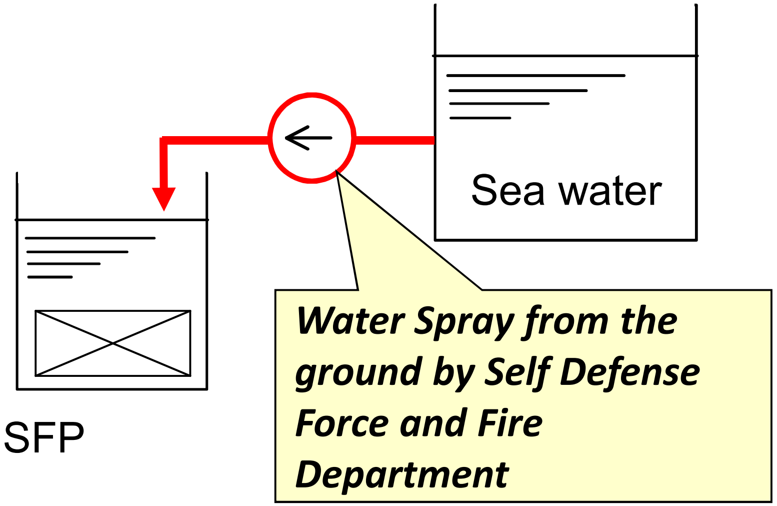
【2nd Stage】Fresh water injection



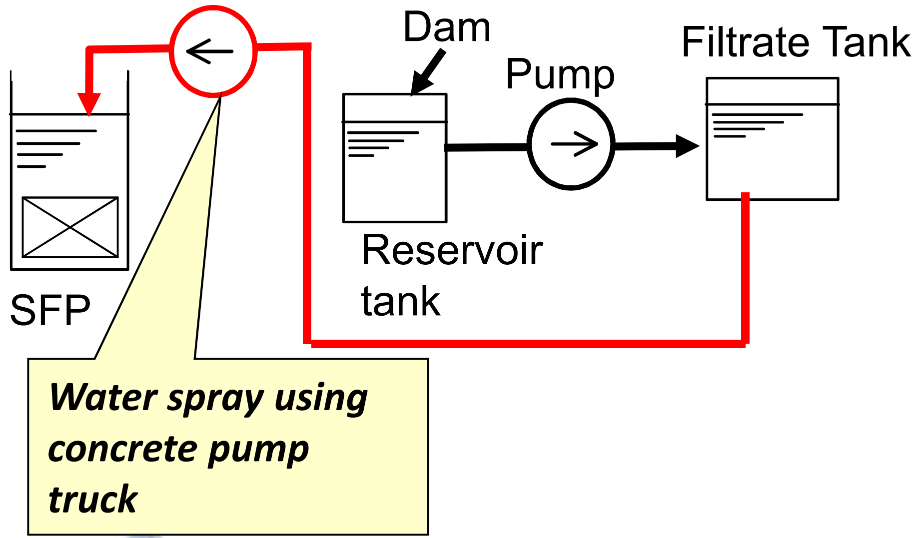
Source: Nuclear and Industrial Safety Agency

Unit 4 : Spent Fuel Pool Cooling

【1st Stage】Sea water injection



【2nd Stage】Fresh water injection

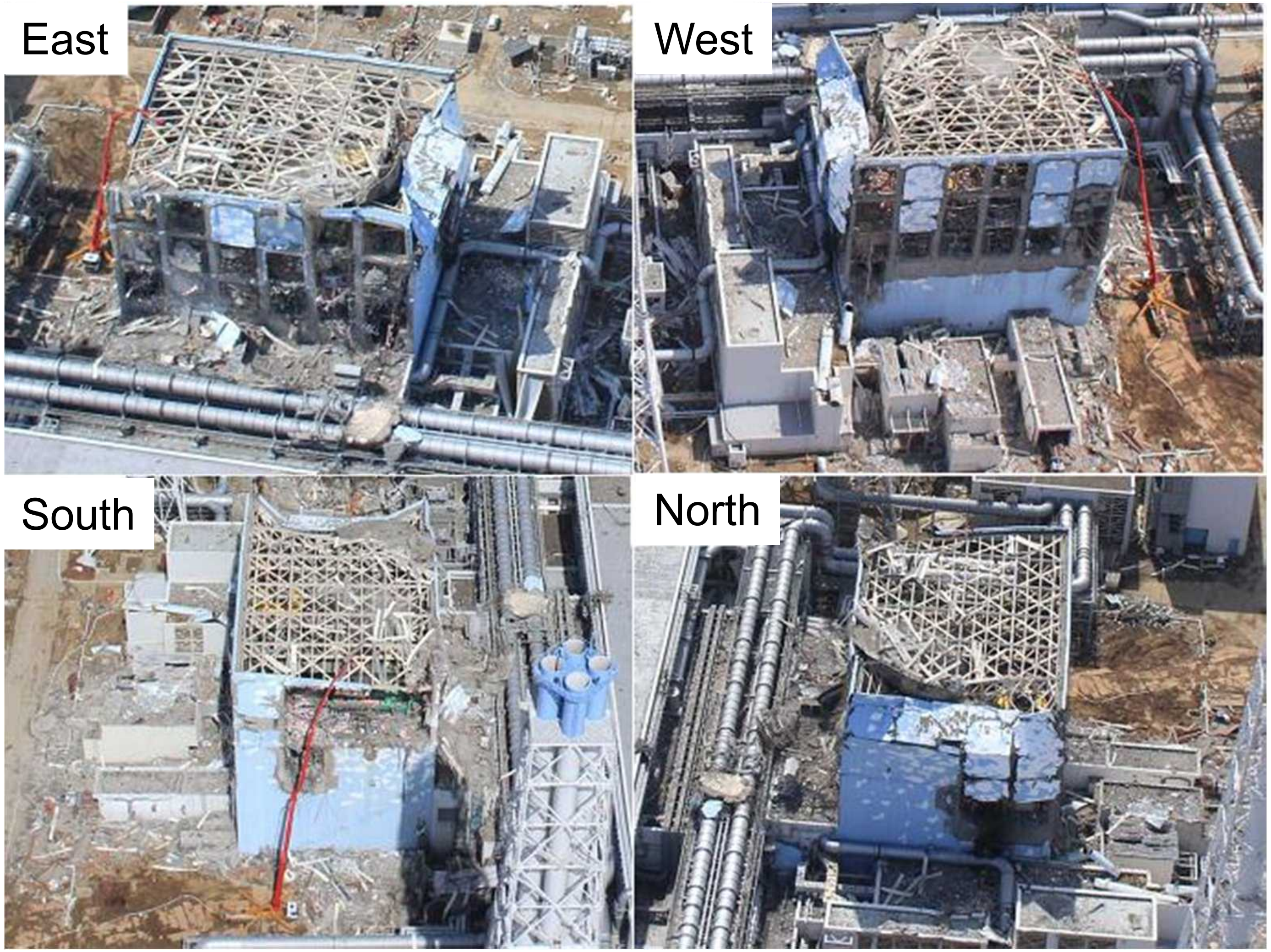


- Reactor building damage on March 15

Source: Nuclear and Industrial Safety Agency

Hydrogen Explosion in Unit 4 ?

Possible mechanisms ; (1) Zr-H_2O reaction in the SFP, (2) H_2 from Unit 3,
(3) Decomposition of H_2O into H_2 and O_2 under radiation



Unit 4 : Spent Fuel Pool

- ***No significant damage was identified by underwater camera inspection***
- ***Water sampling on April 12 also shows relatively low radioactivity in SFP water***

Analysis result of water in the SFP of Unit 4
(Date of Collection 4/12)

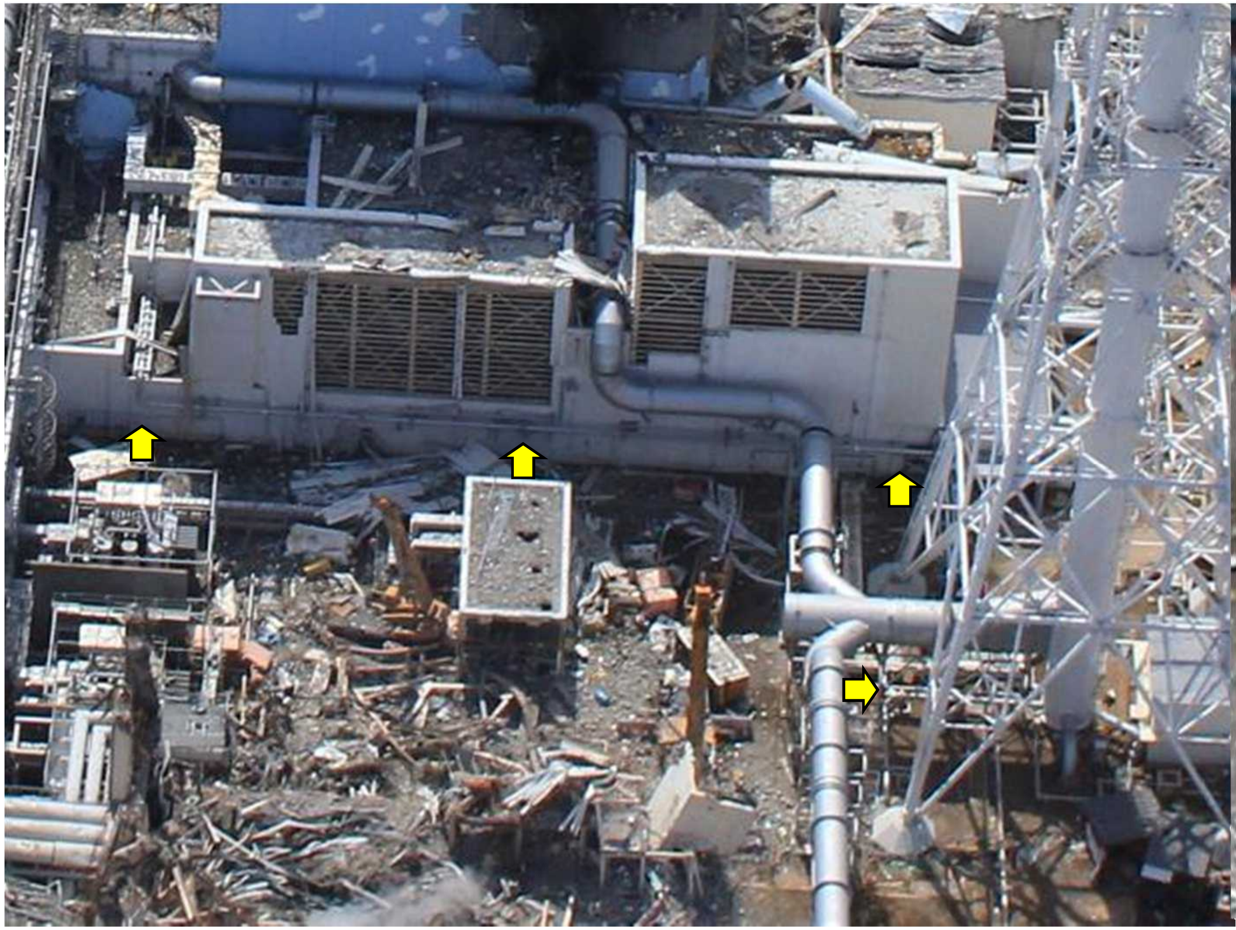
Detected Nuclides	*Half life*	*Density (Bq/cm^3)*
Cesium 134	Approx. 2 Years	88
Cesium 137	Approx. 30 Years	93
Iodine 131	Approx. 8 Days	220

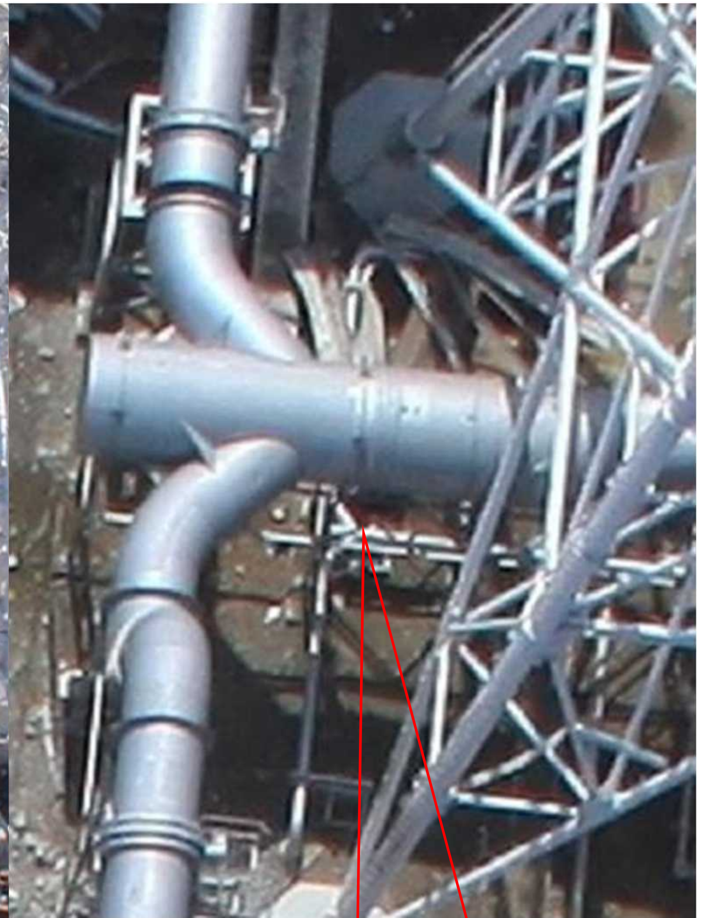
Source: TEPCO

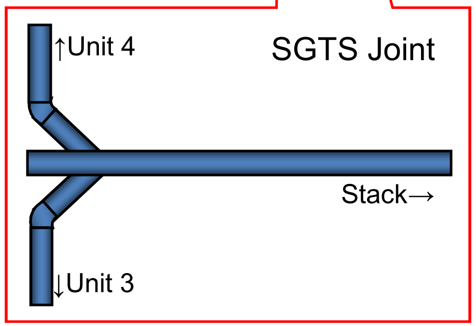
Source: TEPCO

Zr-H_2O reaction in the SFP at high temperature

Stand-by Gas Treatment Systems for Units 3 and 4



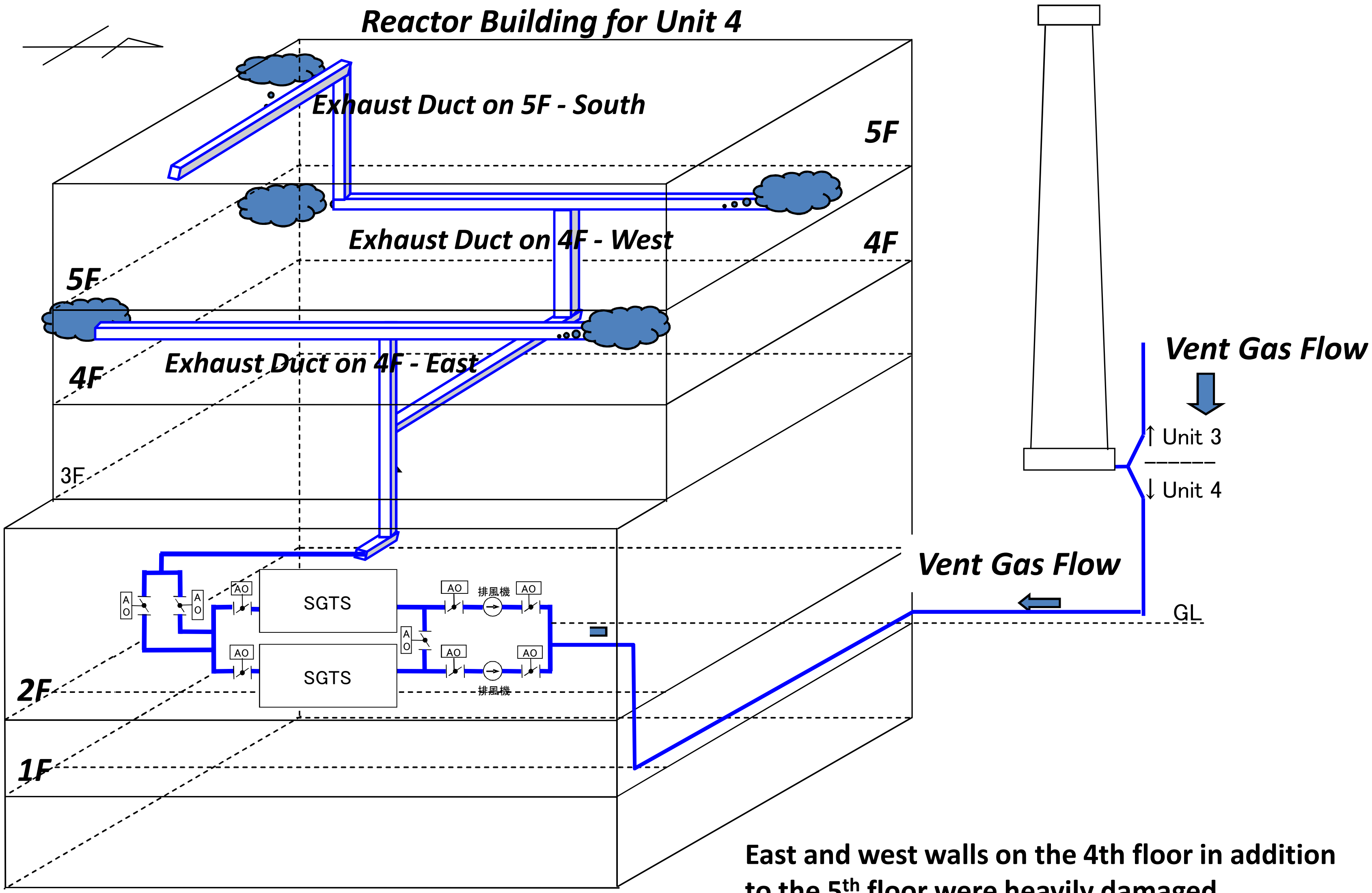




Pipes of stand-by gas treatment systems for Units 3 and 4 are connected.

Source: TEPCO

Possible Mechanism of Hydrogen Explosion in Unit 4



East and west walls on the 4th floor in addition to the 5th floor were heavily damaged.

Source: TEPCO

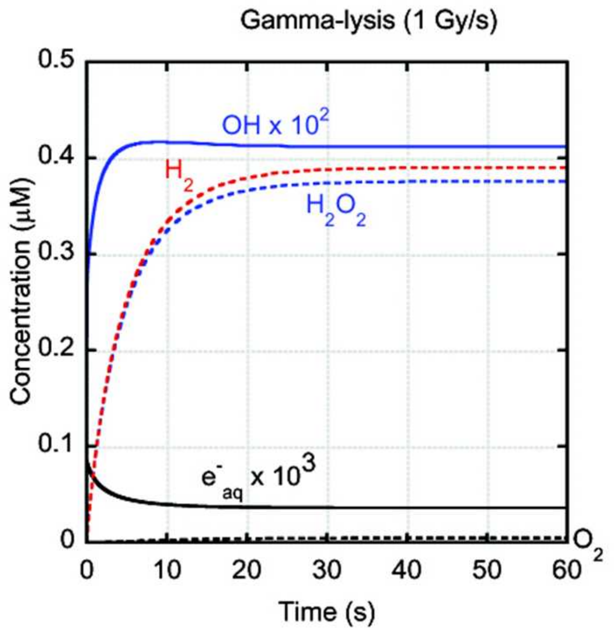
Experiments on High Concentration of Hydrogen Gas under Radiation at Boiling Temperature

G-values	$-H_2O$	e^-_{aq}	OH	H	H_2O_2	H_2	HO_2
Gamma-ray	4.1	2.7	2.8	0.56	0.68	0.45	~0.01
Alpha-ray	2.65	0.06	0.24	0.21	0.985	1.3	0.22

May 16, 2011

Prof. Katsumura Group

The University of Tokyo and JAEA

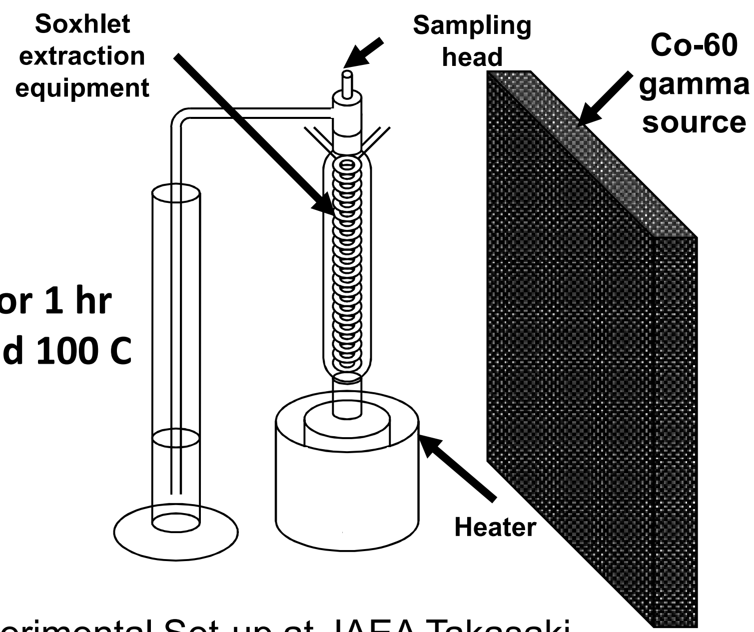


Typical BWR condition simulation of radiation chemistry reactions considering the reaction between H_2 and OH, resulting in steady state concentration of H_2.

New Finding by H_2 production under irradiation;

- ***Effective transfer of H_2 into gas phase at 100 C***
- ***High concentration of H_2 through condensation of H_2O at lower temperature region***

6.8 kGy/h for 1 hr at 80, 97 and 100 C



Experimental Set-up at JAEA Takasaki

INES (International Nuclear Event Scale) Evaluation

INES Level	People and Environment	Radiological Barriers and Control	Defence-in-Depth
Major Accident Level 7	• Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		

- **NISA issued provisional INES ratings , based on "What is known" at the time.**
- **At first, following units were rated as Level 3 based on "Defense in Depth" criteria about 10 hours later from the earthquake.**
  - Fukushima Daiichi Units 1, 2 and 3, Fukushima Daini Units 1, 2 and 4
- **In the evening on March 12, the rating of Fukushima Daiichi Unit 1 was re-evaluated to Level 4 base on the "Radiological Barriers and Control" criteria.**
- **On March 18, Fukushima Daiichi Units 1, 2 and 3 were re-rated to Level 5 based on "Radiological Barriers and Control" criteria because the fuel damage was highly possible. Fukushima Daiichi Unit 4 was evaluated to Level 3 based on the "Defense in Depth" criteria.**
- **On April 12, Fukushima Daiichi NPPs was revised Level 7 based on the "People and Environment" criteria, as a result of discharged estimation.**
- **Official rating will be done after cause and countermeasures are identified.**

NO SAFETY SIGNIFICANCE *(Below Scale/Level 0)*

INES (International Nuclear Event Scale) Evaluation

- On April 12, Nuclear and Industrial Safety Agency (NISA) released;
  - Tentatively assigned Level 7 on INES for the accident at Fukushima Daiichi Nuclear Power Station.
  - The amount of released radioactive material is one-tenth as much as the accident at Chernobyl.

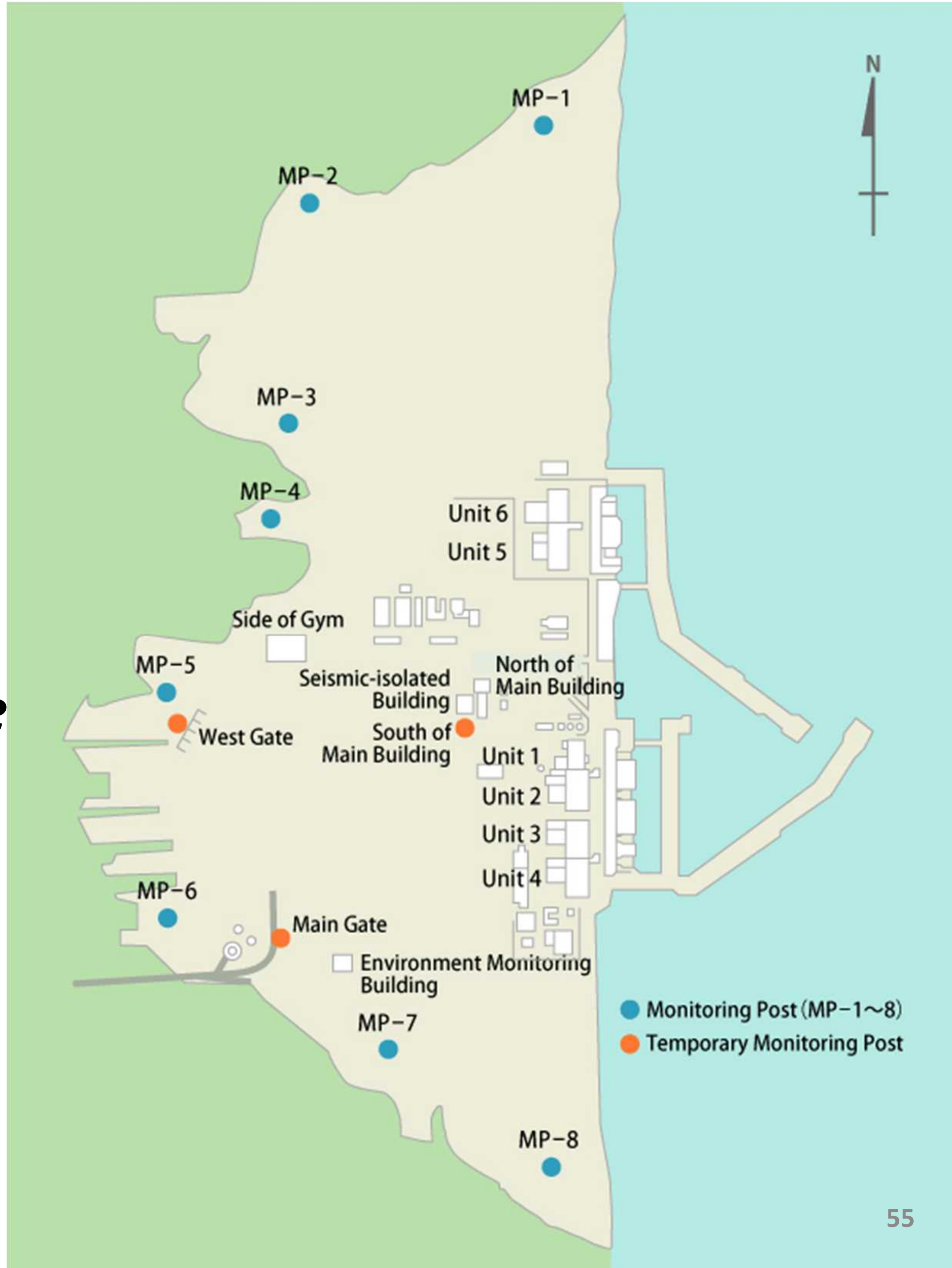
	Estimated release from Fukushima Daiichi		(Reference) Release from Chernobyl
	by NISA	by Nuclear Safety Commission	
Iodine 131 (a)	130 thousands T Bq ($1.3X10^{17}$Bq)	150 thousands T Bq ($1.5X10^{17}$Bq)	1,800 thousands T Bq ($1.8X10^{18}$Bq)
Cesium 137	6 thousands T Bq ($6.0X10^{15}$Bq)	12 thousands 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)

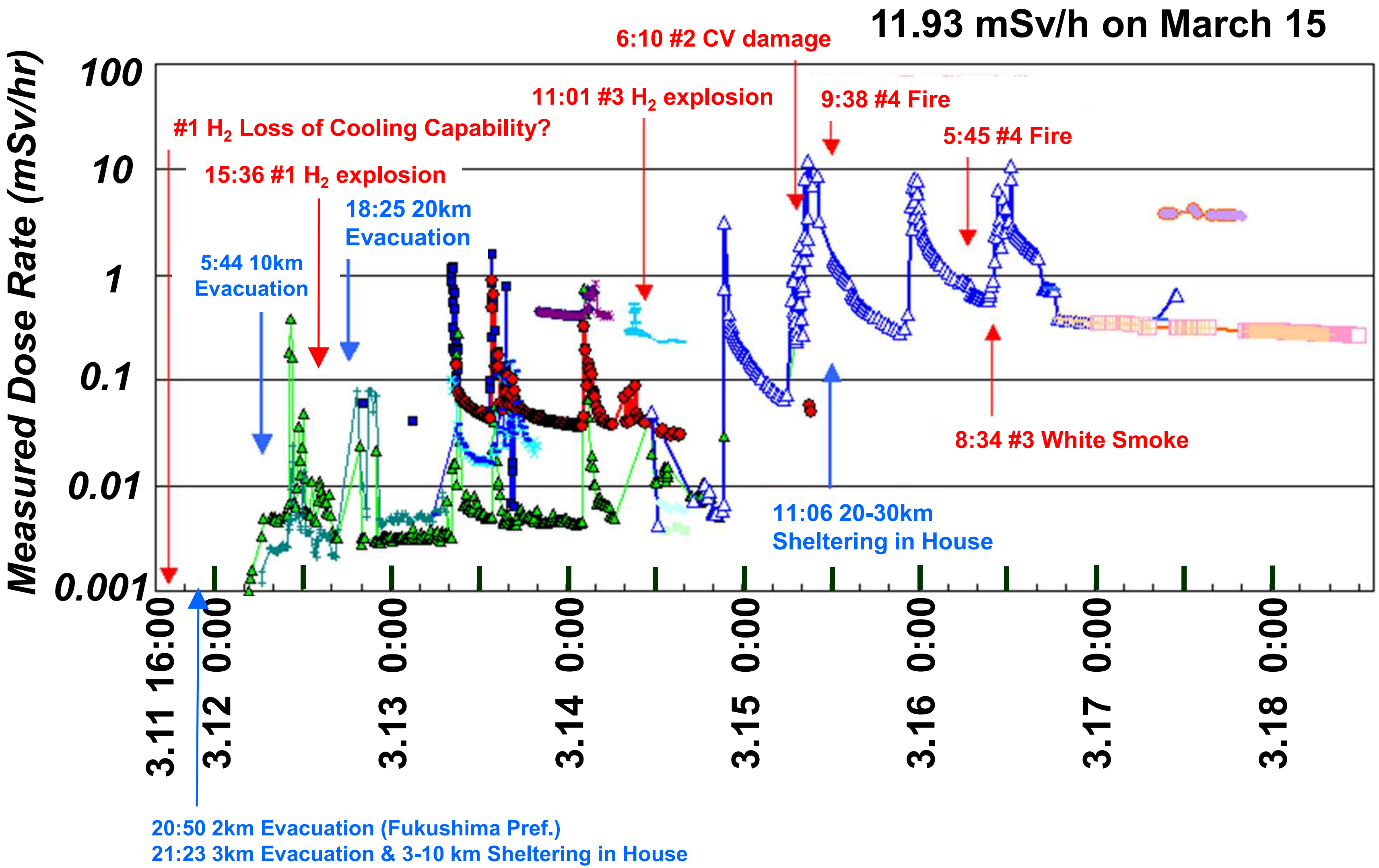
Source: Nuclear and Industrial Safety Agency

Monitoring Posts

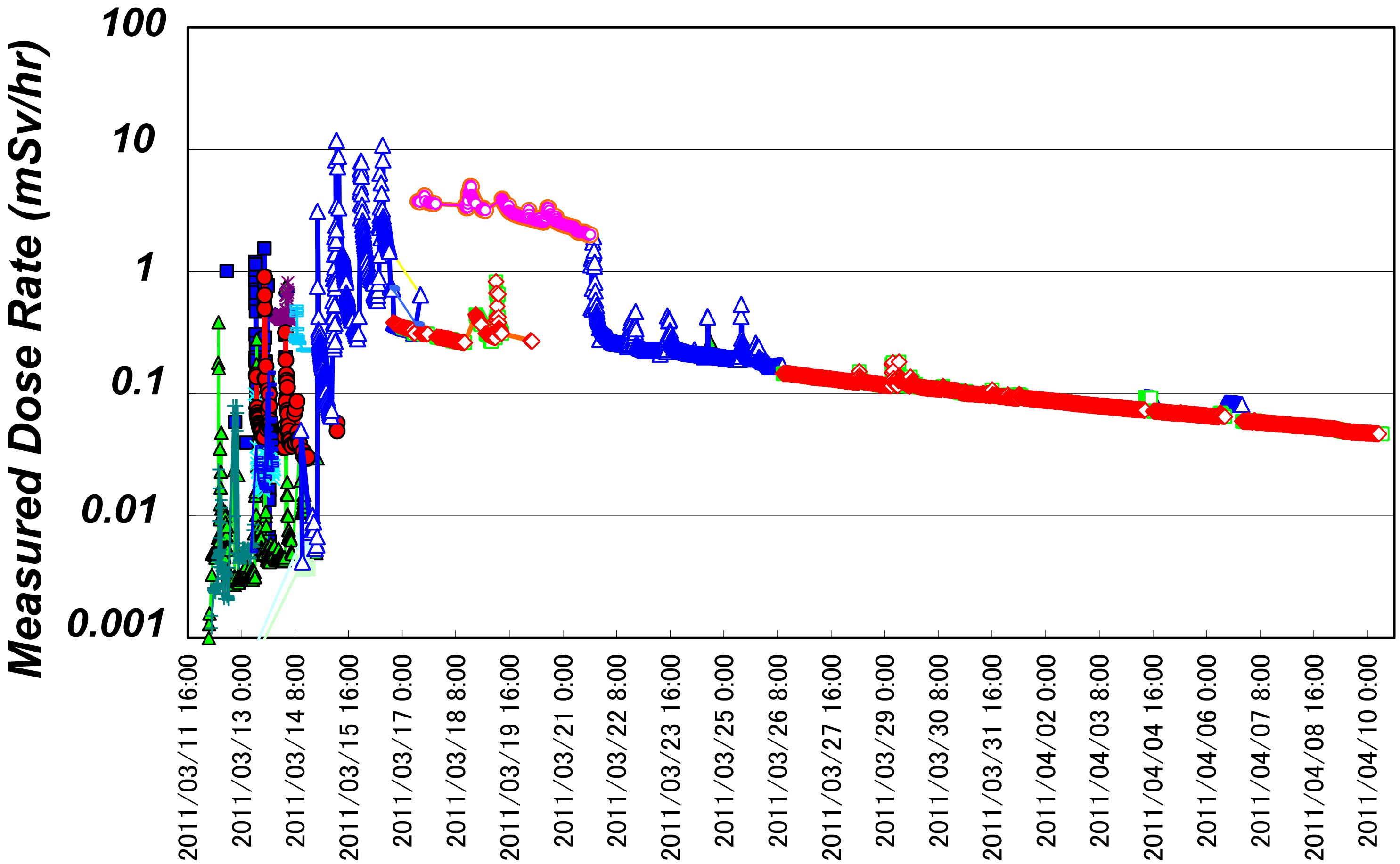
in the Fukushima Daiichi Nuclear Power Plants Site



On-site Radiation Monitoring in Fukushima Daiichi Site From March 11 to 18

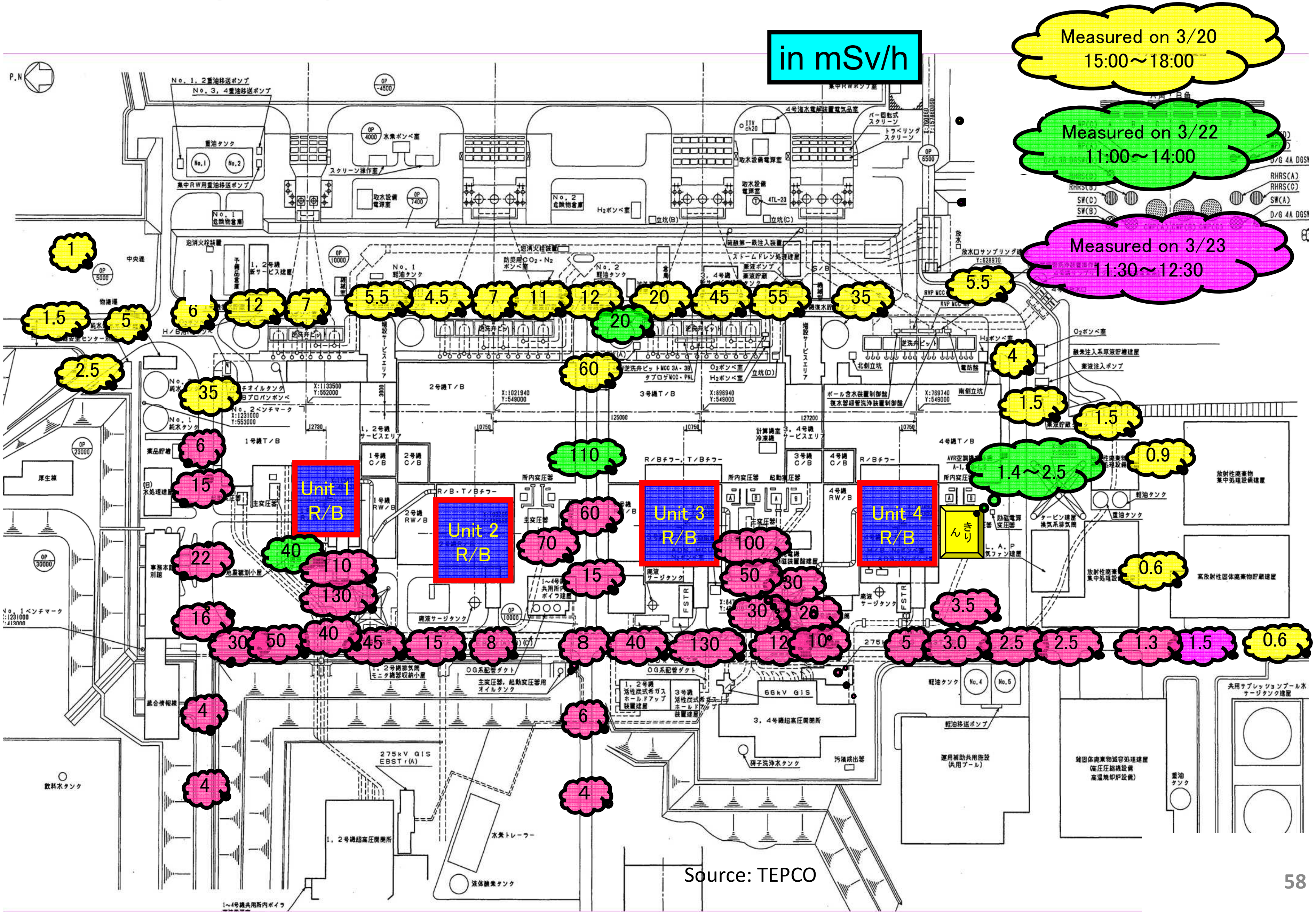


On-site Radiation Monitoring in Fukushima Daiichi Site From March 11 to April 10



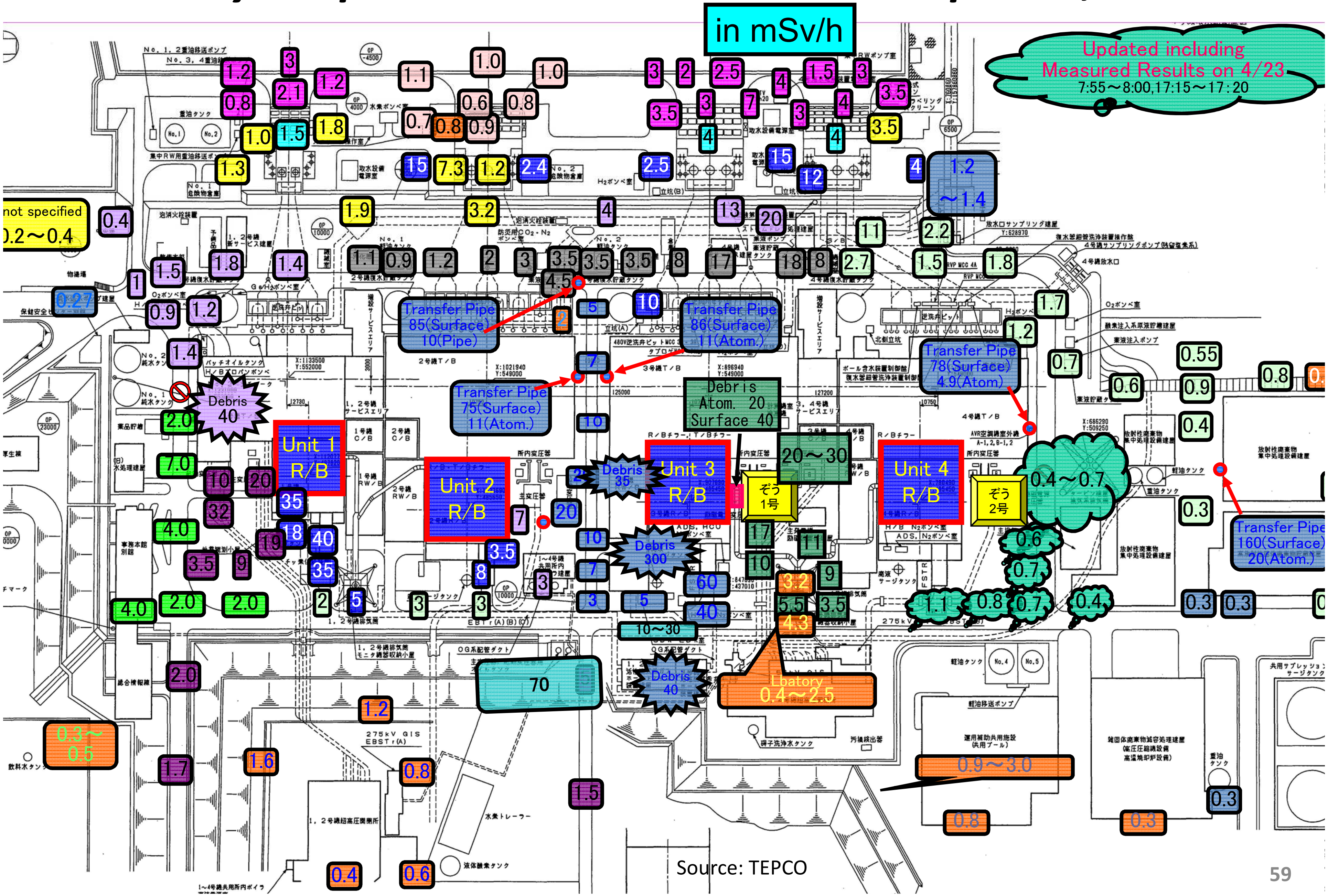
Source: NISA & TEPCO's press release

Survey Map in Fukushima Daiichi Site March 23, 2011



Source: TEPCO

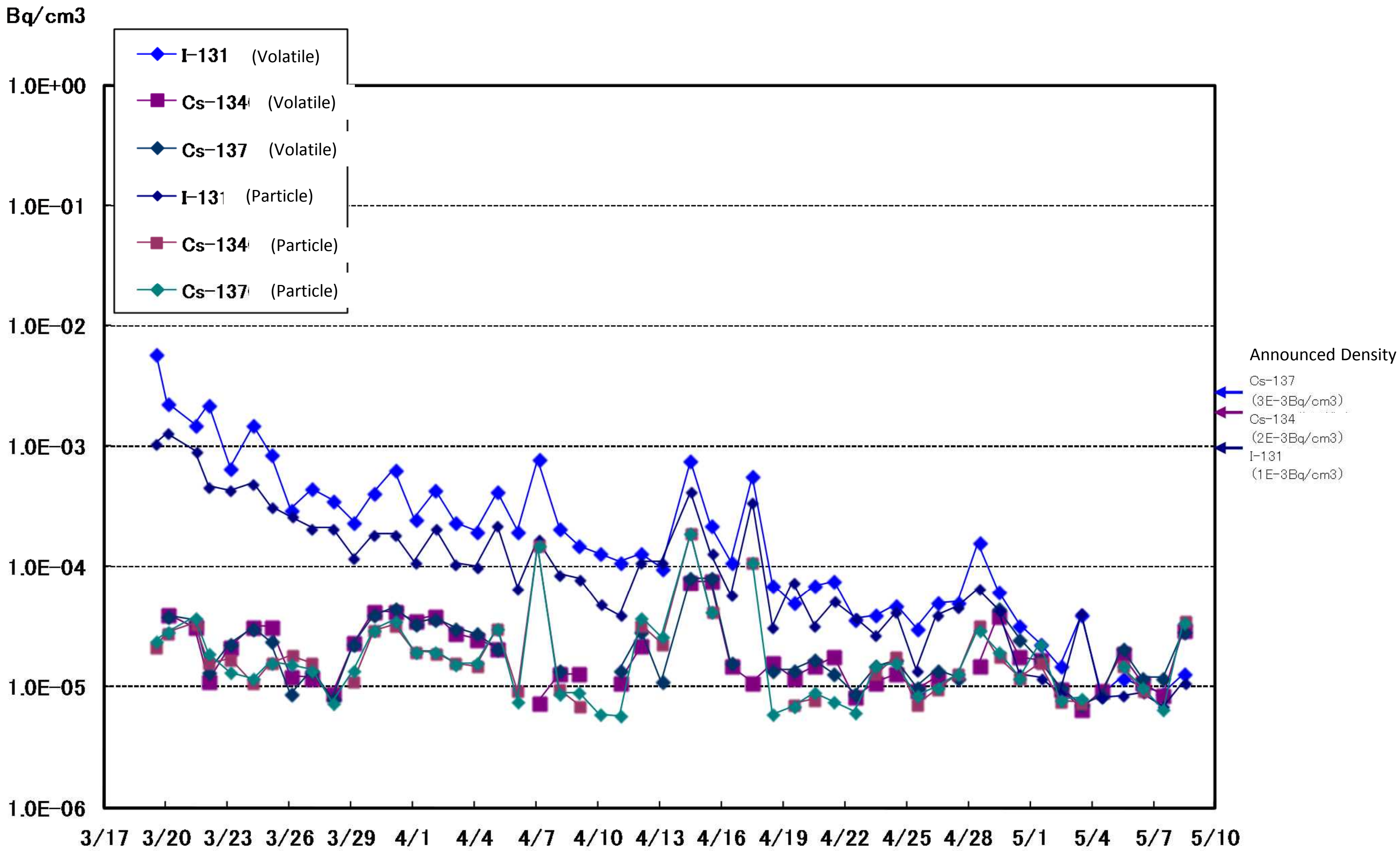
Survey Map in Fukushima Daiichi Site April 23, 2011



Source: TEPCO

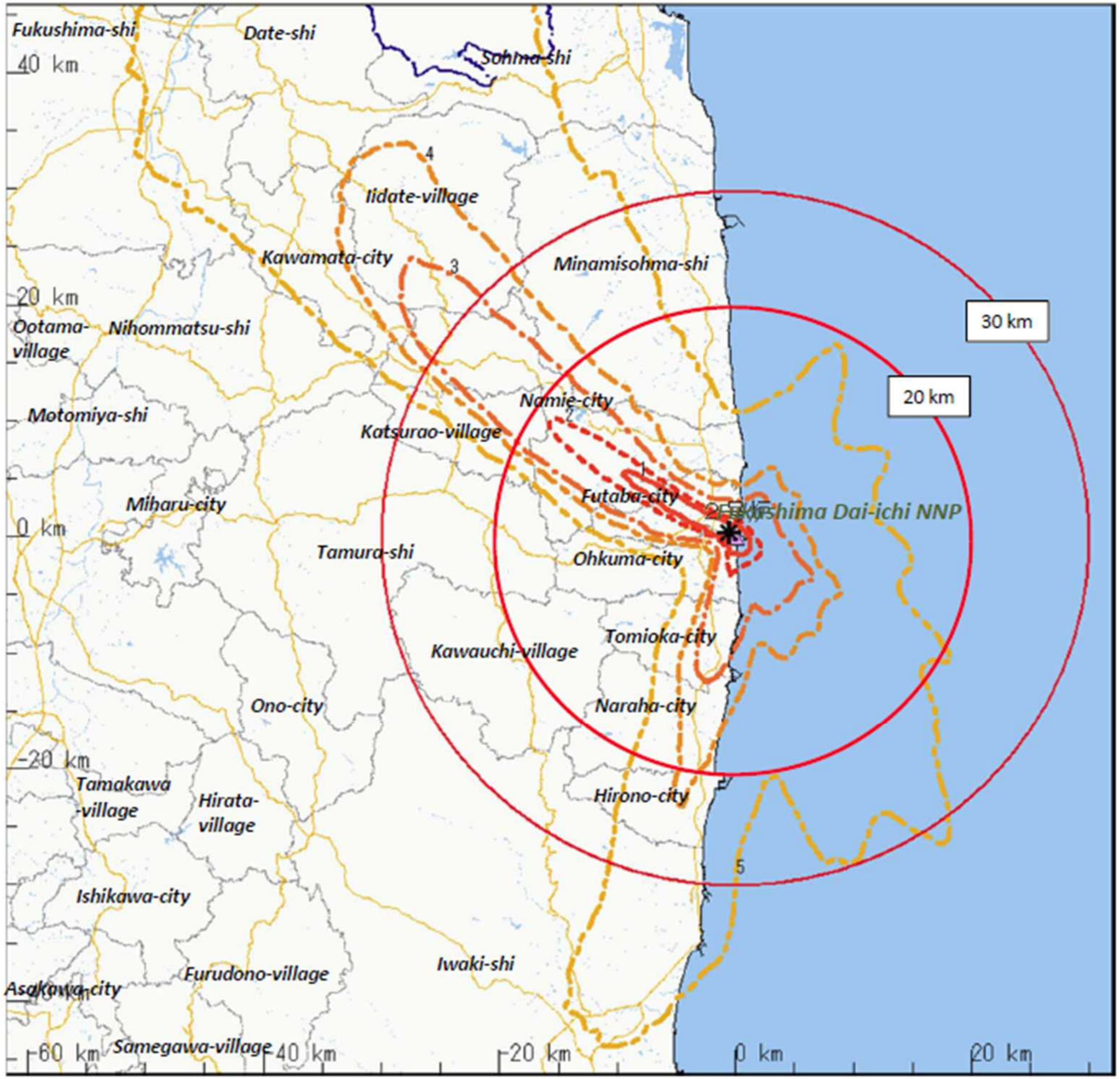
On-Site Monitoring of Radioactive Materials

Radioactive materials in the air measured by TEPCO



Source: TEPCO

Integrated Dose of External Exposure



SPEEDI code

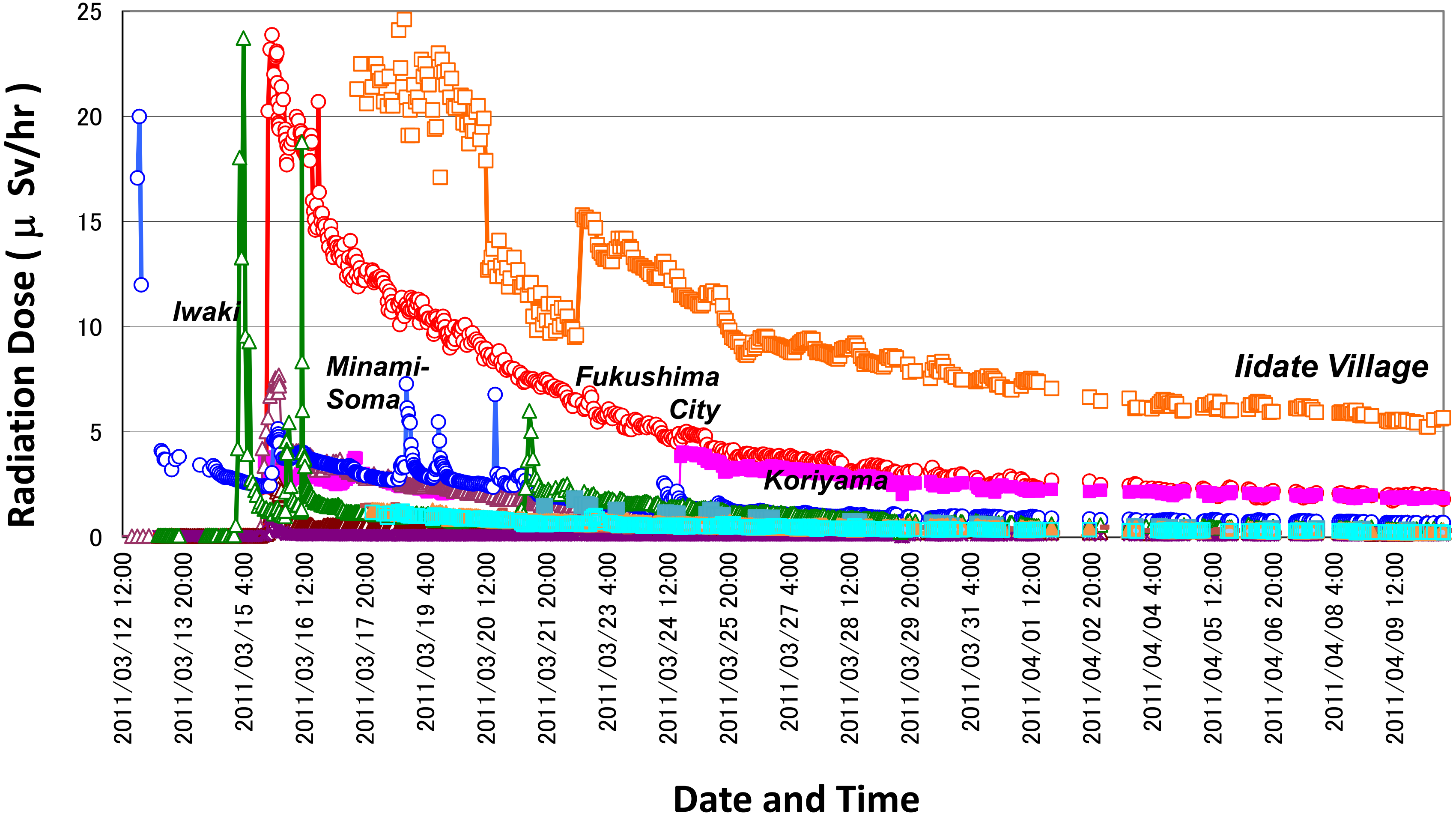
Adult

from March 12 to April 24, 2011

Effective Dose in mSv

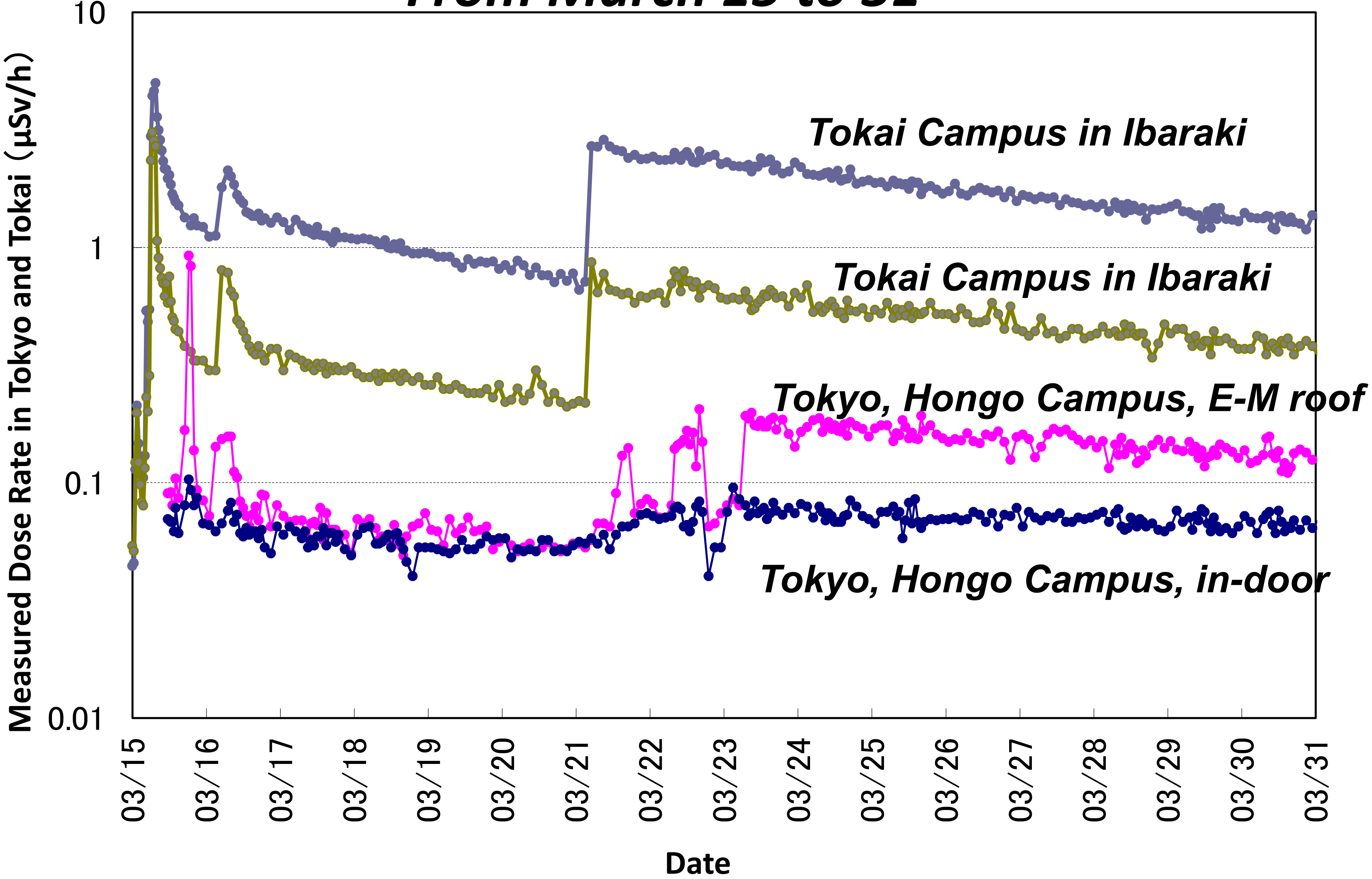
1= 100
2= 50
3= 10
4= 5
5= 1

Monitoring Radiation Dose in Fukushima Prefecture



Source: MEXT press release

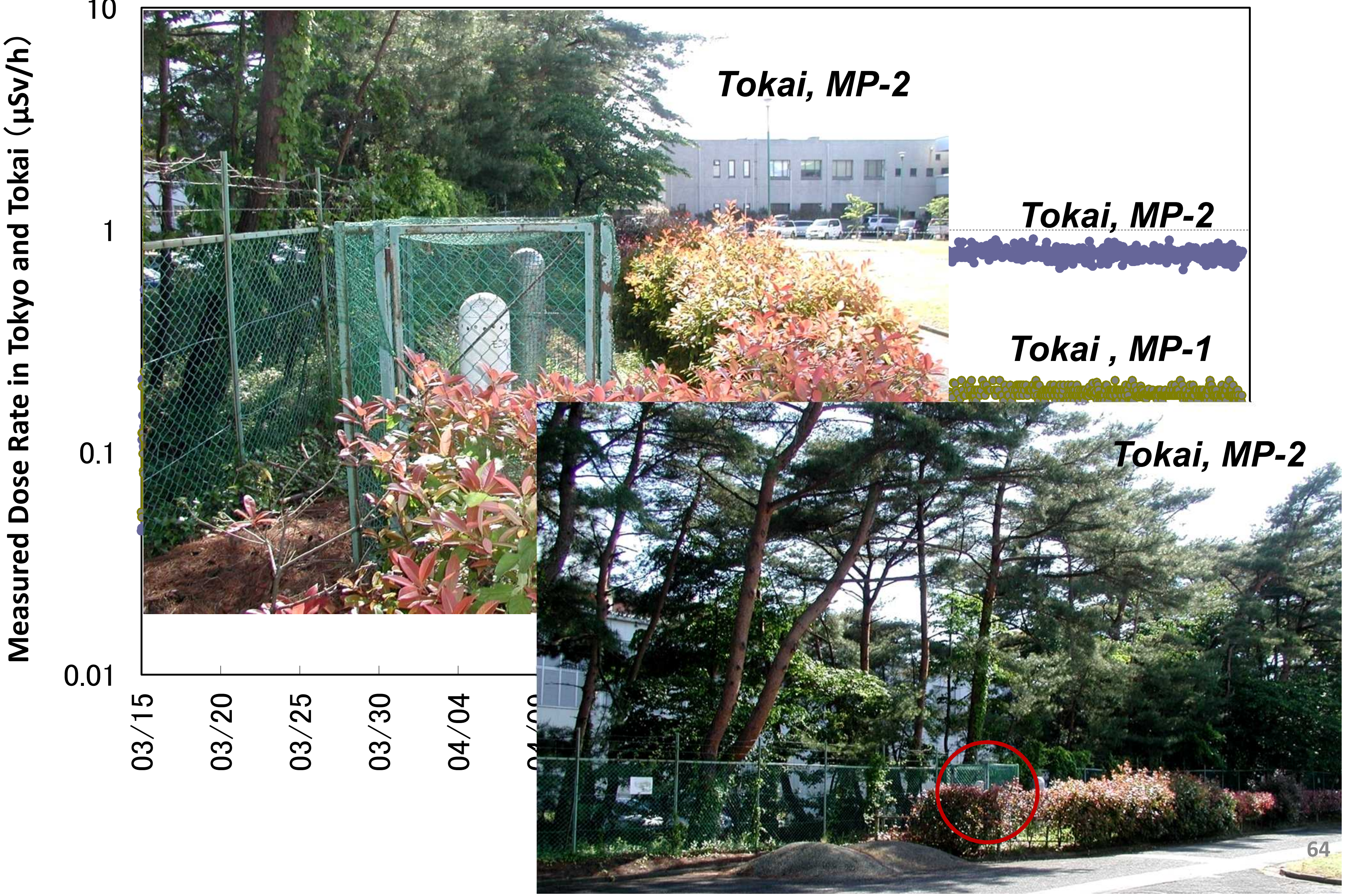
Radiation Monitoring at The University of Tokyo
From March 15 to 31



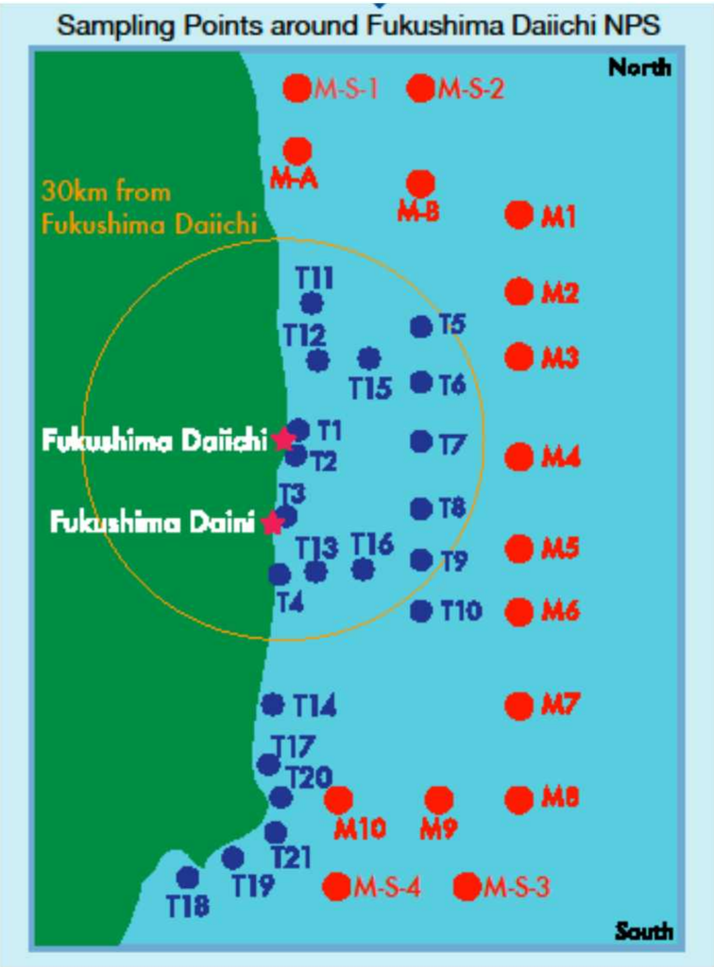
Distance from Fukushima Daiichi NPPs ***Ibaraki, Tokai Campus : 110 km***

Tokyo, Hongo Campus : 230 km

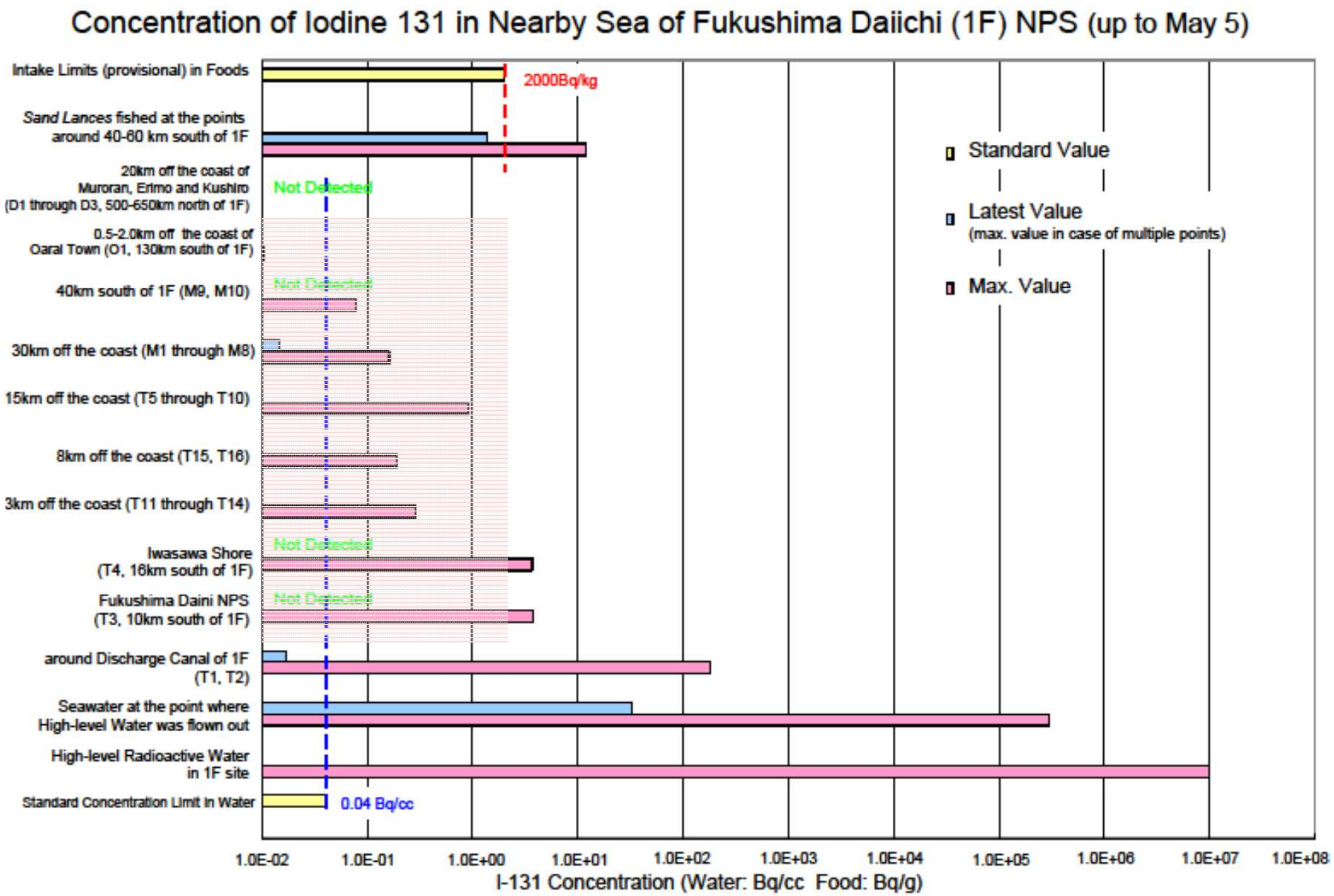
Radiation Monitoring at The University of Tokyo From March 15 to May 24



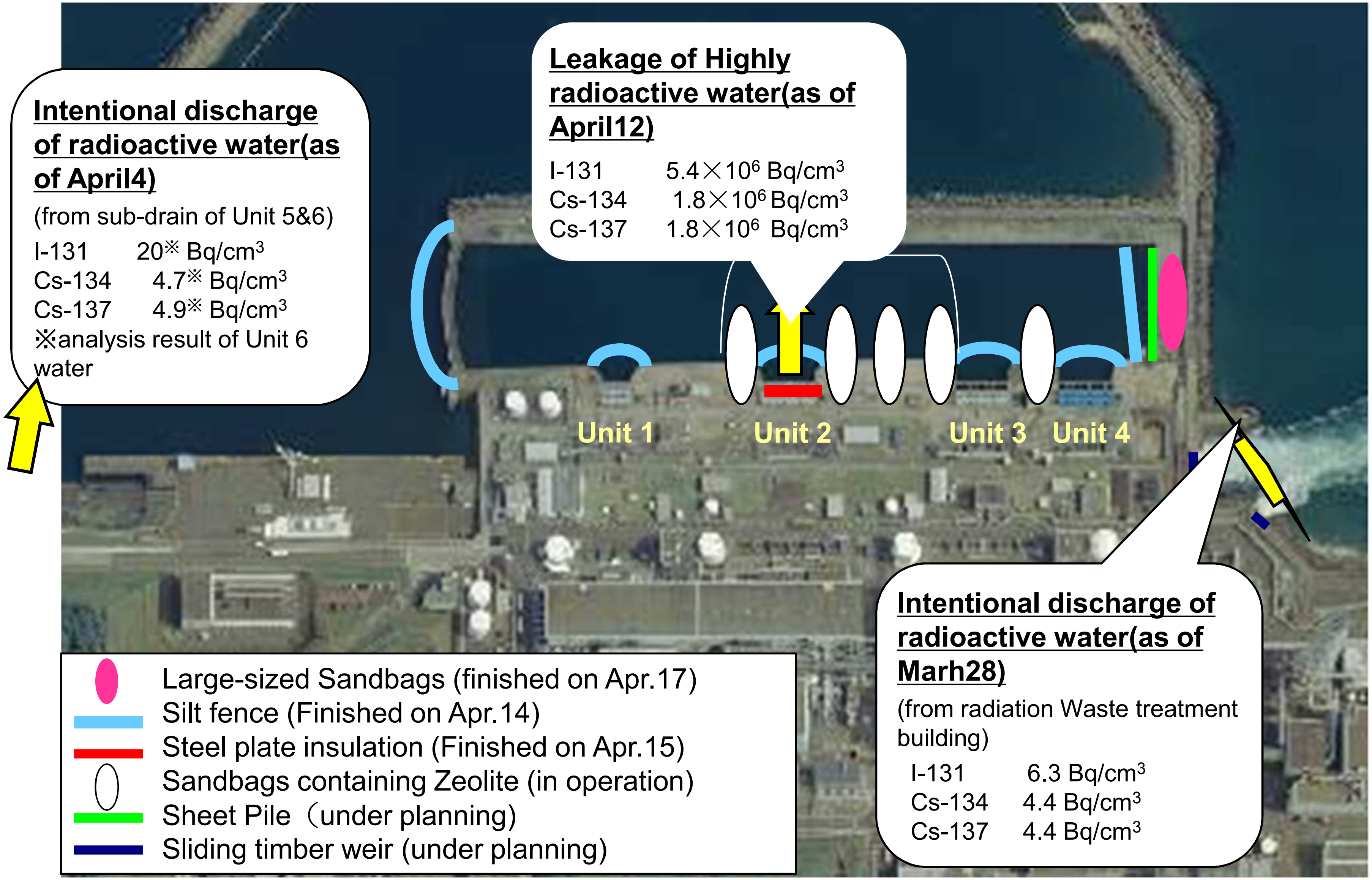
Monitoring of Radioactive Materials in Near-by Sea of Fukushima Daiichi NPPs



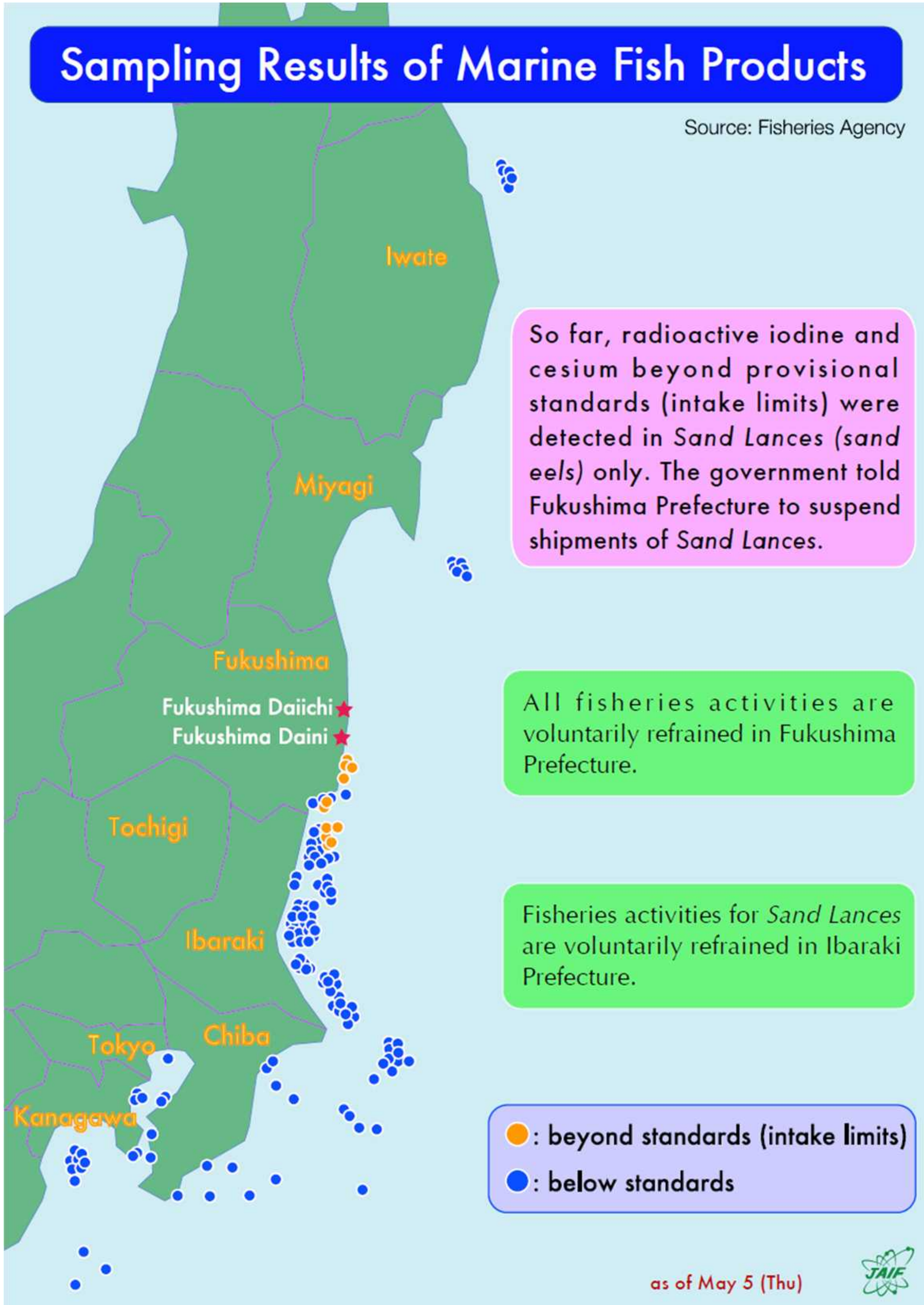
Monitoring of Radioactive Materials in Near-by Sea of Fukushima Daiichi NPPs



Measures to prevent the spread of radioactive water

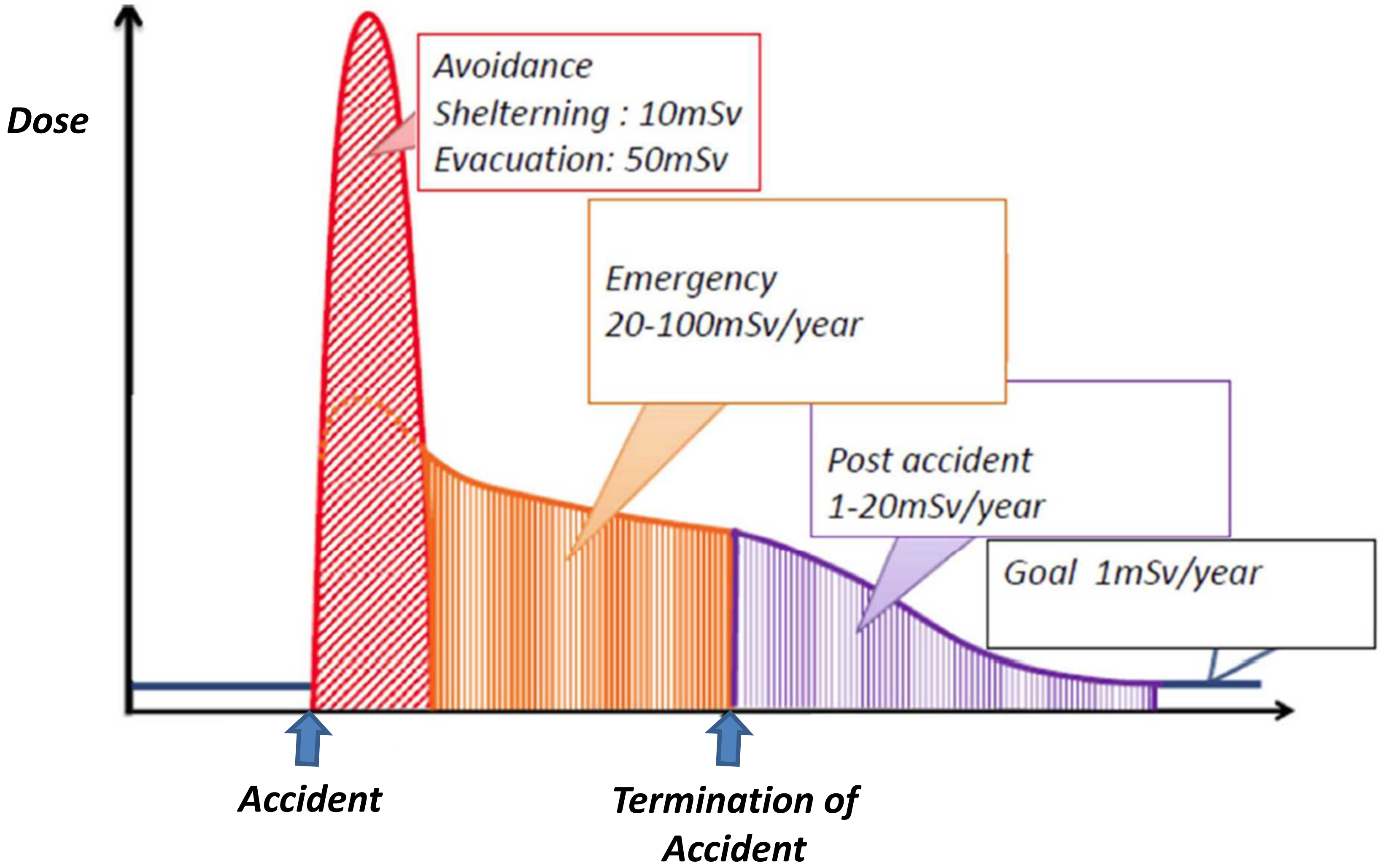


Source: TEPCO

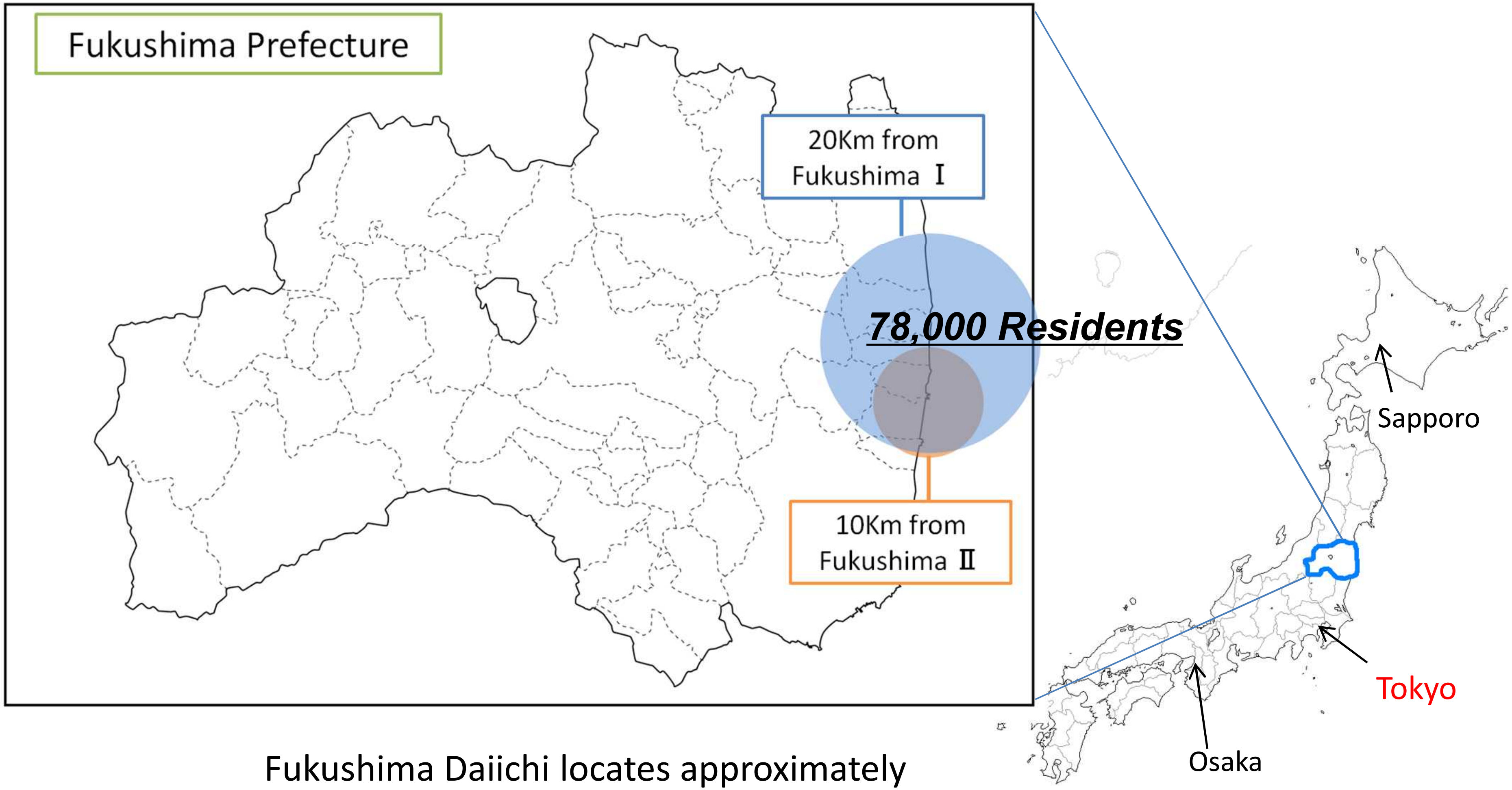

Sampling Results of Marine Fish Products
Source: Fisheries Agency
Iwate
Miyagi
Fukushima
Fukushima Daiichi
Fukushima Daini
Tochigi
Ibaraki
Chiba
Tokyo
Kanagawa
So far, radioactive iodine and cesium beyond provisional standards (intake limits) were detected in *Sand Lances (sand eels)* only. The government told Fukushima Prefecture to suspend shipments of *Sand Lances*.
All fisheries activities are voluntarily refrained in Fukushima Prefecture.
Fisheries activities for *Sand Lances* are voluntarily refrained in Ibaraki Prefecture.
: beyond standards (intake limits)
: below standards
as of May 5 (Thu)
JAIF

Emergency Dose and Goals to Terminate the Accident

Nuclear Safety Commission on April, 12



Evacuation of Residents



Fukushima Daiichi locates approximately
- 230 km from Tokyo
- 580 km from Osaka
- 600 km from Sapporo

Evacuation of Residents

➢The government took measures such as taking shelters or evacuation as follows based on the reports from Fukushima Daiichi & Daini.

<u>Fri, 11 March</u>

14:46 The Earthquake

19:03 Emergency Declaration by the Gov't (Daiichi)

21:23 3 km radius evacuation (Daiichi)

10 km radius taking shelter (Daiichi)

<u>Sat, 12 March</u>

5:44 10 km radius evacuation (Daiichi)

7:45 3 km radius evacuation (Daini)

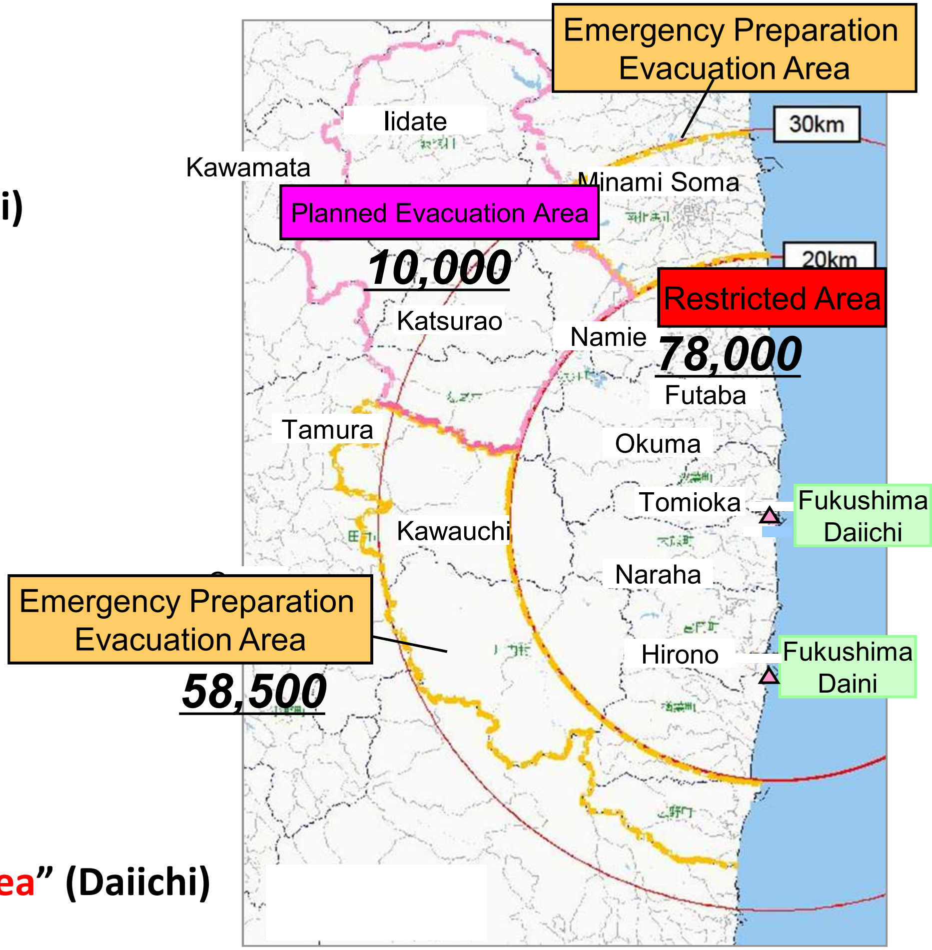
10 km radius taking shelter (Daini)

17:39 10 km radius evacuation (Daini)

18:25 20 km radius evacuation (Daiichi)

<u>Tue, 15 March</u>

11:00 20-30 km radius taking shelter (Daiichi)



Source: NISA website

<u>Thu, 21 April</u>

11:00 20 km radius is designated as "Restricted Area" (Daiichi)

<u>Fri, 22 April</u>

9:44 20-30 km radius taking shelter has been lifted (Daiichi)

Establishment of "Planned Evacuation Area" and "Emergency Preparation Area"

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TEPCO's Roadmap on April 17

	Step1 (About 3 months)	Step2 (Minimum about 6 to 9 Months)
Target	Steady Reduction of Radiation Dose	Controlling Radiation Release and Significant Reduction of Radiation Dose
Reactors	Stable Cooling (Water Filling over the Fuel)	Achieving the State of Cold Shutdown
Spent Fuel Pools	Stable Cooling	Keeping the Sufficient Water Level for More Stable Cooling (Remote Operation)
Radioactive Contaminated Water	Prevention of Outflow to the out of the Site	Processing and Decreasing the Contaminated Water
Radioactive Contaminated Atmosphere/Soil	Prevention of Spread	Covering Up the Entire Reactor Building

TEPCO's Roadmap on April 17

		Current Status	STEP1(3 month)	STEP2(6~9 month)	Mid-term Issues
I. Cooling	(1) Reactors	Injecting fresh water	Nitrogen gas injection; Examination and implementation of heat exchange function, etc; Stable cooling; Flooding up to top of active fuel	Cold shutdown condition	Prevention of breakage of structural materials , etc.
	(2) Spent Fuel Pools	Injecting fresh water	Restore coolant circulation system, etc; Stable cooling	Examination and implementation of heat exchange function, etc; More stable cooling	Removal of fuels
II. Mitigation	(3) Accumulated Water	Storing water with radiation, etc	Installation of storage / processing facilities, etc; Secure storage place	Decontamination / Desalt processing (reuse), etc; Decrease contaminated water	Installation of full-fledged water treatment facilities
	(4) Atmosphere / Soil	Dispersion of inhibitor, Installing reactor building cover, etc			Solidification of contaminated soil, etc
III. Monitoring, etc	(5) Measurement, Reduction, etc	Monitoring of radiation	Expand/enhance monitoring, etc	Sufficiently reduce radiation dose in evacuation area	Continue monitoring environmental safety

Government's response to TEPCO's proposal (Apr. 17)

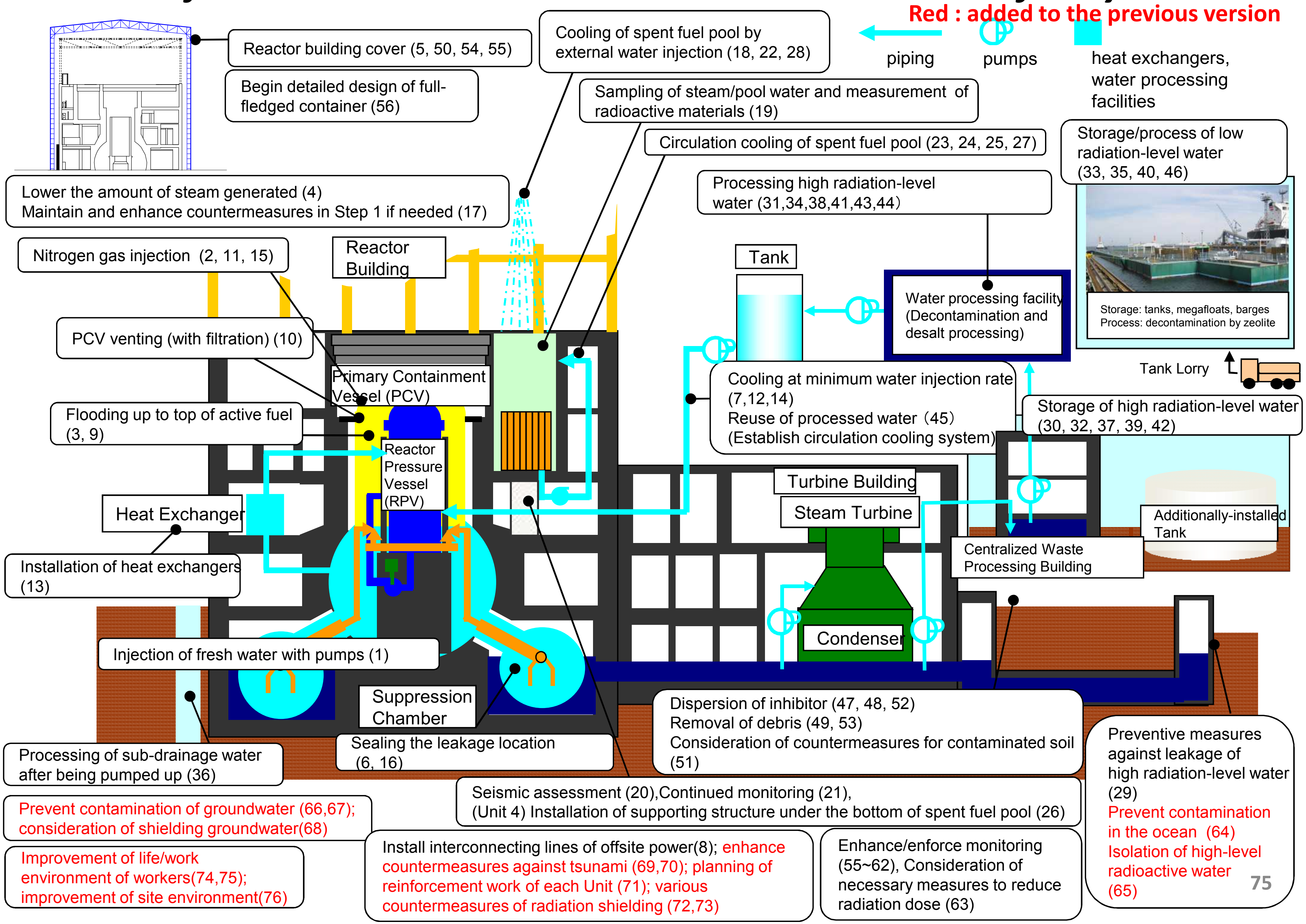
- The Government will request TEPCO to ensure the implementation of this roadmap steadily and as early as possible. To this end, the Nuclear and Industrial Safety Agency and others will make regular follow-up, monitoring of the progress of the works and necessary safety checks.

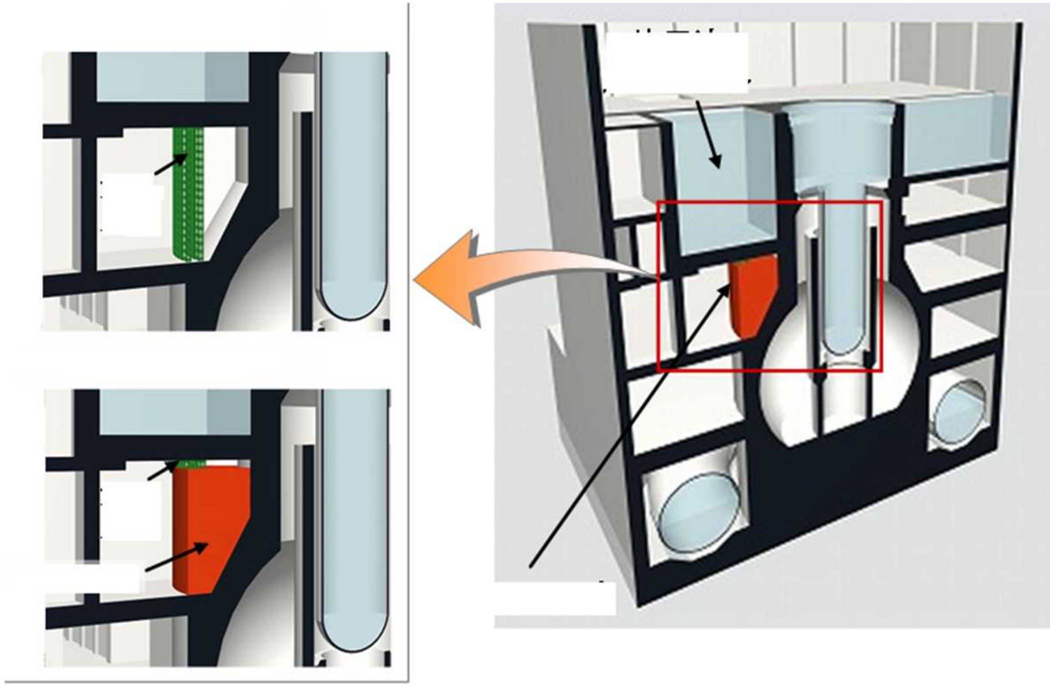
- The Government will request TEPCO to ensure the mobilization and deployment of workers, the procurement and preparation of equipment and materials, and the arrangement of accommodation and other facilities, which are necessary to ensure implementation of the roadmap

- At the end of Step2, the release of radioactive materials will be under control. At this stage, the government will review the Evacuation Area and the Evacuation Prepared Area. Up until that time, we will consider the details of review criteria, and will decontaminate the widest possible area.

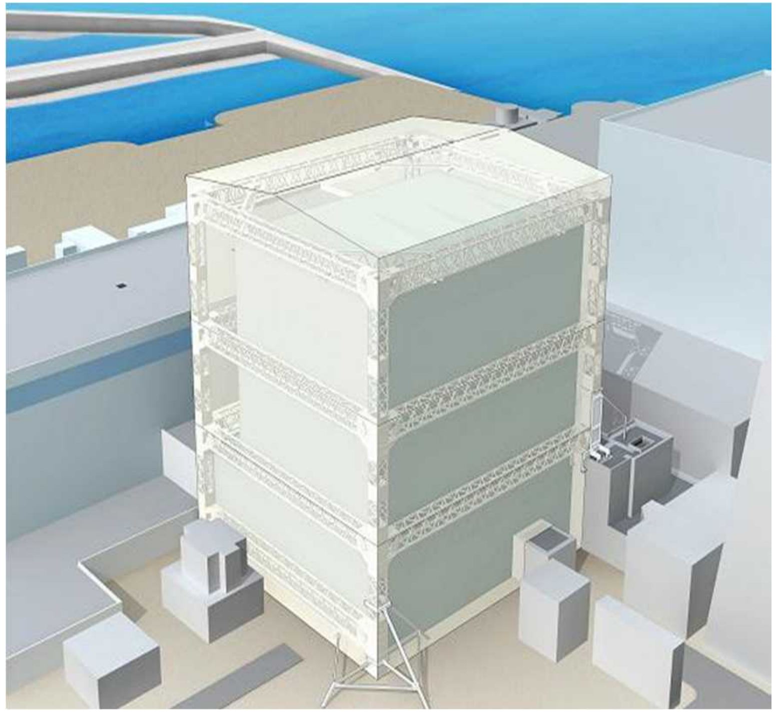
Source: Nuclear and Industrial Safety Agency

Major Countermeasures in the Power Station as of May 17

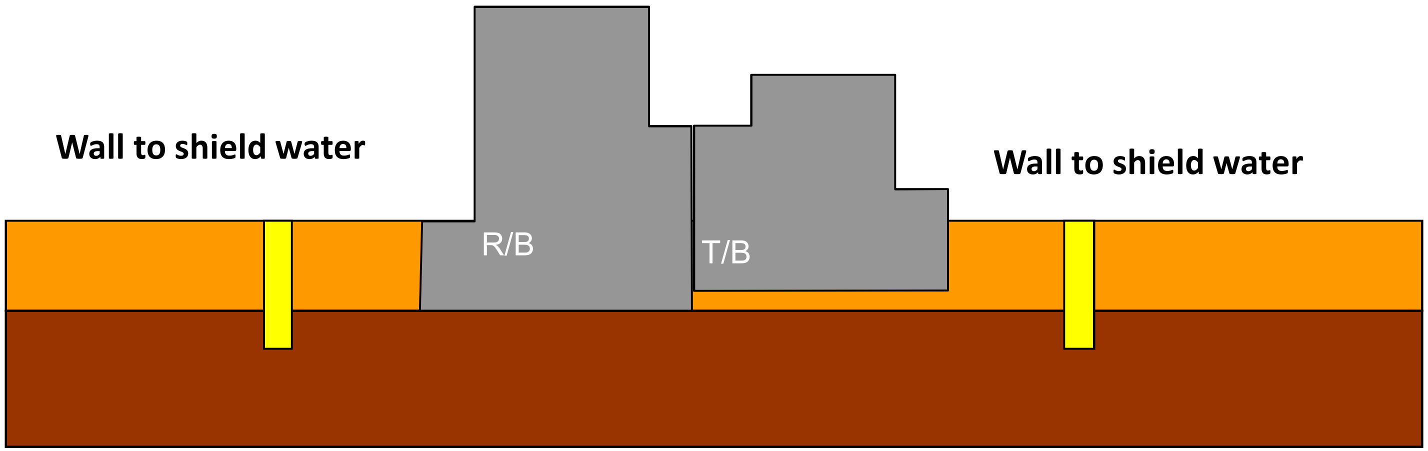




Installing Supporting Structure for SFP in Unit 4



Install of Reactor Building Cover for Unit 1



Measure to shield groundwater

Source: TEPCO

Conclusion : Preliminary Lessons Learned

The importance of <u>Defense in Depth</u> has been recognized with this accident

(1) Appropriate DBAs

Appropriate consideration for natural hazards by design
<u>- Design basis tsunami height 5.7m against 15m of actual tsunami height</u>

(2) Robustness and diversity in responding to beyond DBAs such as station black-out for long-duration, loss of ultimate heat sink

① Appropriate design philosophy to sustain safety function against common cause failures brought by natural hazards

- ***<u>All the emergency DGs, except 1 air-cooled DG, were water-cooled and all were located in the basement of T/Bs</u>***
- ***<u>All the sea-water pumps were located slightly above the design tsunami height and they were with no protection against water</u>*.**

② Appropriate AM measures for both prevention and mitigation of SAs

- ***<u>No AMs for SFP cooling and Hydrogen gas control in the R/Bs</u>***
- ***<u>No AMs training under severe conditions for multi-units under continuous aftershocks</u>***

Conclusion : Preliminary Lessons Learned

(3) Difficult situations for post severe accident recovery

- ***Warning for aftershocks and subsequent Tsunami***
- ***High radiation in the working area***
- ***Massive radioactive debris within the site***

(4) Emergency Preparedness and responses

- ***Evacuation zones***
- ***Function of off-site center***
- ***Communication***
- ***Radiation monitoring***

工学の在り方

Integrated Engineering for Huge Complicated Systems

基礎基盤工学　Fundamental Engineering

土木　Civil

建築　Architecture

都市　Urban

電気電子　Electrical and Electronics

情報　Information

機械　Mechanics

物理　Physics

化学　Chemistry

材料　Material

バイオ　Biology

?

総合工学　Integrated Engineering

原子力　Nuclear Energy

土木　Civil

建築　Architecture

電気電子　Electrical and Electronics

機械　Mechanical

物理　Physics

化学　Chemistry

材料　Material

航空宇宙　Aeronautics and Astronautics

システム創成　Systems Innovation

技術経営　Technical Management

情報理工　Information Science and Technology

Prof. T. Kitamori, Dean of School of Engineering, The University of Tokyo