Demolition and Removal of Structures Damaged or Contaminated as a Result of the Fukushima Accident

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Outline of the presentation

1. Overview of Earthquake, Tsunami and Nuclear Accident and Lessons Learned

2. Current Status of Fukushima Daiichi NPS (1F)

3. Current Topics

4. Mid-and-long Term Roadmap for Decommissioning

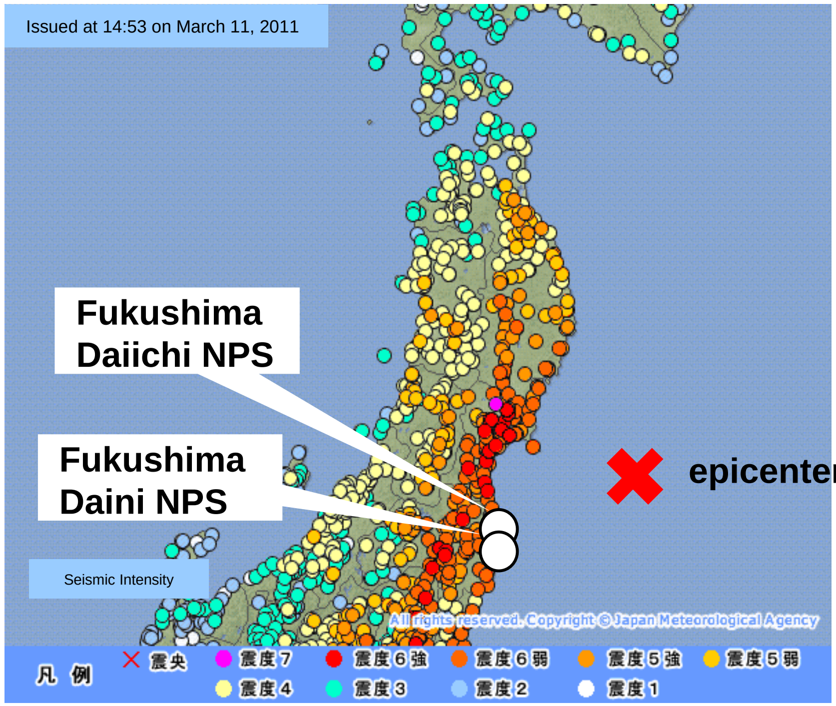
5. Remaining Challenges for Fuel Debris Retrieval

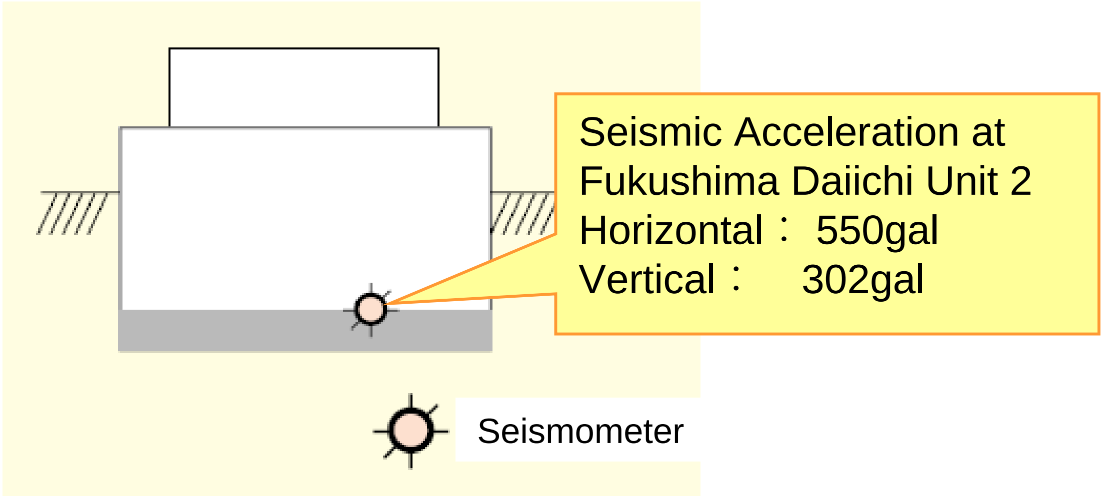
1. Overview of Earthquake, Tsunami and Nuclear Accident and Lessons Learned

Tohoku Pacific Ocean Earthquake

- **Time:** 2:46 pm on Fri, March 11, 2011.
- **Place:** Offshore Sanriku coast (northern latitude of 38.062 degrees, east longitude of 142.516 degrees), 24km in depth, Magnitude 9.0
- **Intensity:** **Level 7** at Kurihara in 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.

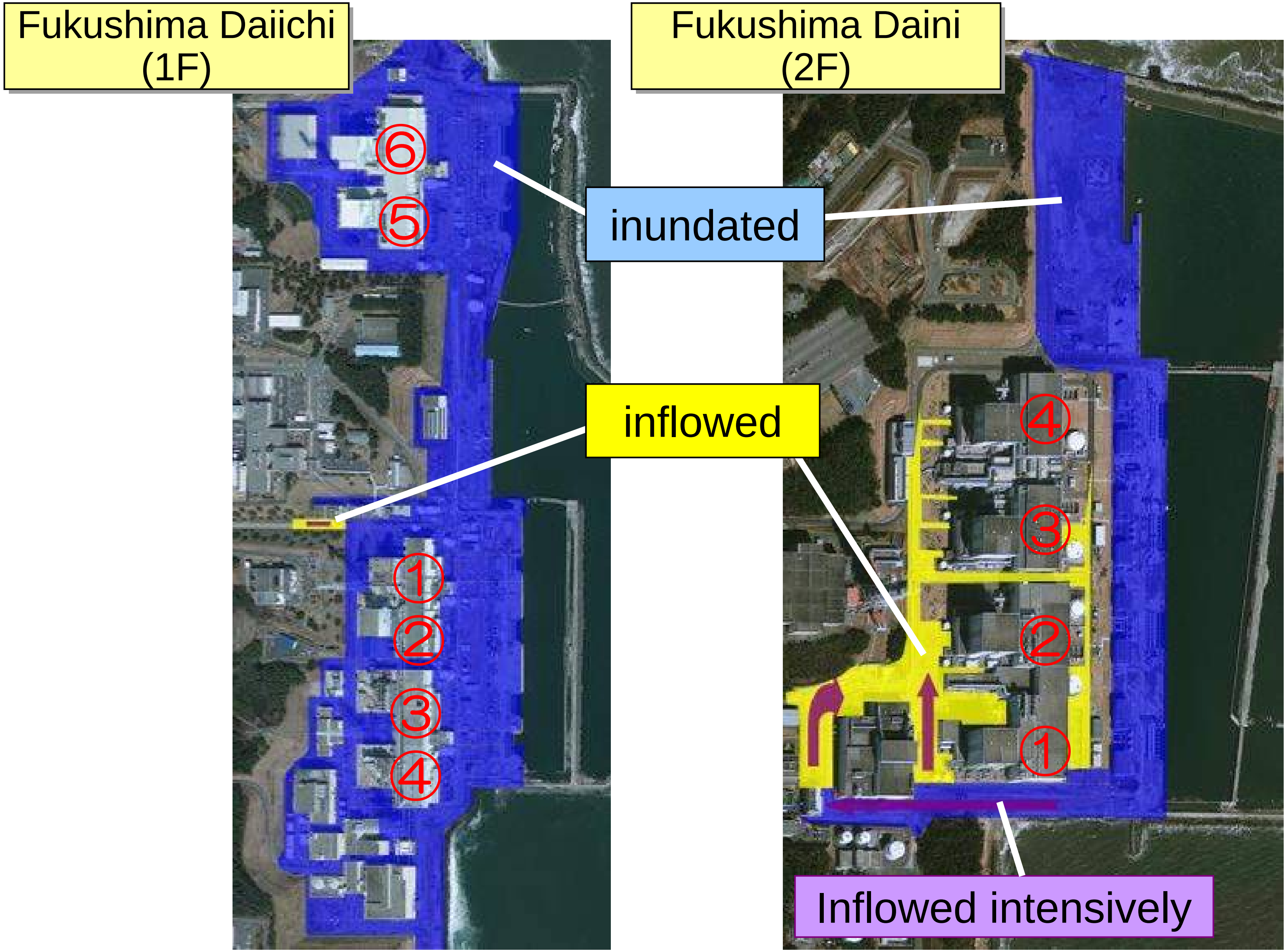
【Epicenter】





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

Inundated and Inflowed Area at 1F and 2F



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Summary of Lessons Learned

- The 1F accident was caused by the simultaneous loss of multiple safety functions due to far beyond design basis of tsunami. The main factors of the accident are **“the simultaneous loss of total AC power and DC power for a extended period of time”** and **“the loss of the heat removal function of the emergency seawater system for a extended period of time.”**

- Preparations had been previously made to receive power from neighboring units in the event that AC power and DC power were not available. During the accident, direct tsunami damage was so widespread that the neighboring units were all in the same condition.

“Carefully consider the robustness of current design of nuclear power plants and emergency preparedness against **beyond design basis events** that could lead to **common cause failures** regardless of their assumed probability demonstrating a continuous **learning organization**.”

2. Current Status of 1F

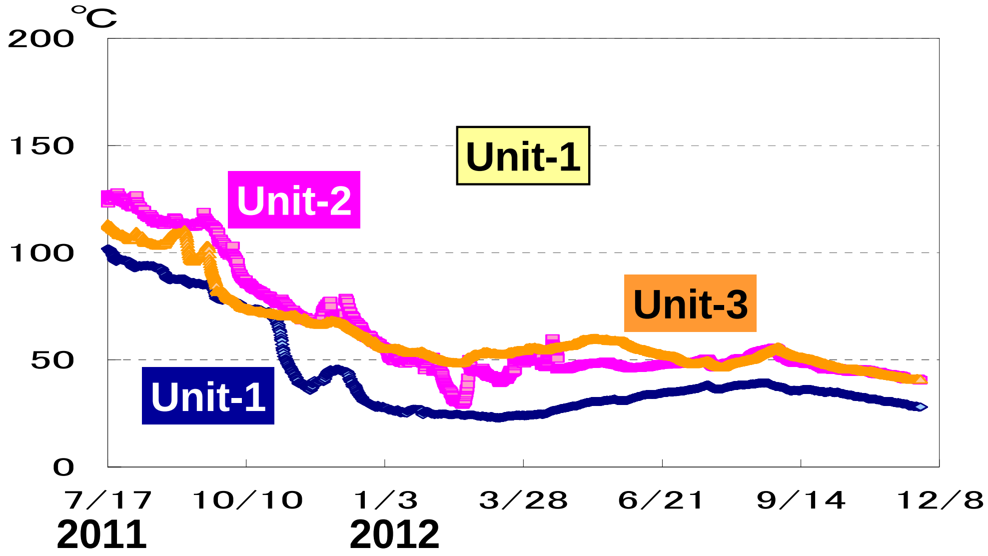
For more detail, please refer to:

2012.12.14 Fukushima Daiich NPS Video Tour

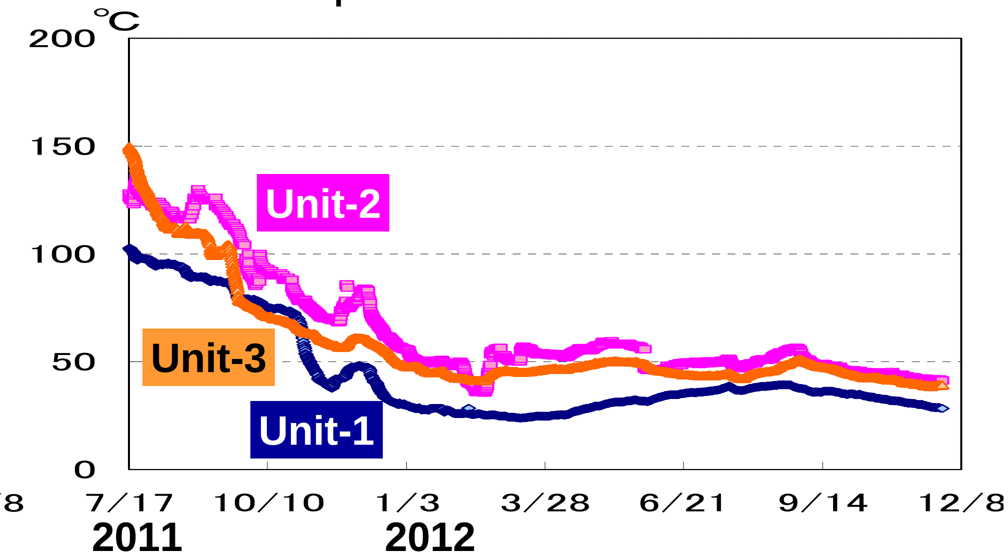
http://www.tepco.co.jp/en/news/library
/movie01e.html?bcpid=59368209002&bclid=239199917002&bctid=353106696002

Status of Core & Spent Fuel Pool Cooling

Temperatures of RPV bottom



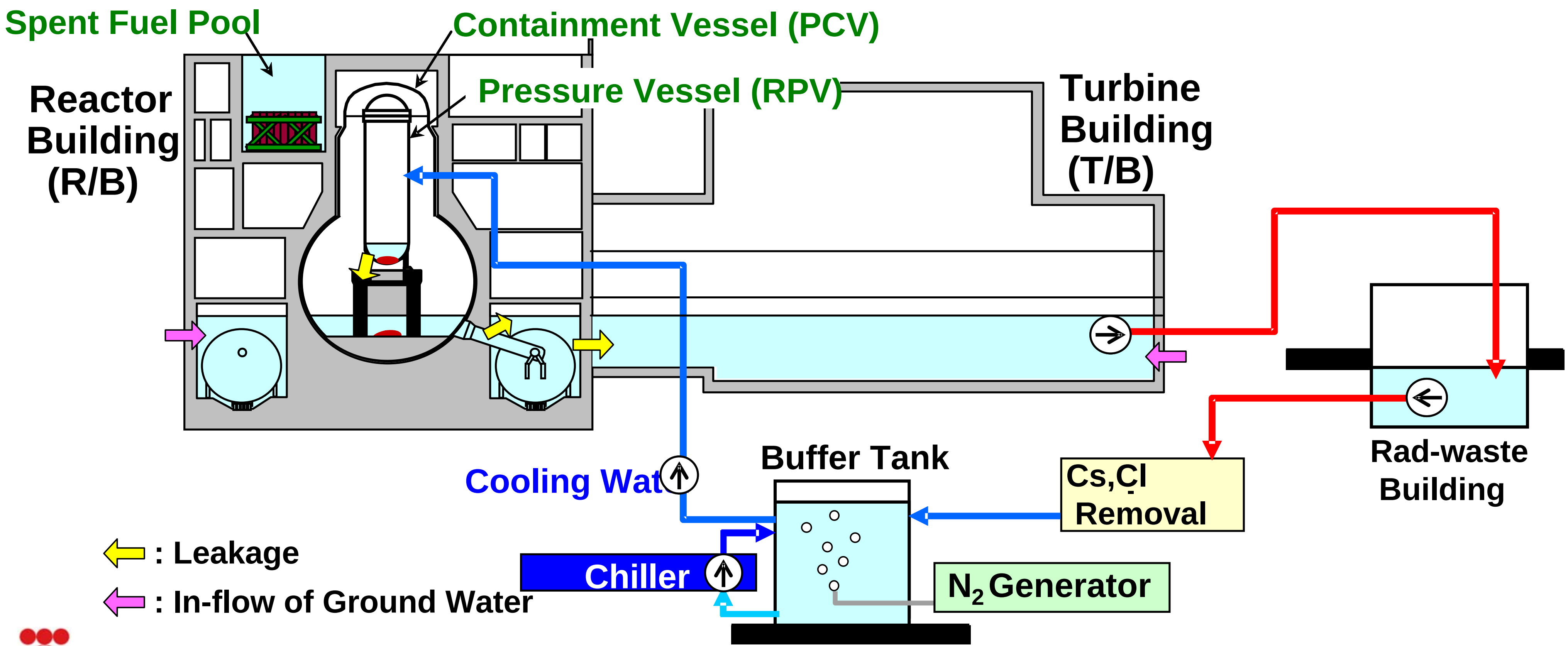
Temperatures inside PCV



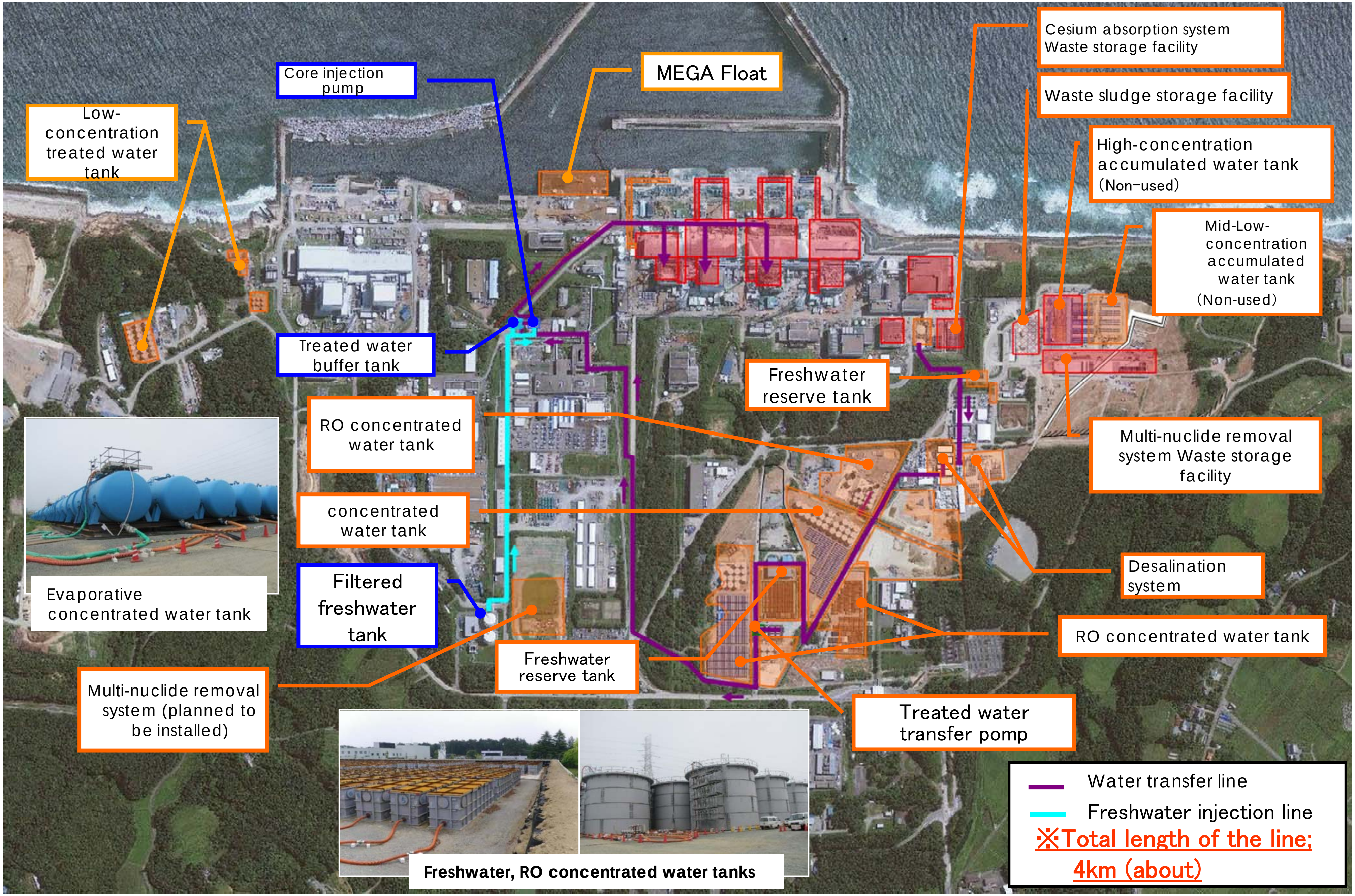
		Unit1	Unit 2	Unit 3	Unit 4	Unit 5/6
Shutdown		○	○	○	(Shutdown for Outages in 3/11)	
Cooling	Reactor	○ Cooled by Circulation Water System			—	○ Cold Shutdown
	Spent Fuel Pool	○ Cooled by air-cooled heat removal system				○
Containment		△ Contaminated water accumulated in building				○

Circulating Water Cooling of 1F Units 1~3

- Cooling water is leaking from RPV, PCV and R/B to T/B
  →Accumulated water in T/B is re-used as a coolant after cleaned with Cs & Cl^- removal system
- In-flow of ground water is increasing the amount of "contaminated water" to be processed by multiplex, diversity, independency systems.



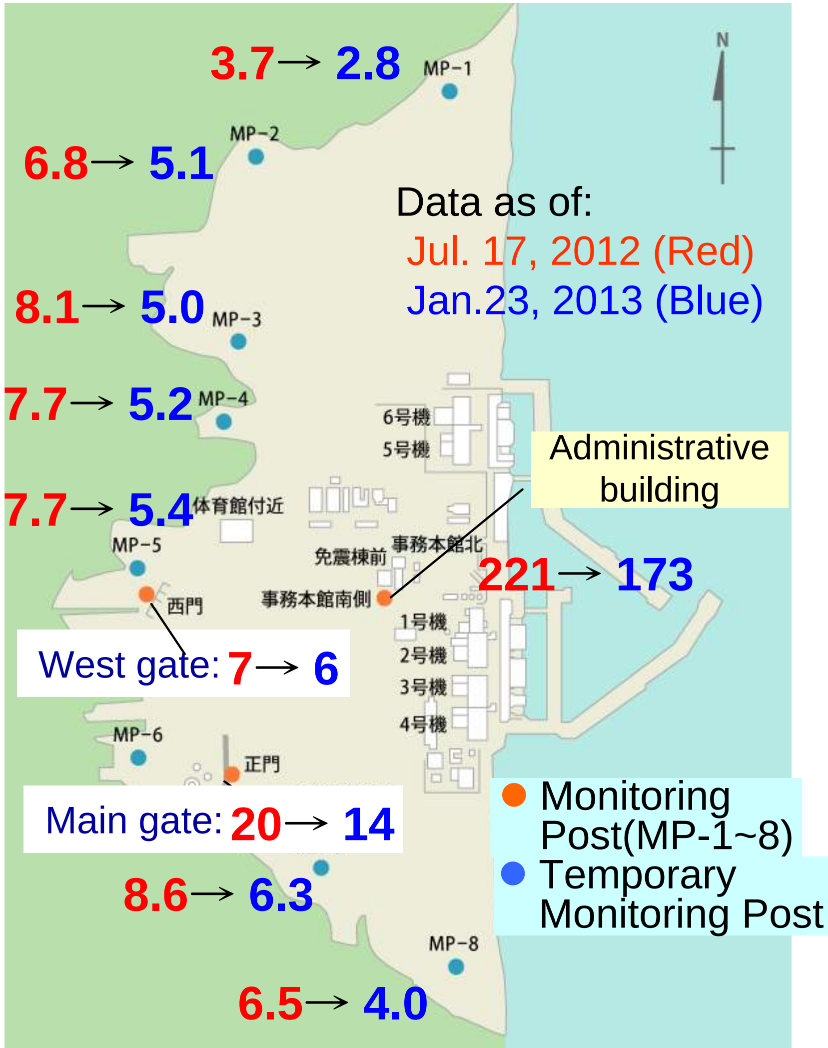
Status of Accumulated Water Storage Tanks



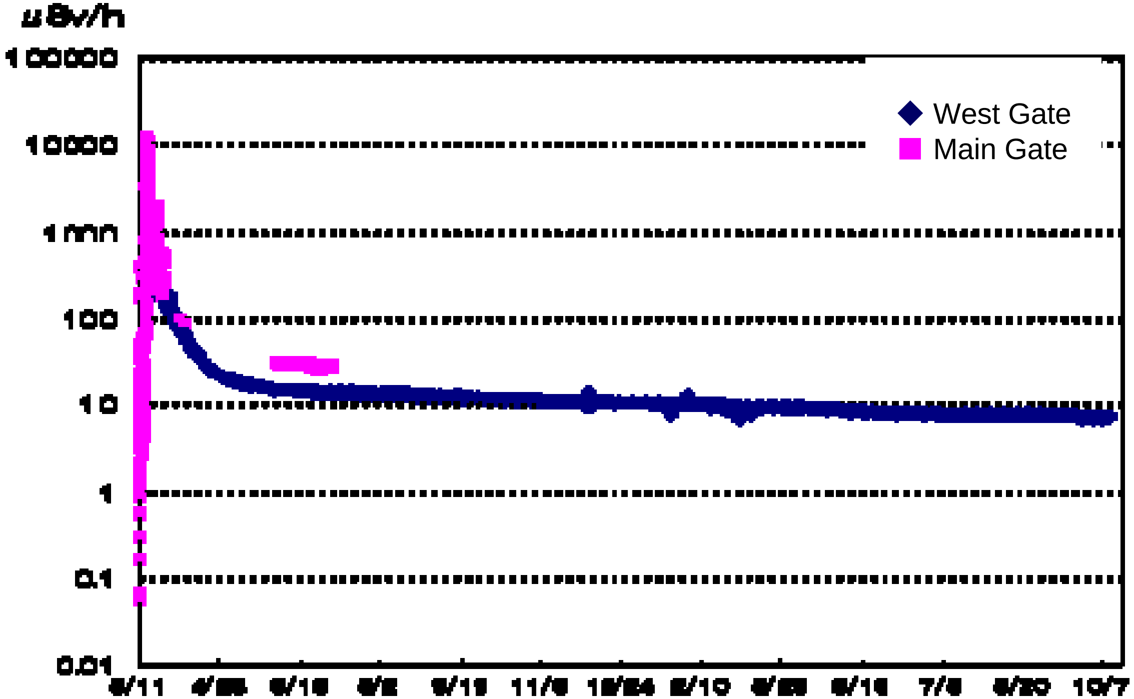
Monitoring Data (at Site Boundaries of Fukushima Daiichi)

Radioactivity has been a declining since the accident, and is now below the legal limit or the criteria requiring that masks be worn. Thus, the management of full-face masks and tyvek has been simplified since March 1st, 2012.

Monitoring Post air dose rate (μSv/h)



Dose Rate Trend at the Site Boundaries of Fukushima Daiichi



Soon after accident

March 2012

Controlling the Release of Radioactive Materials

- **The amount of radioactive materials (cesium) released from Unit 1-3 PCV is assessed based on airborne radioactive material concentrations (dust concentration) at the top of Reactor Buildings**

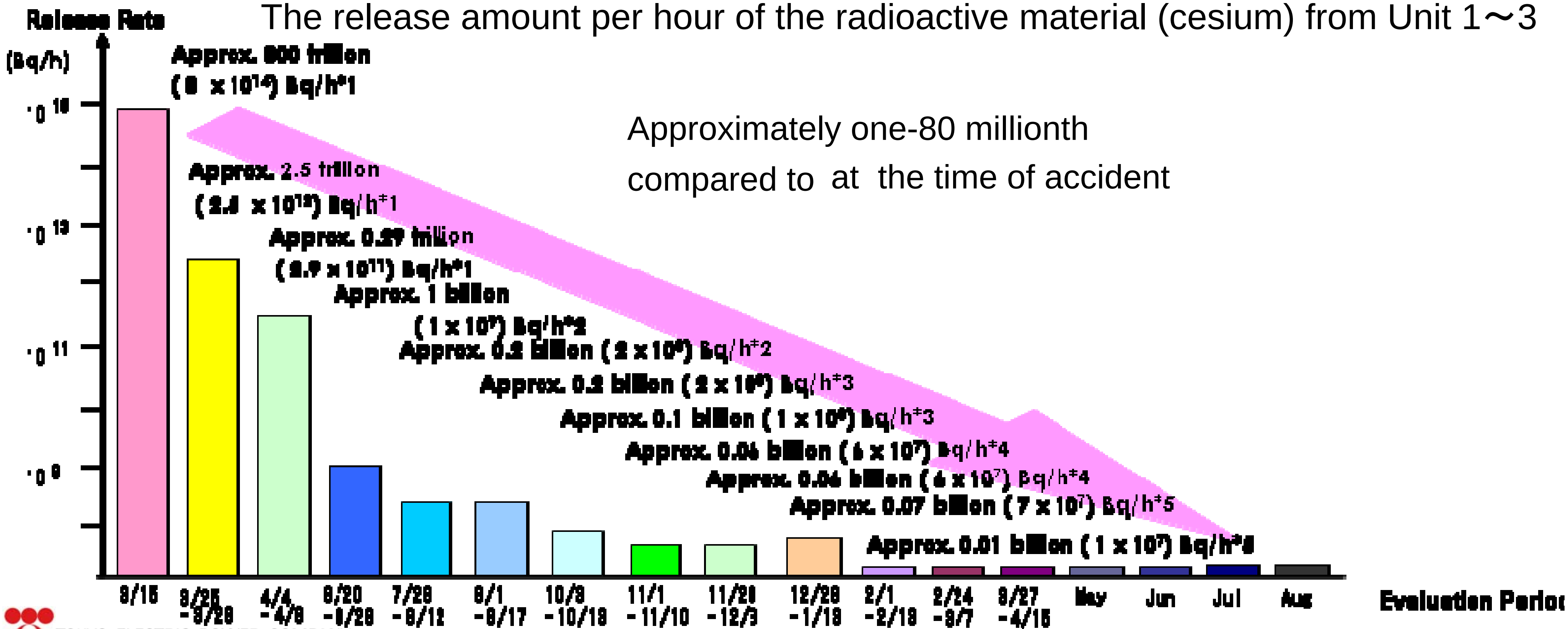
  →Calculated the assessed value of total release amount (as of Jan. 2013) as about 10 million Bq/hr.

  →About one-80 millionth compared to immediately after the accident.

- **Accordingly, assessed the exposure dose at site boundary as 0.02mSv/yr. at maximum.**

(Excluding effect of already released radioactive materials)　Note: Exposure limit established by law is 1mSv/yr.

The release amount per hour of the radioactive material (cesium) from Unit 1～3



3. Current Topics

-1 Investigations on Inside RPV & PCV toward fuel debris removal

-2 Integrity of Unit 4 Spent fuel Pool

-3 Plan to reduce site boundary dose

-4 Processing and Disposal of Waste

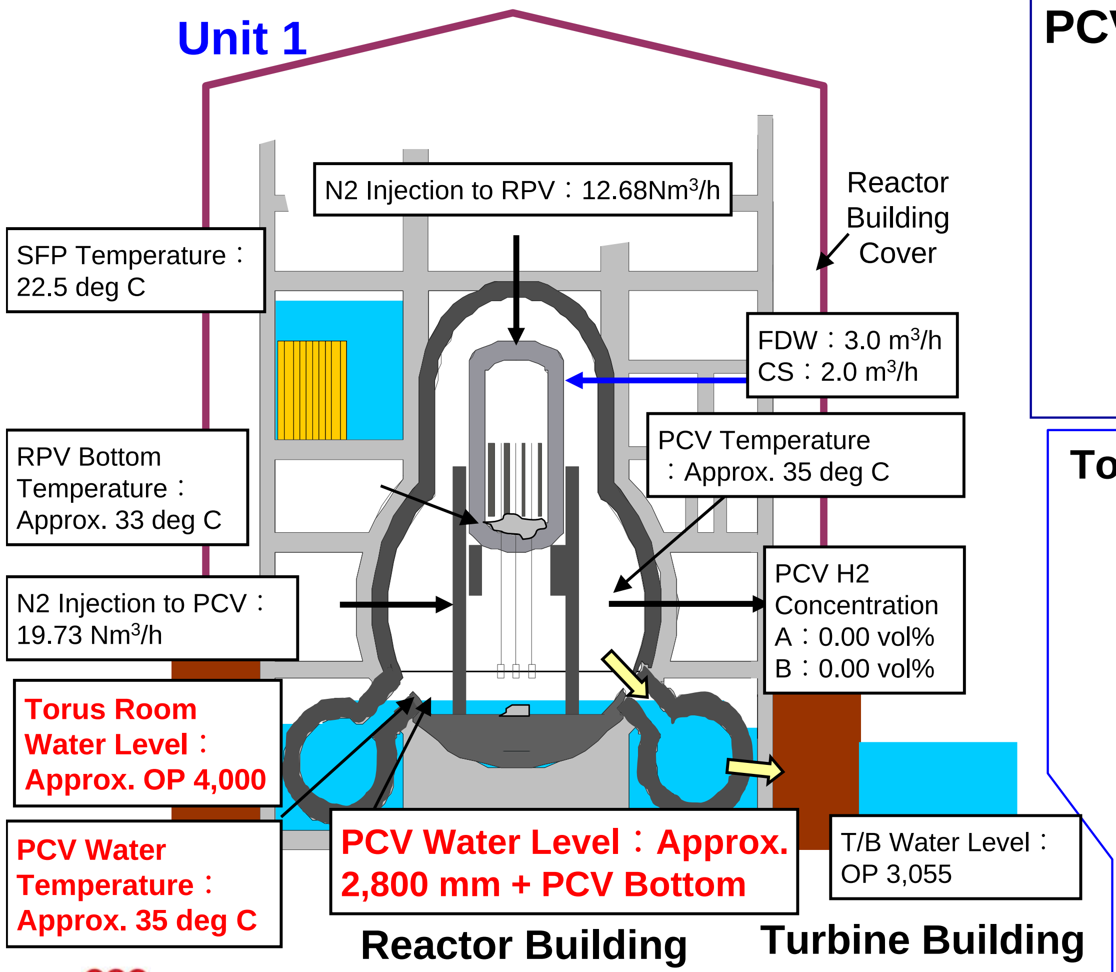
-5 Accumulation of Contaminated Water

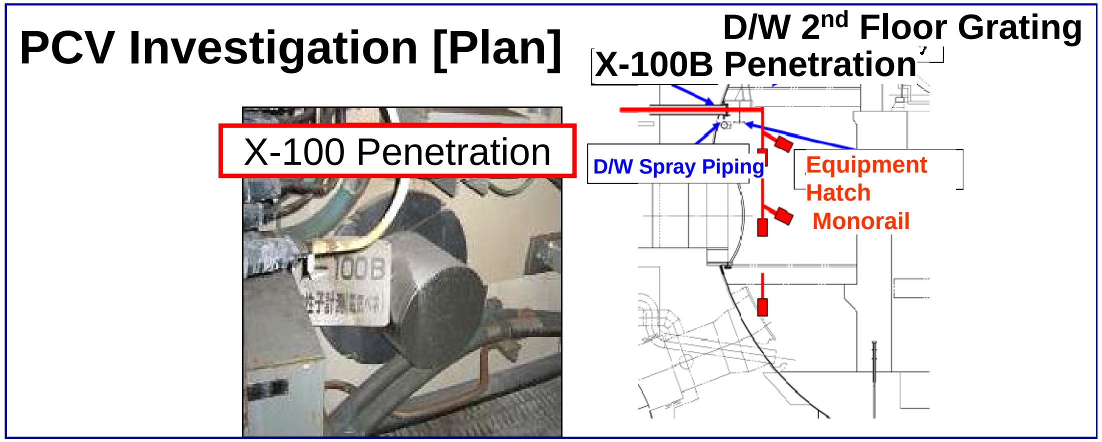
-6 Groundwater Bypass

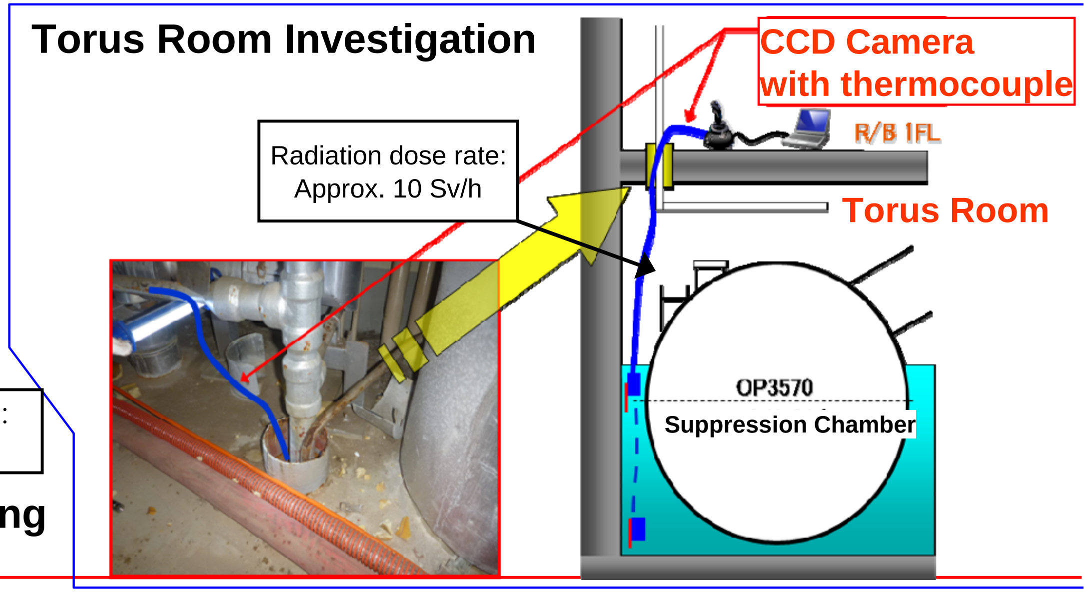
-7 Multi-Nuclides Removal System

Current Topics 1 - Investigation on Inside of RPV & PCV @ Unit1

- **PCV investigation with CCD camera** (2012/10)
  - ⇒**Water Level: Approx. 2,800 mm + PCV Bottom**
  - **Water Temperature：Approx. 35 deg C**
- **Torus Room Investigation with CCD camera.** (2012/6)
  - ⇒ **Torus Room Water Level: Approx. OP 4,000, Temperature: 32-37 deg.C**

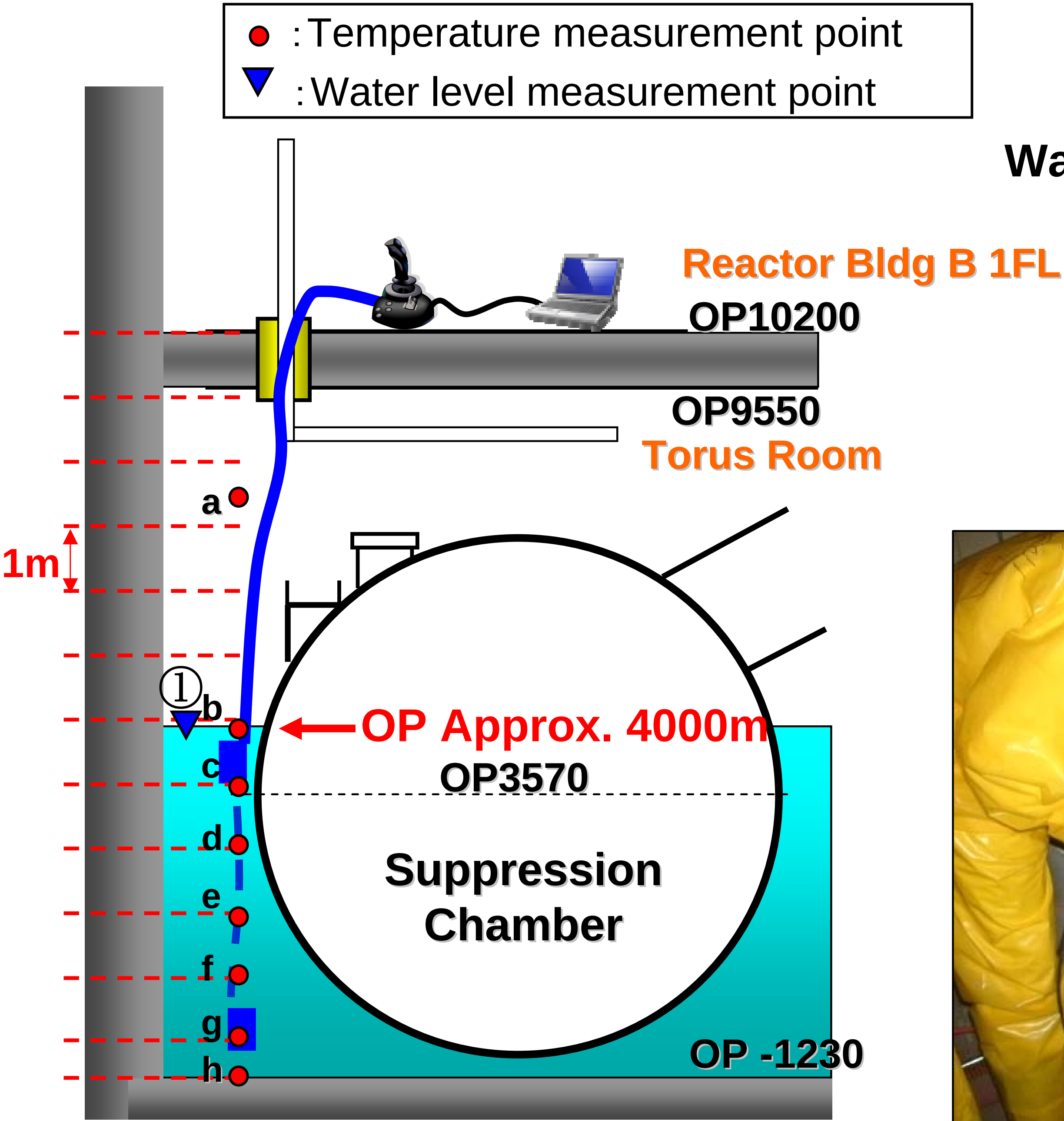






*Parameters as of Oct. 17, 2012

Unit 1 Torus Room Investigation (2012/6/26)



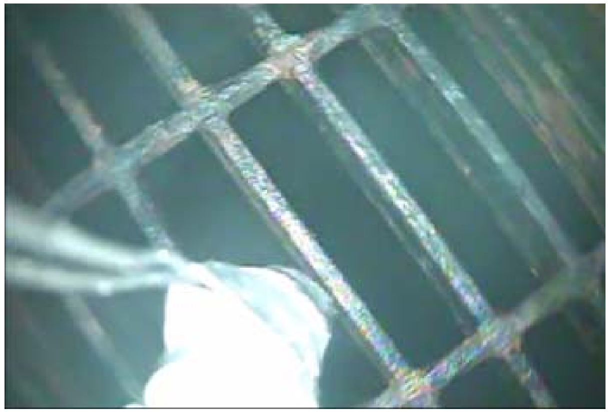
Water Level

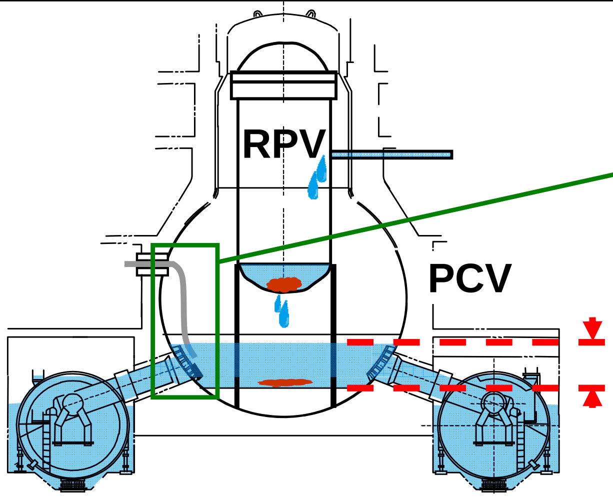
Temperature

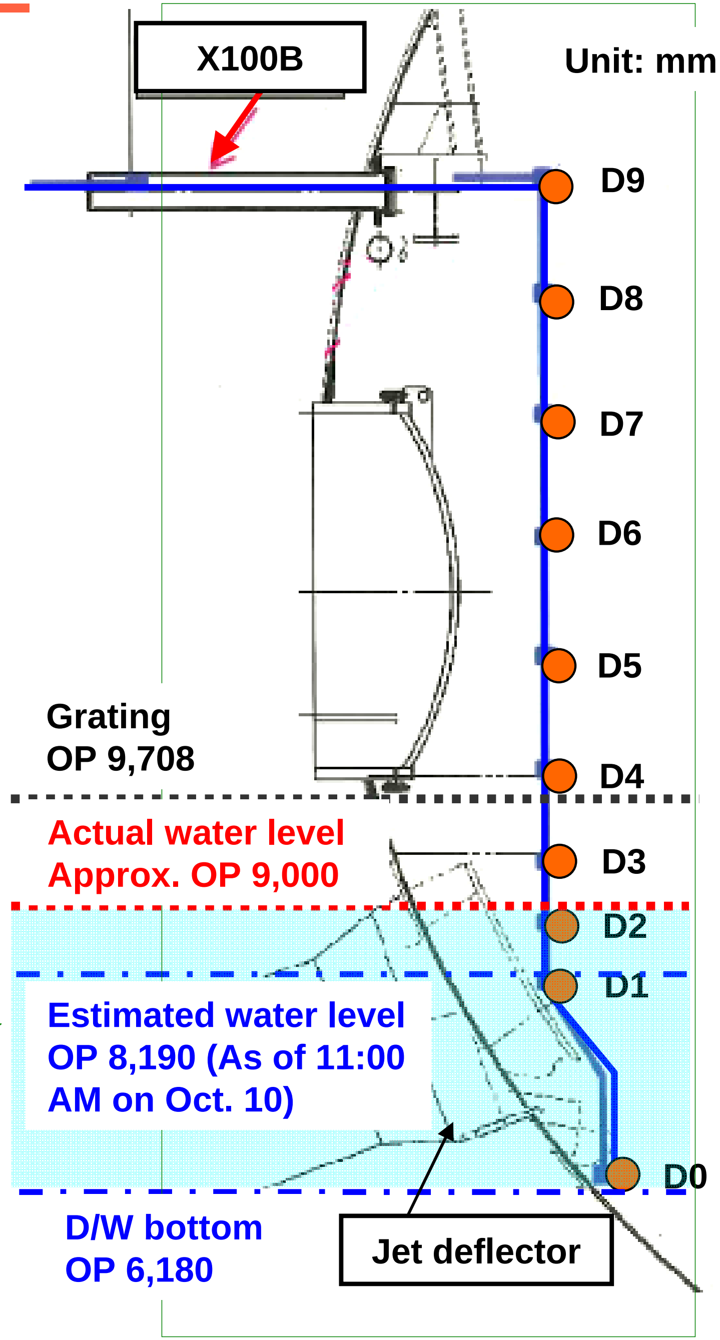
a	OP.7700	28.8℃
b	**OP.4000**	**37.2℃**
c	OP.3200	34.0℃
d	OP.2200	34.0℃
e	OP.1200	34.8℃
f	OP. 200	34.1℃
g	OP. -800	32.4℃
h	OP.-1230	32.0℃

Unit 1 PCV Investigation (2012/10/10)

Water level and dose measurement results			
Measurement point	Distance from D/W bottom	OP (mm)	Dose measurement (Sv/h)
D9	8,595	14,775	9.8
D8	—	(Approx. 14,000)	9.0
D7	—	(Approx. 13,000)	9.2
D6	—	(Approx. 12,000)	8.7
D5	—	(Approx. 11,000)	8.3
D4	—	(Approx. 10,000)	8.2
D3	—	(Approx. 9,500)	4.7
D2 /Water surface	Approx. 2,800	(Approx. 9,000)	0.5
D1	—	—	—
D0	0	6,180	—



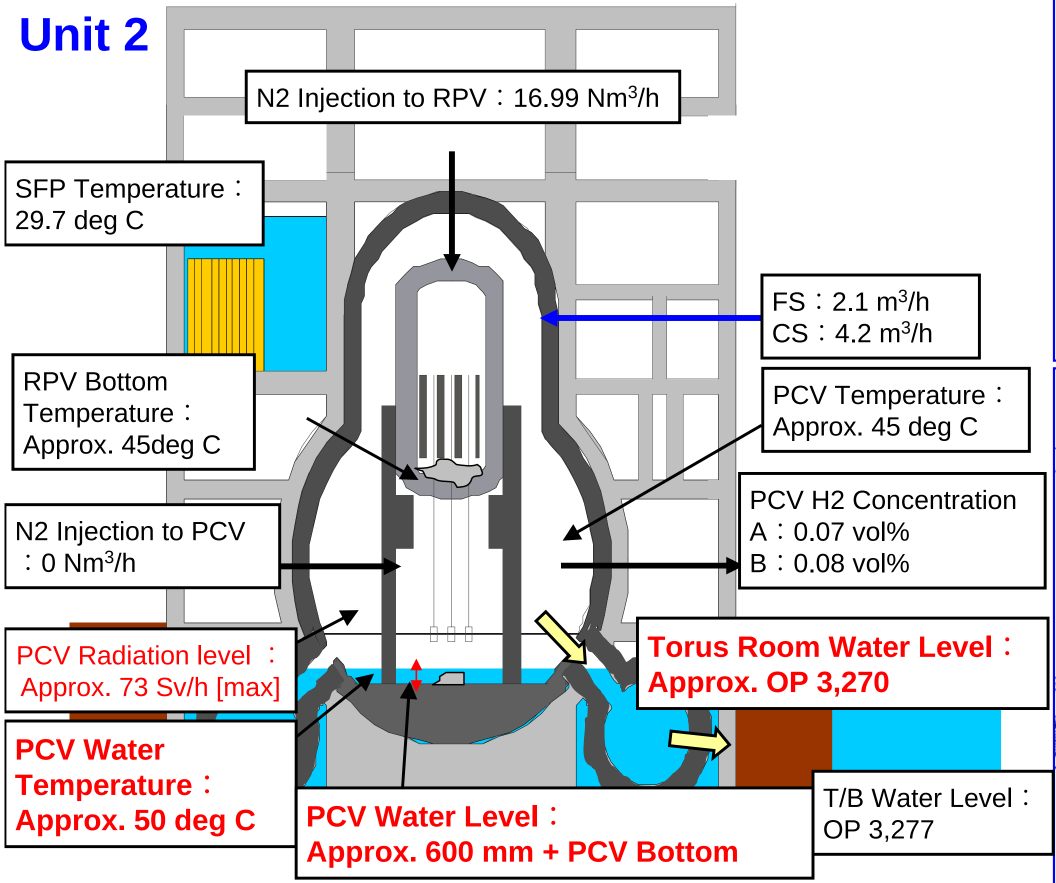




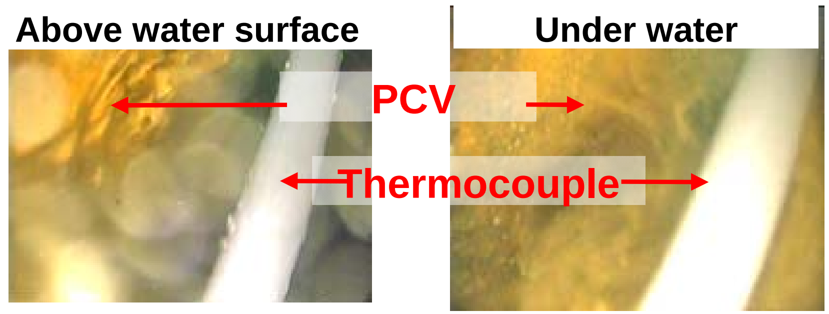
* The dose measured at the penetration tip when the measurement instrument was inserted was approx. 11.1 Sv/h.

Investigation on Inside of RPV & PCV @ Unit2

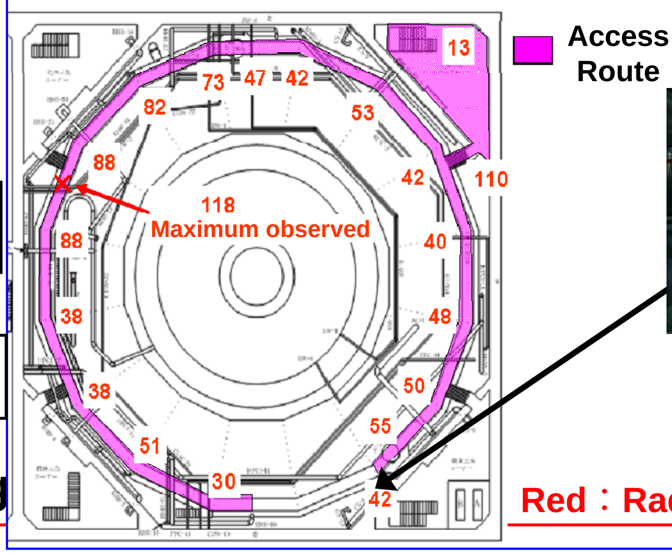
- **PCV Investigation by Borescope** (2012/1, 3)
  - ⇒**Water Level: Approx. 600 mm + PCV Bottom, Water Temperature：Approx. 50 deg C**
- **Robot survey in the Torus Room** (2012/4)
- **Water level measurement in the Torus Room** (2012/6)
  - ⇒**Torus Room Water Level OP3270**



PCV Investigation



Robot survey in the Torus Room

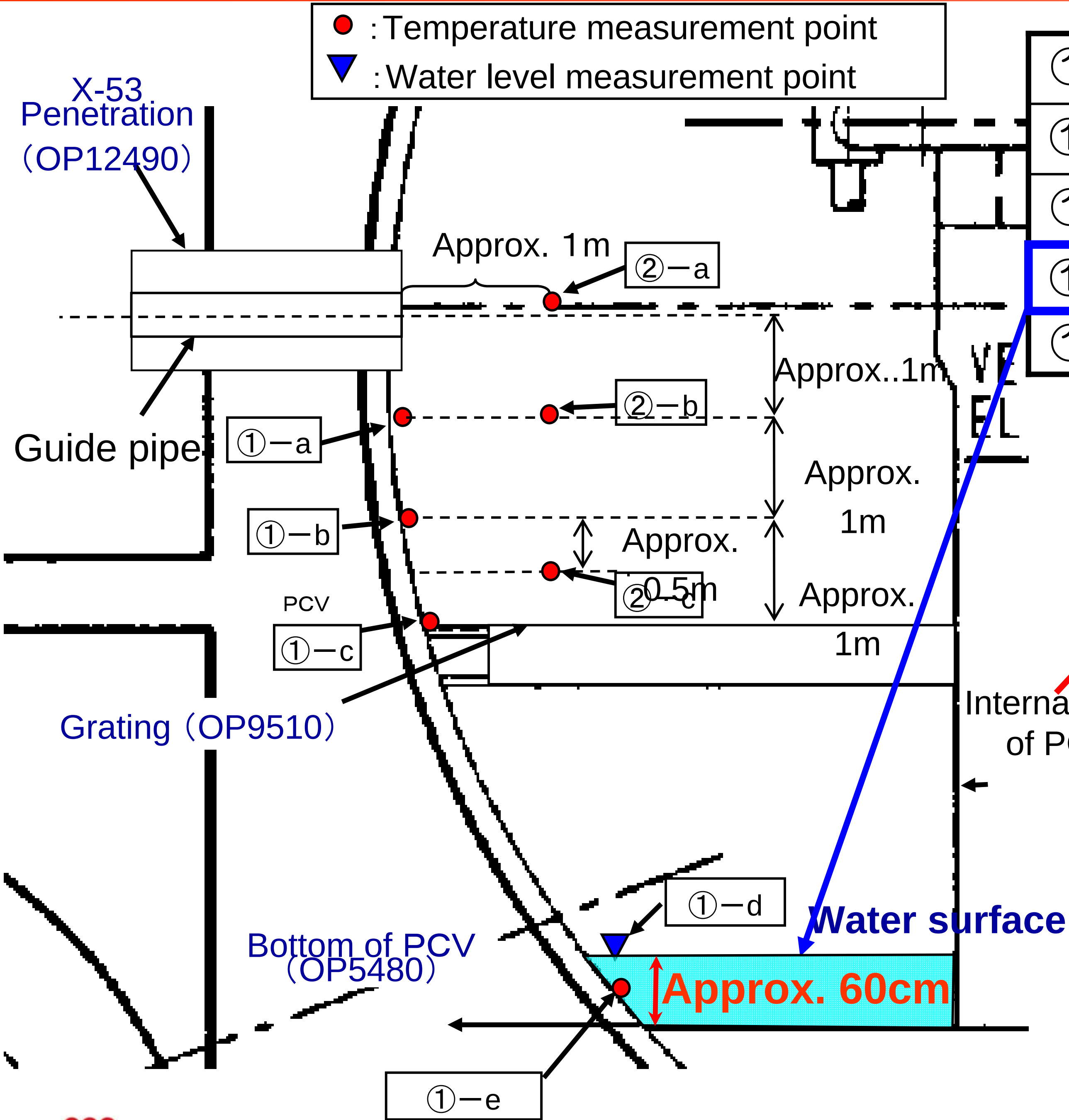


S/C Manhole (Southeast)

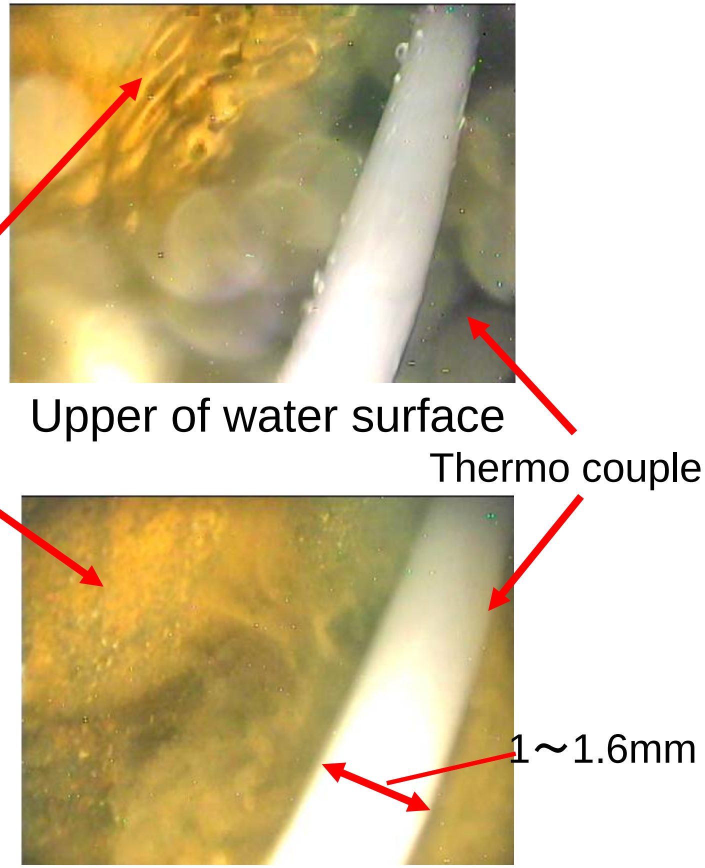
Red：Radiation (mSv/h)

※Parameters as of Oct 17, 2012

Unit 2 PCV Investigation (2012/3/26)



①－a	42.8℃	②－a	44.9℃
①－b	43.0℃	②－b	44.6℃
①－c	43.5℃	②－c	44.5℃
①－d	Approx. 60 cm + bottom of PCV		
①－e	48.5～50.0 ℃		



Upper of water surface

Under water

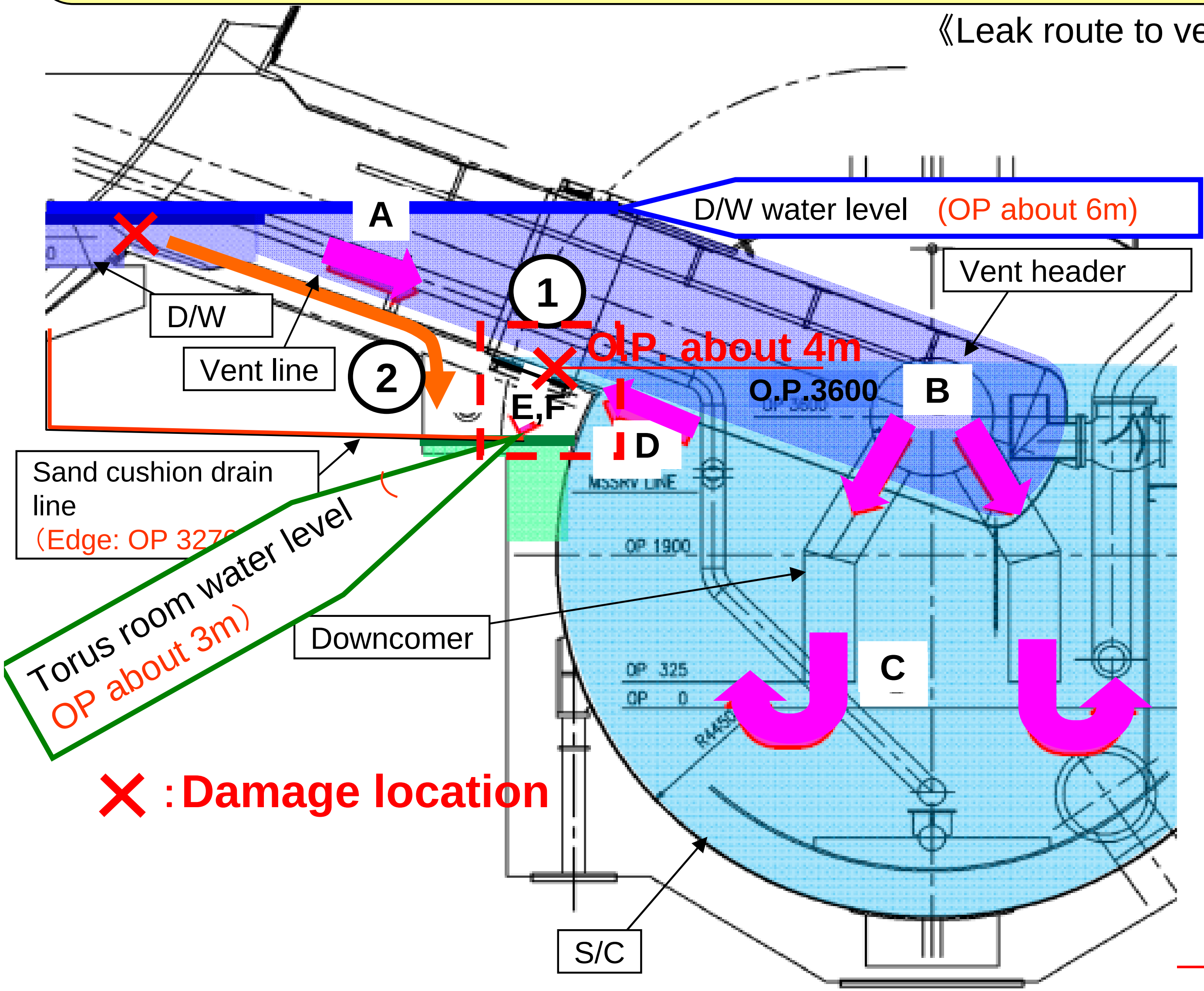
Leak detection of Unit 2 Suppression Chamber

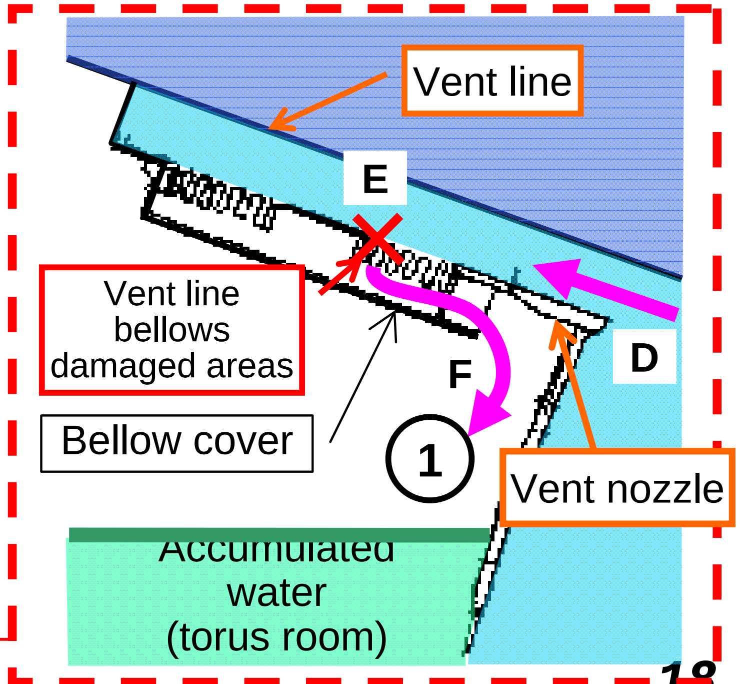
Possible locations (1) Vent line bellow cover bottom edge gap (→)
(2) Vent line and penetration (frame) gap (→)
(3) Lower Part of Suppression Chamber (S/C)

⇒Attempts of robot investigations on (1) and (2) are being made since Dec. 2012.

《Leak route to vent line bellow covers bottom edge》

A	D/W→ vent line
B	Vent header—→Downcomer
C	Downcomer→in S/C shell
D	Vent nozzle→vent line gap
E	Water outflow from vent line bellows damaged area
F	Water instillation from bellow cover bottom edge

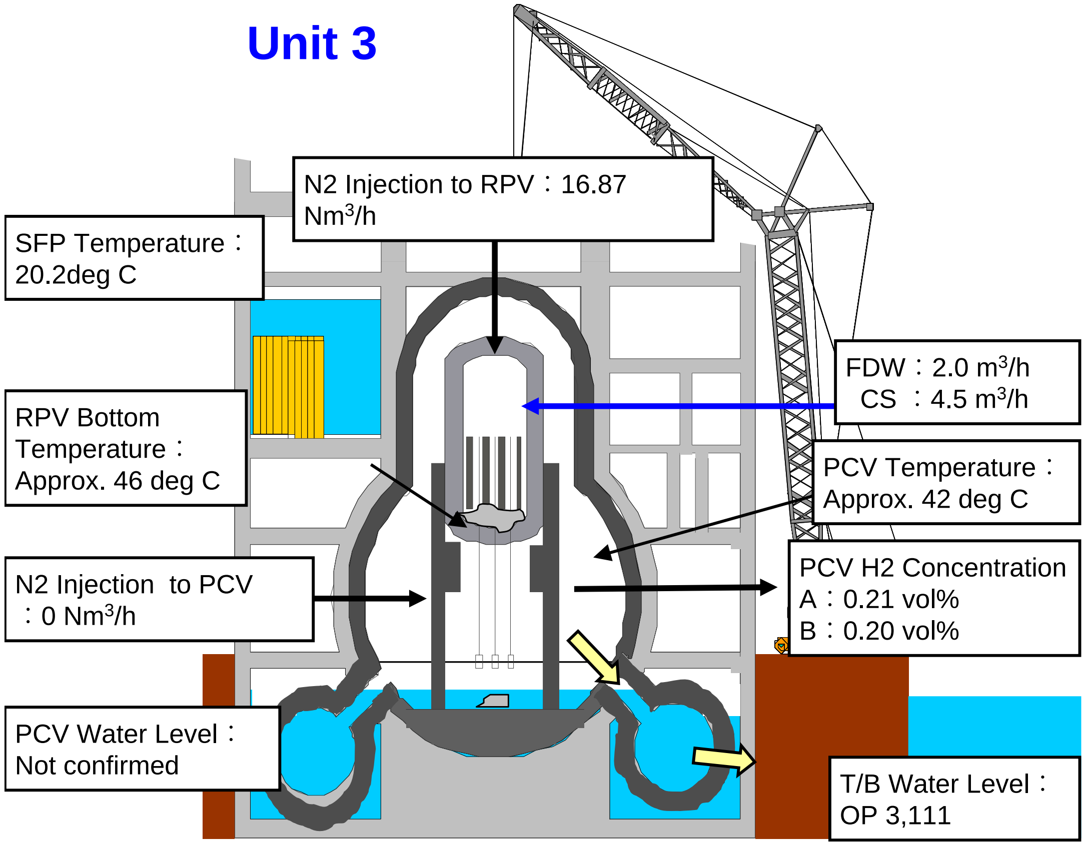




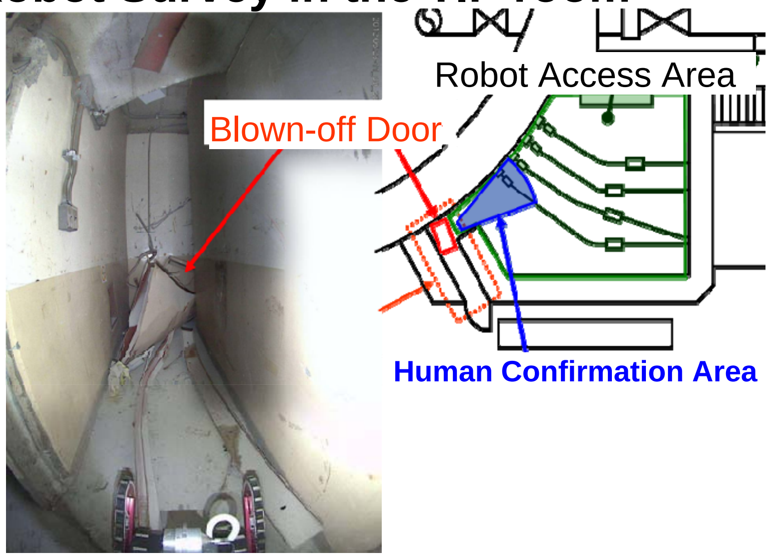
Investigation on Inside RPV & PCV @ Unit3

- ➢**Robot survey in the TIP room in the Reactor Building** (2012/3)
- ➢**Water level measurement in Torus Room**(2012/6, 7)

⇒ **Torus Room Water Level：Approx. OP 3,370**



Robot Survey in the TIP room



Water Level Survey in Torus

Northwest staircases area

	Water Level
Torus Room	OP 3370
Staircase area	OP 3150

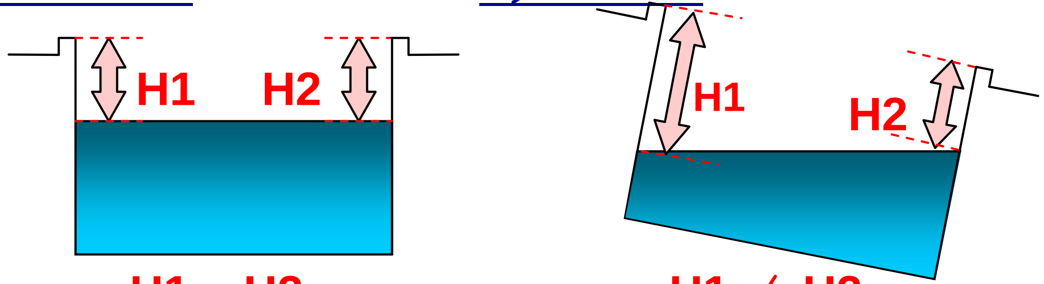
*Parameters as of Oct 17 2012

Current Topics 2 - Confirmed that the building has not tilted -1

- Distance between 5th floor level and water surface was measurements three times on Feb. 7 , Apr. 12 and May 18, 2012
- The measured data at the 4 corners were almost the same.

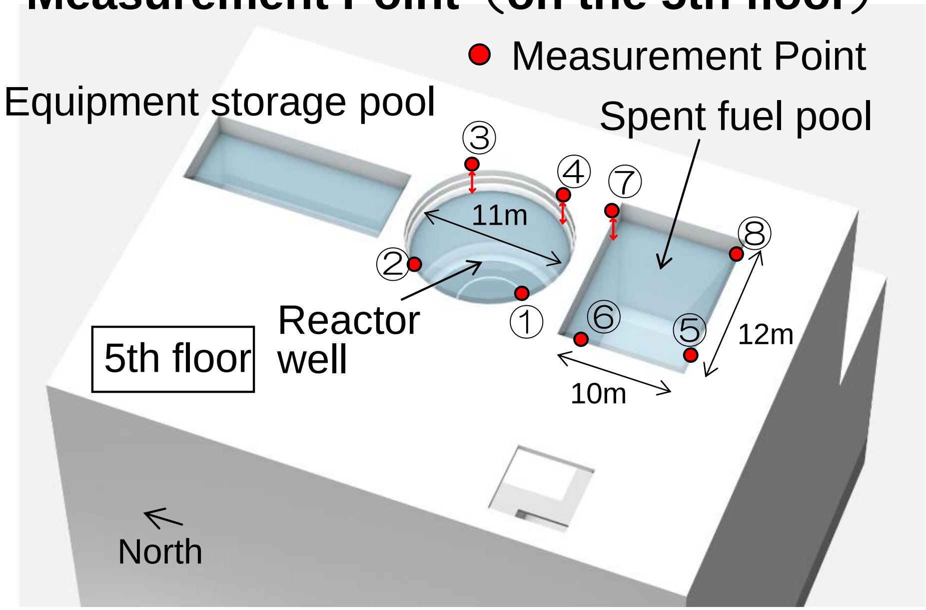
→We confirmed that the floor surface of the 5th floor, water surfaces of the spent fuel pool and the reactor well were leveled.

1) Leveled　　　2) Tilted



H1 = H2　　　H1 ≠ H2

Measurement Point（on the 5th floor）



Measurement results

Unit [mm]

Reactor well	Measurement Date		
	Feb 7, 2012	Apr 12, 2012	May 18, 2012
①	462	476	492
②	463	475	492
③	462	475	492
④	464	475	492

Spent fuel pool	Measurement Date		
	Feb 7, 2012	Apr 12, 2012	May 18, 2012
⑤	—	468	461
⑥	—	468	461
⑦	—	468	461
⑧	—	468	461

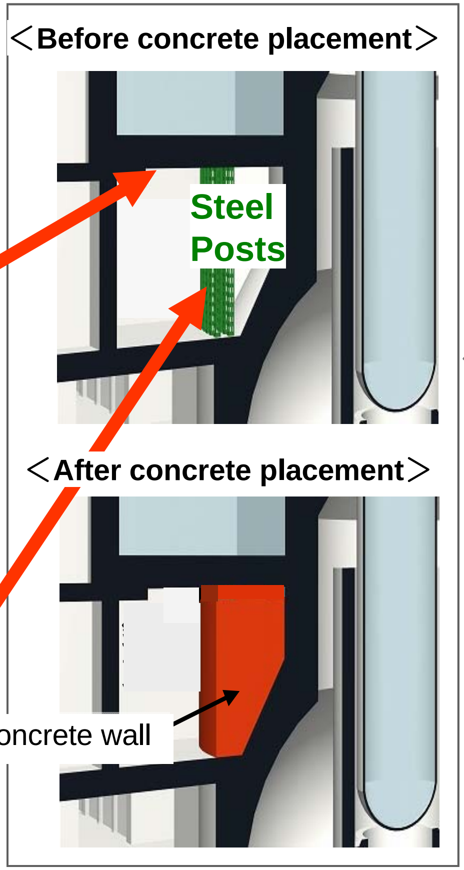
※Only reactor well was measured on Feb. 7

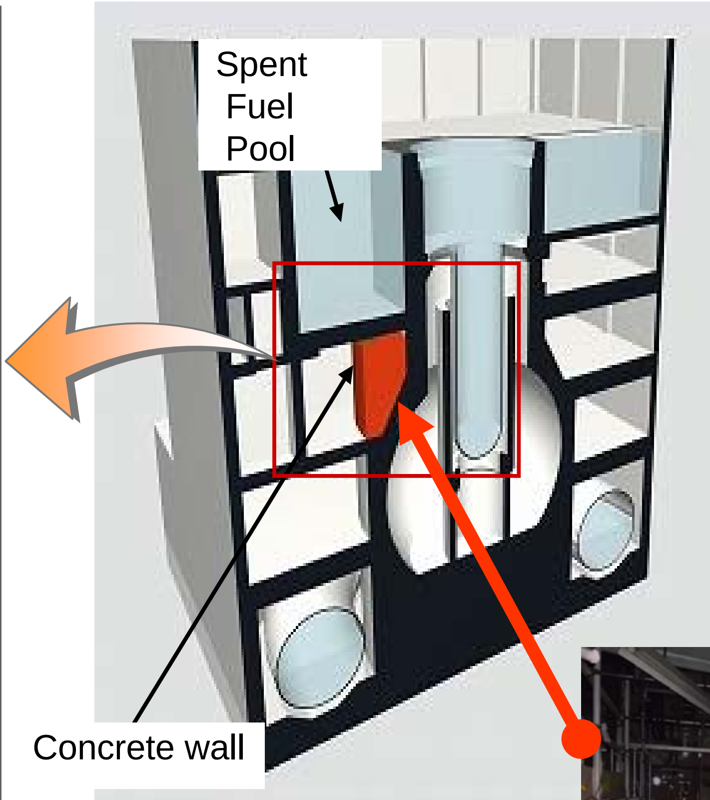
※Water level changes depending on the operation of cooling system

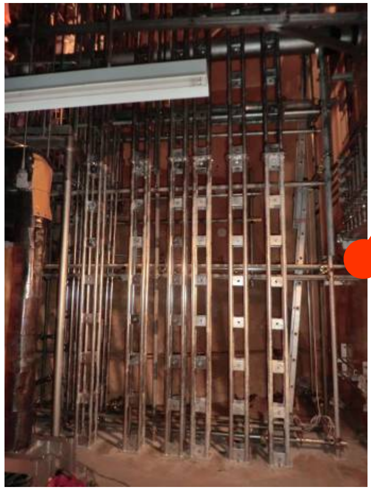
Reinforced the bottom of the spent fuel pool

✓**Support structure at the bottom of the spent fuel pool was installed. This increased the seismic safety margin by 20 %.**

Photo① View from lower floor
(Before concrete placement)







Photo② Steel posts installed condition
(Before concrete placement）

※Concrete placement (red) after posts installation (green)

Photo③ Surface of the 2nd floor shell wall
（Before concrete placement）

※ Photo① May 21, 2011 Photo② June 15, 2011 Photo③ May 20,2011
※ Completed reinforcement on July 30, 2011

Current Work toward Removing Fuels from Spent Fuel Pool

Debris removal from the top of the reactor building

Unit3: Under Working (Completion: by the end of FY2012)

Unit4: Finished in July 2012

Survey of inside spent fuel pool

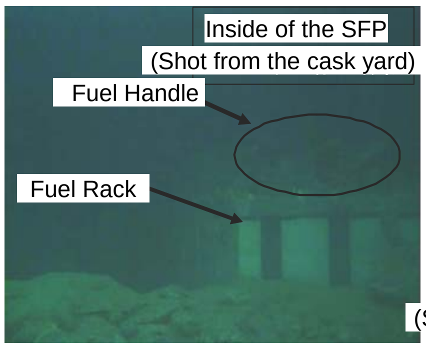
Unit 3: Surveyed by Remotely Controlled Underwater Camera (April 13, 2012)

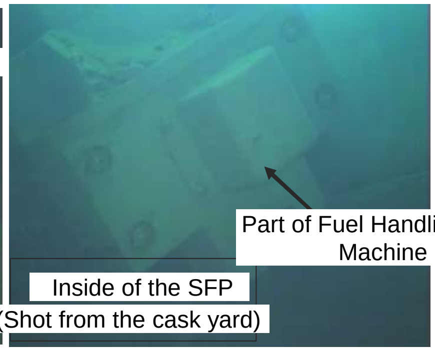
Unit 4: Surveyed by Remotely Operated Vehicle (March 19 ~ 21, 2012)

Unit 3

Unit 4

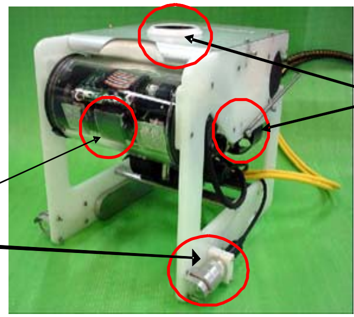
Pre-survey in the water of Spent Fuel Pool (SFP)





Survey on rubble dispersion inside the SFP

Remotely Operated Vehicle (ROV)



Plan to remove spent fuels in Unit 4

- ✓The cover for fuel removal will be installed in order to improve work environment and to prevent radioactive materials from scattering and releasing during the work.
- ✓Start of fuel removal at Unit 4 is planned in 2013.

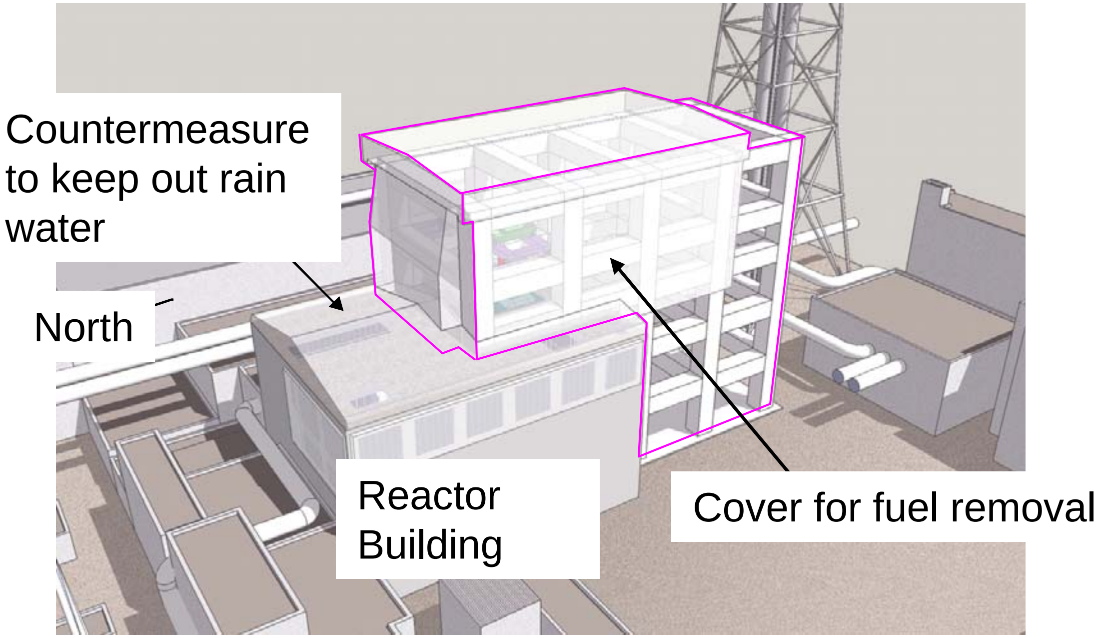


Image of the cover for fuel removal in Unit 4
(This picture shows only a image of the general plan.)

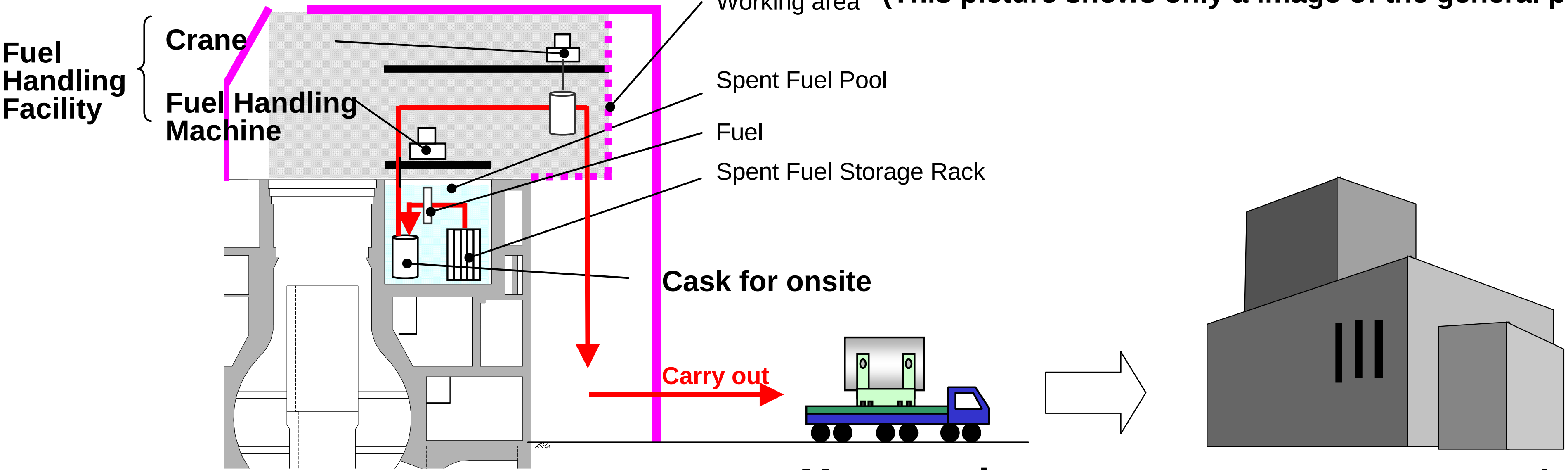


Image of fuel removal

Move onsite

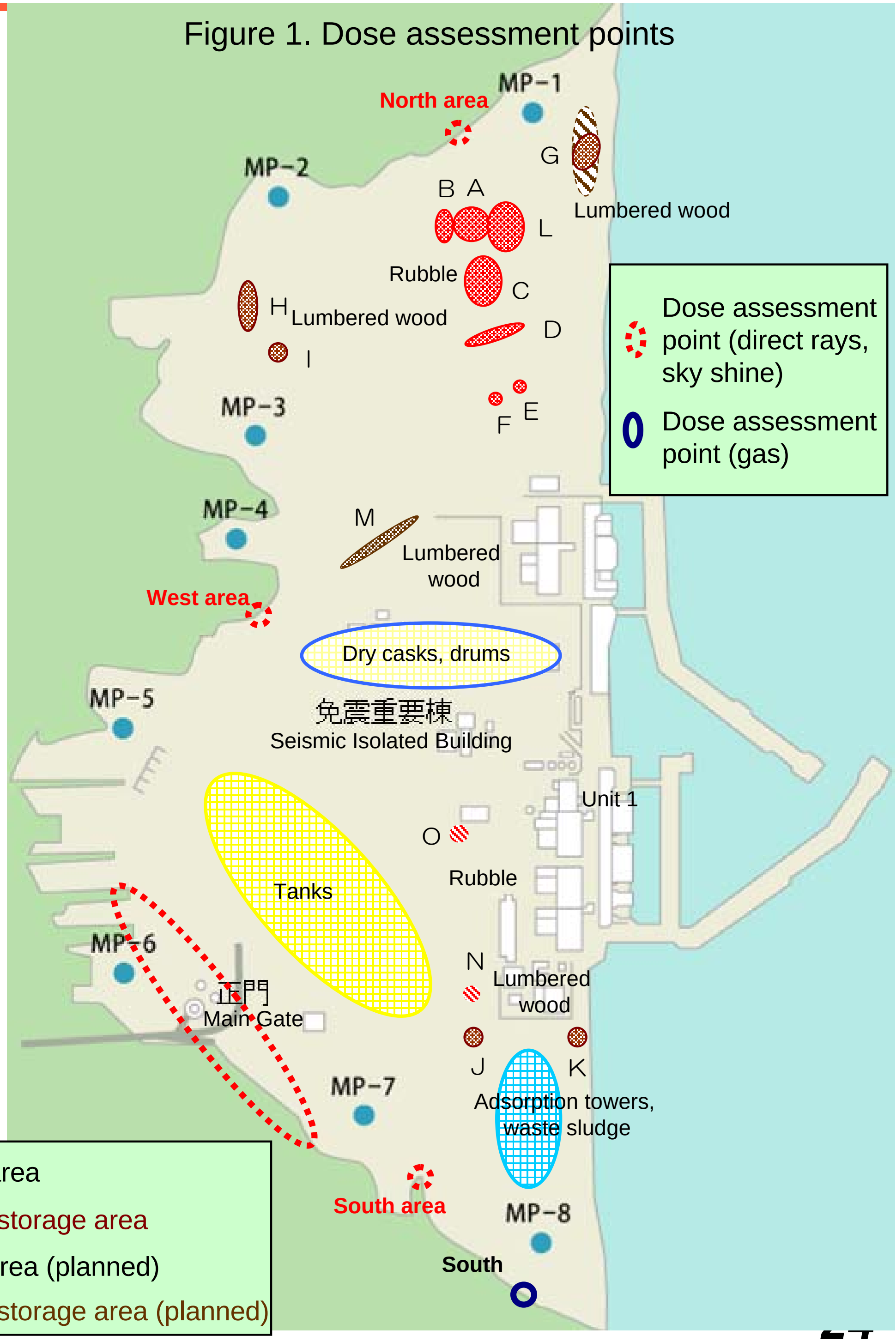
Common pool

Current Topics 3 - Plan to reduce site boundary dose

The plan calls for various dose reduction measures to be implemented to aim for the total assessment value of site boundary dose (gas, liquid, and solid) from newly released radioactive materials and radwaste generated after the accident to be less than 1mSv per year.

- Closing Unit 2 blow out panel opening
- Installing multi-nuclide removal system and related shielding
- Installing soil covered temporary storage facility and move rubble to the facility
- Moving rubble to locations away from site boundary
- Covering lumbered trees with soil
- Installing shielding for spent cesium adsorption vessels and move such vessels

Figure 1. Dose assessment points

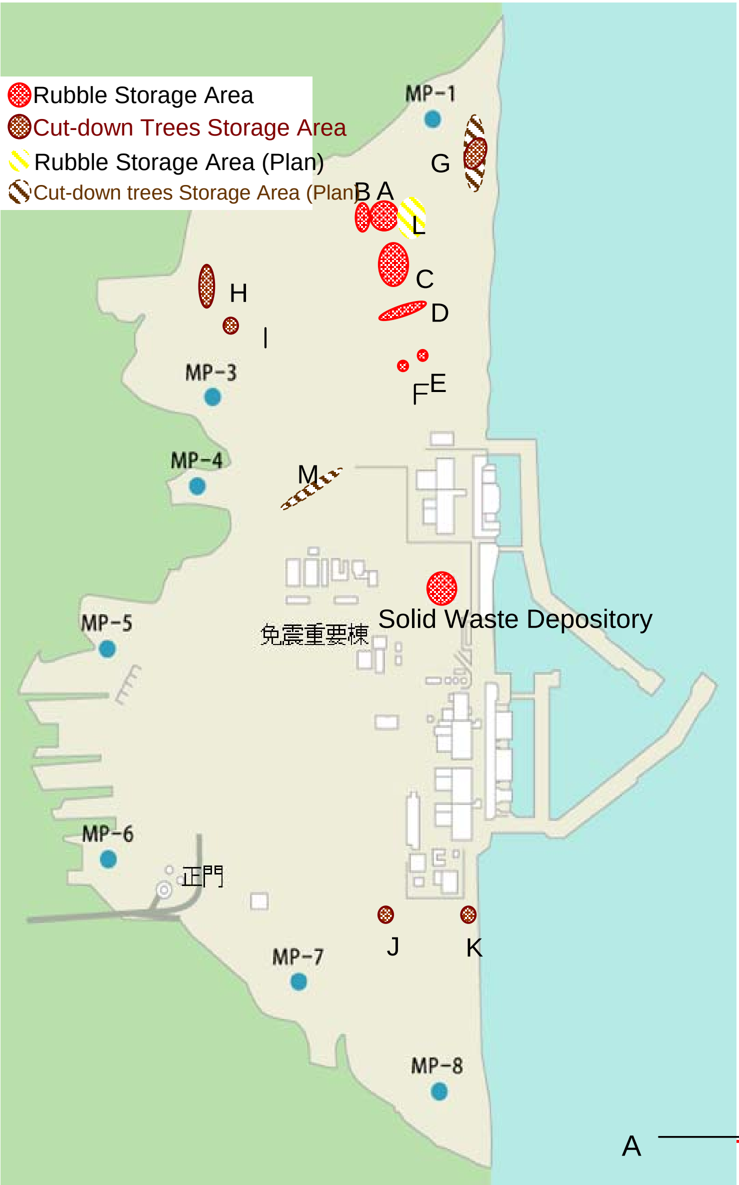


Current Topics 4 - Processing and Disposal of Waste

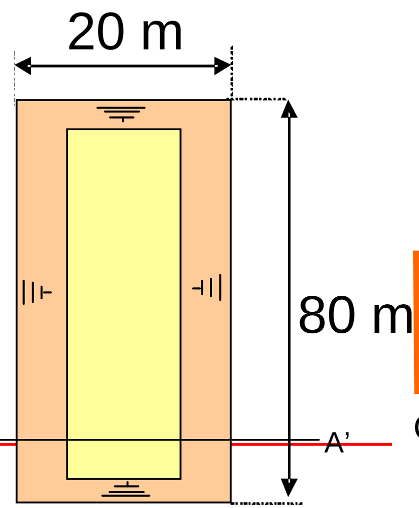
✓49,000 m³ of concrete/metal and 61,000 m³ of Cut-down trees are stored.

✓Temporary storage facilities with shielding measures using soil and sandbags, etc were built to reduce radiation dose at the site boundaries.

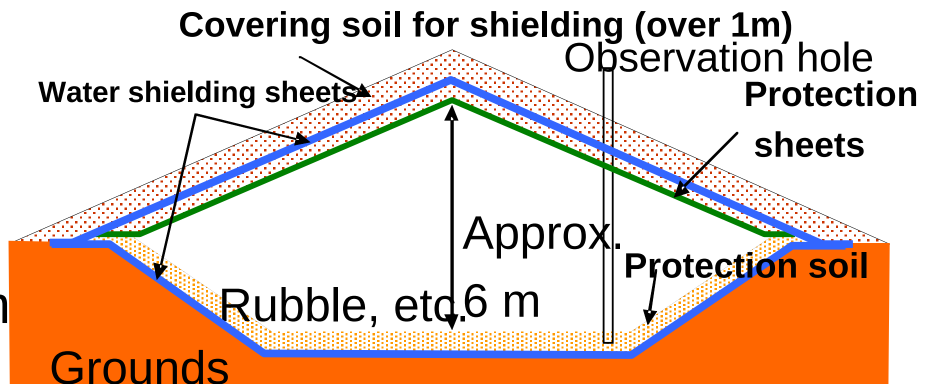
Storage Area	Type	Storage Method	Amount		Area Occupancy
Solid Waste Depository	Concrete,Metal	Container	2,000	m³	35%
A: Northern Site	Concrete,Metal	Temporary Storage Facility	11,000	m³	96%
B: Northern Site	Concrete,Metal	Container	4,000	m³	86%
C: Northern Site	Concrete,Metal	Outdoor Yard	20,000	m³	03%
D: Northern Site	Concrete,Metal	Outdoor Yard	2,000	m³	66%
E: Northern Site	Concrete,Metal	Outdoor Yard	3,000	m³	90%
F: Northern Site	Concrete,Metal	Container	1,000	m³	98%
L: Northern Site	Concrete,Metal	Covering Soil Type Temporary Storage Facility	2,000	m³	25%
Total(Corcrete,Metal)			49,000	m³	76%
G: Northern Site	Cut-down trees	Outdoor Yard	18,000	m³	63%
H: Northern Site	Cut-down trees	Outdoor Yard	16,000	m³	93%
I: Northern Site	Cut-down trees	Outdoor Yard	11,000	m³	100%
J: Southern Site	Cut-down trees	Outdoor Yard	12,000	m³	77%
K: Southern Site	Cut-down trees	Outdoor Yard	5,000	m³	100%
M: Western Site	Cut-down trees	Outdoor Yard	6,000	m³	28%
Total(Cut-down trees)			71,000	m³	74%



Plain View



A-A' Cross-section View



Overview of Covering Soil Type Temporary Storage Facility

Flow of Rubbles removed from top of the R/B*2

Rubbles removed from top of the R/B

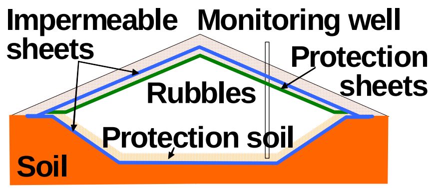
Top of the R/B (Unit 3)

Top of the R/B (Unit 4)

- < 0.1mSv/h*1 → **Open air storage**

- 0.1mSv/h ～ 1mSv/h → **Covered by Sheet**

- 1mSv/h ～ 30mSv/h → **Temporary storage facility or Temporary storage facility with cover soil**



- 30mSv/h ～ 1Sv/h → **Storage in building Or Container**

- > 1Sv/h → **Temporary storage area with shielding** / **Container** / **Container storage in building**

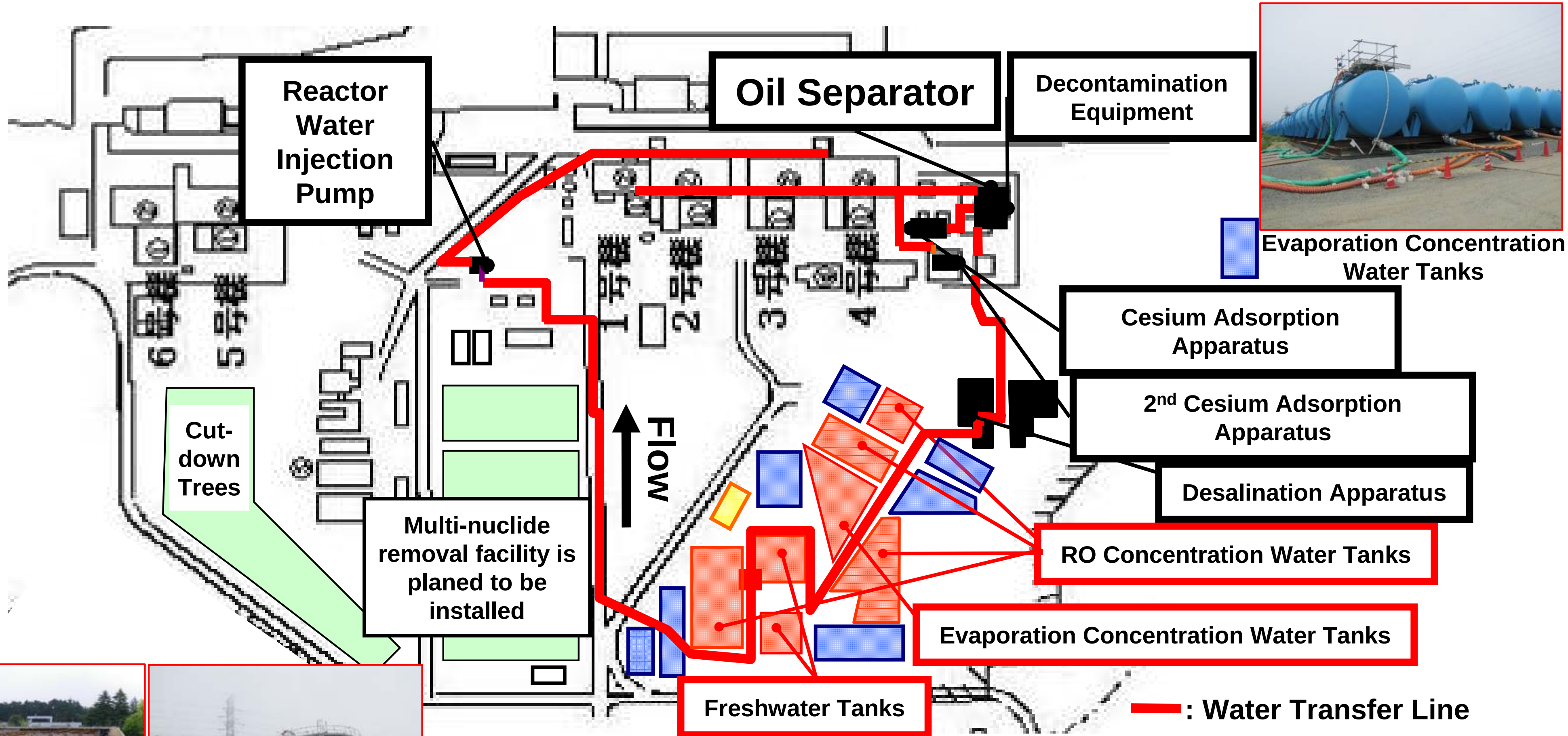
*1 Dose rate at the surface
*2 R/B : Reactor Building

TOKYO ELECTRIC POWER COMPANY

Current Topics 5 – Accumulation of Contaminated Water

✓The capacity of existing tanks is approx. 320ktons (as of Jan.2013).

✓Additional installation of tanks and underground cisterns are planned to increase the capacity to approx 400ktons by Apr.2013 (Max. 700 ktons).



Evaporation Concentration Water Tanks

: Water Transfer Line
: Existing Tank Area
: Additional Tank Area
: Underground Cistern

Arrangement of Water Processing Facility in Units 1 ~ 4

Fresh Water, RO Concentration Tanks

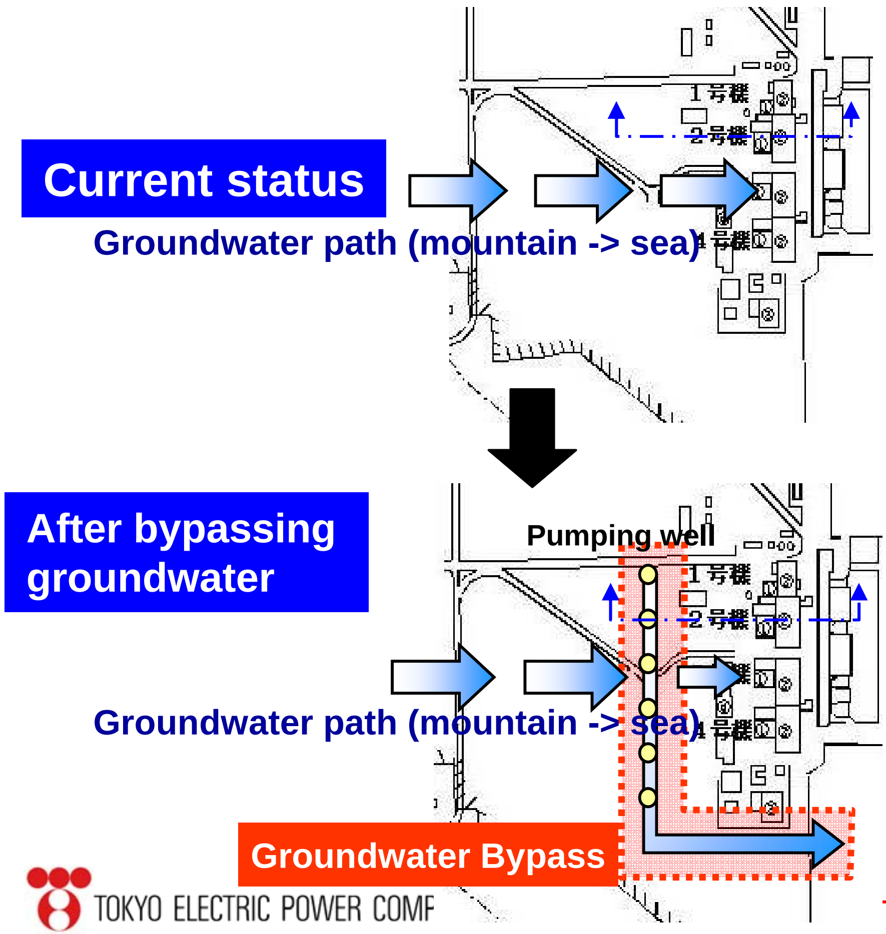
Current Topics 6 – Groundwater Bypass

Groundwater bypass : Suppressing groundwater inflow to the buildings by changing the water path via pumping up the water flowed from the mountain side.

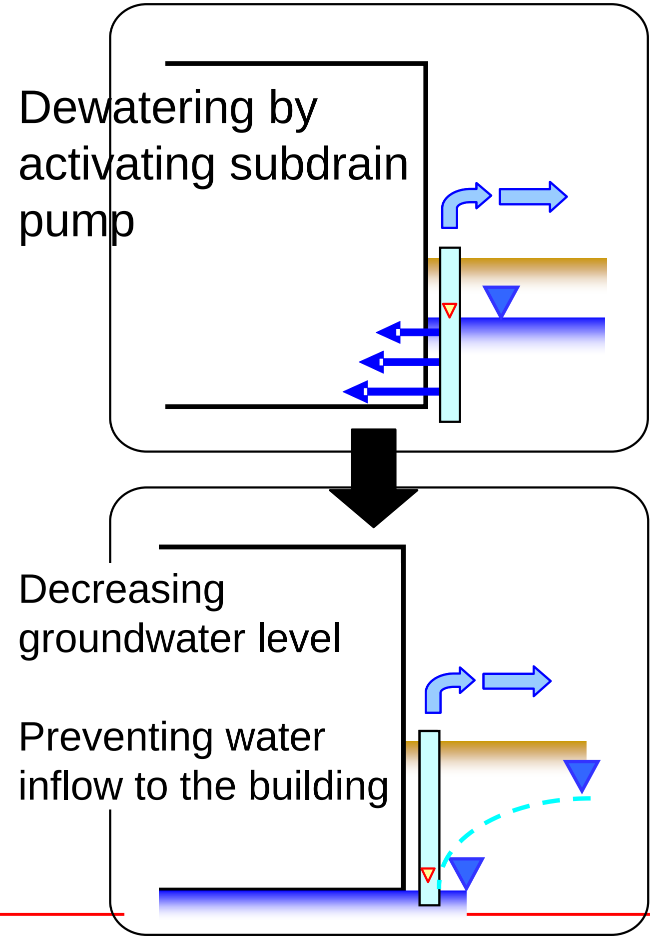
Pumping up groundwater (subdrain*) : Suppressing groundwater inflow to the buildings by decreasing groundwater level via pumping up the subdrain water.

*In order to balance groundwater level, groundwater in subdrain pits is periodically pumped up.

Groundwater bypass

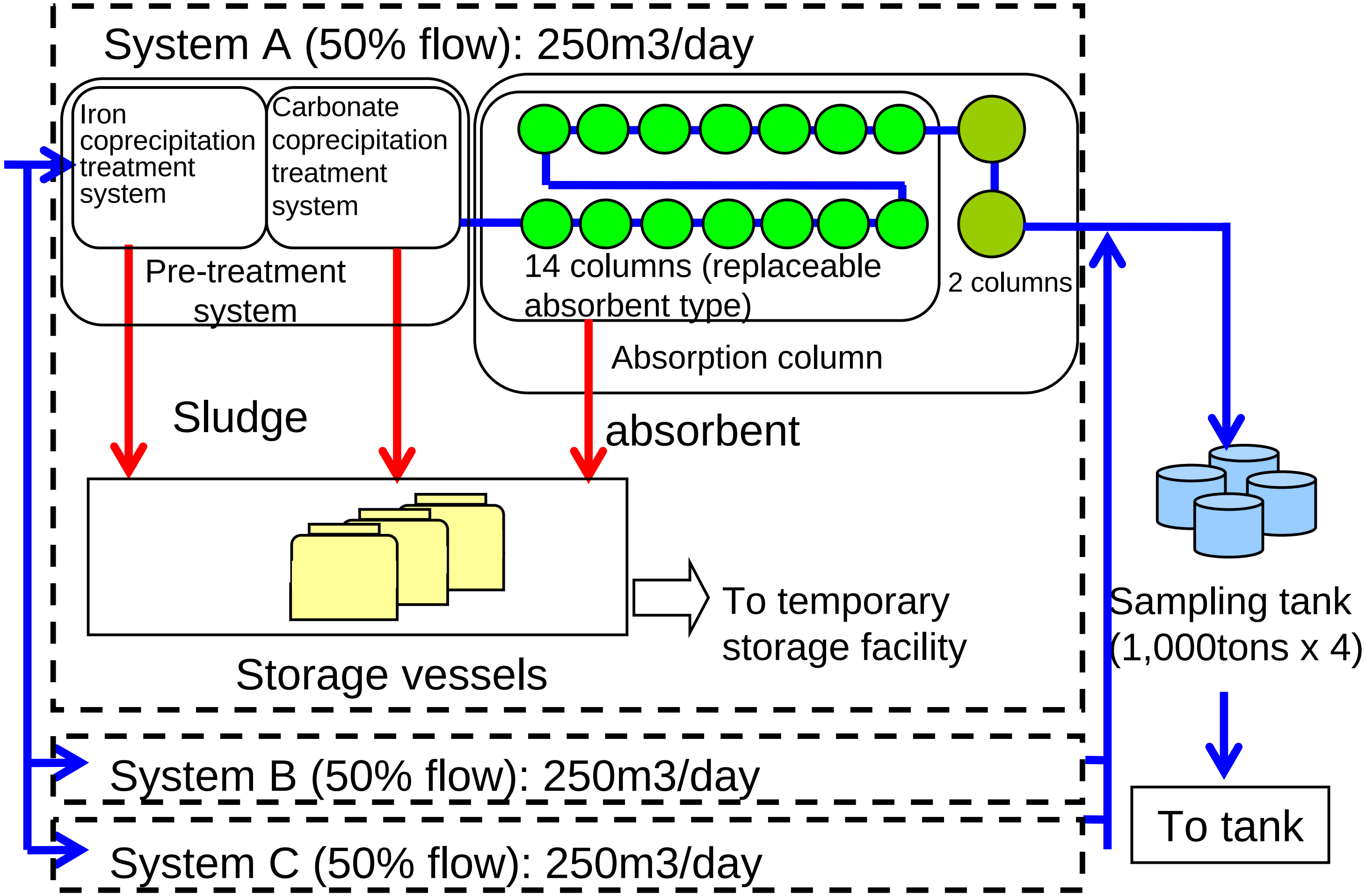


Pumping up groundwater (subdrain)



Current Topics 7 – Multi-Nuclides Removal Equipment

Treatment Water by
① Desalination sys
② Cs absorption sys



4. Mid-and-long Term Roadmap for Decommissioning

Mid-and-long Term Roadmap

Primary Target

Present all possible schedules pertaining to the main on-site works and R&D.

Target Timeline and Holding Points

Established all possible target timelines in the upcoming 3 years, which are updated and released on a yearly basis.

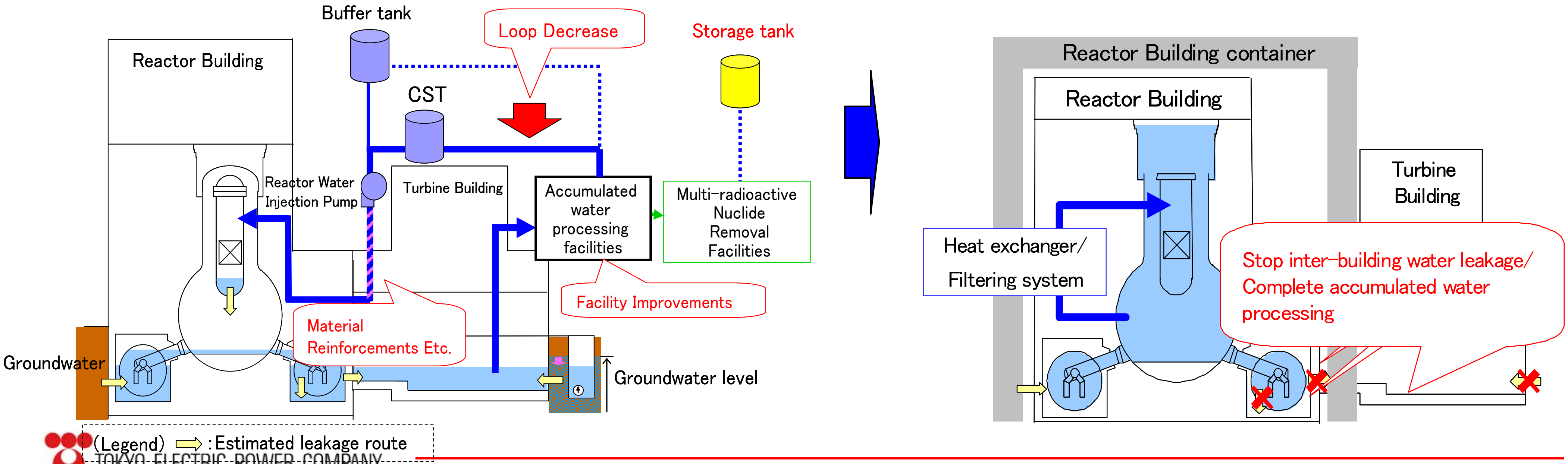
Regarding the schedules after 3 years, established holding points, which are significant to judge whether to go ahead in accordance with the schedule, to implement additional R&D, or to re-schedule the process.

Present（Completion of Step 2）	Within 2 Years	Within 10 Years	After 30-40 Years
Step 1, 2	**Phase 1**	**Phase 2**	**Phase 3**
Achieved Stable Conditions	**Period to the start of fuel removal from the spent fuel pool**	**Period to the start of fuel debris removal**	**Period to the end of decommissioning**
- Quasi-Cold shutdown -Sufficient Suppression of Emissions	- Commence the removal of fuels from the spent fuel pools (Unit 4 in 2 years) - Reduce the radiation impact due to additional emissions from the whole site and radioactive waste generated after the accident (secondary waste materials via water processing and debris etc.) Thus maintain the effective radiation dose to be less than 1 mSv / year at the site boundaries caused by the aforementioned. - Maintain stable reactor cooling and accumulated water processing and improve their credibility. - Commence R&D and decontamination towards the removal of fuel debris - Commence R&D of radioactive waste processing and disposal	- Complete the fuel removal from the spent fuel pools at all Units - Complete preparations for the removal of fuel debris such as decontamination of the insides of buildings, restoring PCVs and filling PCVs with water. Then commence the removal of fuel debris (Target: within 10 years) - Continue stable reactor cooling - Complete the processing of accumulated water - Continue R&D on radioactive waste processing and disposal, and commence R&D on the reactor facilities decommission	- Complete the fuel debris removal (in 20-25 years) - Complete the decommission (in 30-40 years) - Implement radioactive waste processing and disposal

Actions towards systematic staff training and allocation, motivation improvement, and securing of workers' safety will be continuously implemented.

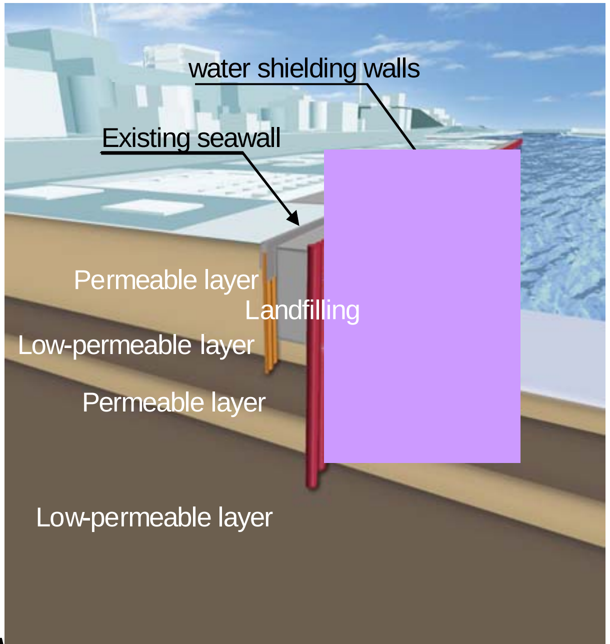
Issue 1: Reactor Cooling, Accumulated Water Processing

- In order to stably maintain "a condition equivalent to cold shutdown", water injection cooling will be continued up to the completion of the fuel debris removal.
- By examining the reliability of the system, system improvements will be continuously implemented. In addition, the water circulation loop will be decreased step-by-step.
- By 2012, water decontamination facilities for multi-radioactive nuclides, which can not be removed by existing Cesium treatment facilities, will be newly installed.
- During Phase 2, processing of accumulated water in the buildings will be finished when sealing of the water leakage between Turbine and Reactor Buildings, and repairs of the lower parts of PCVs are achieved. In order to achieve more stable cooling, scaling down of the circulation loop is being considered.

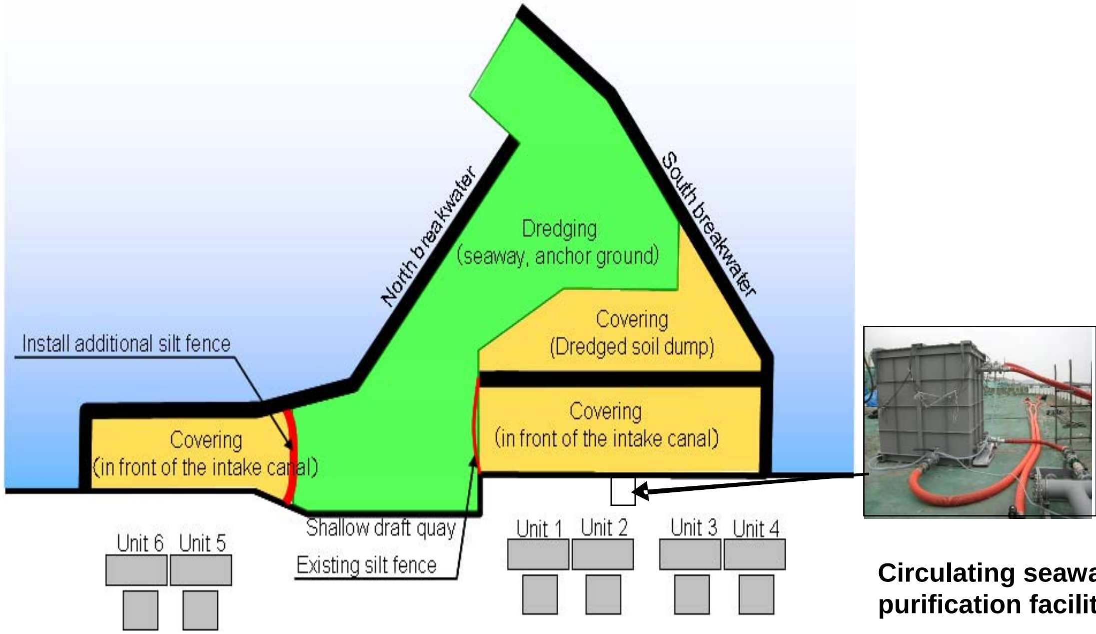


Issue 2: Mitigation of Sea Water Contamination

- Covering and solidifying seabed soil in front of the intake canal will prevent the diffusion of radioactive materials in the soil. By the end of FY2012, the continuous operation of the circulating seawater purification facilities will reduce radioactive materials in the seawater inside the site port to the level below the limit for the outside of environment surveillance areas as determined by a notification of the government. Sediments dredged in order to secure a navigable depth for large ships will be similarly covered.
- Should underground water be contaminated, water shielding walls will be installed by mid FY2014 in order to prevent underground water from flowing into the ocean.
- Afterwards, while maintaining the installed facilities, underground water and sea water etc. will be continuously monitored.



Water Shielding walls (Image)

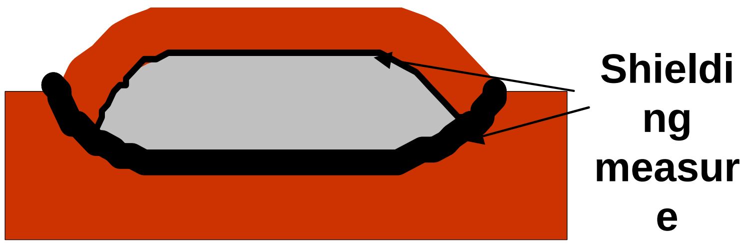


Circulating seawater purification facilities

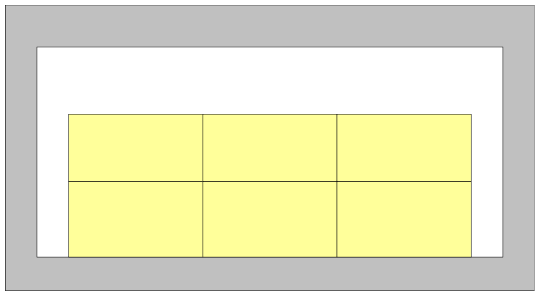
Harbor's Seabed Soil Image

Issue 3: Waste Management & Dose Reduction
4: Onsite Decontamination

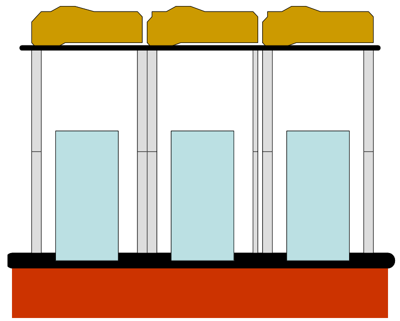
- Plan to reduce the effective radiation dose at the site boundaries to below 1 mSv / year by FY2012 as a target date, due to additional emissions from the whole site and radioactive waste stored on the site after the accident (secondary waste materials via water processing and rubble etc.).
- Plan to develop a facility renewal plan by the end of FY2014 that includes the lifetime assessment of the containers for secondary waste materials via water processing.
- Plan to continue ongoing land and sea environmental monitoring.
- In order to reduce exposure to the public and workers while improving the work environment, step-by-step decontamination measures will be implemented starting from the offices and working areas such as the Main Anti-Earthquake Building in conjunction with efforts to reduce radiation dosage outside the site.



Shielding by soil (rubble)



Shielding by building (rubble)

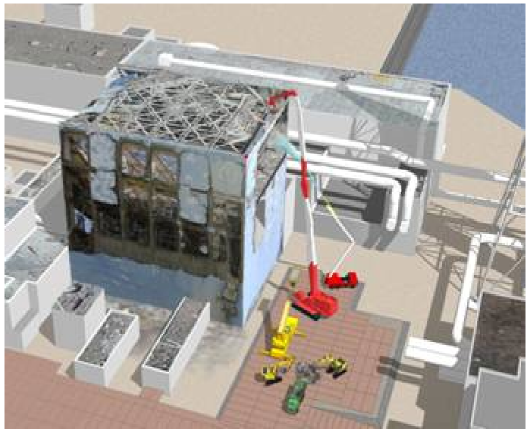


Shielding by sandbags etc. (secondary waste materials via water processing)

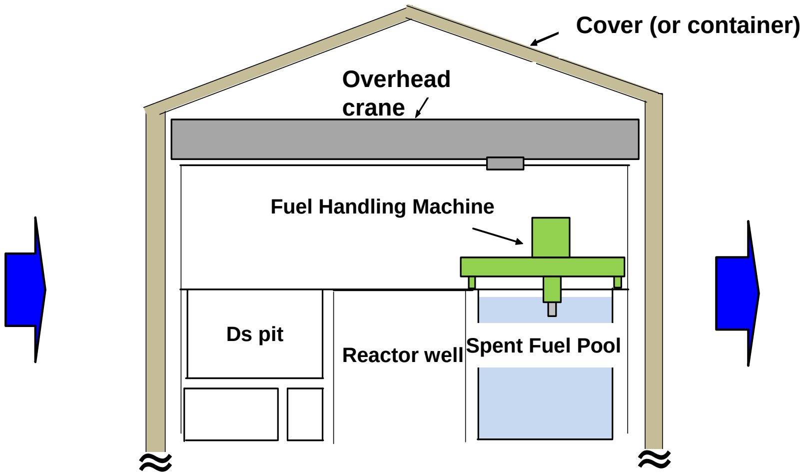
Shielding Measures (example)

Issue 5: Fuels Removal from Spent Fuel Pools

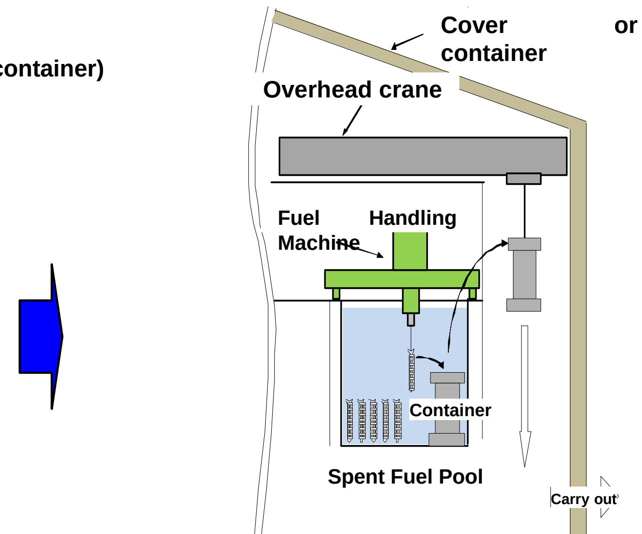
- Plans of Fuel Removal from SFP:
  - Unit 4: Starts in Nov. 2013. Completed by the end of 2014.
  - Unit 3: Starts in approximately 3 years after completing Step 2 .
  - Unit 1: Detailed plan will be developed based on experiences at Units 3 & 4 and investigations of rubble.
  - Unit 2: Detailed plan will be based on the situation after the inside-building decontamination etc. and investigations of the installed facilities.
- Fuel removal from all Units will be completed during Phase 2.
- Reprocessing & storing methods for removed fuels will be determined during Phase 2.



Debris removal from the upper part of reactor building



Installation of cover (or container) / crane



Fuel removal work

Fuel removal work (image)

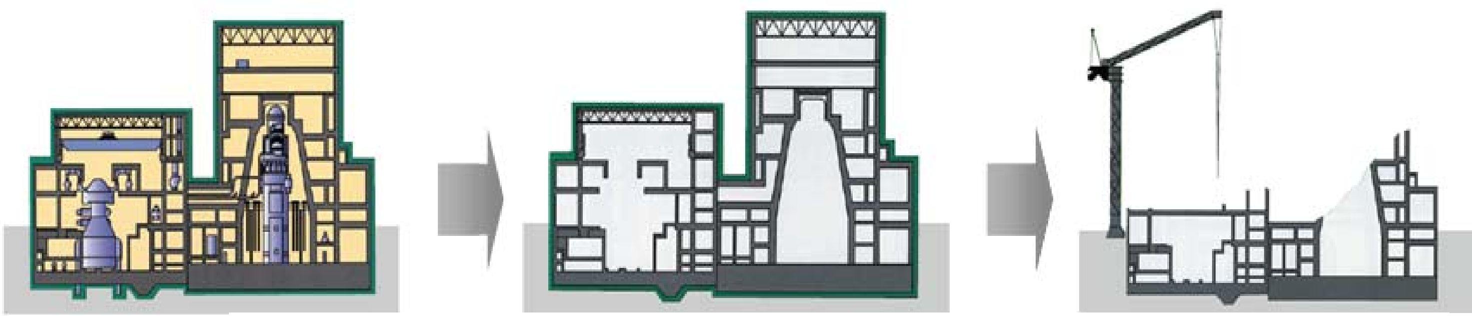
Issue 6: Fuel Debris Removal

- **Plan to start fuel debris removal in the first unit within 10 years after completion of Step 2.**
- **Removal of fuel debris will be implemented in accordance with the following steps in light of the site situation, safety requirements, and R&D progress of the remote control technologies required in the operations.**

(1) Reactor Building Decontamination
(2) PCV Leakage Point Inspections
(3) Stopping Inter-building Water Leakage PCV Lower Parts Repair
(4) Filling the Lower Part with Water
(5) Internal PCV Inspection and Sampling
(6) PCV Upper Parts Repair
(7) Filling PCV and RPV with Water⇒ Open the upper cover on RPV
(8) Internal RPV Inspection and Sampling
(9) Fuel Debris Removal

Issue 7: Reactor Facilities Demolition
8: Waste Processing and Disposal

- Plan to complete the reactor facilities demolition in Units 1 to 4 within 30 to 40 years after the completion of Step 2.
- Plan to commence demolition in Phase 3, after confirmation of establishing a basic database of contamination necessary when considering demolition and decontamination methods, R&D progress for remote controlled demolition operations, and an outlook for the waste disposal after demolition with necessary regulatory modifications.
- Within FY2012, plan to establish an R&D plan for the post-accident waste, whose contents differ from the ordinary waste. (nuclide composition, salt amount, etc.)
- Plan to determine waste form specifications, after confirmation of safety and applicability to the existing disposal concept as well as developing safety regulations and technical standards based on the result of R&D activities.
- Plan to commence treatment and disposal during Phase 3, after development of disposal facilities and preparation of a prospective disposal plan.



Nuclear Reactor Facilities Demolition (Image)

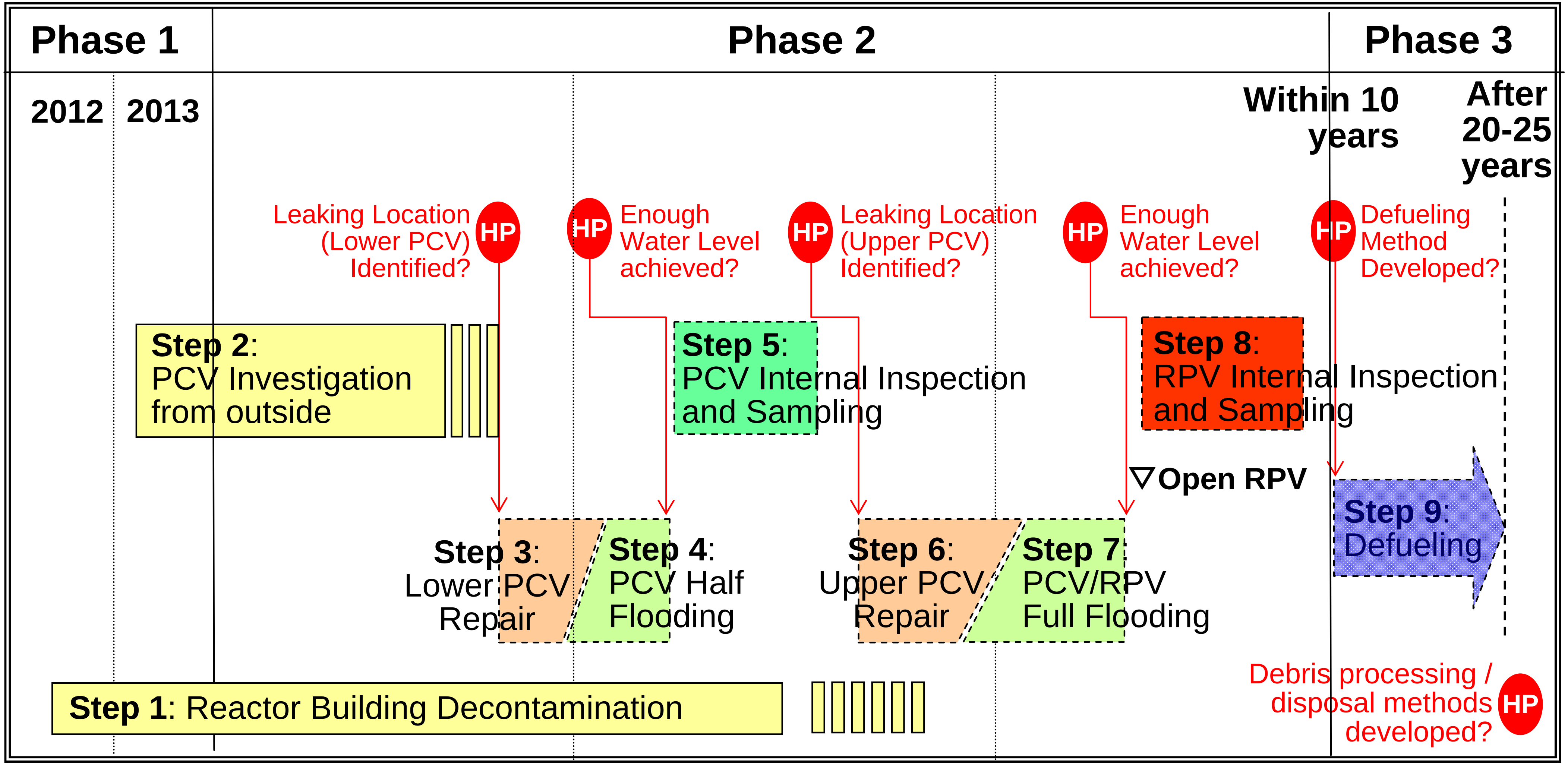
Major Challenges in Decommissioning procedures

- Final goal is to defuel from the Reactor Building (R/B) and to clean up Fukushima Daiichi site.
- Defueling procedure would be much more complicated than TMI-2 case due to differences like:

	TMI-2	Fukushima Daiichi
R/B Damage	Limited	Damaged by H_2 explosion (Units 1,3,4)
Water Boundary	RV remained intact	Both RPV/PCV have leakage (Units 1~3)
Fuel Debris Location	Remained in RV	Fallen out from RPV
Bottom of the Vessel	Simple bottom head structure	Complicated structure with Control Rod Drives

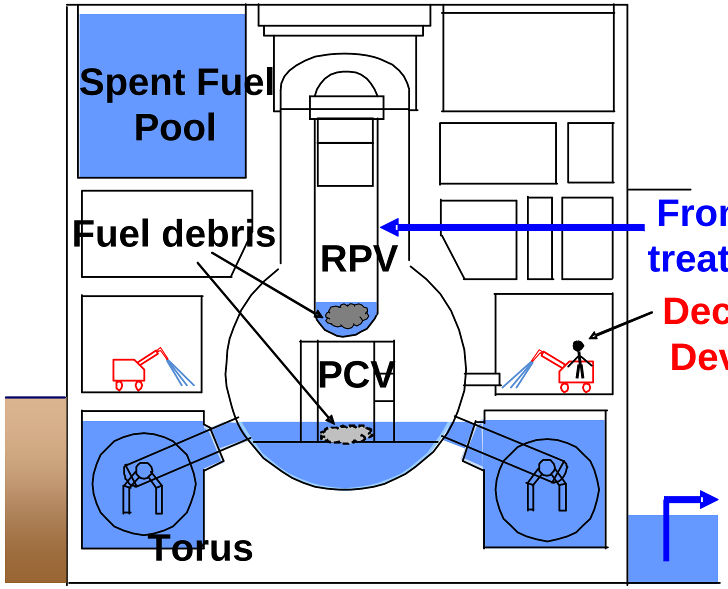
- TMI-2 Experience can be utilized more efficiently for post-defueling procedures in decommissioning.

Tentative Schedule toward Decommissioning



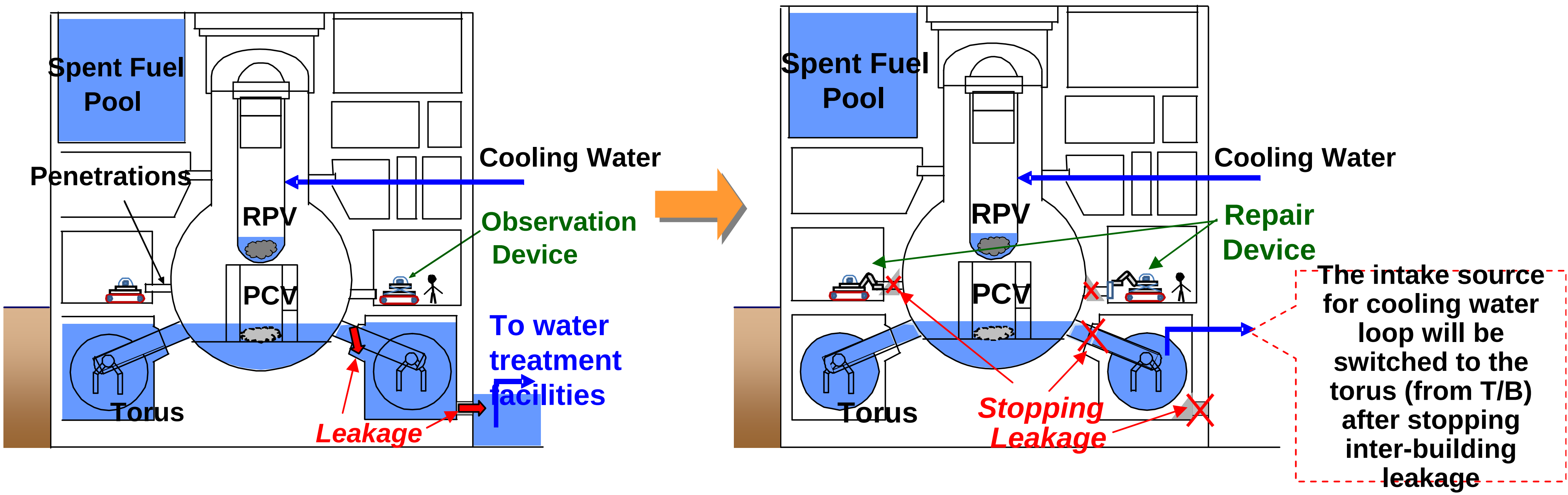
HP : Technical holding points.

Step 1: Reactor Building Decontamination



- **Decontamination of the area is essential to following procedures.**
  - Feasibility of high-pressure washing, coating, scraping and etc. are investigated in the National R&D program.
  - Combined usage of shielding maybe necessary
- **Major Challenges and Difficulties:**
  - High dosage (~ 5 Sv/h).
  - Obstacles like rubble scattered in R/B.
  - Smaller space due to the compact design of BWR4

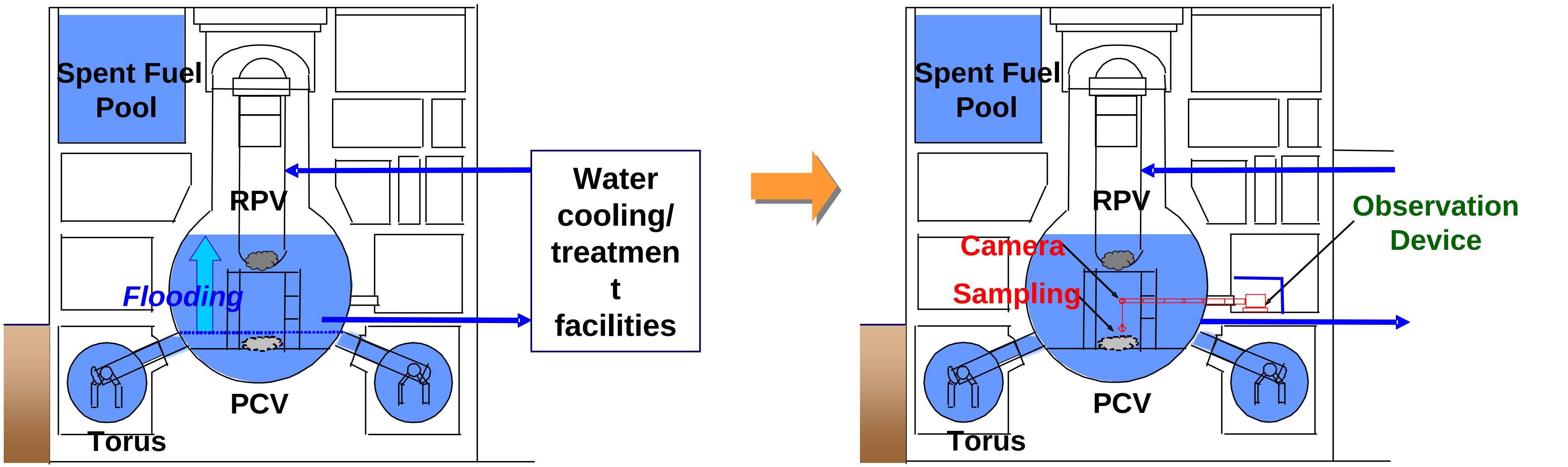
Steps 2, 3: Identification and Repair of the Leakage Points of PCV



- **Leaking Locations will be investigated from Outside of PCV and will be repaired**

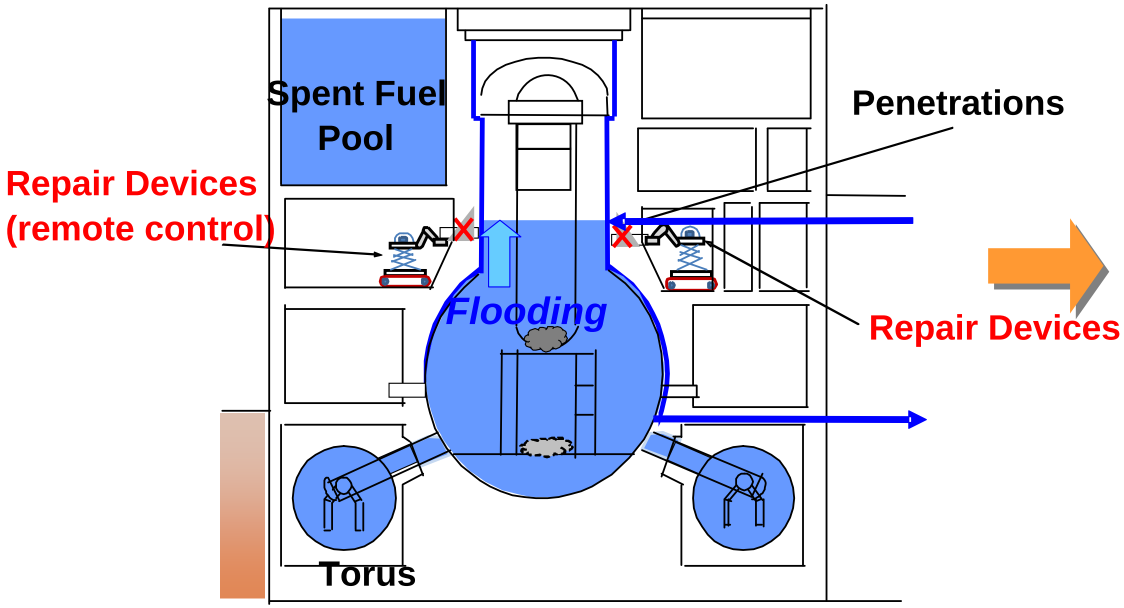
- **Major Challenges and Difficulties:**
  - High dose rate and humidity of PCV inside.
  - Major part of "suspicious locations" are underwater with poor visibility.
  - Repair work has to be conducted while highly radioactive cooling water is running for continuous fuel cooling

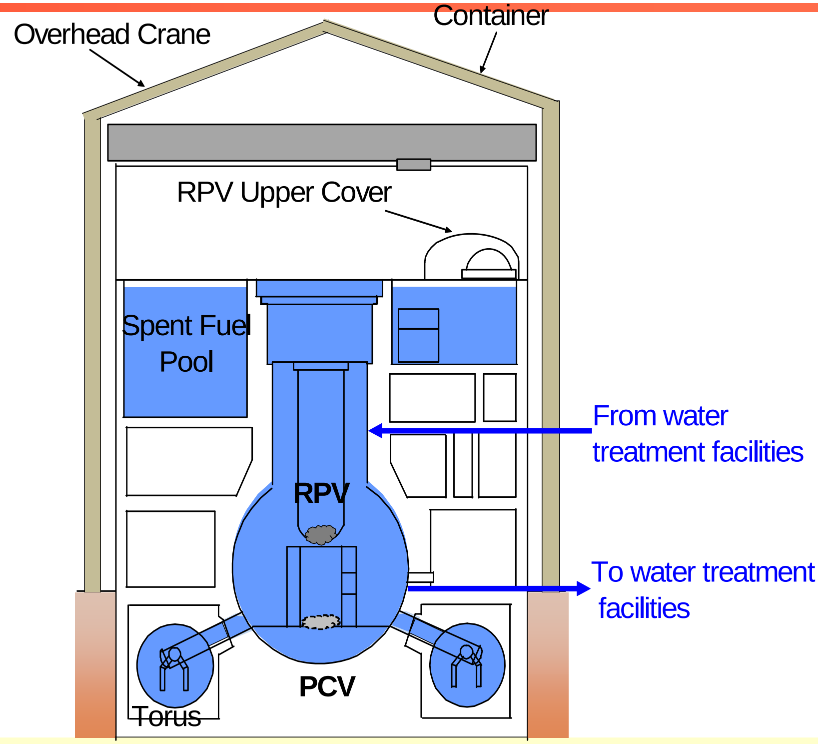
Steps 4, 5: Flooding of the Lower PCV, PCV Inspection & Sampling



- **Filling the lower PCV with water (Flooding)**
- **Distribution and Characteristic of fuel debris will be investigated**
- **Major Challenges and Difficulties:**
    - High dose rate, Limited accessibility and Poor visibility.
    - Leak-tight penetration is required for the investigation device once PCV flooding is achieved.
    - Subcritical assessment

Steps 6,7: Upper PCV repair, Flooding of Entire Reactor Well



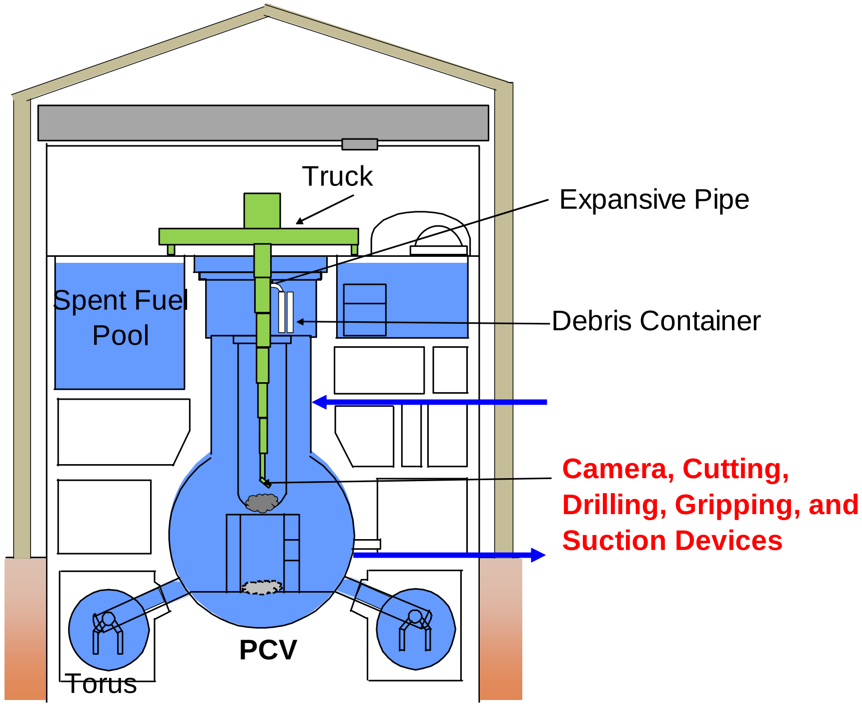


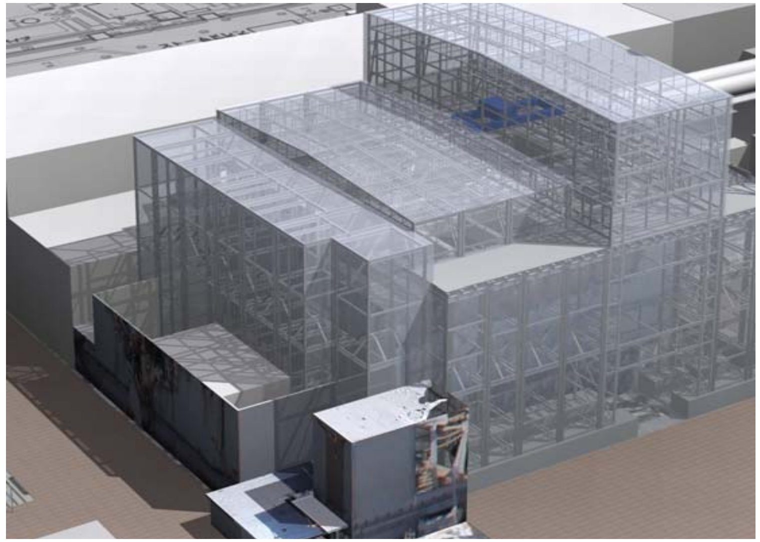
(1) Filling entire PCV/RPV with water after repairing upper PCV
(2) R/B container and overhead crane will be installed for defueling.
(3) RPV/PCV top heads will be removed after sufficient water is attained

Major Challenges and Difficulties:

- High dose rate, Limited accessibility.
- Seismic stability after flooding has to be maintained considering water mass.
- Prevent radioactive substances release from PCVs
- Subcritical assessment

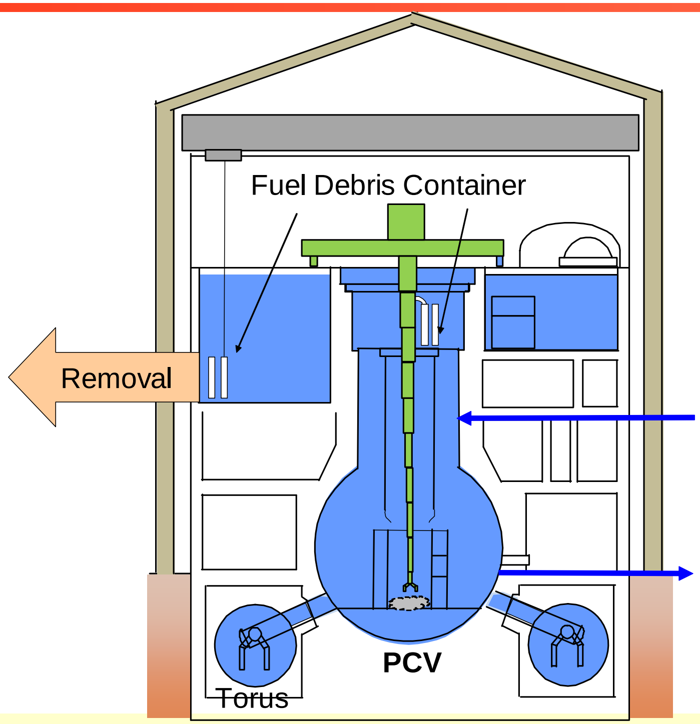
Step 8: Internal RPV Inspection& Sampling





- **Condition of RPV internal and Fuel debris will be investigated**
- **Major Challenges and Difficulties:**
  - High dose rate, Limited accessibility and Poor visibility.
  - Development of necessary device
  - Subcritical assessment
  - Store the removed debris

Step 9: Defueling from RPV and PCV



- **Fuel debris and RPV internal structure will be removed**
- **Major Challenges and Difficulties:**
  - Fuel debris is assumed to have fallen onto the complicated RPV bottom structure (BWR has much more complicated one than PWR)
  - Debris may have fallen even out of RPV (Debris remained in RV in TMI-2)
  - Diverseness of Neutronic-, Mechanical- and Chemical- property of debris as mixture with different types of metal and concrete
  - Subcritical assessment
  - Store the removed debris

R&D Programs for Decommissioning

Black: On going
Blue: Planned

1. Removal of spent fuel from Spent Fuel Pool

- **1.1 Long-term Integrity of Spent Fuel Assemblies (FY2011–2015)**
- 1.2 Damaged spent Fuel Processing (FY2013–2017)

2. Preparation for removal of fuel debris

- **2.1 Fuel debris removal using remote control equipment and devices**
  - **2.1.1 Remote Decontamination of the Reactor Building Interior (FY2011–2013)**
  - **2.1.2 Identifying Leak Areas in the PCV (FY2011–2014)**
  - **2.1.3 PCV Repair Technologies (FY2011–2017)**
  - **2.1.4 Investigation of the PCV Interior (FY2011–2016)**
  - 2.1.5 Investigation of the RPV Interior (FY2013–2019)
  - 2.1.6 Removal of Fuel Debris and Internal Structures in the Reactor (FY2015–2021)
  - 2.1.7 Containment, Transport and Storage of Reactor Fuel Debris (FY2013–2019)
  - **2.1.8 Assessment of RPV/PCV Integrity (FY2011–2016)**
  - **2.1.9 Controlling Fuel Debris Criticality (FY2012–2018)**
- **2.2 Ascertaining and analyzing reactor core status**
  - **2.2.1 Analysis of Accident Progression to estimate reactor status (FY2011– 2020)**
- **2.3 Ascertaining the characteristics of and preparing to process fuel debris**
  - **2.3.1 Study of Characteristics using Simulated Fuel Debris (FY2011–2015)**
  - 2.3.2 Analysis of Properties of Actual Fuel Debris (FY2015–2020)
  - **2.3.3 Development of Technologies for Processing of Fuel Debris (FY2011–2020)**
  - **2.3.4 Establishment of a new accountancy method for Fuel Debris (FY2011–2020)**

3. Processing and disposal of radioactive waste

- **3.1 Processing of Secondary Waste from the Contaminated Water Treatment (FY2011~)**
- **3.2 Processing and Disposal of Radioactive Waste (FY2011~)**

Technical Challenges for Defueling

Decontamination of Reactor Buildings

- Various targets of decontamination; floor, wall, ceiling….
- Not only structural objects, but puddles and atmospherics should be decontaminated.
- Technologies for coating or shielding the radiation sources will also required.

Inspection of Inner PCV & Leaking Points

- Most inspection (photographing, dose measurement, acoustic diagnostics) will be done in the contaminated water or in little/crowded space.
- Various situation such as high temp, high humidity, under water….
- All measurement instruments must have high tolerability to radiation and long distance control system

Repair Works for PCV & Leaking Points

- Leakage mending methods under the highly contaminated water
- Water injection to a reactor cannot be stopped during the PCV/leakage repair.

Current Activities for decommissioning

- Due to the much more complicated situation than TMI-2;
  - So many uncertainties still remain
  - Many R&D activities are needed to be conducted in parallel to the defueling procedures
- Government-supported R&D team has been organized.
  - Government (METI, MEXT)
  - National Labs. (JAEA, AIST etc.) and CRIEPI
  - Fabricator (Toshiba / Hitachi GE / Mitsubishi Heavy Ind.)
  - Academic experts
  - TEPCO (and Japanese LWR owner's group (starting from FY2012))
- Twelve R&D projects have been commenced. Nineteen projects are planned)
- Reaching out for advice and counsel to world community steadily
  - US: DOE, INPO,EPRI,National Labs. Academic
  - UK: NDA
  - France: CEA, LAAS-CNRS
  - Germany: KIT(Karlsruhe Institute of Technology)
  - Russia: Rosatom State Nuclear Energy Corp, Russian Academy of Sciences
  - Ukraine: Chornobyl NPP, Institute for Safety Problems of NPPs

  and Other Countries

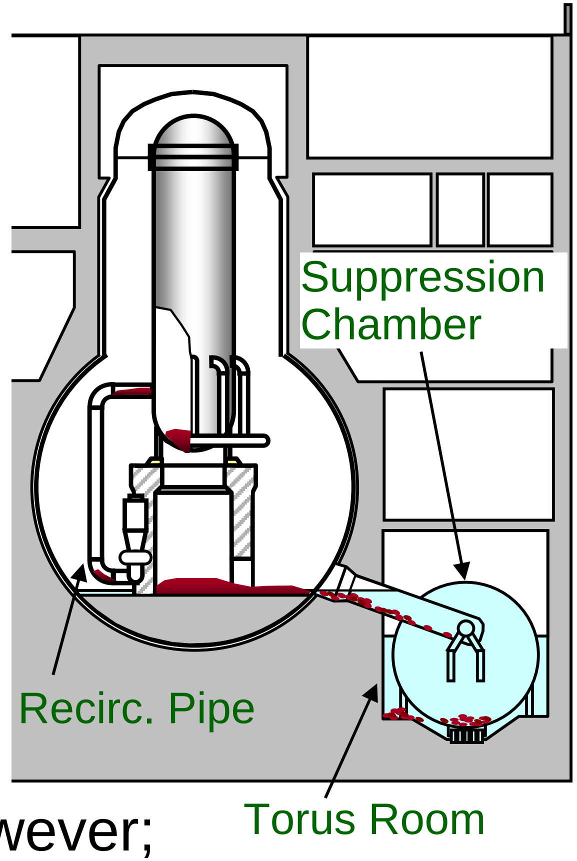
Examples of Lessons learned from Foreign Organization

Integrated Waste Management

- ✓ Fukushima Daiichi(1F)-specific waste management strategy is needed. It has to be regarded as key principles in designing decommissioning procedures.
- ✓ The waste management strategy should include not only long-term storage but also re-using and recycling of materials. The facility and site plans should be established considering their prioritization.
- ✓ Precise estimations of the future waste generation is important in long-term decommissioning planning. Close communication between decommissioning process management- and waste management-teams is indispensable.

5. Remaining Challenges for Fuel Debris Retrieval

Items to be Tackled



1. Identification of debris location

- SA codes predicts that molten debris has fallen downward, out of RPV
- No enough evidence at this moment to deny the existence of debris in recirculation pipes, suppression chamber or torus room
- Attempts such as further visual inspections, SA code improvement and MUON technology are continuing

2. Debris Sampling

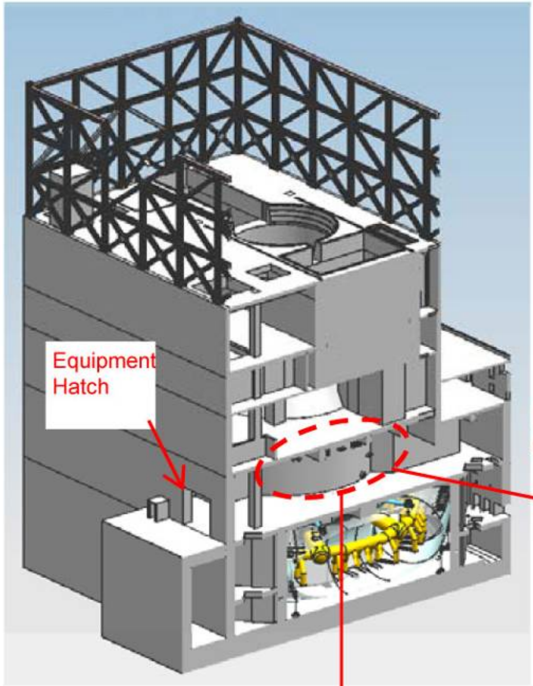
Analyses of actual debris samples will be valuable for subsequent processes of decommissioning, however;

- Large number of samples can be required to assure enough representativeness of various forms of debris
- Debris properties are needed to take out debris samples (Chicken and Egg situation)

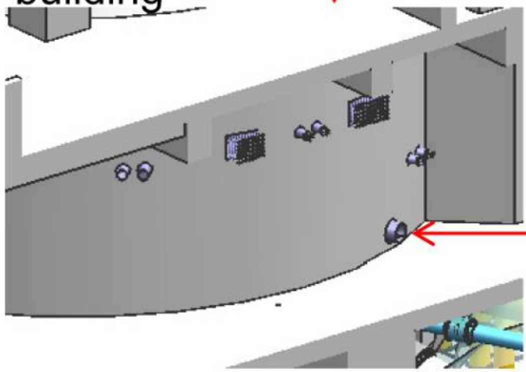
3. Debris Property Evaluation (Main Topic of this Presentation)

Simulate Debris samples can be useful

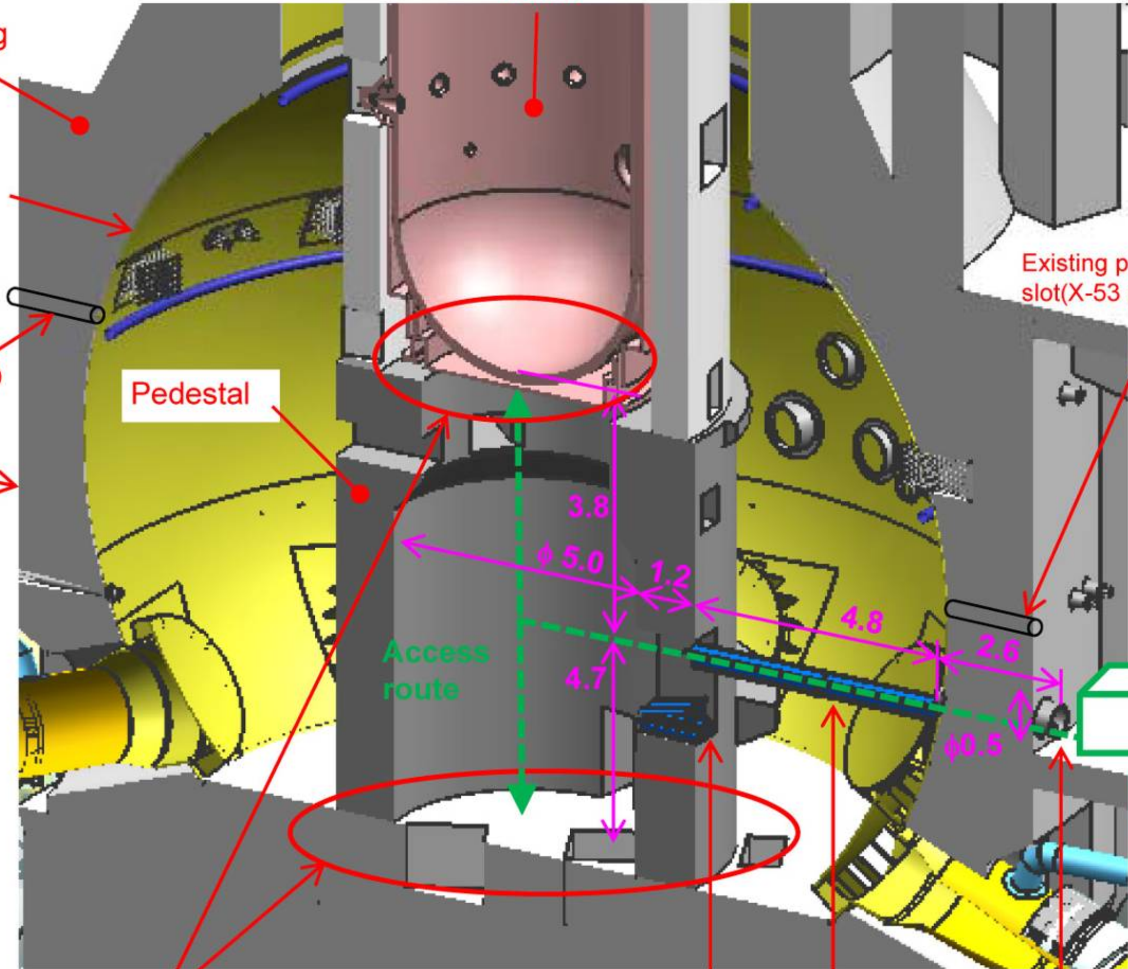
Identification of Fuel Debris Location



Reactor building



Reactor building, first floor



Sectional drawing, investigation area, and outline dimensions (m)

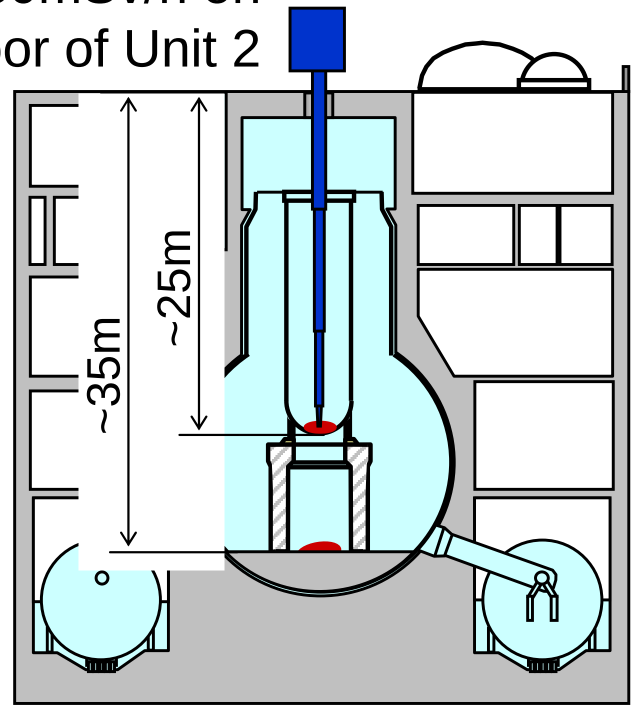
Current Situation toward Debris Retrieval

Limited accessibility to debris:

- High dose rate (~880 mSv/h on the top floor)
- Damaged reactor building structure
- Physical distance between Operating Floor and PCV bottom

Remote operation capability required:

- Core boring
- Plasma arc
- Shearing
- Bulk removal (Vacuum, Gripping)

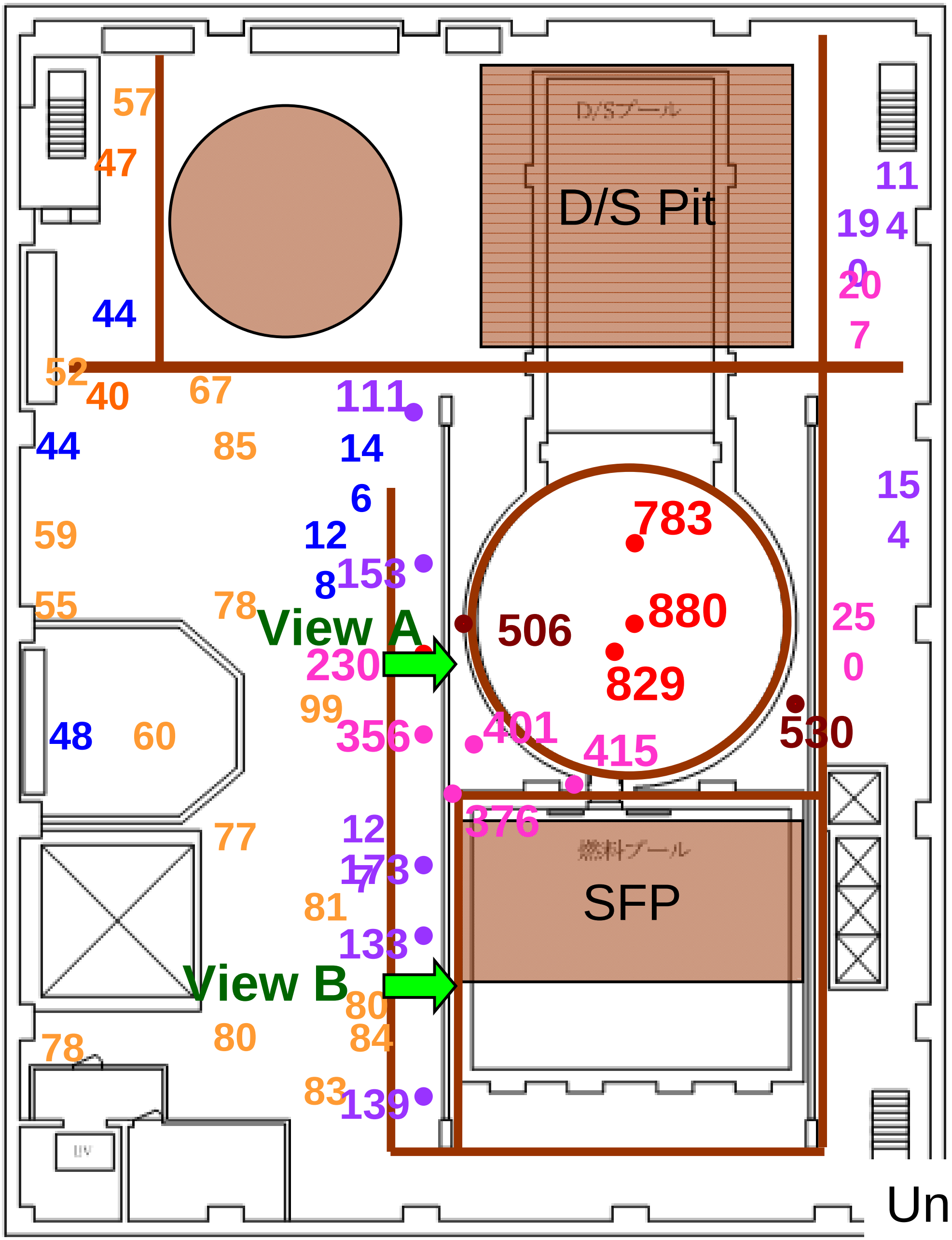


Dose Rate Map of Operating Floor (Unit 2)

Reactor Building
Operating (Top) Floor, Unit 2

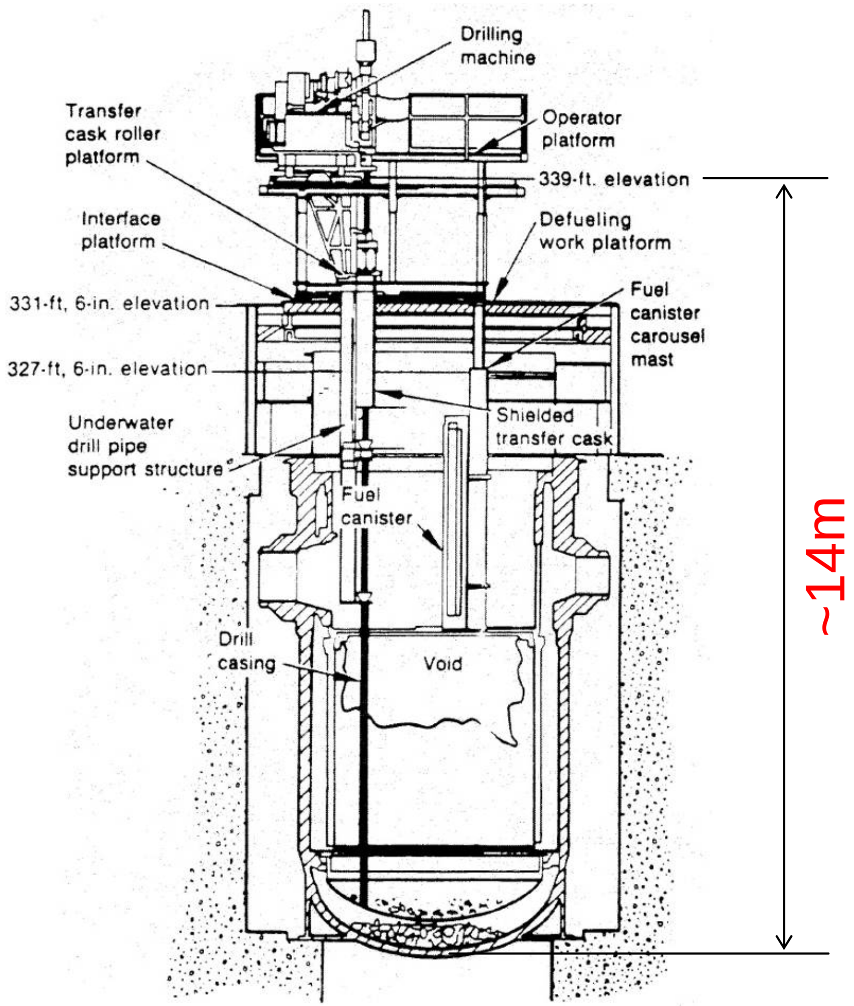
View A

View B



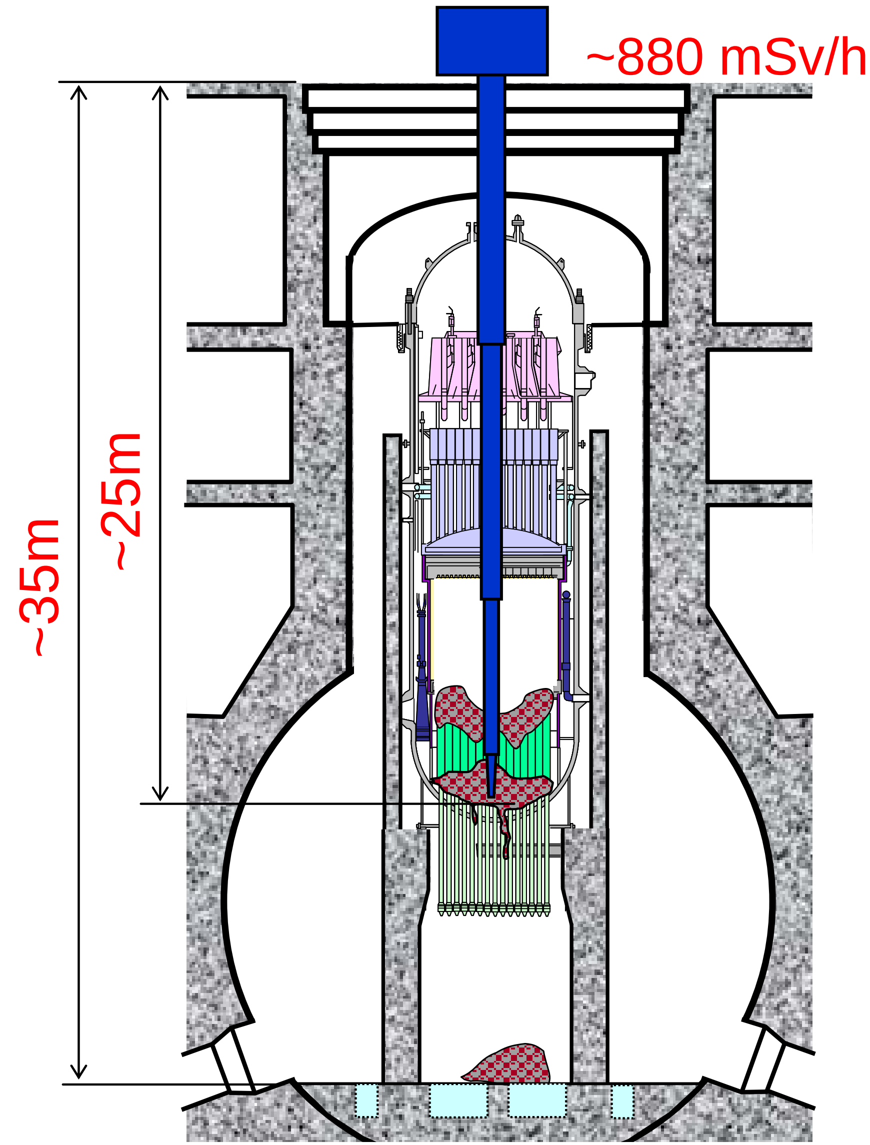
Unit: mSv/h

Comparison with the TMI case



Core Boring Machine for TMI-2

The Cleanup of Three Mile Island Unit 2,
Project 2558-8 Final Report, EPRI NP-6931 (1990)



Fukushima Daiichi

More elaborate tool development is important

Available Information about Fuel Debris

Necessary properties of debris:

- Hardness
- Toughness
- Workability
- Machinability

Available properties are limited.

- Various information from TMI-2 and SA-related research programs are available
- But not directly applicable due to the BWR-PWR differences and Fukushima-specific conditions
  > U/Zr ratio
  > Larger amount of metal (Fe/Ni) mixture (from RPV Internal structure and RPV itself)
  > Concrete mixture (from MCCI (Molten Core-Concrete Interaction))
  > Duration period of high temperature condition

International Studies on Molten Corium

Multiple international projects working on molten corium have been conducted

- OECD/NEA Projects
  > RASPLAV-1, 2 (Chemical Property of corium),
  > MASCA-1, 2 (In-Vessel Retantion),
  > MCCI-1, 2 (MCCI)
- European Projects
  > SARnet-1,2(,3) (SA code ASTEC)
- ISTC (International Science and Technology Center) Projects
  > METCOR, CORPHAD, PRECOS (Corium phase diagram)

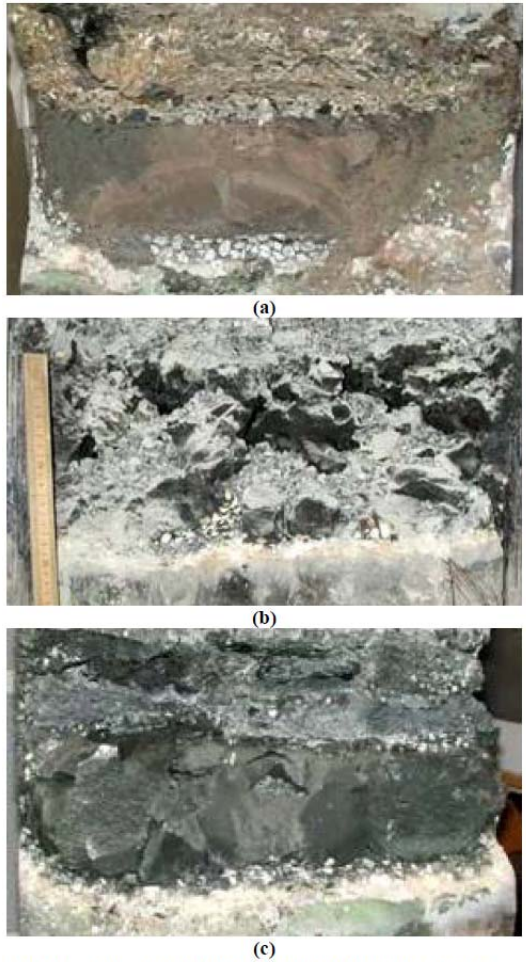


Figure 3-9. Axial Debris Morphology for Test: (a) CCI-1, (b) CCI-2, and (c) CCI-3.

OECD MCCI Project Final Report
OECD/MCCI-2005-TR06(2006)

Main focus was on Chemical- or Thermal-properties and reaction

Few mechanical property information was extracted from those projects

Summary

- Situation in Fukushima is assumed to be much more complicated than the case of TMI-2
- Tentative plan is to start Defueling from RPV within 10 years.
- It is assumed that the Defueling process can take over 20 to 25 years to complete.
- Government supported R&D activities are commenced to achieve defueling and Fukushima Daiichi-Cleanup successfully.
- Many unexpected situations are expected. Flexible program management will be necessary.
- Advices and counsels from the world community would be very much appreciated.