

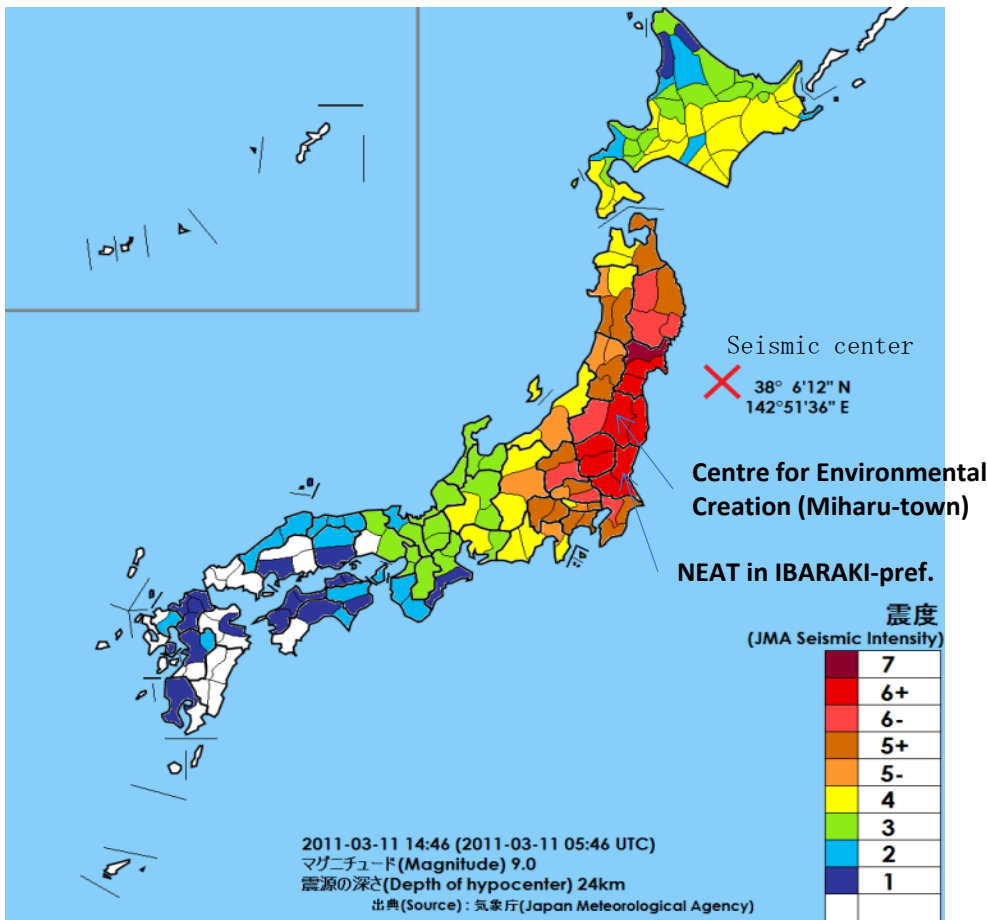
A photograph of a traditional Japanese shrine building with a red and white facade and a dark roof, partially obscured by a white fence. The shrine is surrounded by numerous cherry blossom trees in full bloom, with white and pink blossoms. The background shows a lush green forest and a clear blue sky.

# **Challenges for Enhancing Fukushima Environmental Remediation**

**Dr. Yasuhiro UEZU**  
**Fukushima Environmental Safety Center**  
**Japan Atomic Energy Agency (JAEA)**



# About Great East Japan Earthquake



**The great east Japan earthquake was occurred 2011 March 11 14:46.**

Summary of Tables explaining the JMA Seismic Intensity Scale

**0** No reaction to people.

**1** Fall objects to some people (e.g., light of children).

**2** Fall to many people (e.g., children).

**3** Fall to most people (e.g., children).

**4** Many people are startled; hanging objects such as lamps swing slightly; small items may fall.

**5 Lower** Many people are frightened and feel the need to hold onto things nearby; many objects and items on bookshelves may fall; doors and windows may rattle out.

**5 Upper** Many people find it difficult to walk; many things are swinging wildly; many objects and items on bookshelves may fall; doors and windows may rattle out; structural concrete may walk away.

**6 Lower** Top of light to heavy swinging; many unsecured lamps may swing and may break out; doors may become warped and fall; wall gas and appliances may swing, damage and fall; in wooden houses with low earthquake resistance, gas may fall and the piping may bend or collapse.

**6 Upper** Many people become very frightened; furniture may be thrown through the air; many unsecured lamps may swing and may break out; wooden houses with low earthquake resistance may rattle out; large items may fall and large bookshelves and heavy shelves may be seen.

**7** Wooden houses with low earthquake resistance are seen to rattle out; wooden houses with high earthquake resistance may bend or break; high-rise concrete buildings with low earthquake resistance are seen to rattle out.

**If you feel a tremor**  
 Remain calm, and secure your personal safety.  
 Protect your head and shelter under a table.  
 Don't rush outside.  
 Don't worry about turning off the gas in the kitchen.  
 Panic leads to injury.

**If you see/hear an Earthquake Early Warning's**  
 When driving a car, turn on your hazard lights, then slow down smoothly.  
 Keep away from gates, walls, vending machines and buildings.  
 Leave immediately to highland when a strong shake has been felt on the seashore.

**Make residences earthquake resistant and fix furniture to prepare for earthquake.**

Ministry of Land, Infrastructure, Transport and Tourism  
 Japan Meteorological Agency  
 Address: 1-1-1 Honcho, Chiyoda-ku, Tokyo 100-8505  
 Phone: 03-5225-5000  
 Website: http://www.jma.go.jp

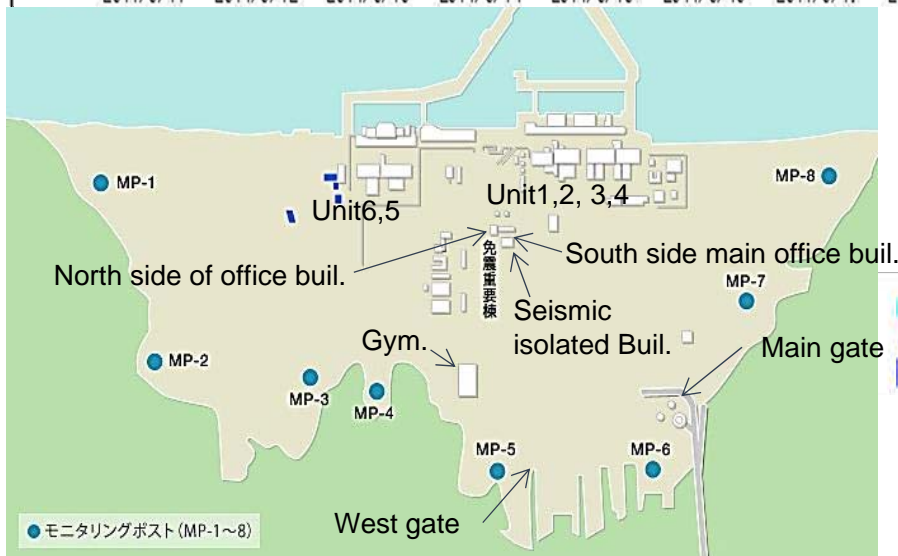
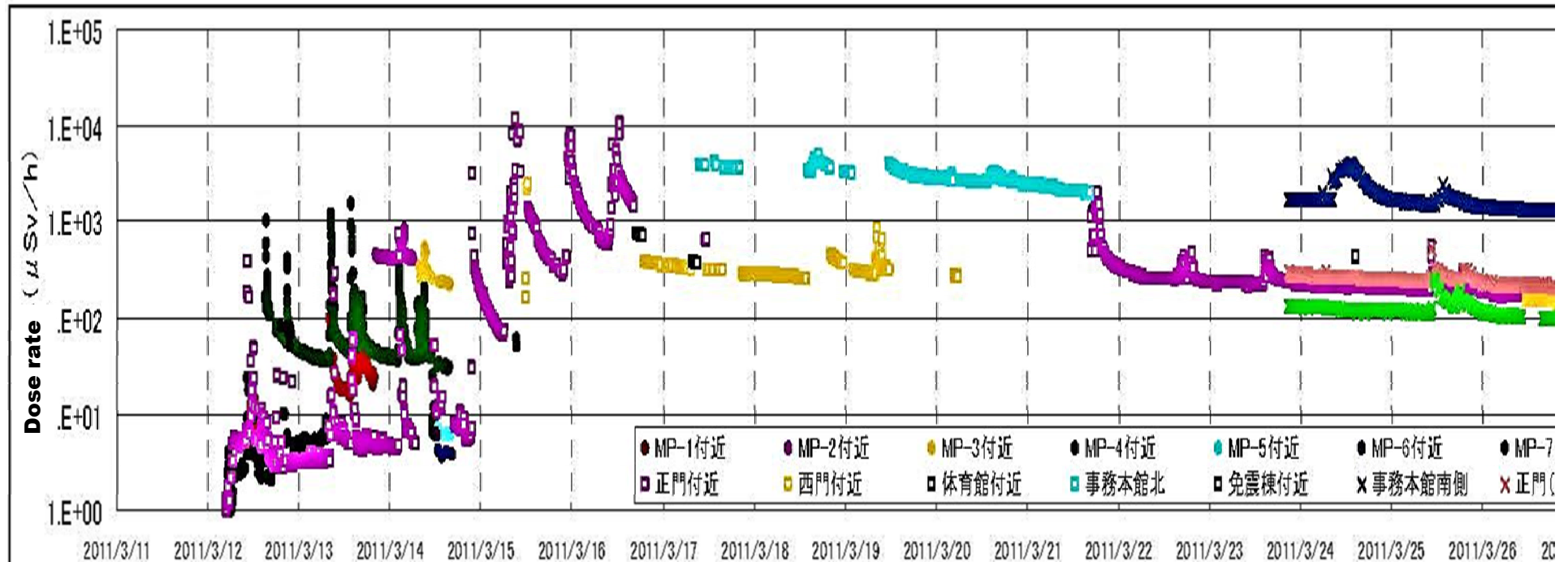


# The Fukushima Dai-ichi Nuclear Power Plant Accident

- **14:46 Mar. 11** ; Earthquake and following big wave (tsunami) struck the power plant (**Magnitude 9.0, max height of tsunami: over 15 m**)
- **15:42** ; Loss of all electric power through unit 1 to 5 (without unit 6) , and data from 24 MPs around plant had been stopped.
- **19:03** ; *The Prime Minister declared “**Nuclear Emergency**”*
- **21:23** ; Residents evacuation within 3 km and shelter-in-place within 10 km, **5:44, Mar. 12** ; expanded evacuation within 10km.
- **23:00 Mar. 11** ; **1.2mSv/h in front of the north door to reactor and turbine buildings of unit 1.**
- **15:36 Mar. 12** ; Hydrogen explosion occurred in the unit 1 reactor building.
- **18:25** ; Evacuation zone had been expanded within 20km.
- **11:01 Mar. 14**; Hydrogen explosion occurred in the unit 3 reactor building.
- **6:14 Mar. 15**; Hydrogen explosion occurred in the unit 4 reactor building.



# Increasing air dose rate around plant



- |                               |                                |                                |                                |
|-------------------------------|--------------------------------|--------------------------------|--------------------------------|
| ● Near MP1                    | ● Near MP2                     | ● Near MP3                     | ● Near MP4                     |
| □ Near main gate              | □ Near west gate               | □ Near gym.                    | □ North side of office buil.   |
| ● Near MP5                    | ● Near MP6                     | ● Near MP7                     | ● Near MP8                     |
| □ Near seismic isolated buil. | □ South side main office Buil. | □ Main gate (Transportable MP) | □ West gate (Transportable MP) |
|                               |                                |                                | □ Near administration buil.    |





# Dispatched specialists to Fukushima OFC

**March 11 to 12, 2011**



**22:46 Mar. 11** ; Requested by MEXT(Ministry of Education, Culture, Sports, Science and Technology), JAEA gathered the 1st specialist team at the Operation Room of NEAT in IBARAKI pref.



**06:00 Mar.12**; Arrived at the monitoring center (Atomic center) next to Fukushima OFC in Ookuma town

**1:54 Mar. 12** ;  
The 1st team started from NEAT to Hyakuri Air Base, and moved to Fukushima OFC at Ookuma town by a helicopter of JSDF.

Boarded a helicopter of Japan Self Defense Force(JSDF)



Brought radiation measuring devices



Dispatched a monitoring Vehicle



**6:30 Mar.12**; The 1st JAEA Team joined with emergency response meeting at Fukushima OFC



# Dispatching Special Vehicles

## Monitoring vehicle installed Ge spectrometer with shielding



- **Mar.14** : monitoring vehicle installed Ge detector was dispatched from NEAT-Fukui



## Whole-body counter (WBC) vehicle for Internal Exposure survey for occupational



- **Mar.12** : Dispatched from NEAT-Ibaraki
- **Mar.16** : Located at Fukushima Medical College.
- **Mar.21** : Located at TEPCO Onahama
- **May.30** : Another WBC vehicle was dispatched
- Internal doses were measured and evaluated for about 330 workers until April 25.



## Monitoring vehicle



- **Mar.15** : A monitoring vehicle was dispatched from NEAT-Ibaraki (Three monitoring cars had been worked in Fukushima from JAEA)

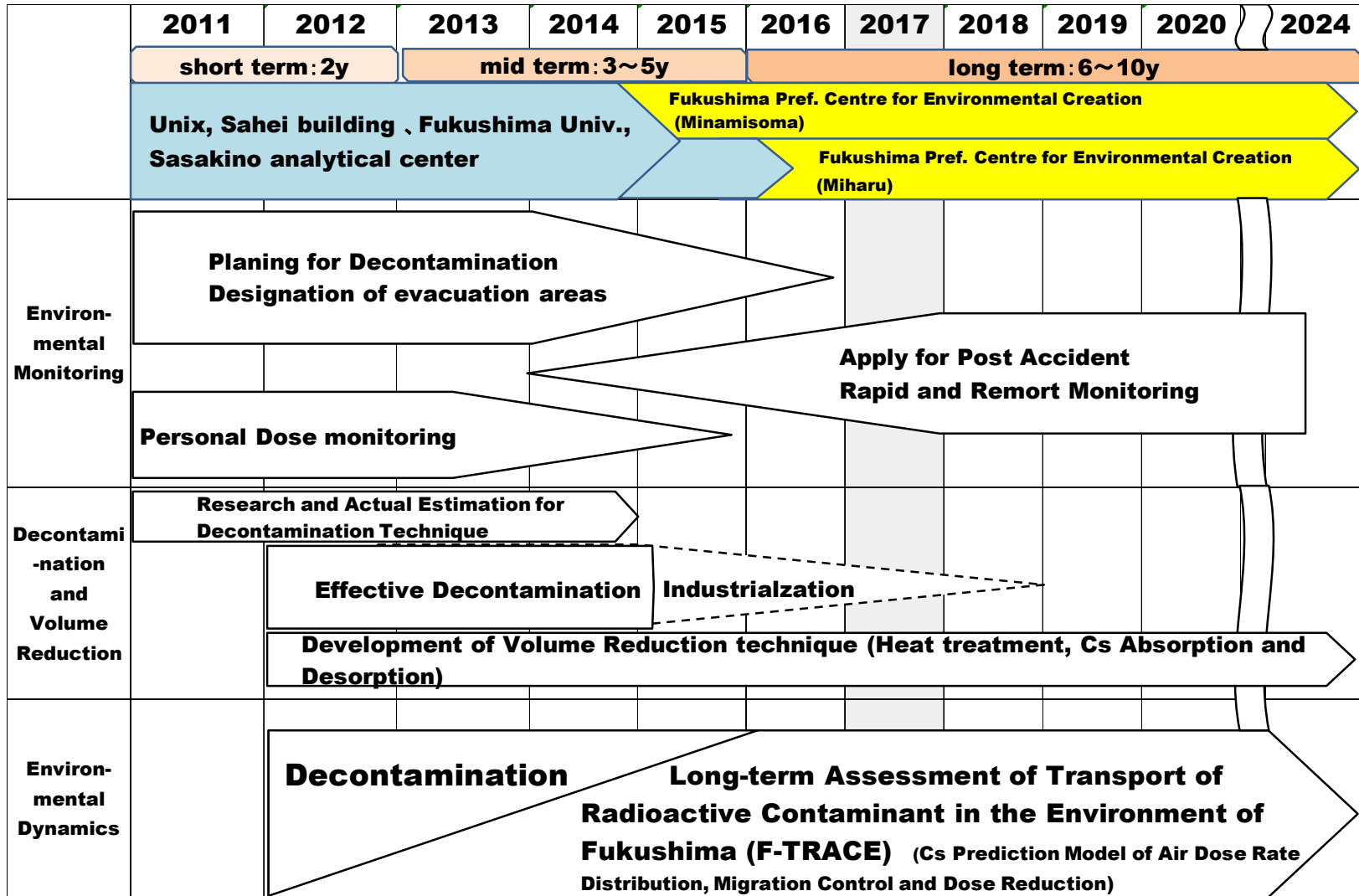
## Surface contamination monitoring vehicle and decontamination vehicle



- **Mar.15** : Dispatched from NEAT-Ibaraki
- **Mar.16** : Located at Fukushima Medical College.



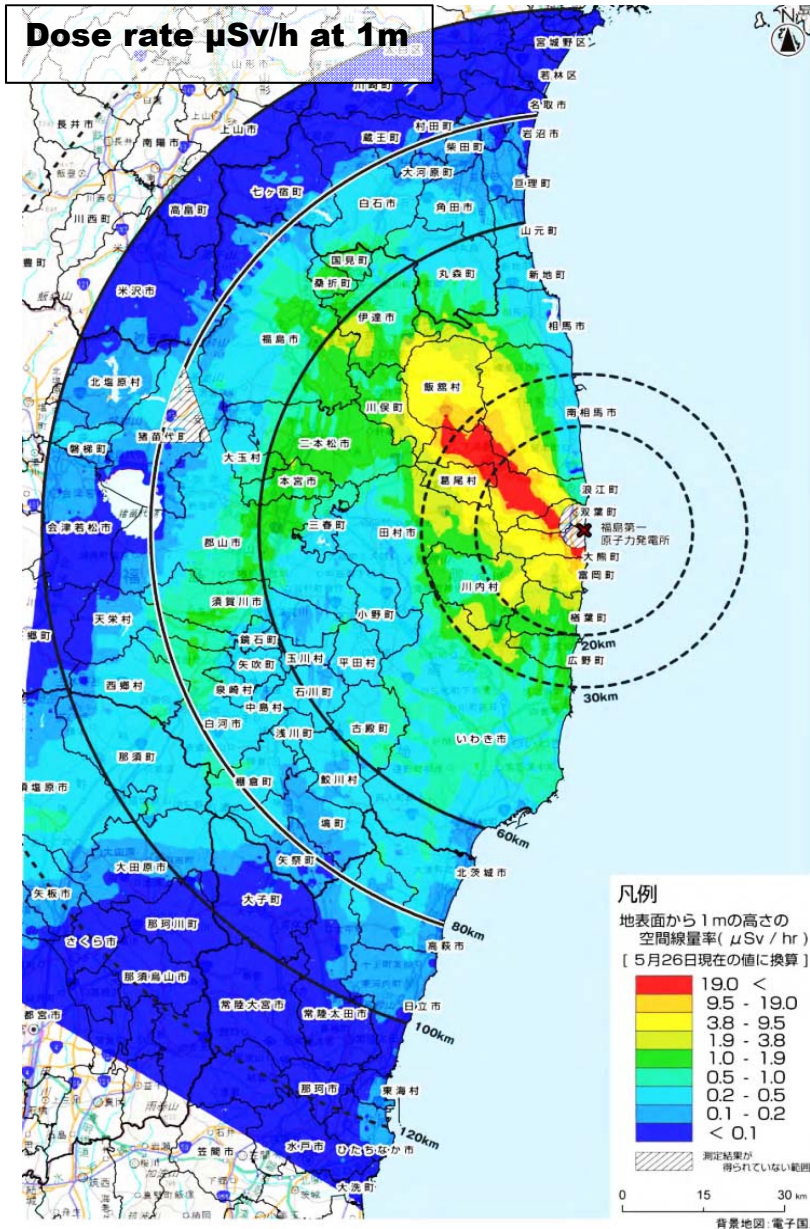
# Milestone of Fukushima Environmental Remediation By JAEA Fukushima



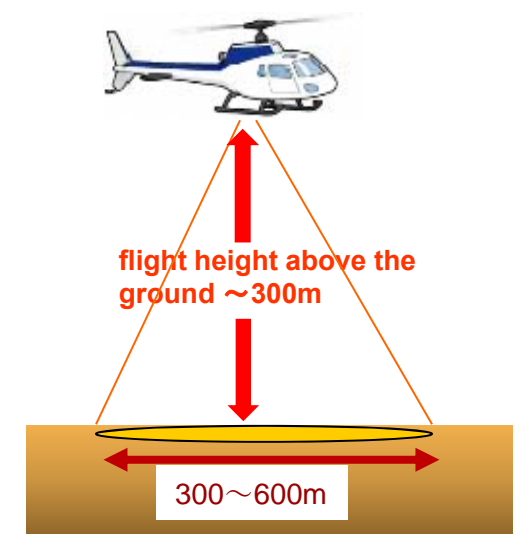
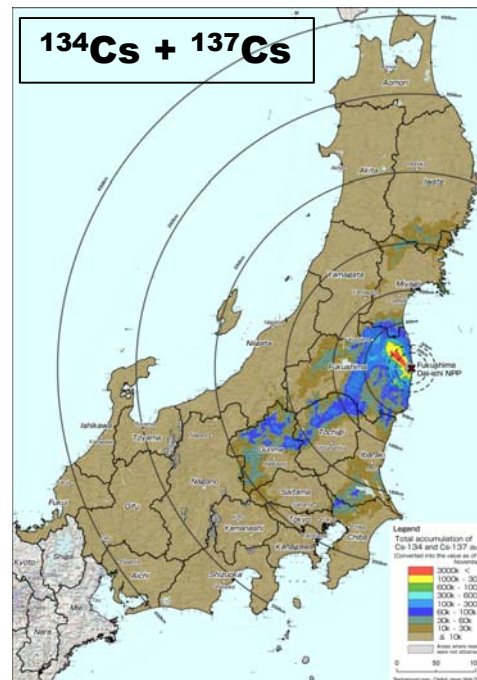


# Environmental Monitoring

## Aerial monitoring



Det.size(inch), quantity	Energy range	Channel	Altimeter
16" × 4" × 2", 6 detector	0.02 - 3 MeV	1,024 ch	GPS

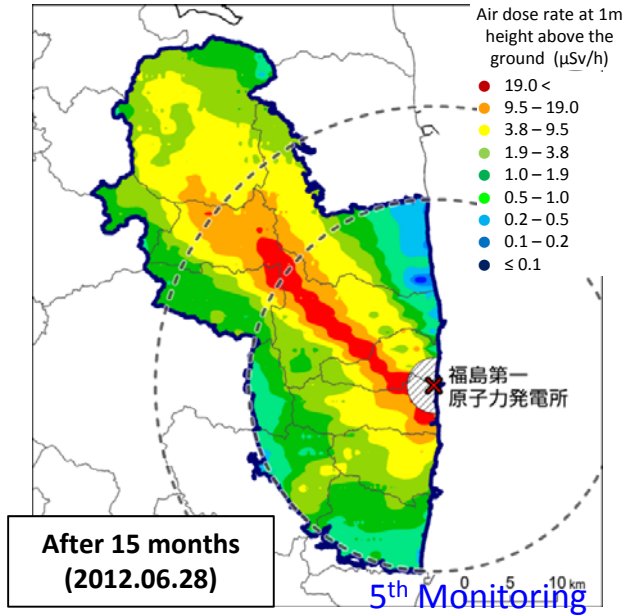
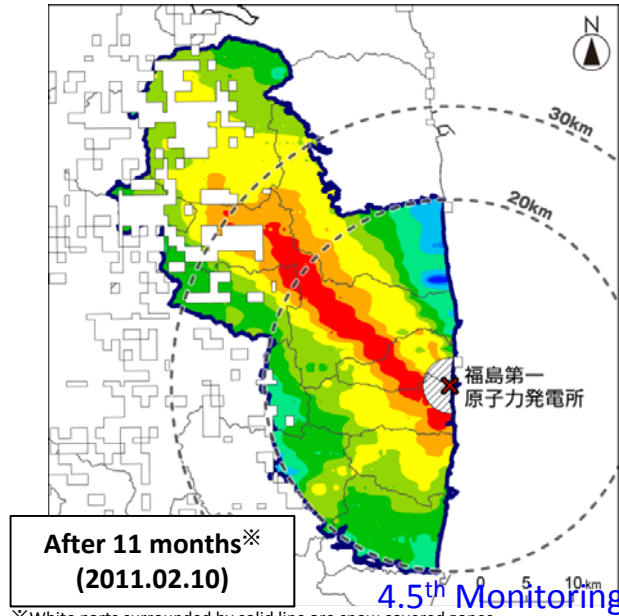
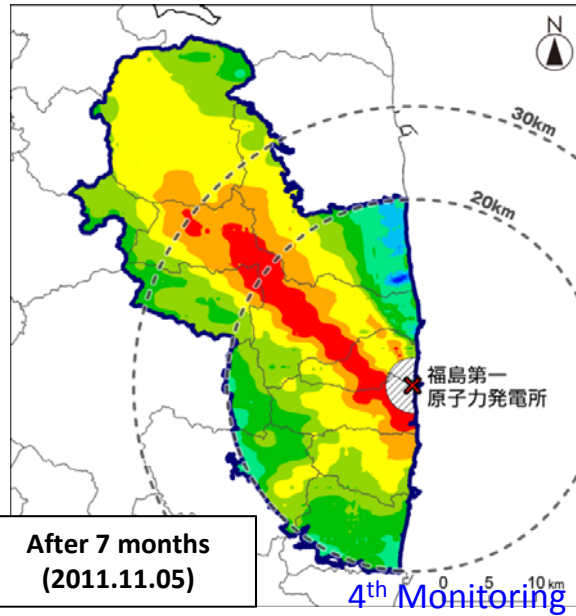




# Environmental Monitoring

## Dose Rate Distribution as a Passing Time

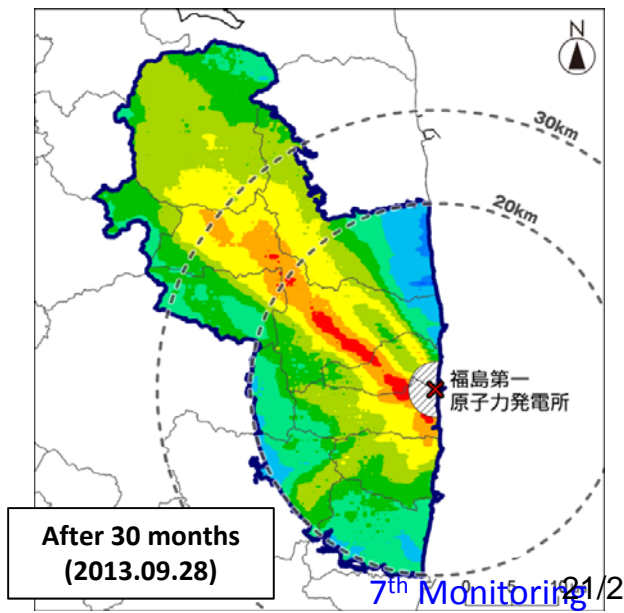
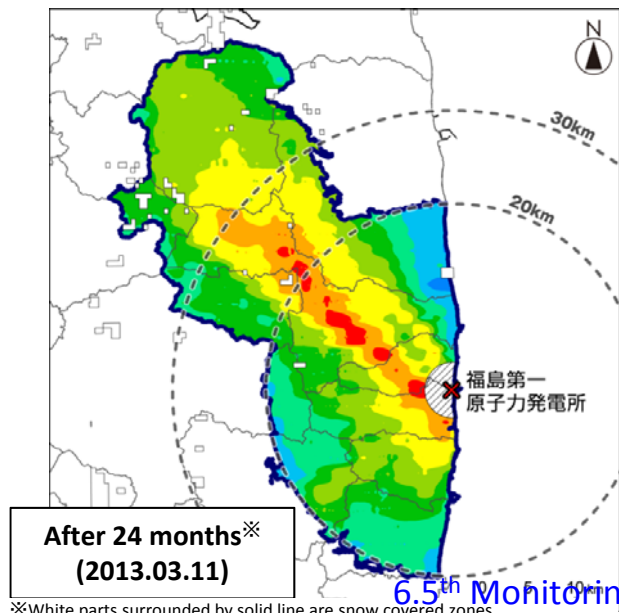
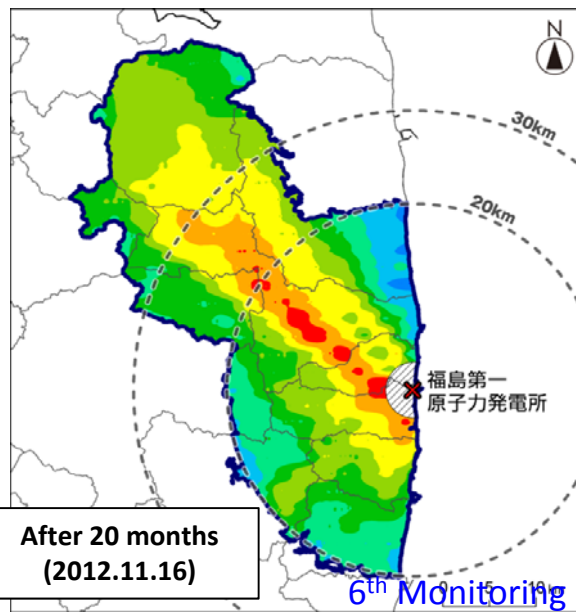
- by aircraft monitoring -



Air dose rate at 1m height above the ground ( $\mu\text{Sv/h}$ )

- 19.0 <
- 9.5 - 19.0
- 3.8 - 9.5
- 1.9 - 3.8
- 1.0 - 1.9
- 0.5 - 1.0
- 0.2 - 0.5
- 0.1 - 0.2
- $\leq 0.1$

※White parts surrounded by solid line are snow covered zones



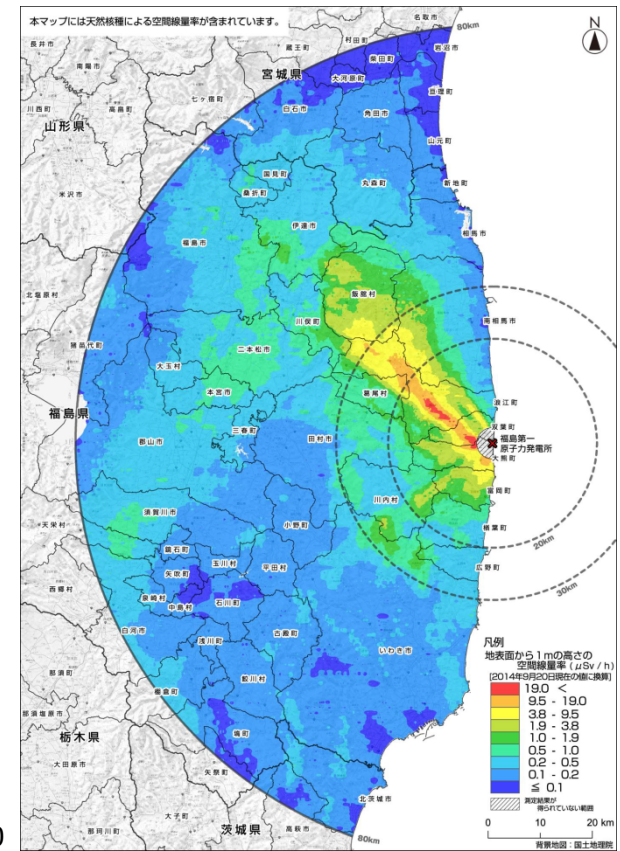
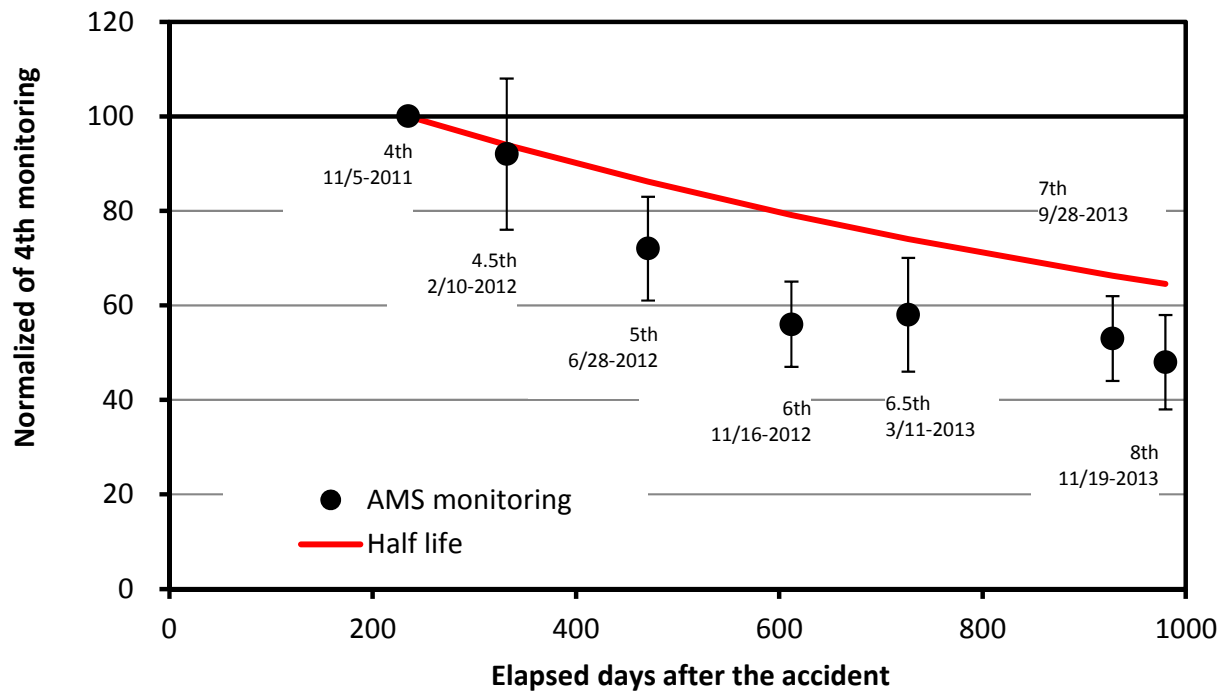
※White parts surrounded by solid line are snow covered zones

# Environmental Monitoring

## Dose rate variation with time based on airborne monitoring

FY	2011				2012				2013			
	4-6	7-9	10-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	1-3
<80 km	1st	3rd	4th		5th		6th			7th		8th
>80 km	2nd *	East Japan 1st		West Japan and Hokkaido		East Japan 2nd		East Japan 3rd		East Japan 4th		

\* Covering of a part of 100 - 120 km



9<sup>th</sup> monitoring after 42 months  
(2014.09.20)



# Environmental Monitoring Protective Actions

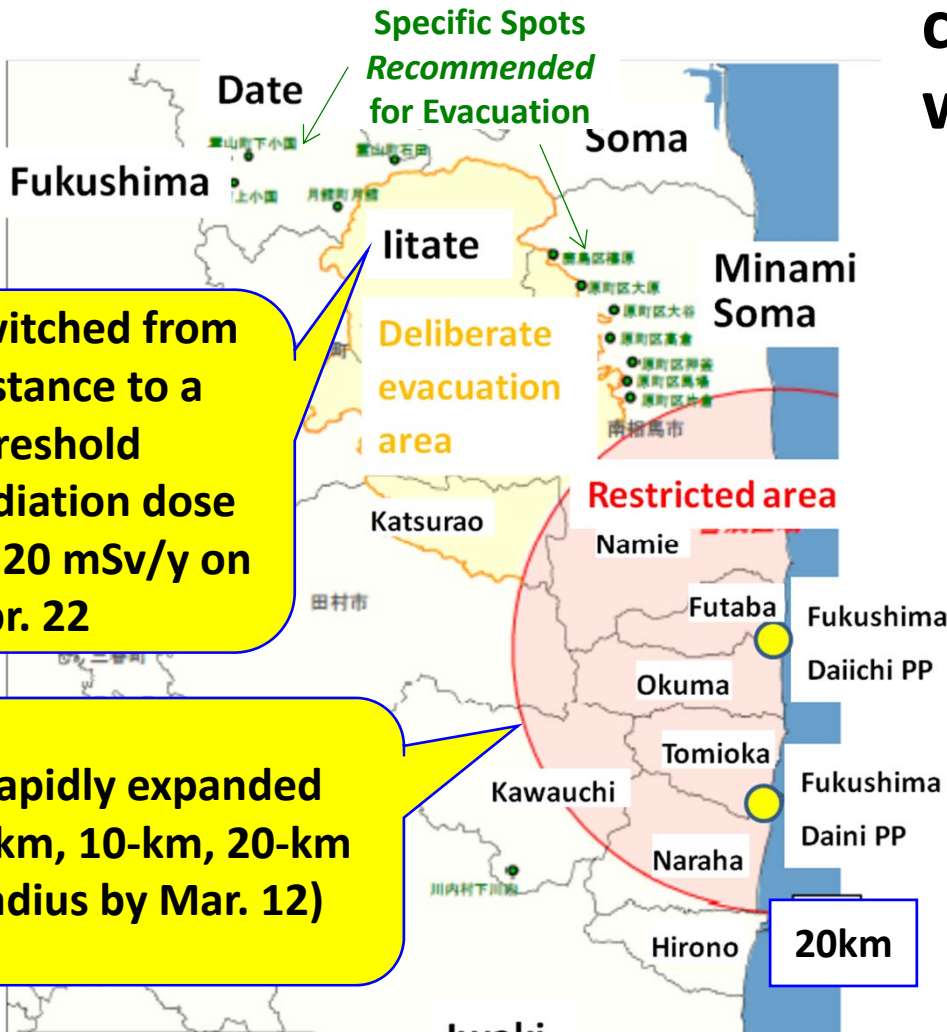
## Evacuation Order Areas

Designation of evacuation areas is completed just after the accident  
(Apr. 22, 2011)

## Food and water restrictions

●Regulatory limits for contaminated food and water based on

- <5 mSv/y (March 20, 2011)
- <1 mSv/y (April 1, 2012)



Category	Limit (Bq/kg)
Drinking water	10
Milk	50
General Foods	100
Infant Foods	50



# Environmental Monitoring

## Result of Estimation (External Exposure)

Target	Reply	Estimate	Notice
2,055,305	565,904 (27.5%)	551,510 (97.5%)	551,110 (97.4%)

**For 4 months after accident  
Excluding occupationally exposed person**

Effective Dose	Less than 1mSv	1~2 mSv	• •	Over 15mSv	Total
Number	288,401	146,701	• •	15	463,659

**Max.:25mSv**

**2016.12.27, Fukushima pref.**

## Result of Estimation (Internal Exposure)

Committed Effective Dose	Less than 1mSv	1mSv	2mSv	3mSv	Total
Number	316,496	14	10	2	316,522



**2017.1.30, Fukushima pref.**





# Decontamination and Volume Reduction

## Recommended Clean-up Technologies

Land use classification		Comprehensive evaluation	
	Forest	◎Removal of leaf litter and humus layers (on flat ground and slopes), ○Removal of leaf litter, humus layers and topsoil (on flat ground), ▲Trunk washing, ○Branch trimming in the lower part (evergreen tree)	
	Farmland	◎Machine that strips off surface of soils, ○Backhoe (stripping off depth of 5 cm of the soil), ◎Reversal tillage (by tractor and plough), ○Ploughing to replace surface soil with subsoil (by backhoe)	
Residential area	Roof	▲High pressure water, ○Brushing, ○Wiping, ▲Apply a remover	
	Gutter	△High pressure water, ○Wiping	
	Wall	○Brushing	
	Topsoil	○Removal of topsoil	
	Rubble	○Washing of the rubble, ○Removal of the rubble	
	Turf	○Removal of the Turf	
	Garden tree	▲Clipping a garden tree	
Large structure	Interlocking block	△High pressure water	
	Concrete and Mortar surface	△Sanding machine with the dust-collection (Plane which scrapes concrete), ○Ultrahigh pressure water (Over 150MPa), ○High pressure water (10-20MPa), ○Iron shot blasting	
	Roof floor	Concrete surface	○High pressure water (including brushing)
		Waterproof coating surface	○High pressure water (including brushing)
		Downpipe	○High pressure water(Maximum 50MPa)
	Playing field	○Strips off surface of soils (Large mower+Sweeper), ○Strips off surface of soils (Road planers), ○Strips off surface of soils(Motor grader), ○Ploughing to replace surface soil with subsoil	
	Swimming pool	○High pressure water	
	Turf	○Turf stripper	
	Paved road	▲Road cleaners + Riding style road sweepers, △High pressure water (About 15MPa)+Brushing, △Car of a functional recovery drainage pavement, ○Ultrahigh pressure water (120~240MPa),○Iron shot blasting, ○TS Road planers	

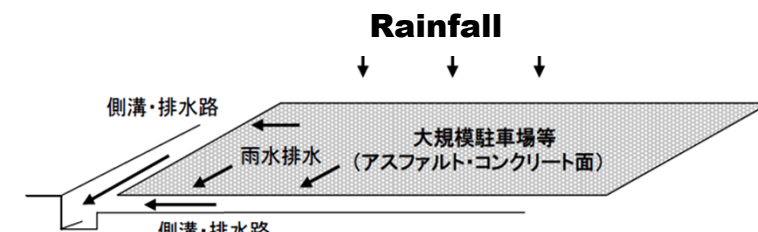
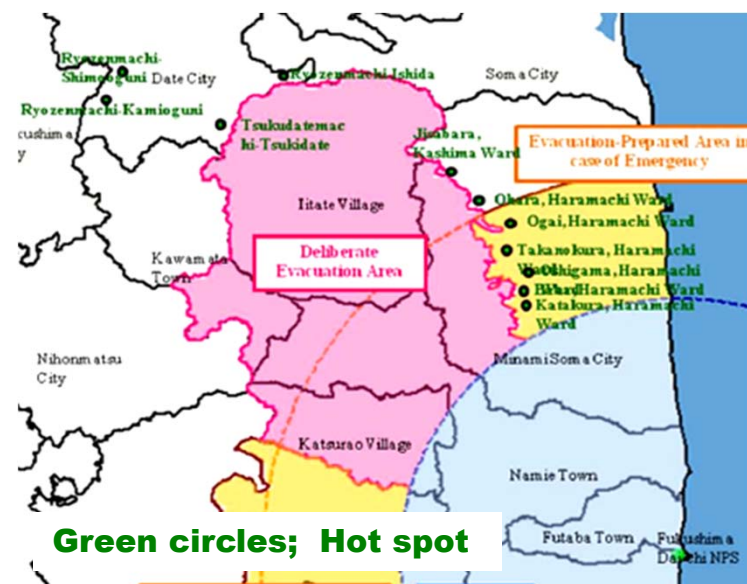
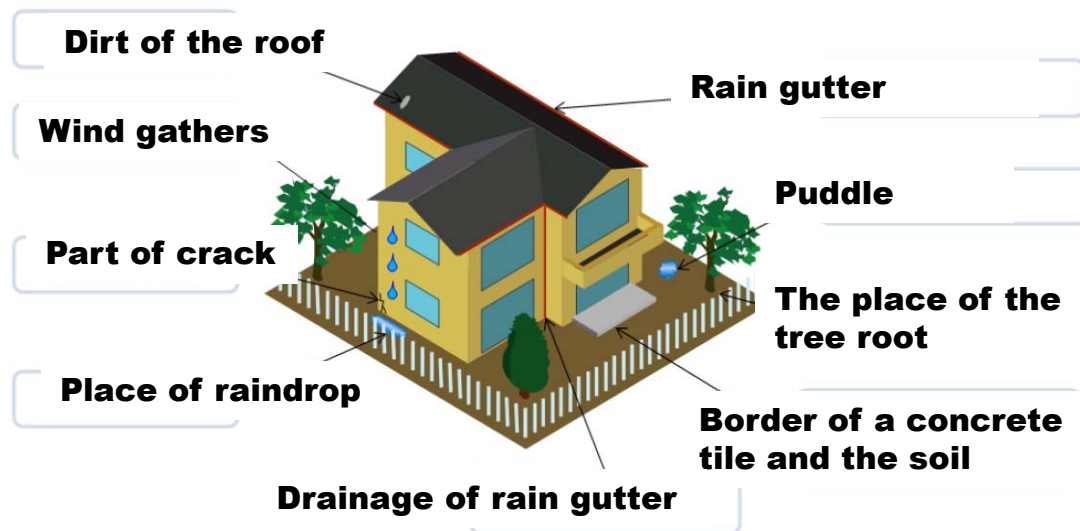


◎ : highly effective, ○ : effective, △ : moderately effective, ▲ : limited effect

## Hot spot monitoring

**Hot spots in evacuation area** /Geographical features  
e.g. Way of the wind in valley line and weather condition

### Places of hotspots around housing



**Cs is moved to drainage with rain water**

### Large pavement

Refer to MOF: "the Decontamination Guidelines ( in Japanese) "(2013), <http://josen.env.go.jp/en/>, and the Technical Advisory Council on Remediation and Waste Management: "The radiation measurement manual for confirmation of decontamination effect(in Japanese) "(2013)



# Decontamination and Volume Reduction

## Hot spot monitoring(continue)



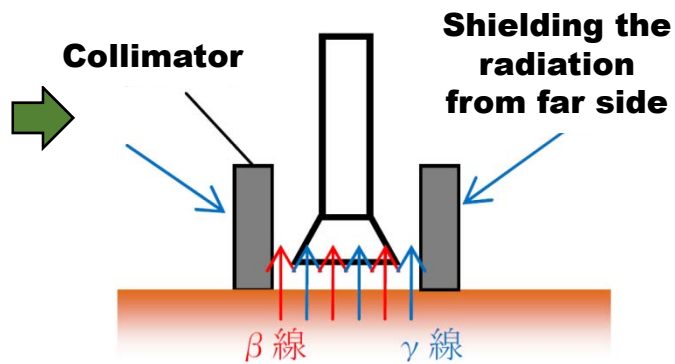
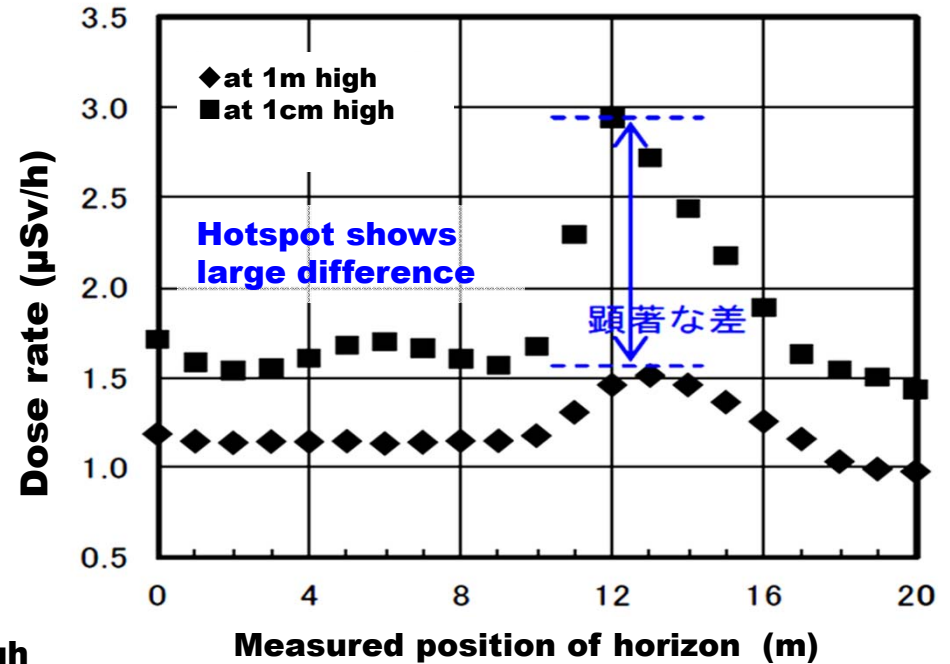
Survey for horizontal distribution of dose rate



Measurement at 1cm high



Measurement at 1m high

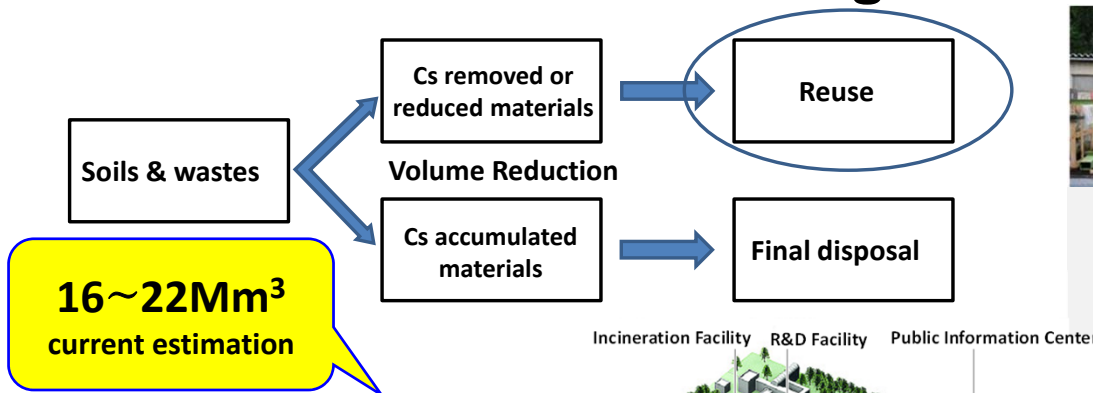


Surface soil sampling

Measurement using the Collimator to eliminate scatter radiation from far area

Refer to MOF: "the Decontamination Guidelines ( in Japanese) "(2013), <http://josen.env.go.jp/en/>, and the Technical Advisory Council on Remediation and Waste Management: "The radiation measurement manual for confirmation of decontamination effect(in Japanese) "(2013)

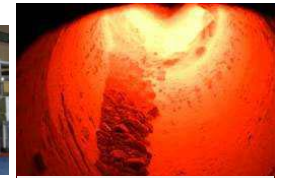
# Decontamination and Volume Reduction Waste Management Challenges



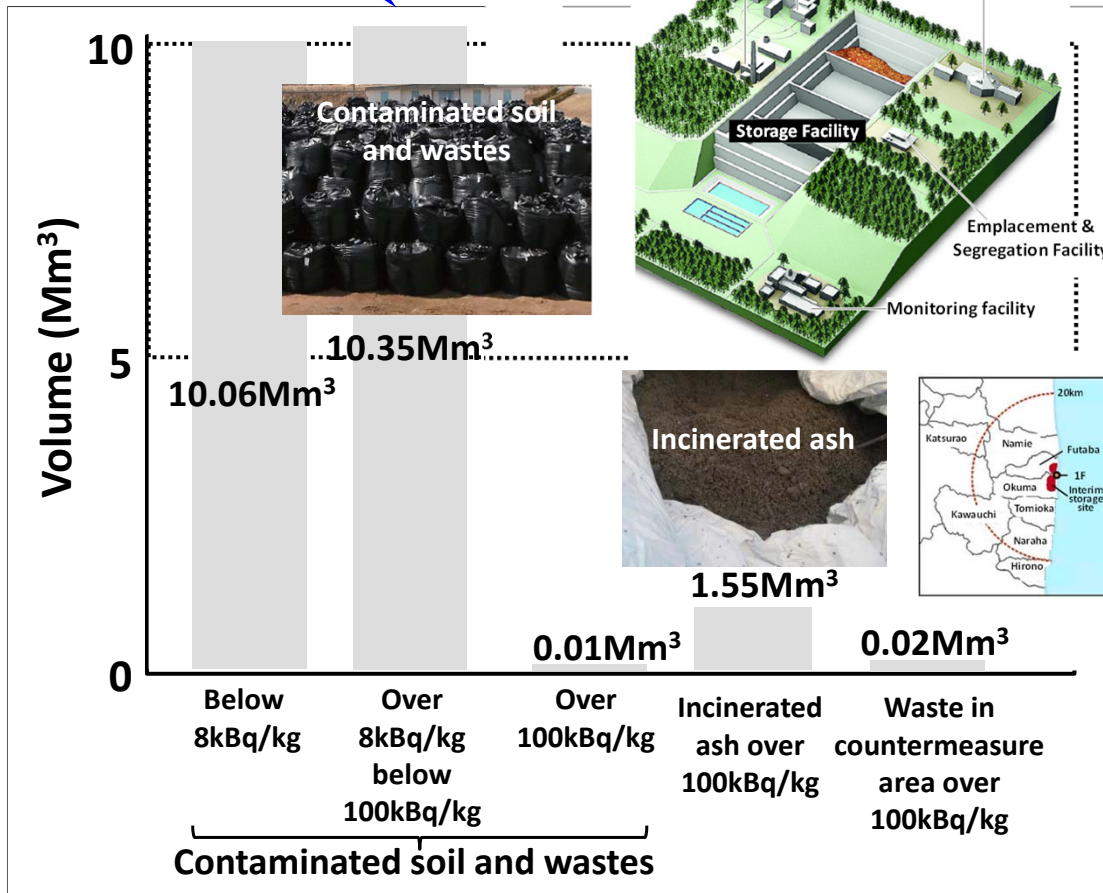
Wet sieving  
(particle-size  
Separation)



Chemical  
treatment



Heat treatment

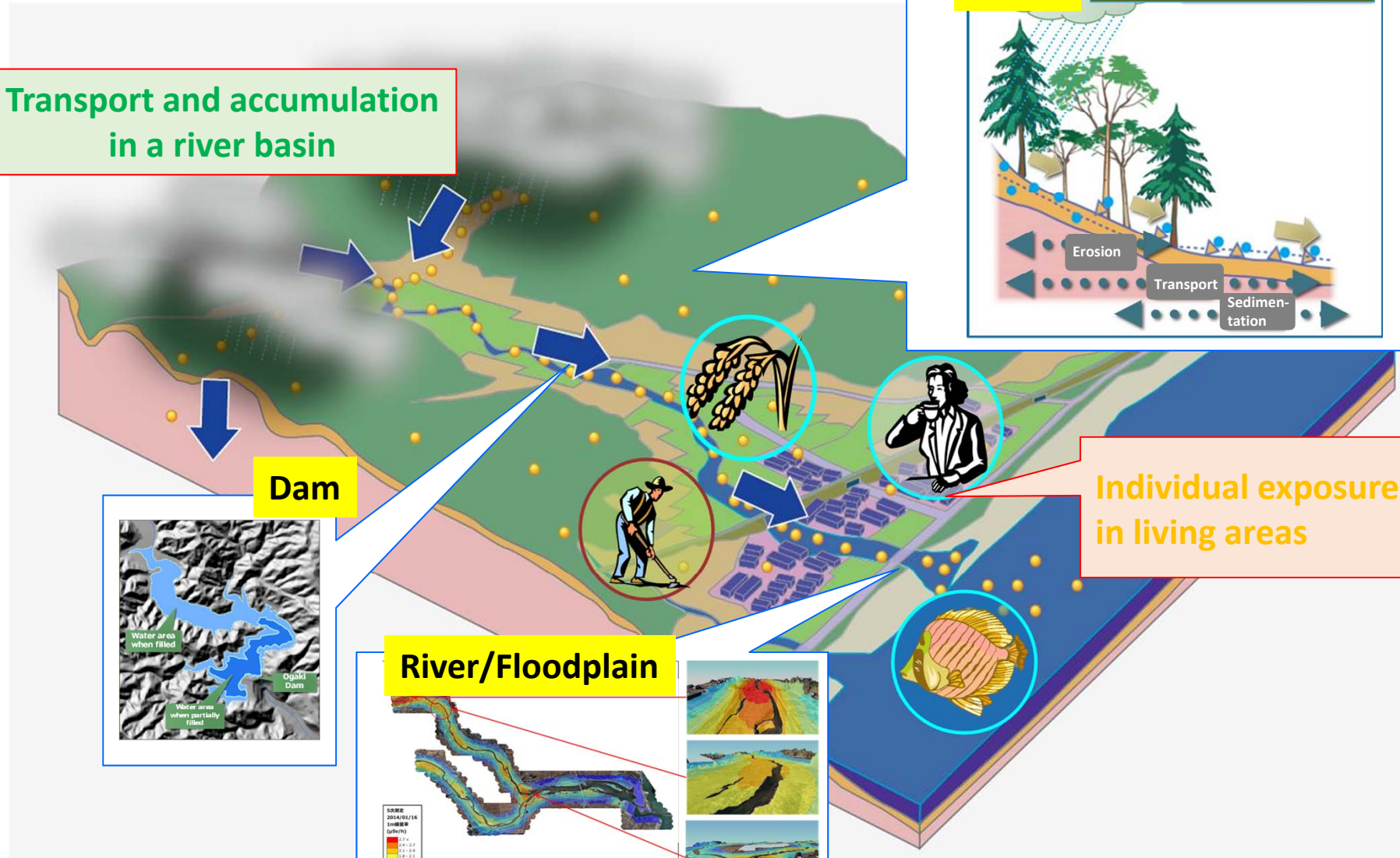


- Clean-up efforts are generating huge volumes of contaminated soil and waste, which must be managed in a safe and cost-effective manner, wherever possible implementing waste volume reduction
- Future reuse of soil for construction purposes is an important option, if constraints in terms of allowable organic and clay content can be managed

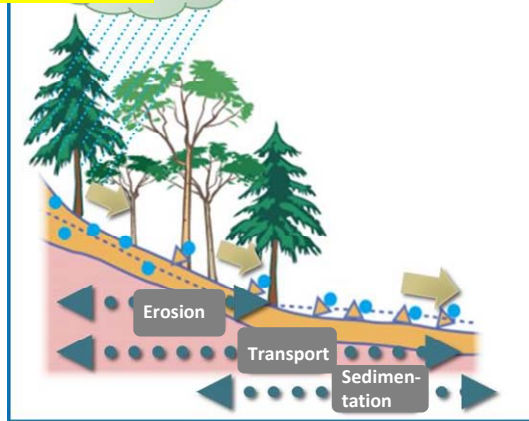


# Environmental Dynamics

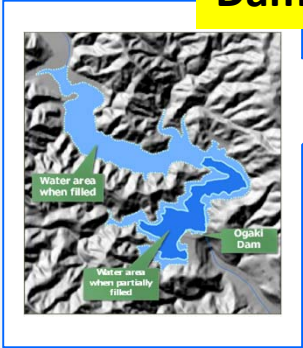
Transport and accumulation in a river basin



**Forest** Transport process

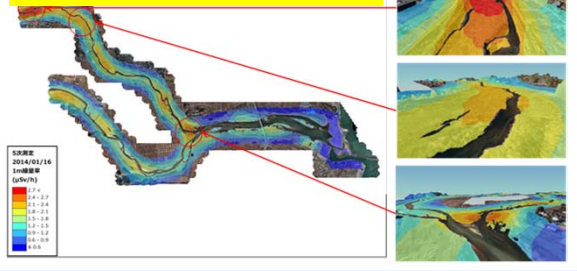


**Dam**



Individual exposure in living areas

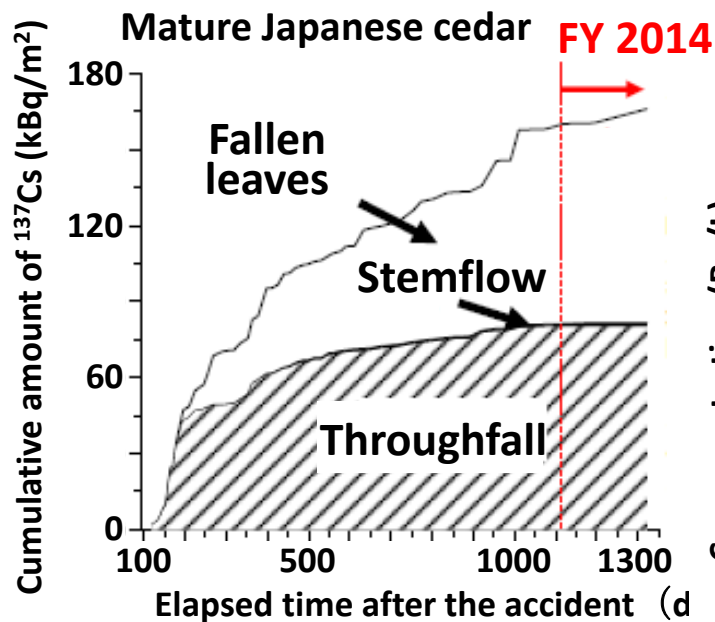
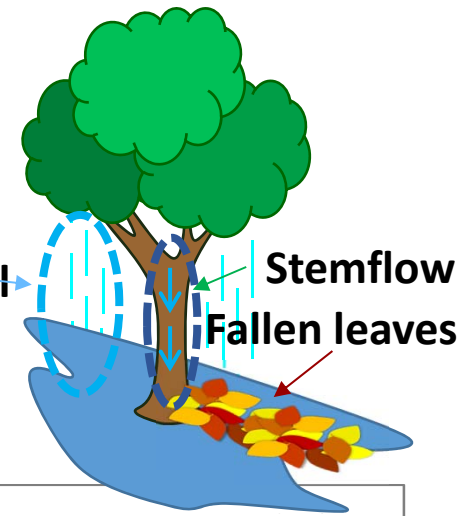
**River/Floodplain**



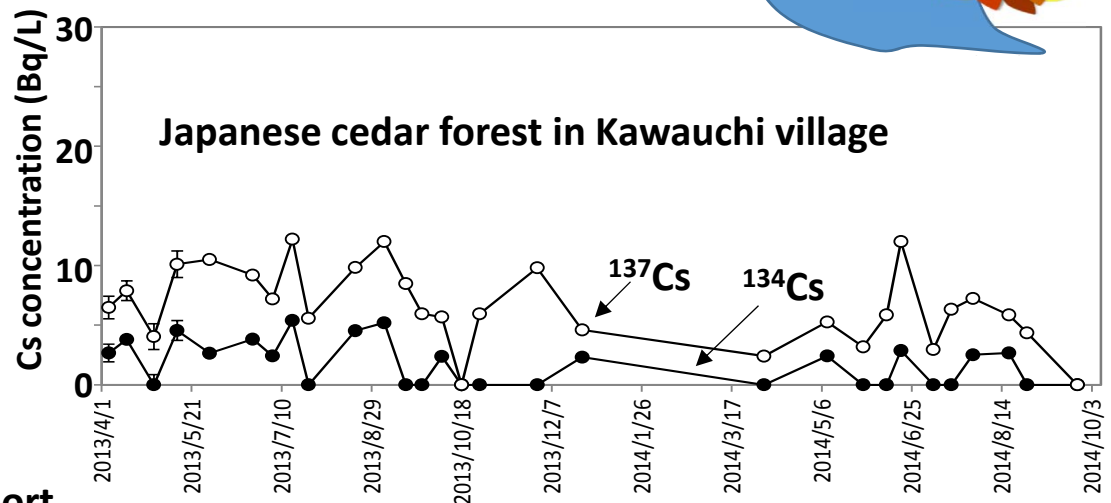
# Environmental Dynamics

## Cs Transport in the Forest

- Currently, most of Cs deposited on tree has transported to forest floor



Evolution of cumulative Cs due to transport from tree crowns to forest floor

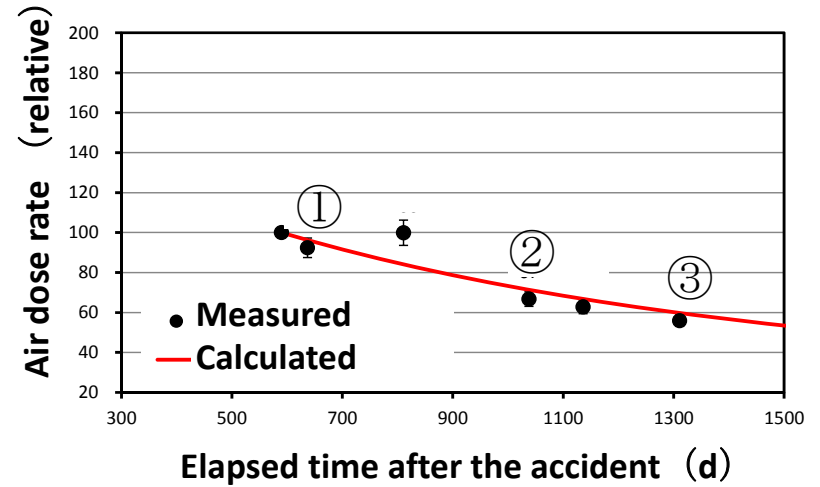
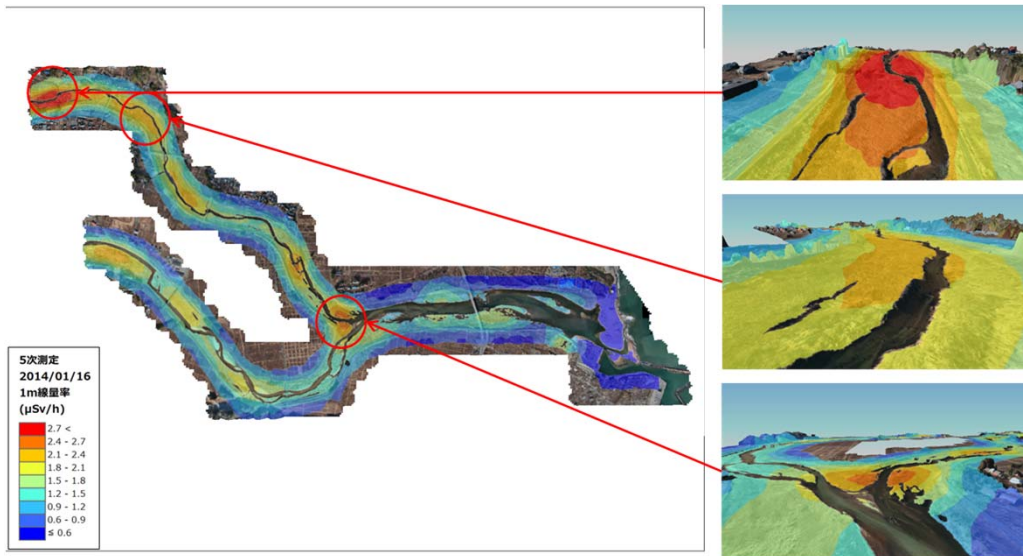


Evolution of Cs concentration in stemflow ( $\text{Bq}/\text{L}$ )



# Environmental Dynamics

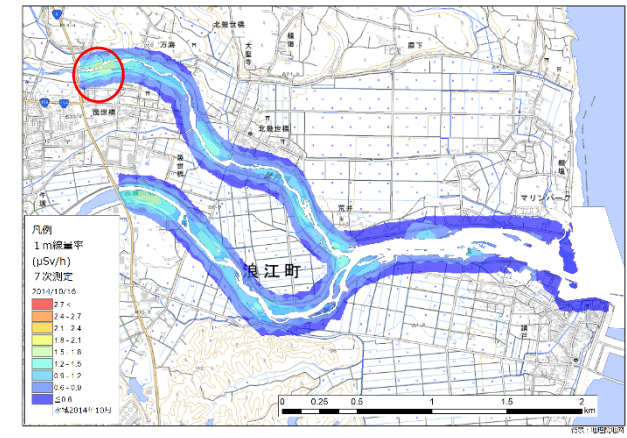
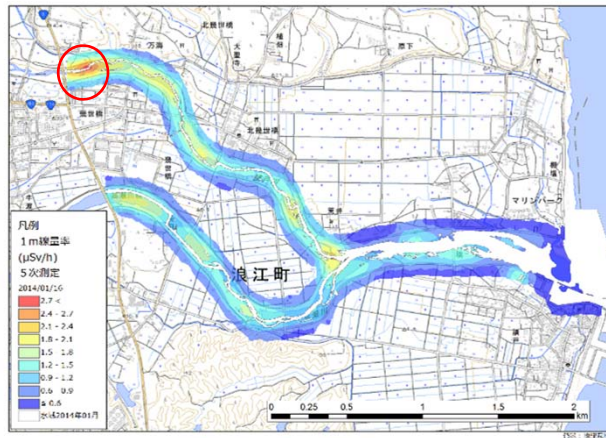
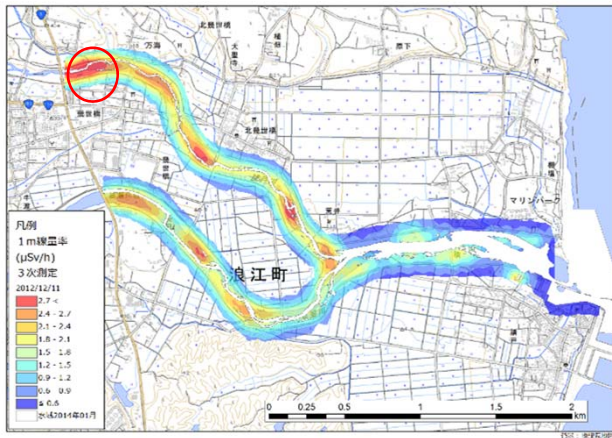
## Transport and accumulation in a river basin Recovery of a river system



① Dec. 11, 2012

② Jan. 16, 2014

③ Oct. 16, 2014





# Other Projects

## Human Resources Development and Communications

【Nagaoka University of Technology】  
2016. 9. 16～  
lecture and Practice



【Koriyama Women's University】  
2016. 9. 28～  
lecture and Practice

【National Institute of  
Technology, Fukushima  
College, 】  
2016. 11. 5～  
lecture and Practice







## Other Projects

# Knowledge and experience gained for Enhancing Fukushima Environmental Remediation

### ● Cleanup Navi

<http://c-navi.jaea.go.jp/en/>

The Cleanup-navi Communication Platform provides an overview of regional contamination due to the accident and approaches to remediation. It also includes background information on the nature of ionising radiation and its health effects to allow the user to make informed judgements as to the value of the remediation actions that are being undertaken.

### ● DPP reports

<http://fukushima.jaea.go.jp/english/outline/20150327.html>

Part 1 summarises the Decontamination Pilot Project, providing the background required to put this work in context for an international audience. In Part 2, the subsequent application of output from this project to regional remediation is discussed, along with a status update on such work (including radioactivity monitoring), an overview of JAEA's associated R&D and international input to / review of regional environmental decontamination in Fukushima.

### ● Lessons learned report

<http://fukushima.jaea.go.jp/english/outline/20150327.html>

This report provides a concise overview of knowledge and experience gained from the activities for environmental remediation after the Fukushima Daiichi accident. It is specifically tailored for international use, to establish or refine the technical basis for strategic, off-site response to nuclear incidents.



## Summary

- ✓ **JAEA had been acted many projects (Environmental monitoring, Decontamination, etc.) in Fukushima as a first response**
- ✓ **Environmental Dynamics of Cs is studying as a long term basic research**
- ✓ **Harmonization between science and communications (Public Acceptance) were very important**