Technical Volume 5

‘Post-Accident Recovery’

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Technical Volume 5: The Major Attributes

- The **road to recovery** after such a major accident is inevitably long:
  - It is a road with many difficulties, but experience with recovery and revitalization projects also would suggest one of opportunities.
- Vol. 5 analyses the **early steps towards post-accident recovery**, up until June 2015, and also the plans for the way ahead.
- To put the recovery effort in Japan in perspective:
  - This is the **largest remediation/decommissioning programme** ever attempted following a major nuclear accident.
- There are some good **indicators of success** in terms of, e.g.:
  - The ability of some evacuees to return;
  - Areas of land that are able to revert to normal use;
  - All damaged nuclear reactors have been stabilized and preparations are in place for their eventual decommissioning.

Technical Volume 5: Two-fold Objective

1. To provide a **comprehensive description of the recovery**, both on-site and off-site, following the emergency phase of the Fukushima Daiichi accident.
   - This is an important component, since until now, the information on the recovery is widely dispersed
2. To draw conclusions on these facts and to **formulate lessons learned**:
   - What do we know about the recovery from the Fukushima Daiichi accident?
   - What is the status and effectiveness of remedial and management actions?
   - Which findings are specific for the Fukushima Daiichi accident?
   - What general findings are useful for the international community to enhance nuclear safety worldwide?

Technical Volume 5: Scope

The scope is determined by the recovery activities and where they sit in the timeline for the progression of the accident:

- **Phase 1 (emergency phase):** From March 2011 to December 2011 ('cold shutdown state' officially brought the accident phase of events to a close). This period is covered in Technical Volumes 1–3.
- **Phase 2 (transitional phase):** This phase covers an indeterminate period of time with regard to off-site remediation, with some aspects beginning as early as 1 April 2011 and continued until the end of March 2012.
- **Phase 3 (existing exposure situation):** This period is considered to have begun in December 2011 for on-site stabilization and decommissioning, and in April 2012 for off-site remediation.

The Fukushima Daiichi Accident

Technical Volume 5, Section 5.1

BACKGROUND TO POST-ACCIDENT RECOVERY

5.1. Background to Post-Accident Recovery

- Immediately following the accident, **priority was given to stabilizing the plant** and to ensure safety of the public.
  - Measures taken included the evacuation of residents from selected areas and the radiological monitoring of food.

- As **conditions improved, greater emphasis was given to off-site recovery** including the re-establishment of an acceptable environment, infrastructure, and community.

5.1. Background to Post-Accident Recovery

- Recovery means the **achievement of conditions** within which **society** can again **fully function**, as:
  - **Stabilization** of the damaged reactors leading towards eventual dismantling;
  - **Remediation** of affected areas to reduce radiation doses to people to an acceptable level;
  - Effective and safe **management of contaminated material and radioactive waste** leading to its ultimate disposal; and
  - **Re-establishment of infrastructure** and the revitalization of communities.

- However,
  - the goal of a return to a ***condition of normality*** cannot mean a return to the same situation that existed prior to the accident.
  - It is to be expected that, even after remediation, **some constraints** on people's ways of life **may remain** in some specific areas.

5.1. Background to Post-Accident Recovery

Definition of 'normality'

- The expectation of recovery is that many aspects of a ***new normality*** will be at least equivalent to the pre-accident quality of life, and, wherever possible, enhancements of lifestyle experiences can be achieved.
- What is meant specifically by ***'normality'*** is not easily defined, nor will the definition be universally agreed upon. Indicators of a revitalized infrastructure and community are:
  - a place to call home and a sense of **safety**;
  - **community structures** including facilities for health and aged care, education and leisure,
  - stability and the certainty of governing structures;
  - availability of **employment**, including opportunities for farming and local food production;
  - the involvement of **stakeholders** in decision-making.

The Fukushima Daiichi Accident

Technical Volume 5, Section 5.2

REMEDIATION STRATEGY

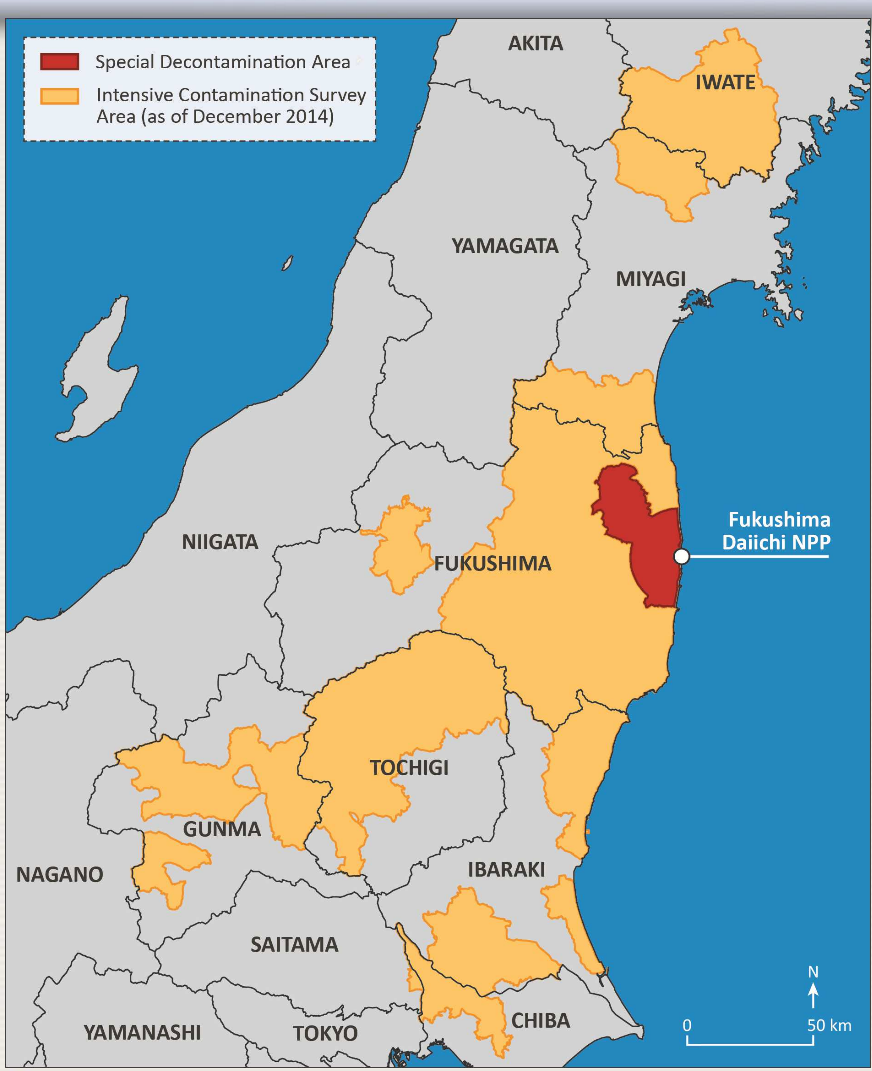
5.2. Remediation policy

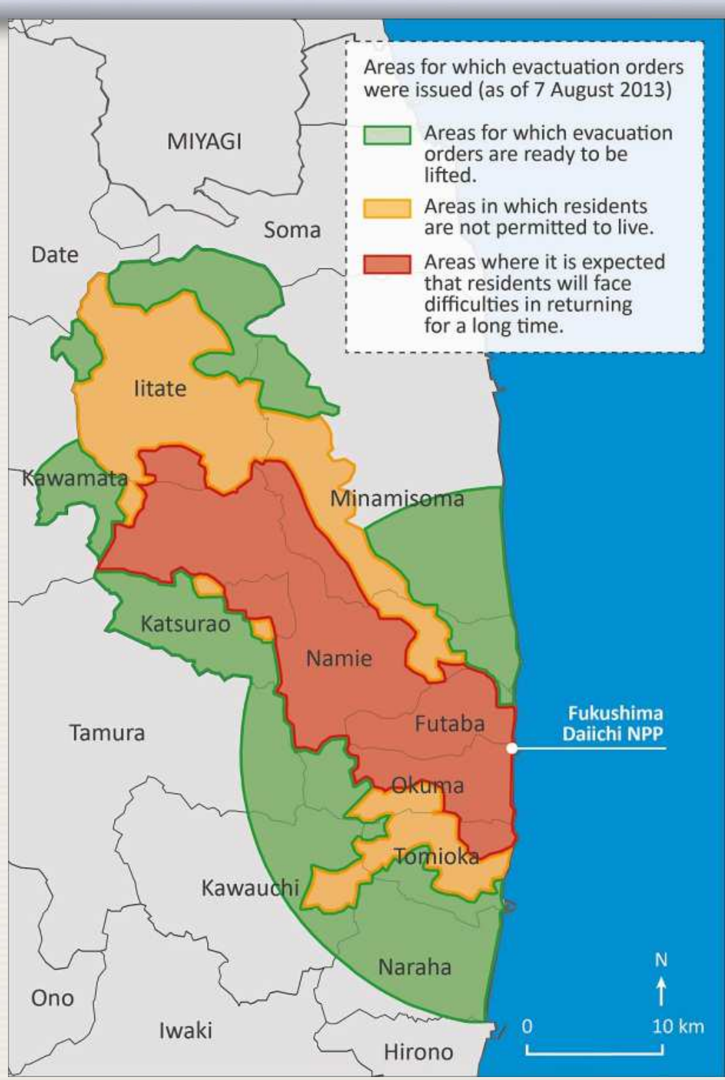
- **Prior to the accident, no policies and strategies** for post-accident recovery existed in Japan; they were developed in the period after the accident.
- The **aftermath of an accident is not an ideal time to develop frameworks** for accident recovery.
  - In particular, it is difficult to involve stakeholders in determining the recovery criteria and strategies.
- Preparedness for post-accident recovery is distinct from emergency preparedness planning.
- In 2011, the goals for dose reduction were determined to reduce the additional radiation dose due to the accident to a ***'reference level'*** of **1 mSv/y or lower <u>on the long term</u>**.

5.2. Remediation strategy

- **Internal doses were largely avoided** through restrictions on food and drinking water.
- Remediation actions **focused on efforts to reduce external doses**.
- A **stepwise approach was set up to reduce doses**
  - In residential areas and farmland,
  - Forest areas **close** to residential or agricultural areas.
- In 2011, the affected area was separated **according to the additional annual doses for** individuals:
  - ***Special decontamination area*** – (SDA) comprising evacuation zones where doses could exceed 20 mSv in the 1st year.
    - Responsibility for remediation is with the national government.
  - ***Intensive contamination survey area*** – (ICSA) municipalities where doses in the 1st year were estimated to be between 1 and 20 mSv.
    - Municipalities identify areas requiring decontamination, and plan and carry out remediation activities.

5.2. Remediation - Areas





5.2. Remediation - Progress

Pilot studies

- Many small-scale studies were performed **to test the effectiveness** and applicability of **decontamination techniques** and to establish procedures for radiation protection of workers.

Important remediation techniques

- **Topsoil removal**, which generates a large amount of waste, was widely used in the first years of remediation.
- **Cleaning roofs and walls**, high-pressure washing, removal of branches and leaves in forests.
- **Soil treatment** (enhanced fertilizer application), ploughing, etc.

Progress in Remediation in the ICSA (March 2015)

- Outside the Fukushima Prefecture: Remediation **completed in about 80% of the municipalities**.
- Within the Fukushima Prefecture: Around **90% of the public facilities**, **60% of residential houses** and **50% of roads** had been decontaminated.

5.2. Remediation – before and after

Landscapes before and after remediation in Tamura City.

5.2. Remediation – Monitoring of food

Bags of locally grown rice are screened for possible contamination in Motomiya City.

5.2. Remediation – Observations and Lessons

- **Pre-accident planning** for post-accident recovery **is essential** to avoid decision-making under pressure in the post-accident situation.
- When choosing a reference level for remediation, it must be clearly understood that this level is a ***long-term target***.
- Remediation **strategies need flexibility** and need to consider:
  - **Decay** of the radionuclides, and **natural weathering and migration processes**;
  - **Resource constraints** (funds, storage/ disposal capacities, manpower);
  - **Effectiveness of measures** and amount of contaminated material generated.
- As part of the remediation strategy, rapid implementation of rigorous **food monitoring** is key to minimize ingestion doses.
- Further international guidance is needed on **the practical application of safety standards** for radiation protection in post-accident recovery.

The Fukushima Daiichi Accident

Technical Volume 5, Section 5.3

ON-SITE STABILIZATION AND PREPARATIONS FOR DECOMMISSIONING

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5.3. On-Site Stabilization and Preparations for Decommissioning

- ***'Decommissioning'*** refers to the administrative and technical actions taken for removal of regulatory controls from a facility.
- It involves the removal of the facility's structures, systems and components. Under normal circumstances, it is a planned activity initiated after the decision to end operations.

- **Post-accident decommissioning** presents a different set of challenges:
  - **Conditions of the facilities** and the **status of the fuel** and the plant equipment need to be determined.
  - This may require development of new technologies and methodologies.
- If reactor shutdown is due to an accident, a safe configuration (***'stabilization'***) is necessary before approving a decommissioning plan
  - Stabilization comprises actions to ensure stable and functioning plant structures, systems and components

5.3. On-Site Stabilization and Preparations for Decommissioning

Strategic planning

- Following the emergency phase, TEPCO and government agencies established a strategic plan - the **‘Roadmap towards Restoration from the Accident**’ - for stabilization and decommissioning.
  - **First issued in December 2011**, the plan has subsequently been revised to take account of improved understanding of the on-site conditions.
  - Decommissioning is projected on a **timescale of 30 – 40 years**.

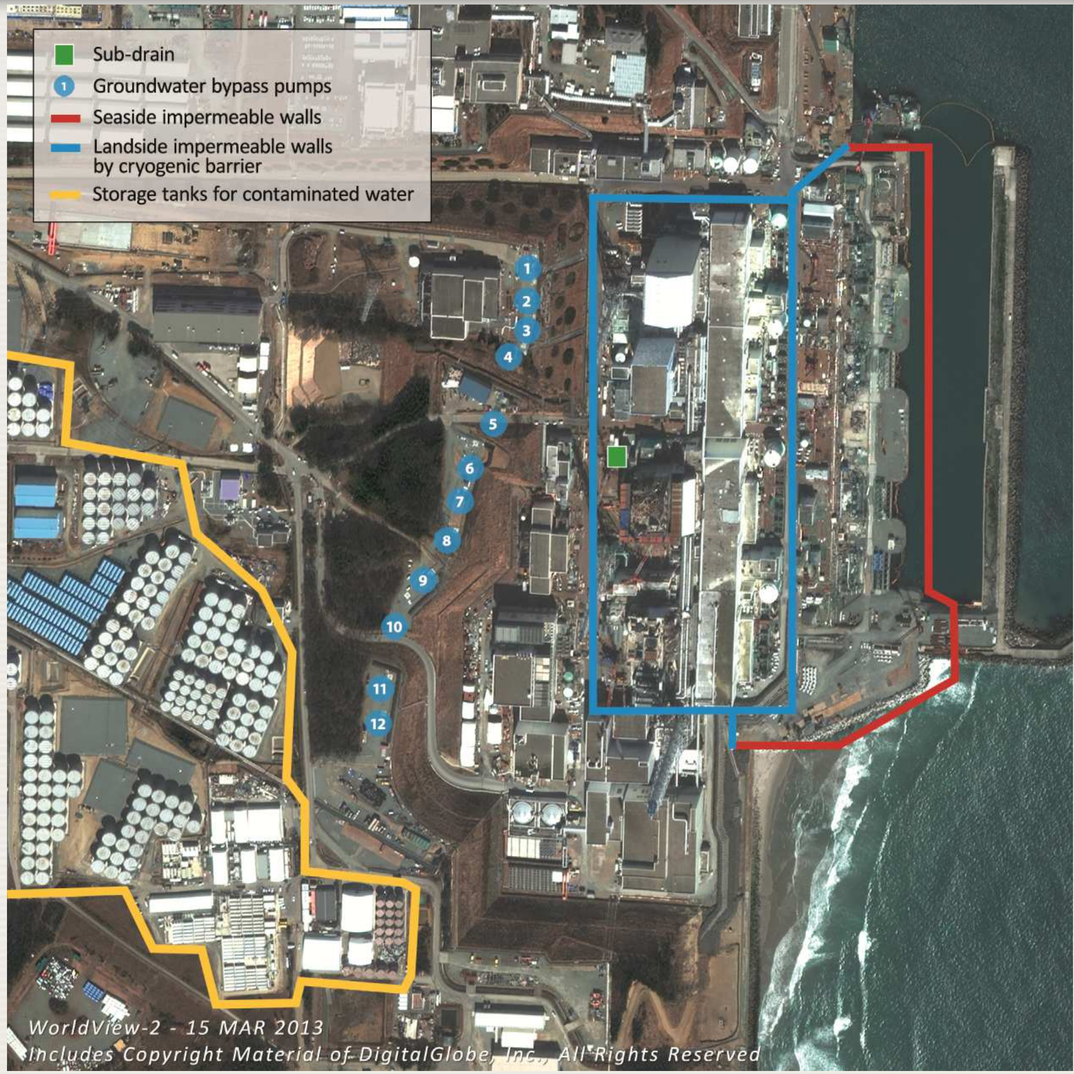
- **Safety functions have been re-established** for long-term reliability of stable conditions, including:
  - Monitoring of plant conditions, backup electrical supplies, structural stability;
  - Cooling systems for fuel and fuel debris, and controlling hydrogen levels.

5.3. On-Site Stabilization and Preparations for Decommissioning

Management of contaminated water

- **Water** entering the reactor buildings becomes contaminated and **is a challenging problem** due to the large volumes involved.
- Two sources of water exist:
  - **Water** being **injected into the reactor** cores for cooling purposes;
  - There is an ongoing **ingress of groundwater**.
- Various water management techniques have been applied, or are being planned, including:
  - Improvement and installation of **treatment** systems and **storage** tanks;
  - **Restoration of the sub-drain system** and installation of sea-side impermeable walls;
  - **Bypassing of uncontaminated groundwater** from uphill of the damaged facilities around the facilities and into the ocean; and
  - A **cryogenic 'frozen' wall** around the reactor buildings is under construction to prevent further water ingress.

5.3. On-Site Stabilization and Preparations for Decommissioning



Water management efforts

5.3. On-Site Stabilization and Preparations for Decommissioning

Management of contaminated water

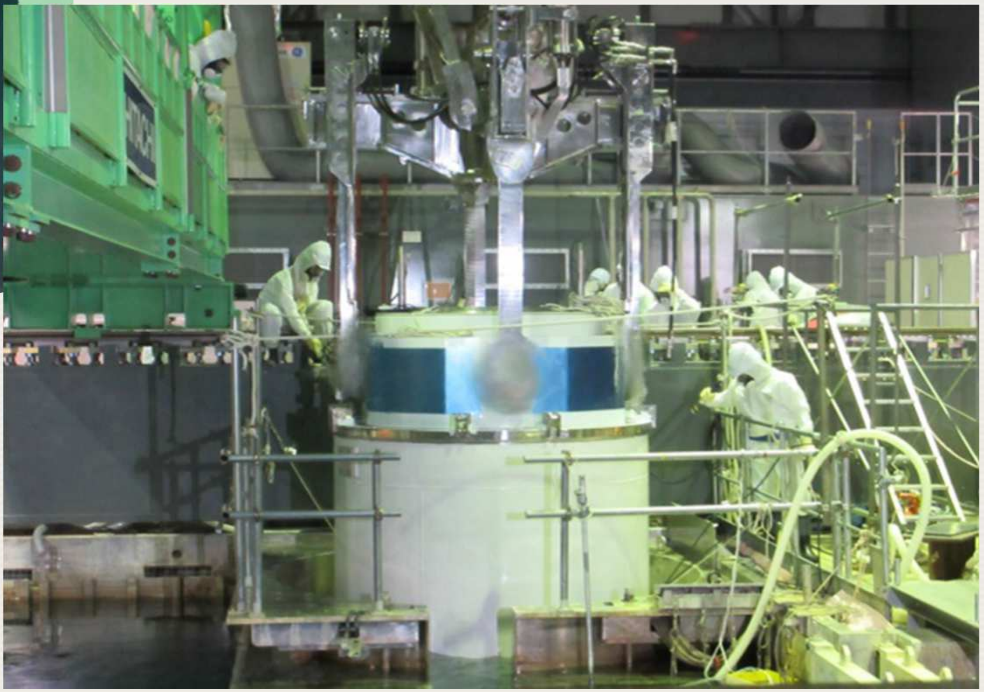
- The large quantities of contaminated water on the site present certain risks.
- Owing to **malfunctions** of tanks, pipes and valves or during heavy rainfall:
  - **Leaks of radioactively contaminated water** have been observed.
  - In some cases, the leaks led to releases of radionuclides to the sea.
  - Such leaks **triggered more intensive monitoring**, both on the site as well as in the marine environment.
- Although measures are being implemented to stop or reduce the leakage, more sustainable solutions are needed:
  - All options need to be considered,
  - including the **possible resumption of controlled discharges to the sea**.

5.3. On-Site Stabilization and Preparations for Decommissioning

Removal of spent fuel and fuel debris

- Preparation for decommissioning includes removal of spent fuel and new fuel assemblies from storage pools inside the damaged reactor buildings.
  - **Removal of fuel** from Unit 4 storage pool into the common spent fuel pool was completed in December 2014.
  - **Several years** will be required **to remove** the spent fuel and new fuel assemblies from the storage pools in Units 1–3.
- **Removal and management of debris** from the melted fuel in the reactor cores is much more complex.
  - Visual confirmation of configuration and composition of the damaged fuel (‘fuel debris”) was not yet possible due to high radiation levels
  - Conceptual studies are in progress to explore access removal of fuel & fuel debris.
  - New technologies for removal of fuel & fuel debris are being developed.

5.3. On-Site Stabilization and Preparations for Decommissioning



Removing the transport cask from the spent fuel pool

Fuel assemblies in storage racks within the spent fuel pool

5.3. On-Site Stabilization and Preparations for Decommissioning – Observations and Lessons

- Following an accident,
  - a **strategic plan** for achieving and maintaining **long term stable conditions** and for the decommissioning of accident-damaged facilities is needed.
  - It needs to be **flexible and readily adaptable** to changing conditions and new information.
- Once on-site stabilization has been achieved,
  - the **long term reliability of essential structures**, **systems and components** needs to be assured and maintained.
- Cooling fuel of a damaged nuclear reactor may require large volumes of water that will entail treatment, conditioning and storage.
- Characterizing and removing damaged fuel & fuel debris **necessitate accident-specific solutions** and may need the development of special methods and tools.

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Technical Volume 5, Section 5.4

MANAGEMENT OF CONTAMINATED MATERIAL AND CONTAMINATED WASTE

5.4. Management of Contaminated Material and Radioactive Waste

Sources of waste

- **On-site,** activities for stabilization of damaged NPPs generated large amounts of contaminated solid and liquid material and radioactive waste:
  - Building **debris and trees**;
  - Large volumes of **water** with high concentrations of radionuclides, oil and salt;
  - Contaminated water, resulting from ongoing reactor cooling and groundwater leakage into the reactors;
  - Damaged and **spent nuclear fuel**.
- **Off-site**, large amounts of contaminated soil and waste were generated during the remediation and as consequence of the tsunami.

5.4. Management of Contaminated Material and Radioactive Waste - Challenges

- Waste quantities are much larger compared with waste originating from routine operations.
- **Large quantities of on-site and off-site waste** with varying physical, chemical and radiological properties were managed in an urgent manner
  - It has required enormous efforts for segregation, treatment, conditioning, transportation, storage and future disposal.
  - Amendments were required to legislation and to the national approach to radioactive waste management.
- The quantities of contaminated material arising from off-site remediation have presented **difficulties in establishing storage** places.
  - Several hundred temporary storage facilities have been established in local communities.
  - Efforts to establish an interim storage facility are on-going.

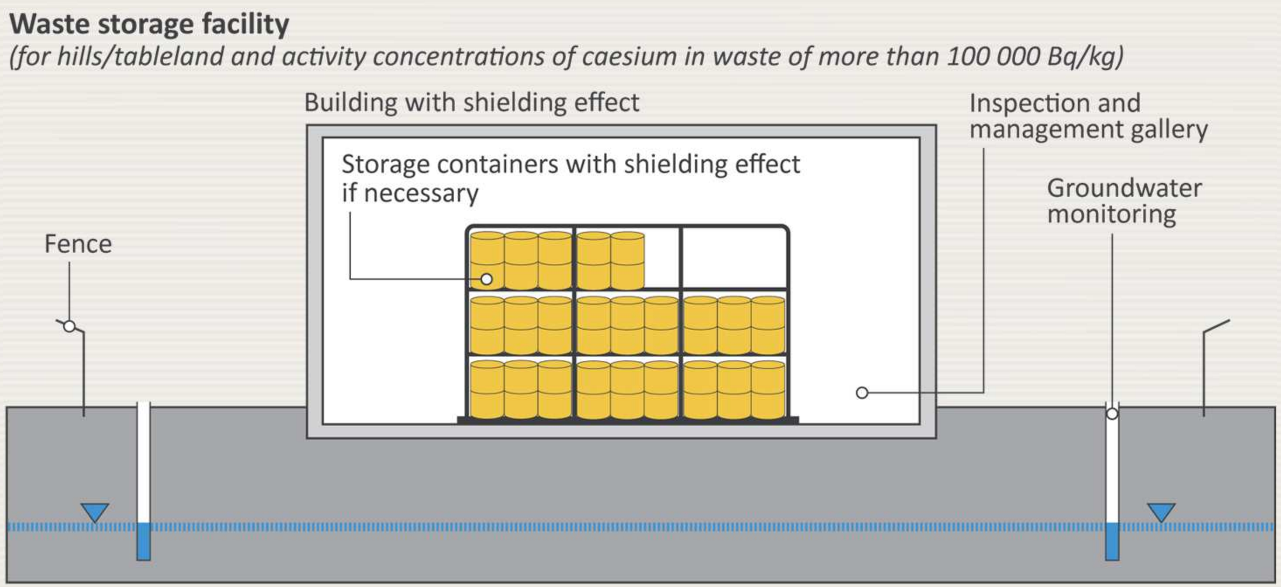
5.4. Management of Contaminated Material and Radioactive Waste – Storage

- Contaminated soil and remediation waste are to be collected and stored at, or near, the sites undergoing remediation in ***Temporary Storage Facilities***.
- Afterwards, the material will be placed in the ***Interim Storage Facility*** (ISF) for up to 30 years.
- ***Final disposal*** will take place outside the Fukushima Prefecture.


Examples of temporary storage sites

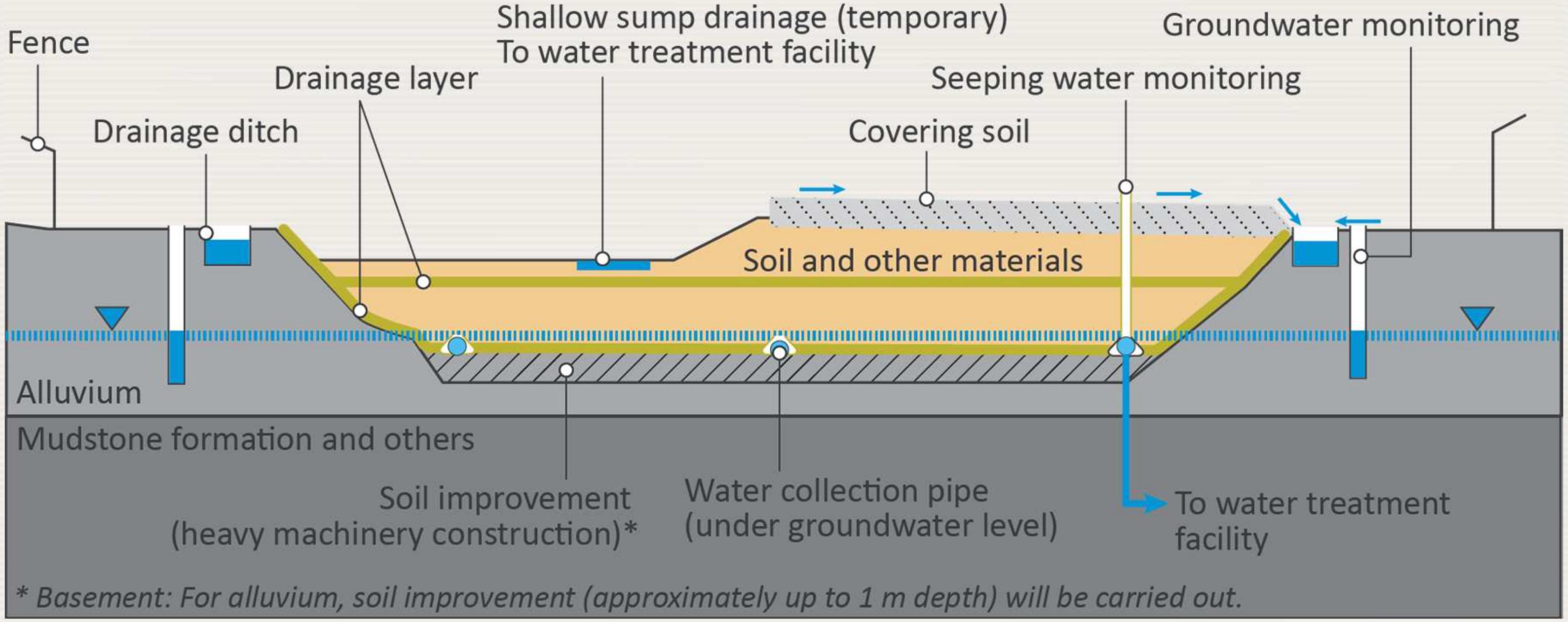
5.4. Management of Contaminated Material and Radioactive Waste – Storage

- ISF need to ensure **safety and complete control** over the contaminated materials (soil and waste) until a disposal site is available.
  - An ISF will consist of facilities for emplacement and segregation, volume reduction, storage, R&D, and monitoring.
  - Currently, sites have been identified to construct ISFs in Okuma and Futaba Towns.



5.4 Concepts of Interim Storage Facilities

Type-I soil storage facility
(for lowlands and activity concentrations of caesium in soil of up to 8000 Bq/kg)



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5.4. Management of Contaminated Material and Radioactive Waste - Disposal

- The **National Government** is responsible for the disposal of waste from decontamination operations.
  - Material that cannot be disposed of in conventional or special landfills will require the establishment of new disposal facilities.
- MOE has proposed building **new** designated **waste landfill** sites to dispose of designated waste.
  - Such facilities would be underground concrete structures covered with bentonite and soil and designed to prevent the migration of radionuclides out of the facility.
- Under Japanese law, there is **no limit on the total activity** that can be disposed of in such a facility.
- A **dose limit of 1 mSv/y** is applied for members of the public living in the vicinity of the facility.

5.4. Management of Contaminated Material and Radioactive Waste – Observations and Lessons

- Planning for post-accident recovery needs to include a **generic strategy for managing** contaminated liquid and solid **material and radioactive waste**
  - Such plans need to supported by generic safety assessments for discharge, storage and disposal facilities.
- Advance planning, prior to any accident, is needed for a framework:
  - **To regulate** contaminated material and radioactive waste generated during remediation is needed and
  - **To clearly define roles and responsibilities** of the various institutions involved.
- **Controlling the amount of contaminated material** generated during remediation is important.
- The availability of generic **storage and disposal** facility concepts would be beneficial.

The Fukushima Daiichi Accident

Technical Volume 5, Section 5.5

COMMUNITY REVITALIZATION AND STAKEHOLDER ENGAGEMENT

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5.5. Community Revitalization and Stakeholder Engagement

Societal aspects

- The nuclear accident and the radiation protection measures introduced, had **far-reaching consequences on the way of life** for affected communities.
- Consequences associated with **evacuation, relocation**, and agricultural restrictions are of particular note.
- The importance of the societal aspects of the **tsunami, earthquake and nuclear accident** are recognized, and physical and socioeconomic reconstruction is part of the recovery.
- **Revitalization** plans address various issues, such as the reconstruction of infrastructure, community support and compensation.

5.5. Community Revitalization and Stakeholder Engagement

Community and infrastructure revitalization

- The earthquake, tsunami and the accident at the NPP resulted in:
  - **Loss of infrastructure** (schools, hospitals and commercial enterprises);
  - Impacts on **trade and the economy**;
  - Demographic changes brought about by the movement of the population;
  - **Separation of families**.
- Economic development is closely linked with **consumer trust**:
  - Activities as agriculture and tourism, are vulnerable to changes in public confidence
  - Consumers can easily choose alternatives.
- A major **goal** of the post-accident recovery programme in the Fukushima region is that people will again **feel safe** living there.
  ➡ It is therefore important to answer the question that the community invariably asks, '**what is safe**?'.

5.5. Community Revitalization and Stakeholder Engagement

Stakeholder engagement

- The response to the accident has provided many examples underlining the benefits of **involving affected populations** in recovery:
  - From consultation and dialogue to remediation actions (***‘self-help actions’***).
- **Communication with the public** is a central part of revitalization:
  - An **information hub** (Decontamination Information Plaza) was opened in Fukushima City in January 2012.
  - It has been beneficial to **involve stakeholders in** decision-making processes, especially siting of storage and treatment facilities and other waste management activities.
- The accident highlights the **diversity of stakeholders** and challenges connected to their respective roles and responsibilities.
  - Different stakeholders have **different information needs**, and the communication needs to be adapted accordingly.

5.5. Community Revitalization and Stakeholder Engagement – Observations and Lessons

- It is necessary,
  - To recognize the **socioeconomic consequences** of any nuclear accident and of the subsequent recovery actions,
  - To develop projects that address **reconstruction of infrastructure, community revitalization and compensation**.
- **Self-help activities** by local residents - as monitoring and participation in remediation - are important mechanisms:
  - Such actions foster understanding of remedial measures and providing the public with **a degree of control over their situation**.
- **Involvement of the affected populations** in decision making and remediation:
  - Essential for success, acceptance and efficiency of recovery**.**

The Fukushima Daiichi Accident

Technical Volume 5, Appendix I

PILOT DEMONSTRATION PROJECT FOR REMEDIATION IN JAPAN

APPENDIX I. Pilot Demonstration Projects for Remediation in Japan

- **Describes testing of remediation measures** carried out for residential areas, agricultural land, aquatic ecosystems and forests.
- **Demonstration projects** and field based experimental studies (in 2011) to identify the remediation measures that are most effective and suitable for implementation in Japanese conditions.
- Several factors led to the decision to test the measures in Japan, as:
  - The need **to assess the effectiveness** and applicability of remediation solutions to the site-specific conditions prevailing in Japan;
  - Lack of experience in Japan in dealing with the remediation of large areas;
  - The need to **collect site-specific information** on effectiveness in dose rate reduction associated with individual remediation measures;
  - The need to **train workers** on the use of different equipment to be used in remedial work, with a focus on ensuring radiation safety of workers.

Annexes

There are four annexes (included on the CD-ROM attached to Volume 5):

- **Annex I** provides an overview of reference levels for remediation and of the development of a comprehensive framework for post-accident recovery.
- **Annex II** includes information on international best practices for assessing recovery operations.
- **Annex III** provides an outline of the guidelines on the scope of nuclear damage.
- **Annex IV** includes a comparative analysis of remediation strategies and experience after the Fukushima Daiichi accident and the Chernobyl accident.

THANK YOU