中興工程顧問股份有限公司
SINOTECH ENGINEERING CONSULTANTS, LTD

Current Status of Low Level Radwaste Disposal Technical Development in Taiwan, LLWD2024 summary

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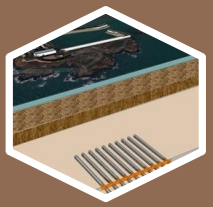
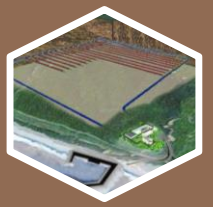
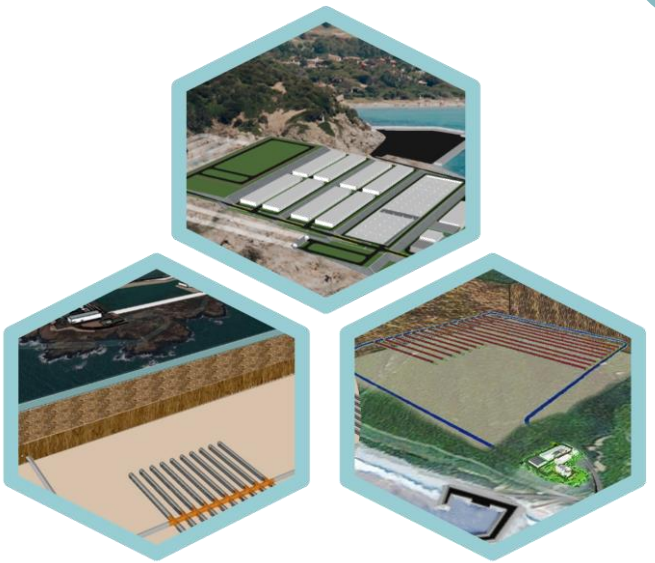
21 Oct. 2024

Outline

1. The Introduction of LLWD Project.
2. The Current Status of the Final Disposal Plan.
3. Recent Developments in LLWD Project.
4. Next Phase of Development.

1 The Introduction of LLWD Project.

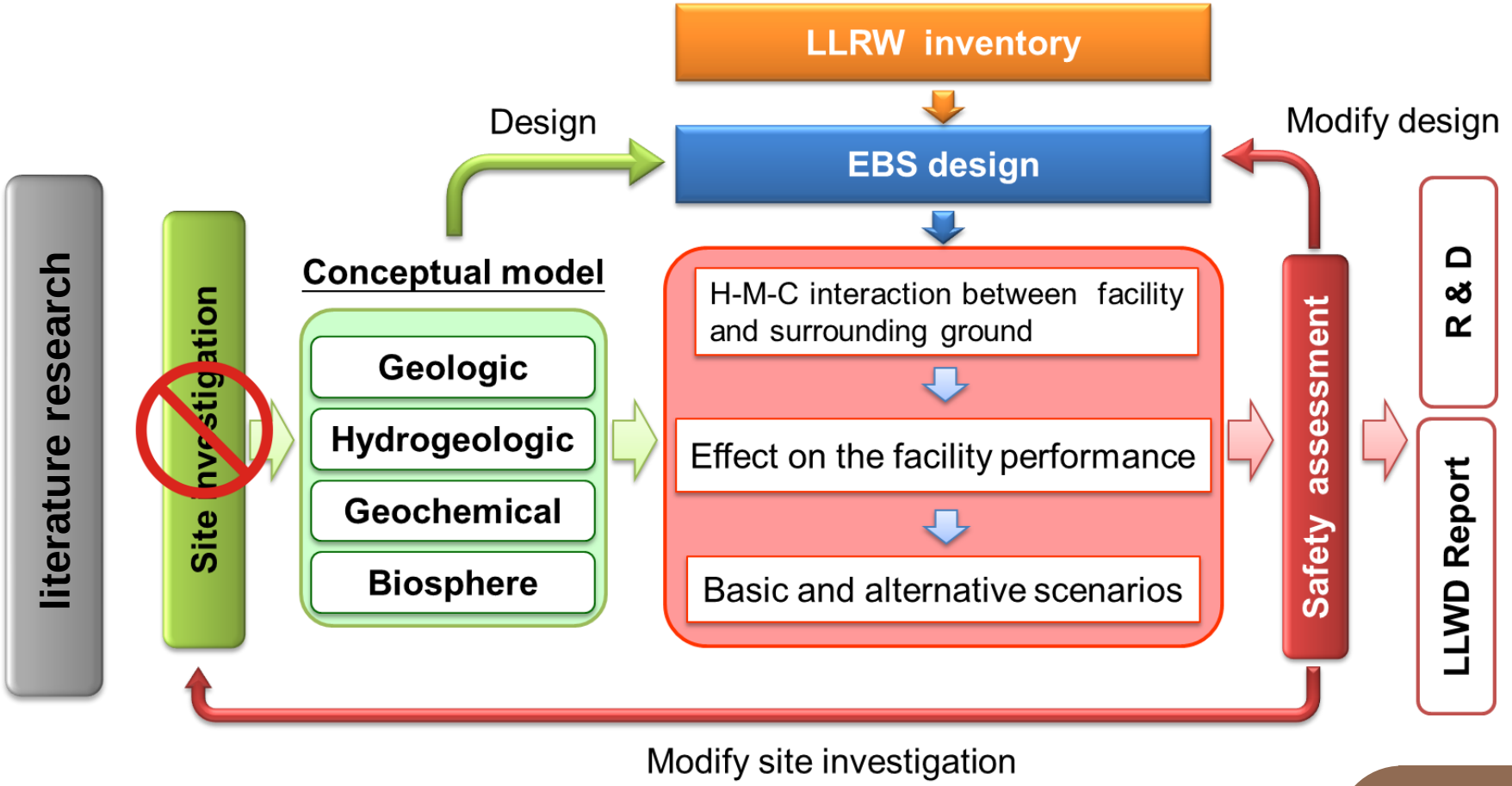


Introduction of LLWD Project

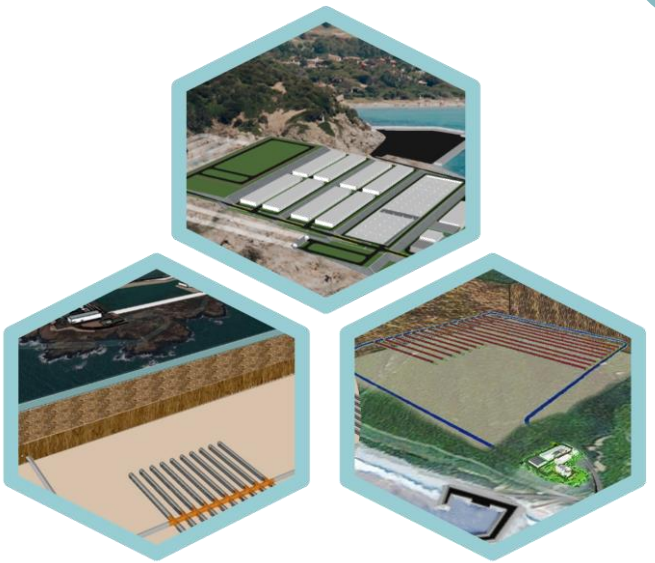
- 2013.08 The LLWD project starting.
  - The LLWD project office was officially established.
- 2016.05 LLWD 2016 report
  - focus on the safety assessment for two candidate sites.
- 2020.10 LLWD 2020 report
  - more discussion and verification on the SDM and EBS model.
  - strength the results of performance analyses
- 2024.07 LLWD 2024 report
  - discussing near surface disposal
  - new container T-Box

LLWD Project Target at the Current Stage

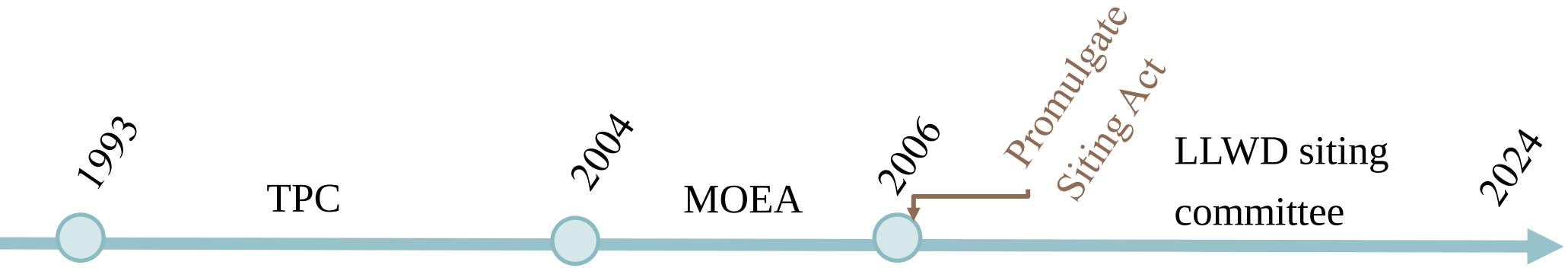
- Follow the LLWD 2020 report framework
- Enhancing technical feasibility
- Strengthen the concept of Defense-in-Depth



2 The Current Status of the Final Disposal Plan.



Siting History for LLWD in Taiwan



First Stage

- Conducting site selection process and seeking volunteers.
- One potential site was proposed. (~2000)

Second Stage

- Site selection responsibility transfer to the MOEA due to protest.
- 2006, NSC promulgate Siting Act.
- MOEA restart the site selection process base on Siting Act .

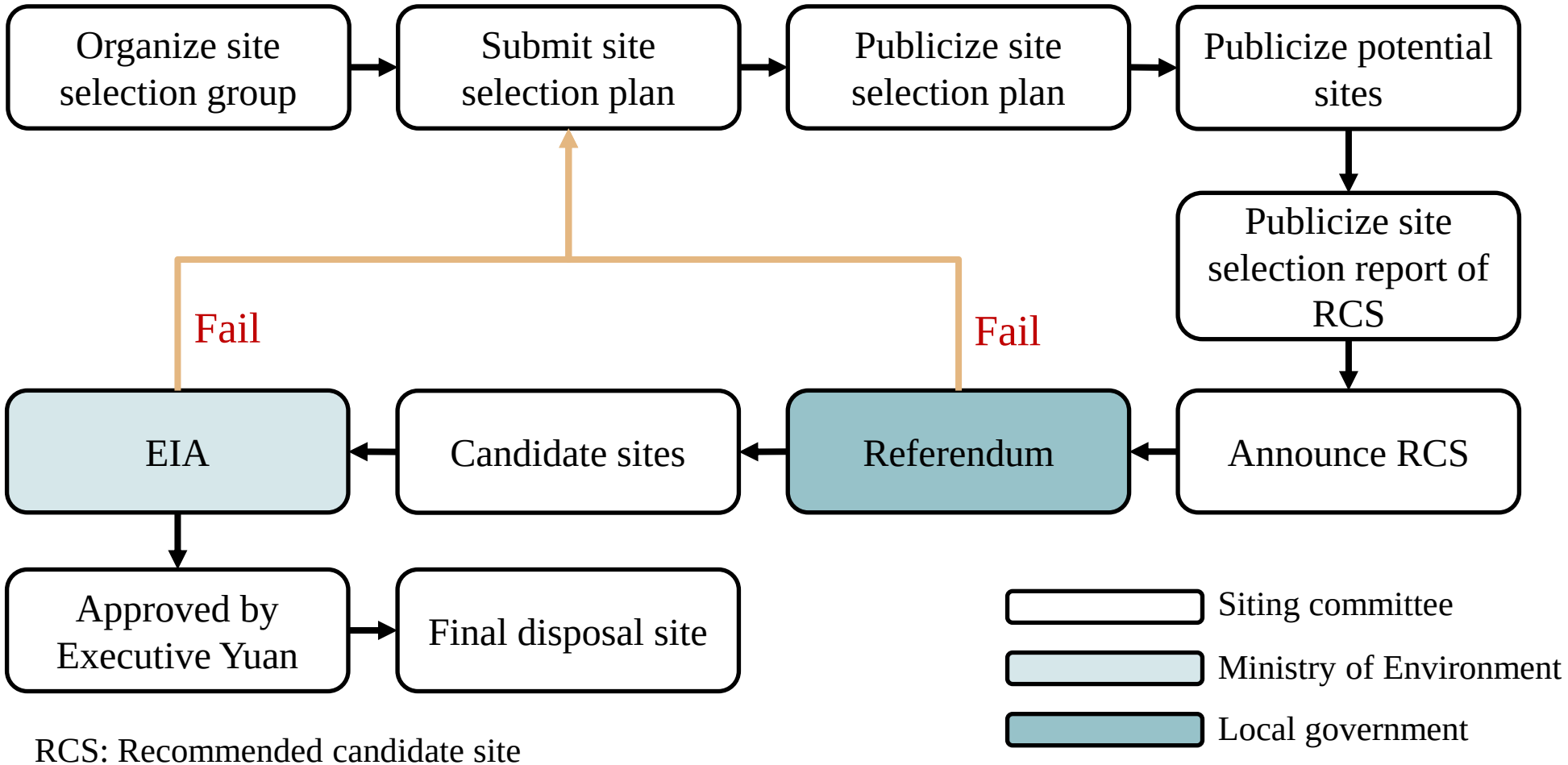
Current Stage

- 2 Recommended candidate site .(~2012.07)
- Waiting for referendum.
- Site investigation suspended.

MOEA: Ministry of Economic Affairs
NSC: Nuclear Safety Commission

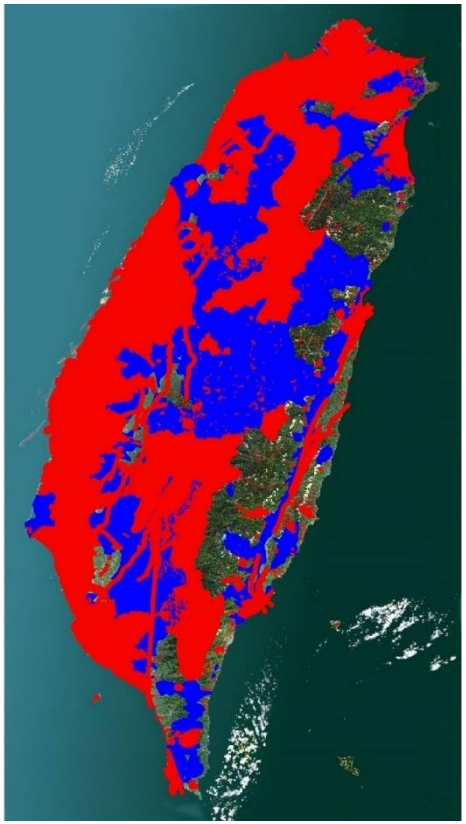
Site Selection Process of Current Stage

Base on “Act on sites for establishment of low-level radioactive waste final disposal facility”



RCS: Recommended candidate site
EIA: Environmental Impact Assessment

Site Selection Process and Results

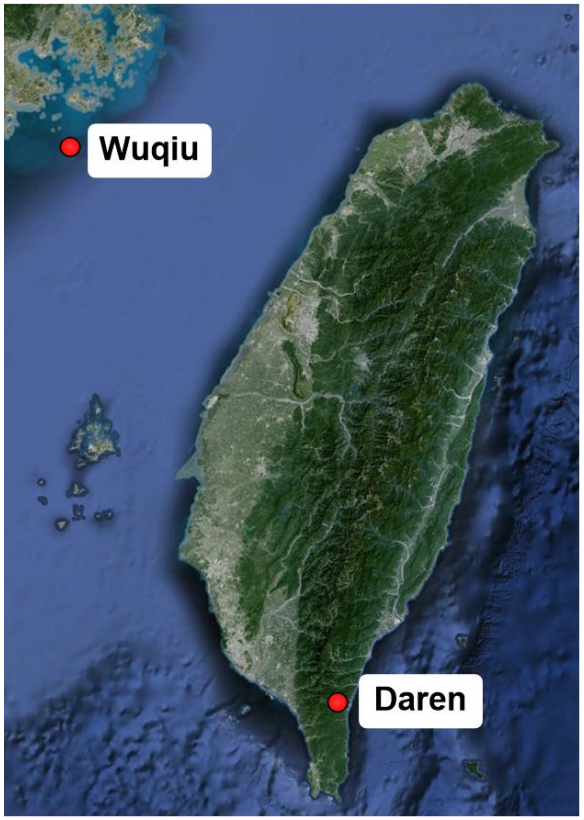


Prohibited setting area

- The must not be located criteria
- The prohibited setting area by other regulations

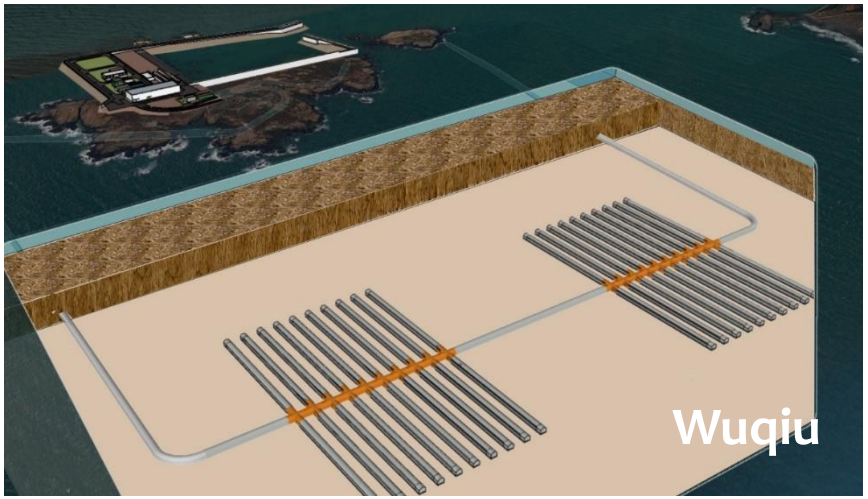
Environmentally sensitive area

- Water resource protect area
- Wildlife conservation area
- National park
- ……



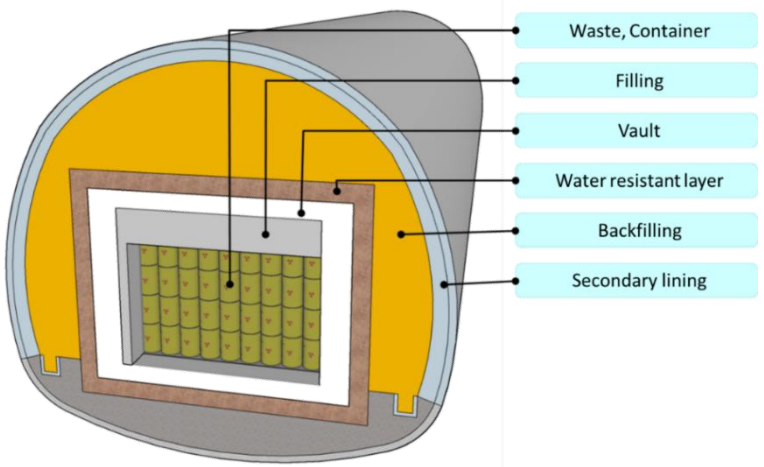
Recommended Candidate Sites

Island, granite



Mountainous and coast, argillite

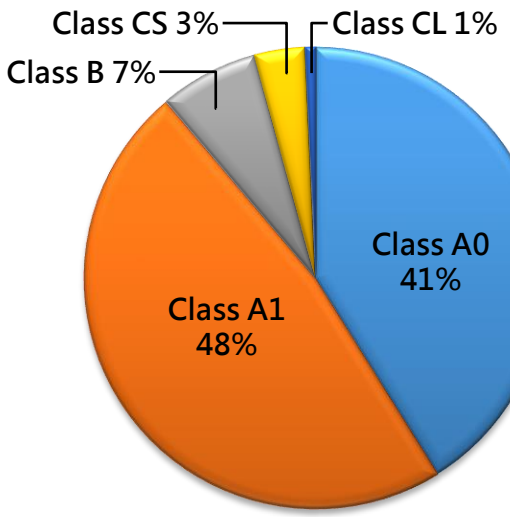
- Surface (auxiliary) area
  - Port
  - Receiving building
  - Affiliated facilities
- Underground area
  - Access tunnel
  - Disposal tunnel and concrete vault



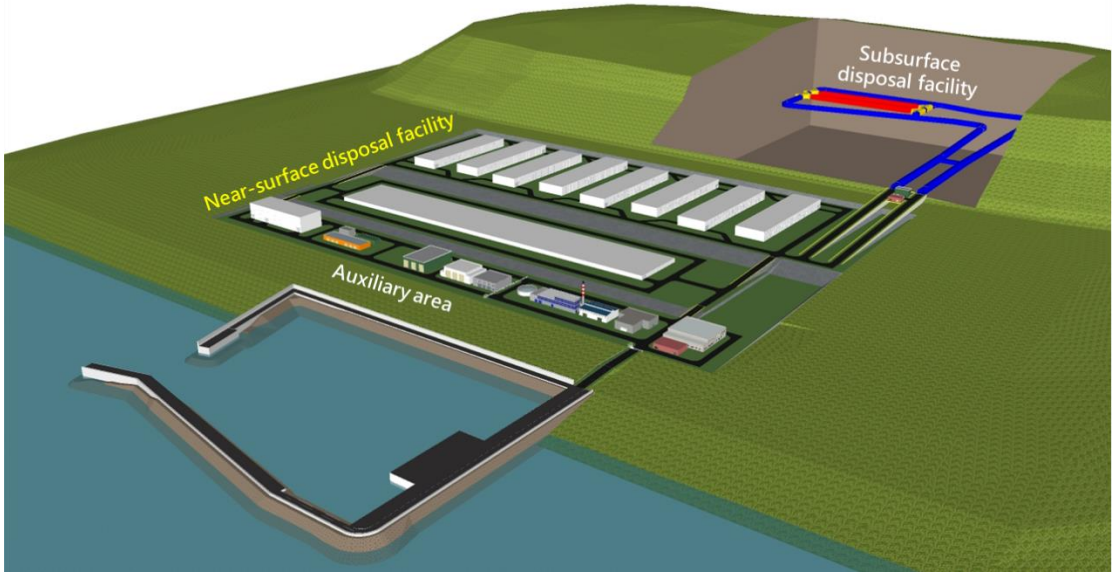
Where to Go Next ?

Consideration

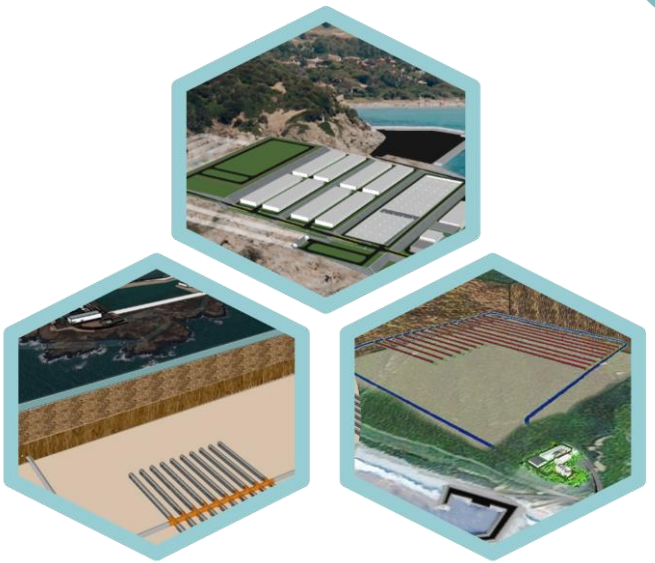
- The site selection process has been suspended for over 10 years.
- 90% of waste is classified as Class A.
- A more economical and efficient disposal design.



Proportion of Waste Classification



3 Recent Developments in LLWD Project.



Optimization of Waste Classification

- **Follow the IAEA's classification of low-level radioactive waste.**
- **Optimal design of disposal facility to reduce costs.**

LLWD 2020 Report

- Class A waste is divided into **A0** and **A1** categories.

The boundary is set at 1/100th of the regulatory limit for Class A waste.

LLWD 2024 Report

- Class C waste is divided into **CS** and **CL** categories

Referring to the classification limits for LILW in France.

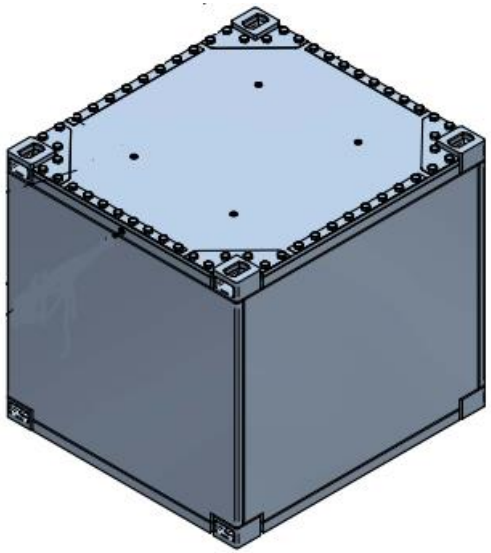
Class CS	
Total specific activity of waste	$<3.7\times10^{8}$ Bq/kg
Total specific activity of α-emission nuclide	$<2.2\times10^{6}$ Bq/kg

Class CL	
Total specific activity of waste	$\geqq 3.7\times10^{8}$ Bq/kg
Total specific activity of α-emission nuclide	$\geqq 2.2\times10^{6}$ Bq/kg

New Container : T-Box

- The feature of T-BOX
  1. Meets **transportation standard requirements**.
  2. The main body is made of **carbon steel** material.
  3. Stackable up to **5 containers**.
  4. Corrosion resistance during storage phase is achieved through **coating**.
  5. Surface radiation dose rate is below 2 mSv/hr, and below 0.1 mSv/hr at 2 m distance.
  6. The outer container uses full perimeter welding, the top cover is secured with screws.

	T2	T3	T4	T5
Waste	CL	CS	B	A0、A1
Wall thickness (mm)	65	65	65	15

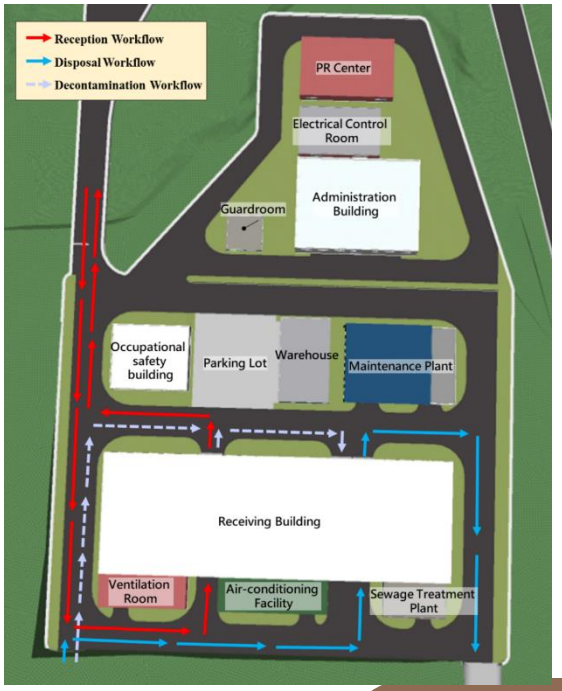


Adjustment for the Disposal Facility

Required adjustment items for the disposal system:

1. Improve the auxiliary area and operational rules to accommodate T-BOX containers.
2. Adjust the configuration of engineer barrier units according to package characteristics.
3. Review and verify the disposal stacking plan and design capacity.

- Adoption of multi-axle trailers with a load capacity of 60 tons.
- Adjustment of vehicle entry and exit routes in the receiving building.
- Modification of the unloading area in the receiving building to use bridge cranes for unloading.



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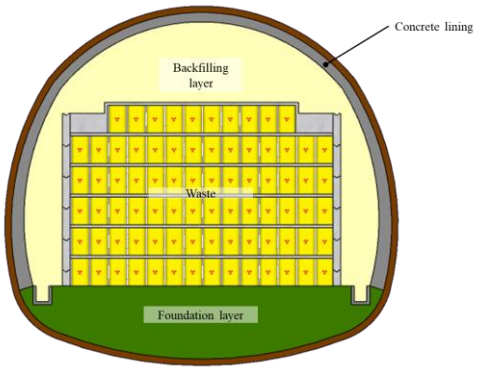
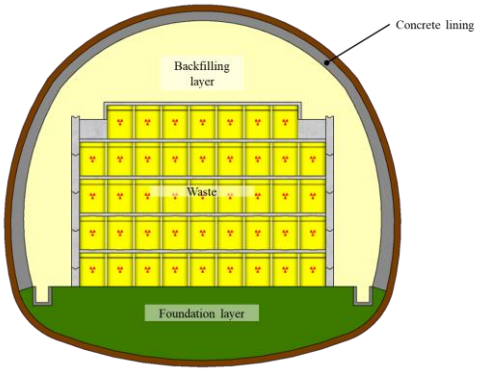
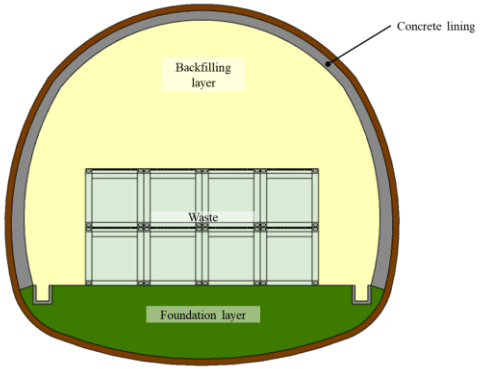
Basic type disposal system



55 gallon drum



HPCC



T-BOX

Adjustment for the Disposal Facility

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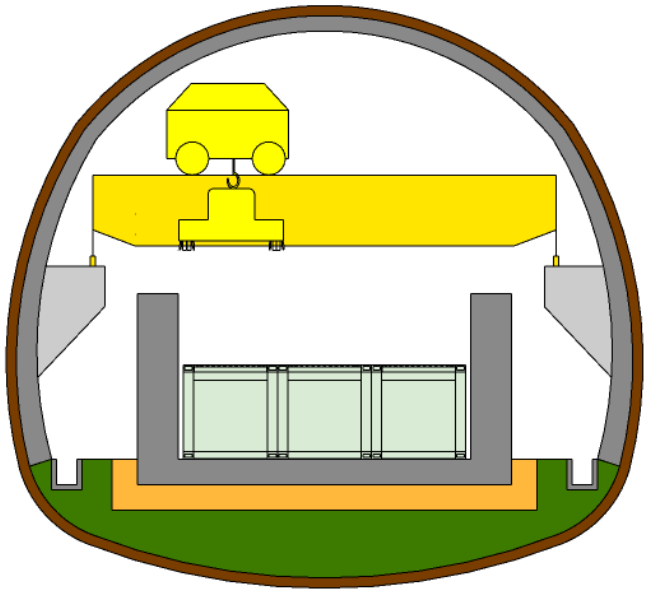
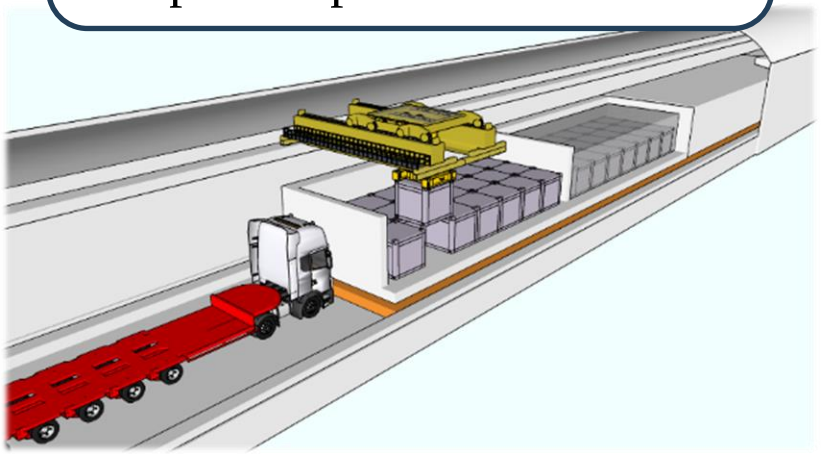


- Crane space requirements
- Lifting height limitations
- Special specification cranes



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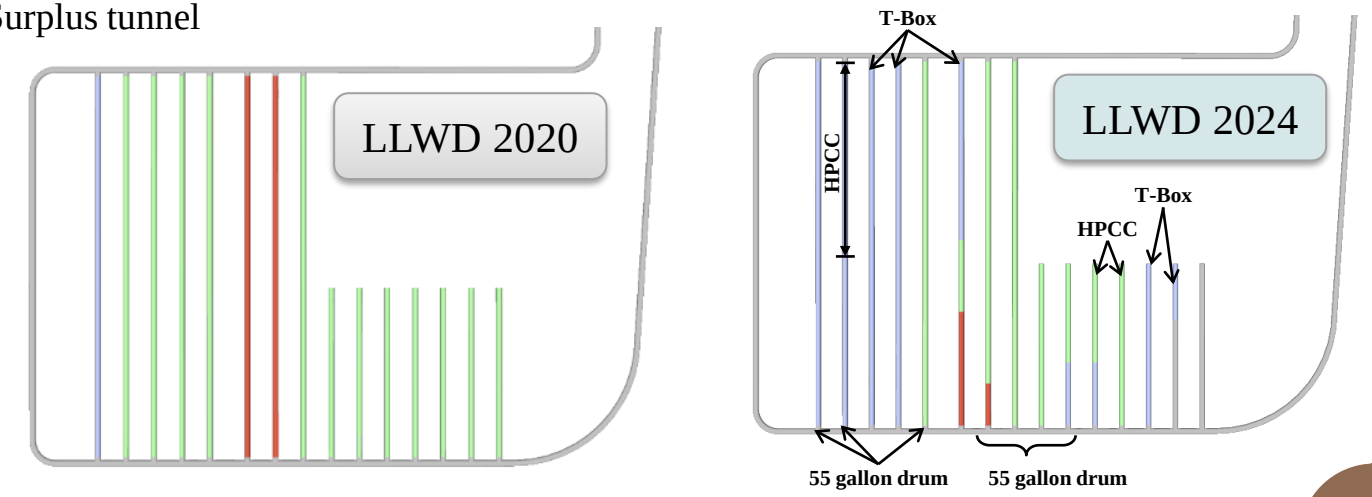
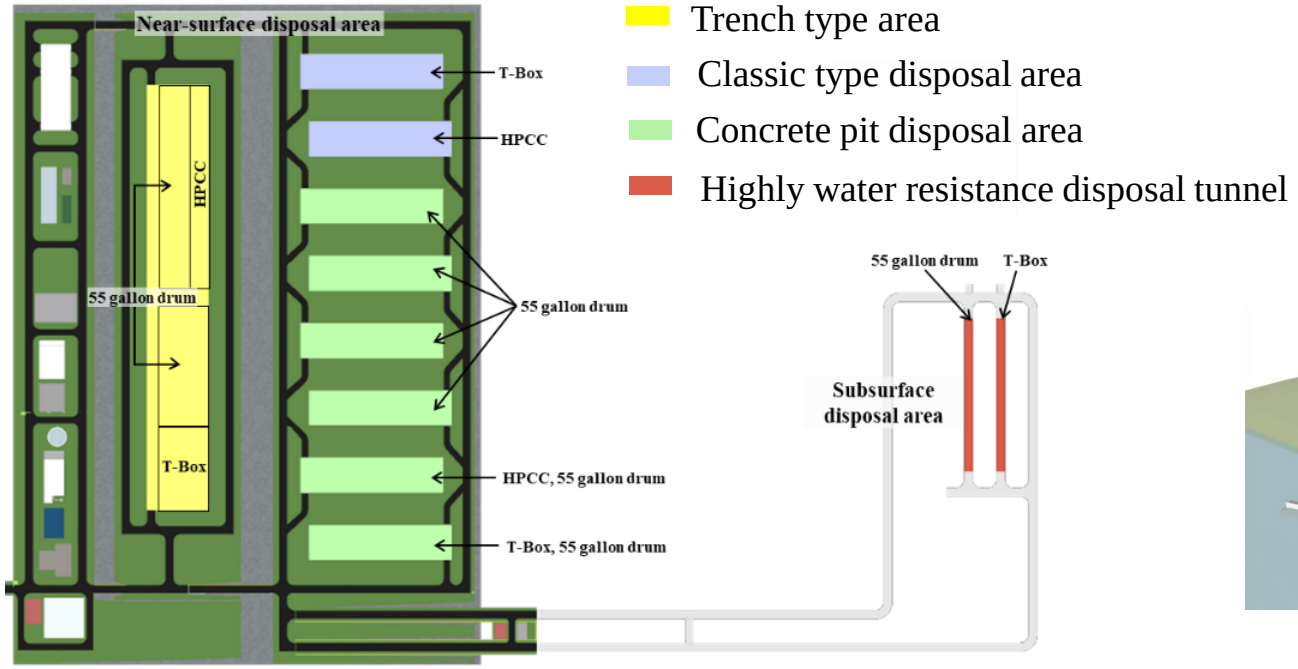
Basic type disposal tunnel
Concrete vault disposal tunnel
Highly water resistance disposal tunnel
Surplus tunnel

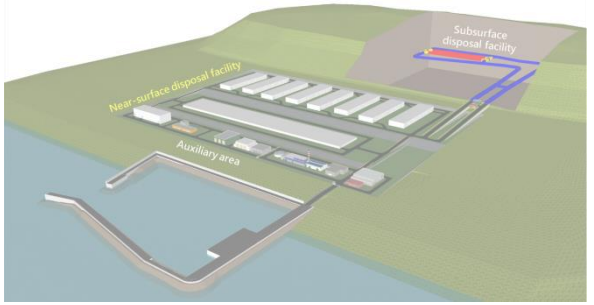


Near Surface Disposal at Pseudo Site

Design Concepts

- A more economical and efficient disposal design.
- Follow the national regulations and IAEA recommendations.
- Protection of general public, inadvertent intruders and staff.
- Ensure facility stability after closure.





Improvement of Safety Case Technology for EBS

Concrete material

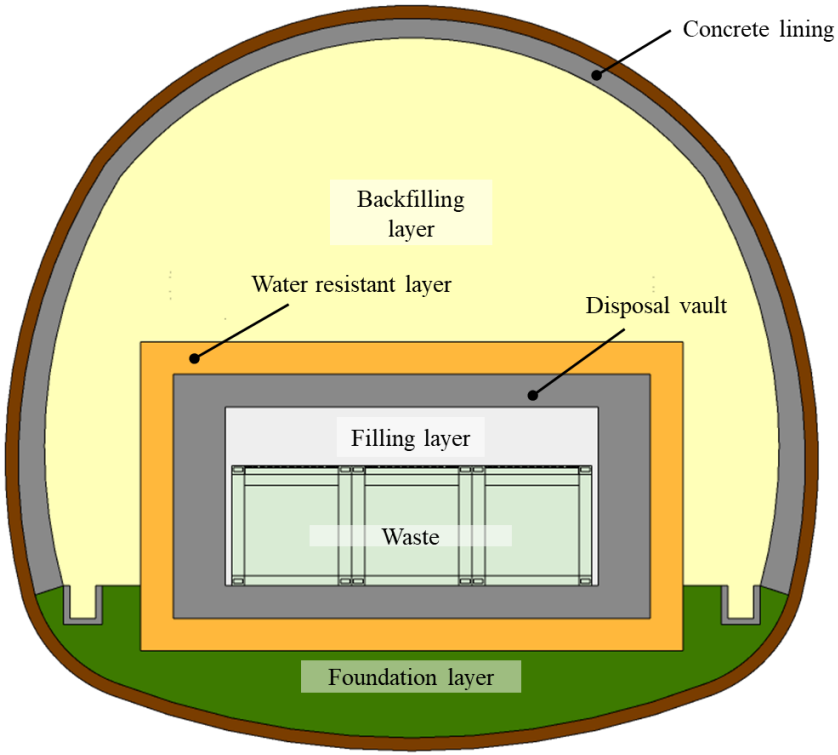
- Deterioration by sulfate or chloride.
- The performance of mechanical and hydraulic properties .
- Concrete damage due to corrosion-induced expansion of reinforcing steel.

Bentonite material

- The retardation factor. (Kd)
- Calcium leaching effect.
- Deterioration by dry-wet cycle effect.
- The performance of swelling pressure and hydraulic properties.

Metal material

- The metal corrosion rate of T-Box.



Improvement of Safety Case Technology for EBS

Concrete material

- Chloride attack test
- Sulphate attack test
- Mechanical tests
- Porosity test
- Diffusion coefficient test
- Hydraulic conductivity test
- Steel corrosion induced expansion test
- Nuclide adsorption tests

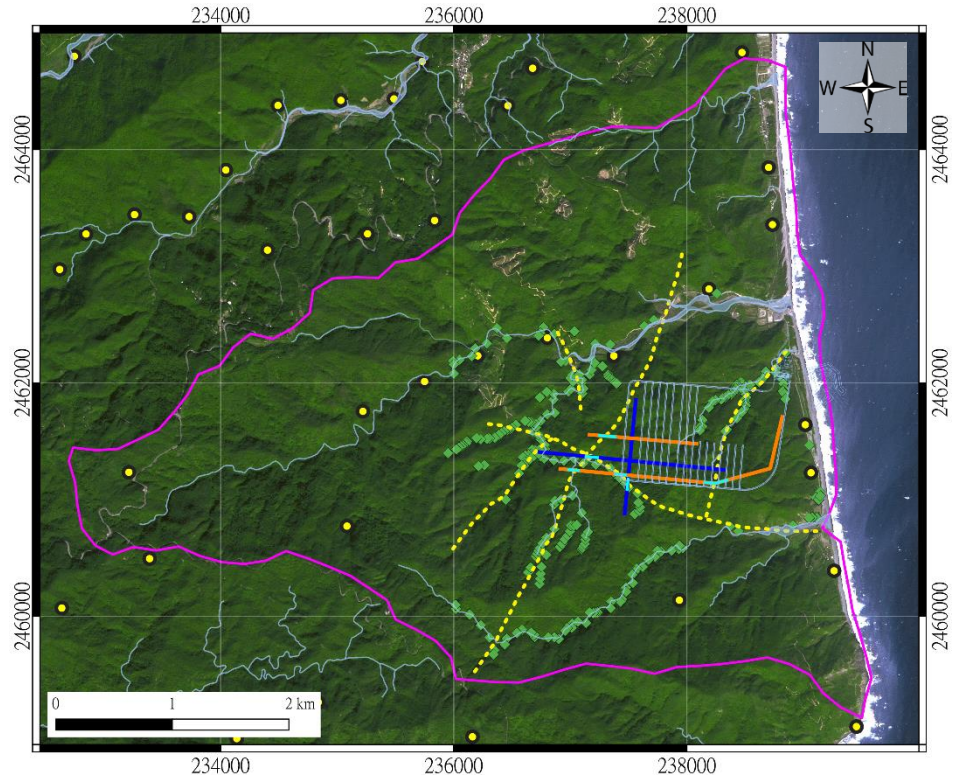
Bentonite material

- Accelerating migration test
- Dry-wet cycle test
- Chemical stability test
- Water resistant tests
- Hydraulic conductivity test
- Nuclide adsorption tests

Metal material

- Metal corrosion test

The Hydrogeological Model ~ LLWD2016



Electrical resistance (2004)

Seismic refraction (2007)

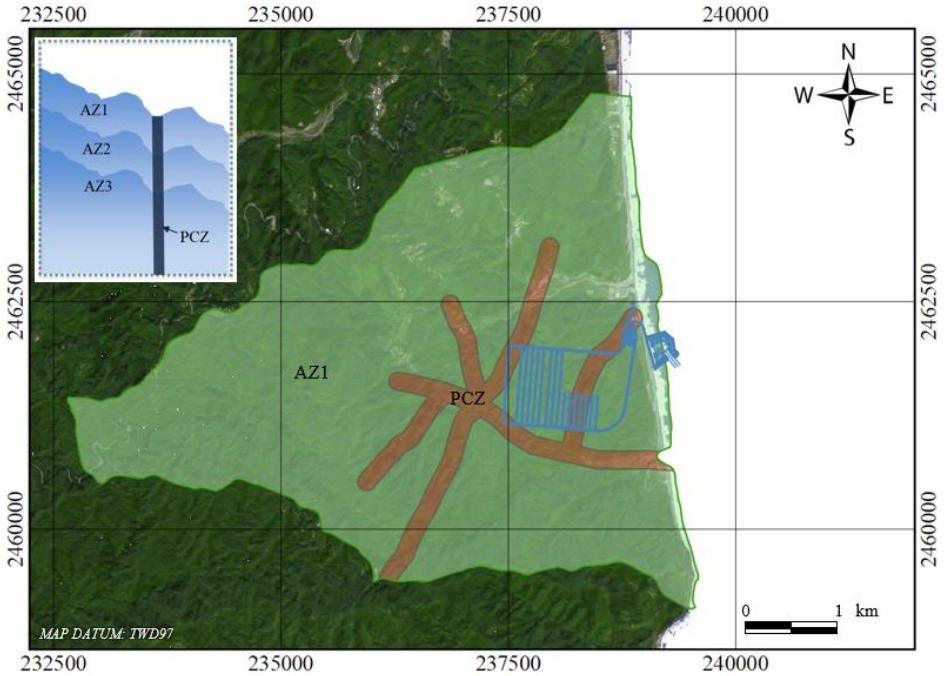
Low-resistance zone
Low-speed zone

Surface outcrops(2005)

Surface outcrops(1993)

Inferred discontinuity

- Spatial distribution of discontinuity
- Bed rock distribution
- Data quality and quantity



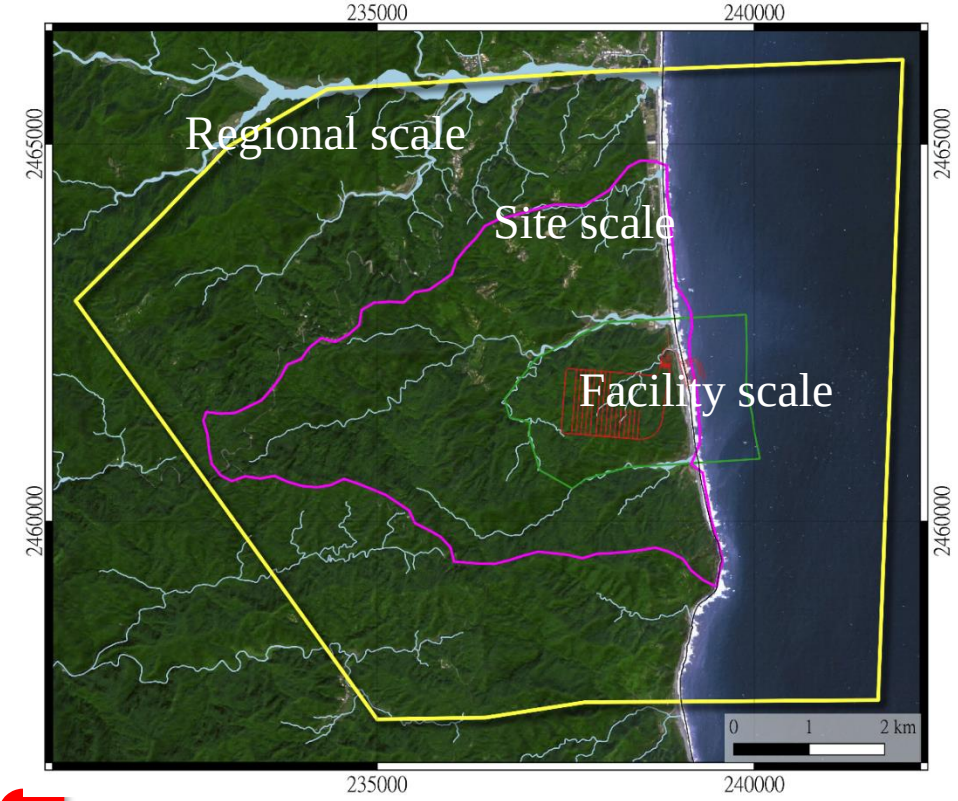
PCZ — Fracture zone in argillite formation as potential water-conducting fractures

AZ1 — Argillite formation outside the fracture zone

LLWD2020 Site Characterization Approach

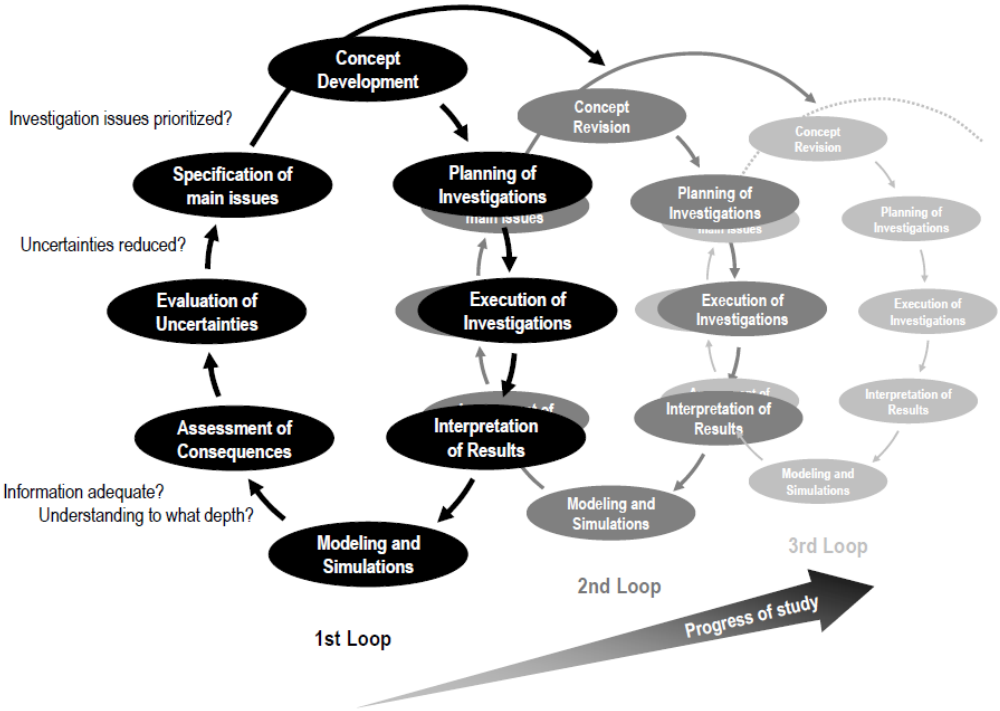
Multi-scale approach

- Clarify influence in various scale.
- Different plans for each scale.
- Involve the iterative concept.



Iterative approach

- Apply the loop concept in site characterization.
- Import the validation and correction processes.



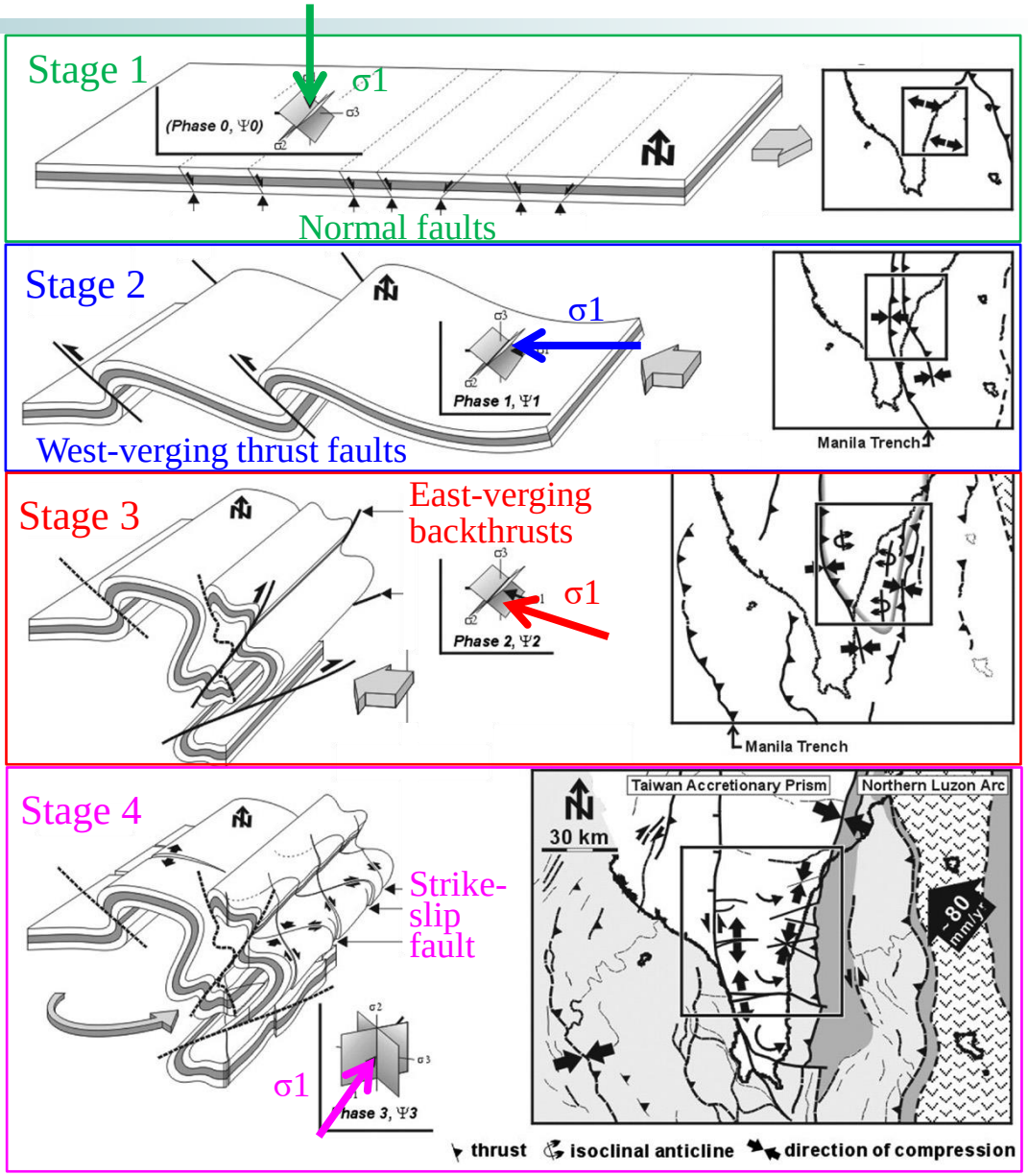
Conceptual Model Update

Issues to be clarified

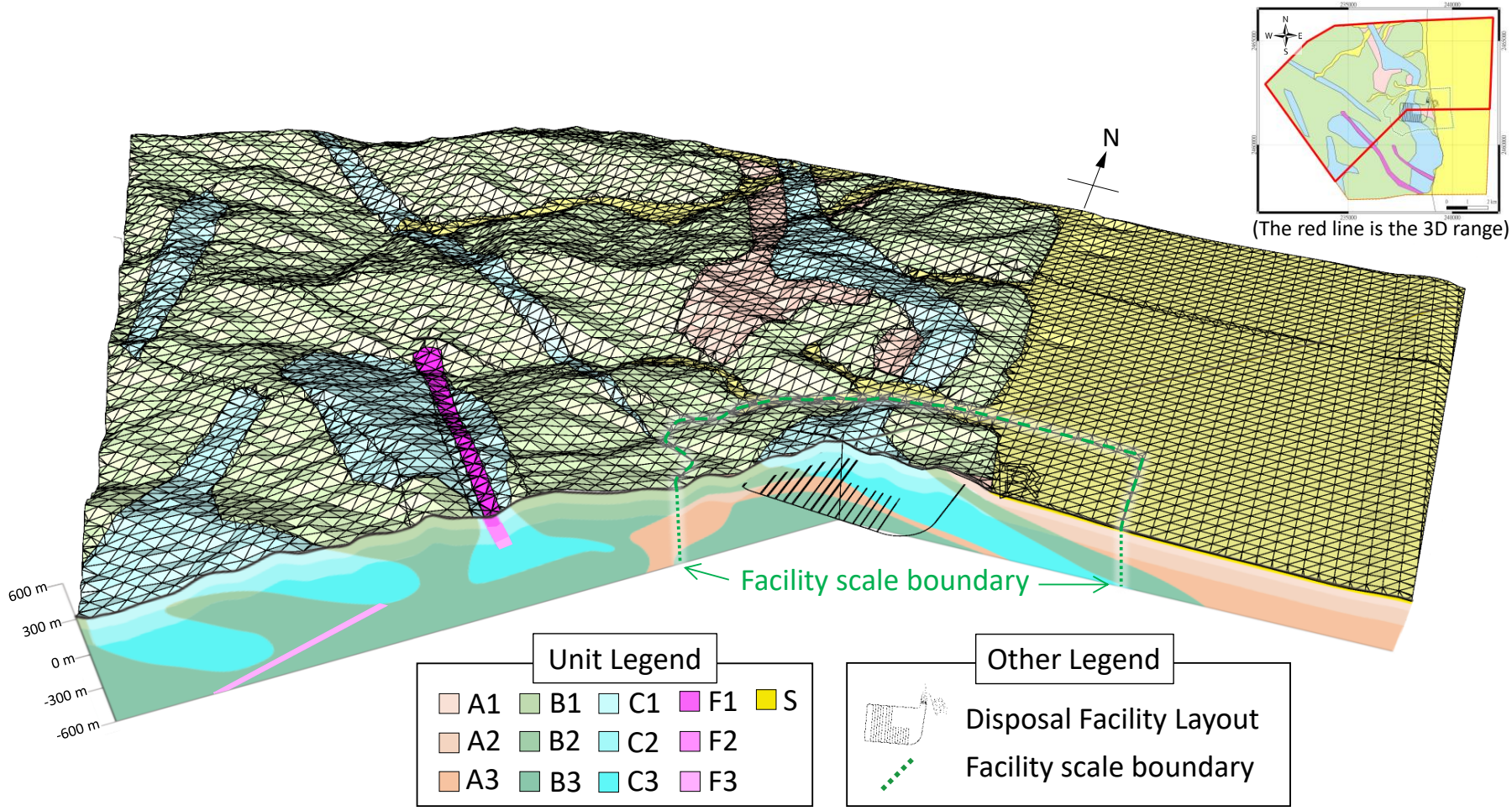
- Overly simplified zoning.
- Spatial characteristics of water-conducting fractures.

LLWD 2024 update

- Base on geological history and credible academic literature.
- Conceptual model of lithology, geological structure, stress.
- Integrate structural characteristics with 2016 achievement.



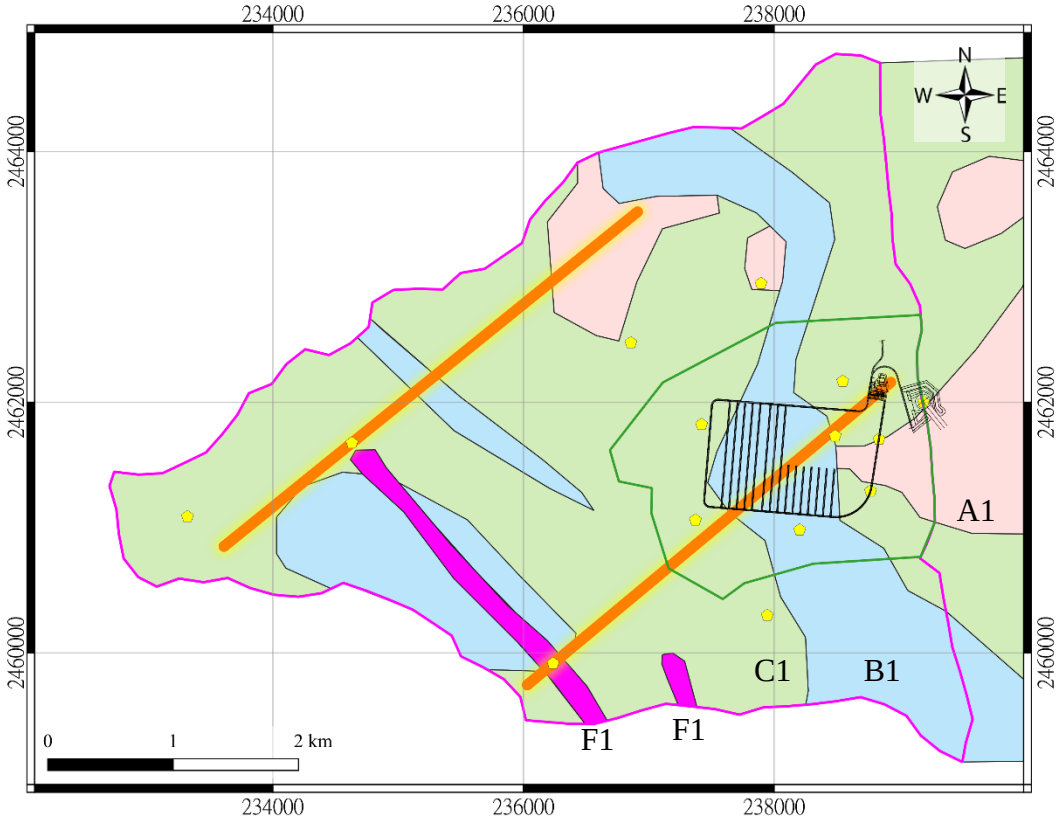
3D Geological Conceptual Model



LLWD2024 Investigation Plan

Site Scale

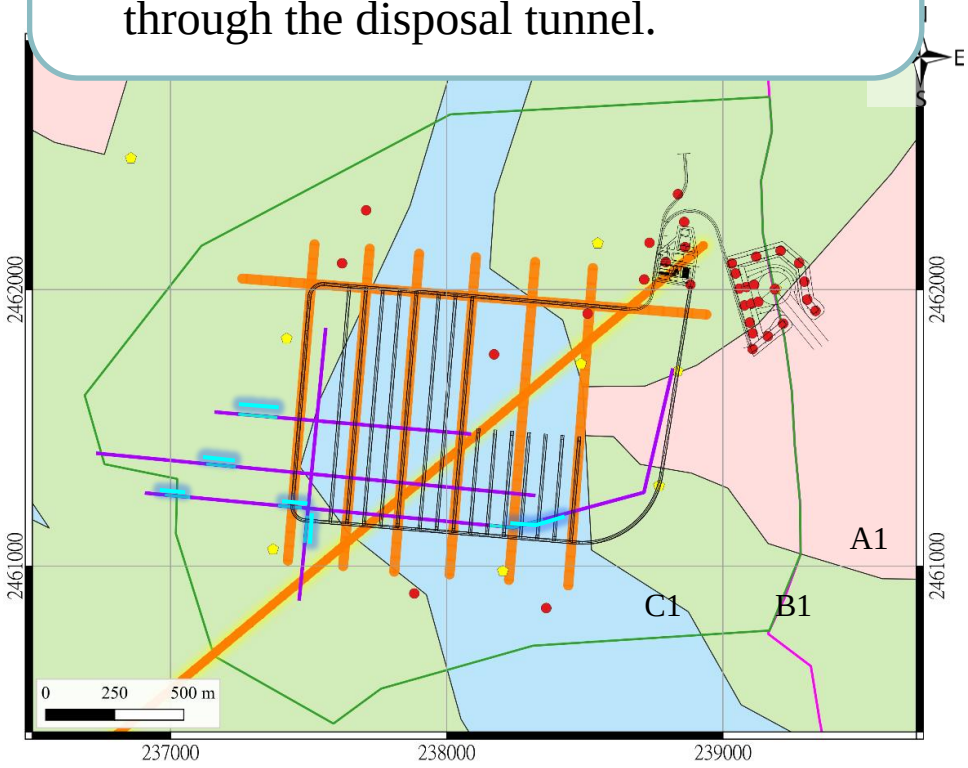
- Verify location and depth of folds.
- Verify the water-conducting fractures.



Geophysical exploration Preliminary borehole survey

Facility Scale

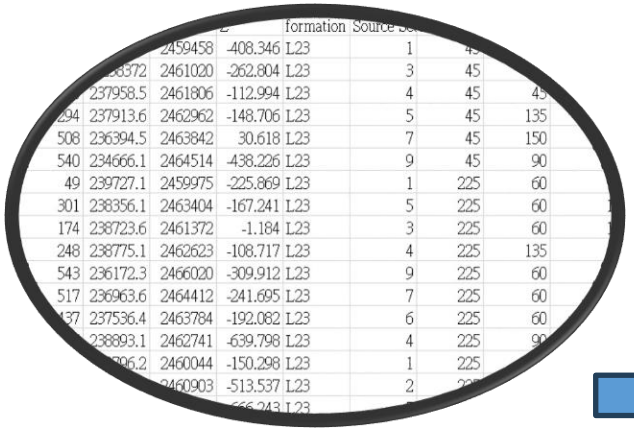
- Verifying the location of lenticular sandstone.
- Verify whether the fracture zone passes through the disposal tunnel.



Geophysical exploration Literature Survey line

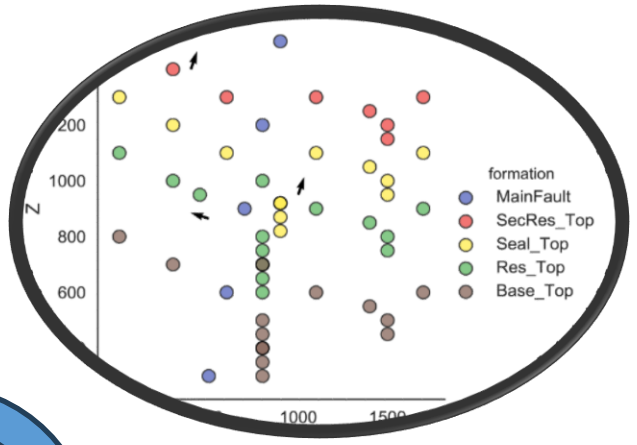
Detailed drilling survey Literature Fracture zones

The Improvement of the Analysis Processes

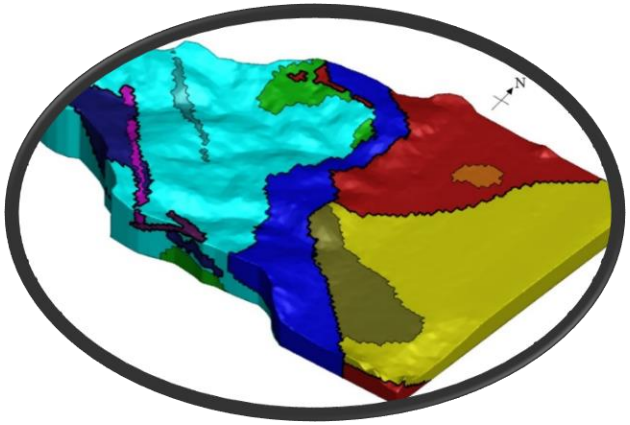


				formation	Source		
		2459458	-408.346	L23	1		
	372	2461020	-262.804	L23	3	45	
	237958.5	2461806	-112.994	L23	4	45	45
294	237913.6	2462962	-148.706	L23	5	45	135
508	236394.5	2463842	30.618	L23	7	45	150
540	234666.1	2464514	-438.226	L23	9	45	90
49	239727.1	2459975	-225.869	L23	1	225	60
301	238356.1	2463404	-167.241	L23	5	225	60
174	238723.6	2461372	-1.184	L23	3	225	60
248	238775.1	2462623	-108.717	L23	4	225	135
543	236172.3	2466020	-309.912	L23	9	225	60
517	236963.6	2464412	-241.695	L23	7	225	60
137	237536.4	2463784	-192.082	L23	6	225	60
	238893.1	2462741	-639.798	L23	4	225	90
	96.2	2460044	-150.298	L23	1	225	
		2460903	-513.537	L23	2		

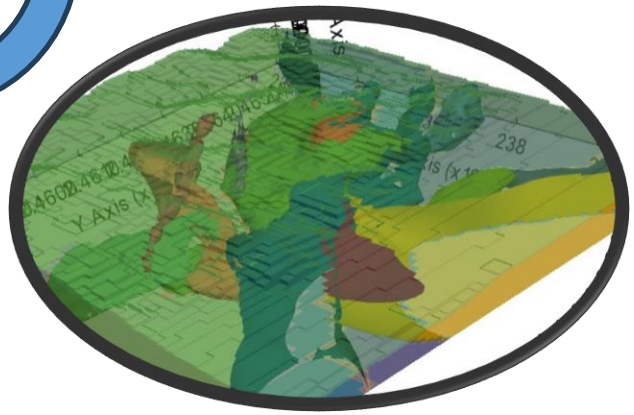
Raw data



Data analyze

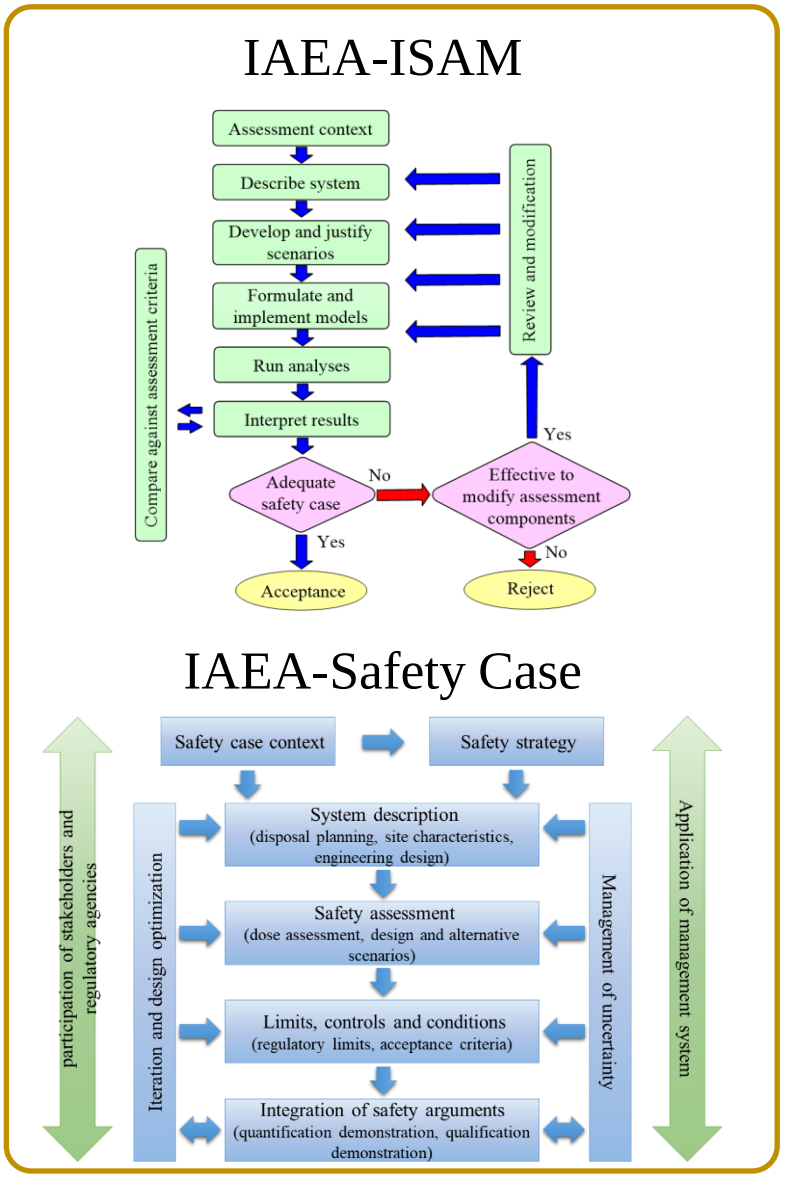


Groundwater model



3D geological model

Improvement of Safety Assessment Processes



FEPs Update

Climate Change

Scenario Evolution

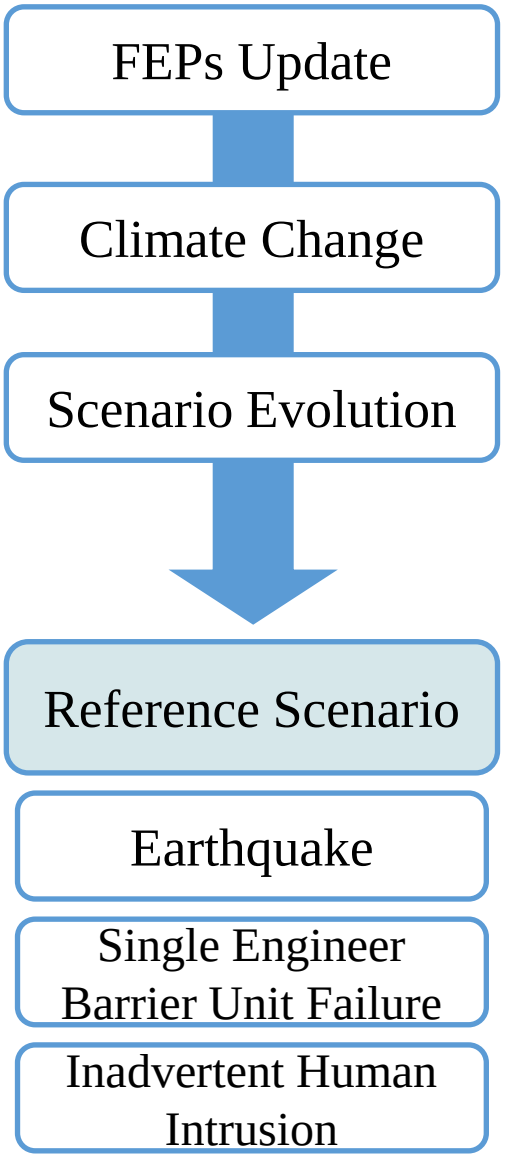
Reference Scenario

Earthquake

Single Engineer Barrier Unit Failure

Inadvertent Human Intrusion

Improvement of Safety Assessment Processes



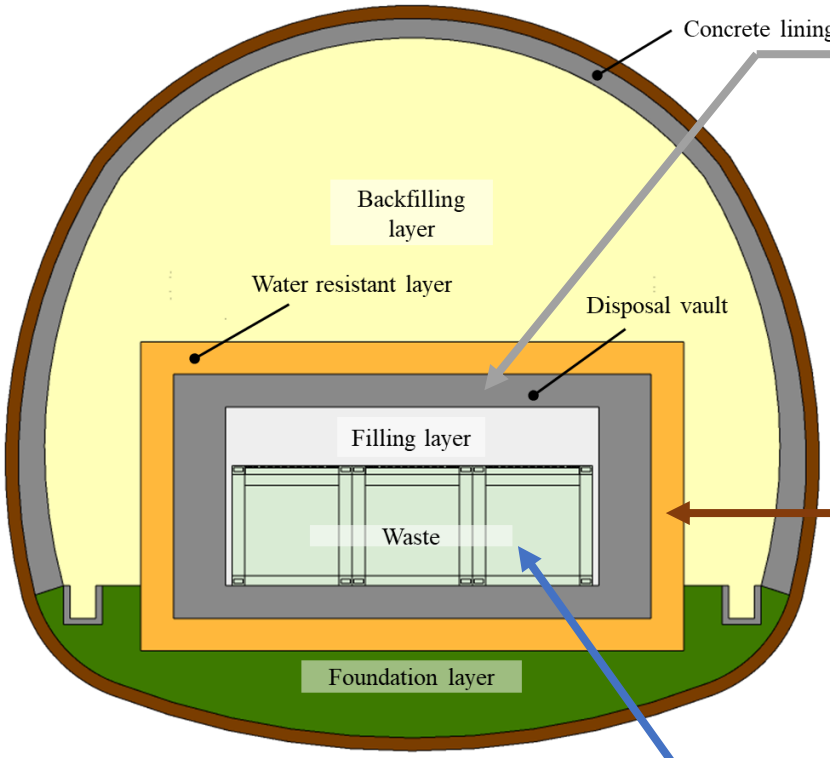
- IAEA-ISAM FEPs list
- Added 4th-level definitions to FEPs

- Keep climate warming scenario
- Added warming followed by glacial cycle

- Predict environmental characteristics based on climate evolution
- Predict EBS degradation time and results

- Demonstrate defense-in-depth capabilities.
- Do not rely on the function of a single barrier unit.

Degradation of the EBS



Concrete material

- The concrete continues to undergo leaching of calcium, sulfate erosion, and chloride ion intrusion.
- Steel expansion results in fracture and penetrates the disposal vault, forming a connected fracture.

Bentonite material

- Calcification of the sodium-type bentonite.
- The loss of bentonite due to erosion, cause the decreased water barrier performance.

T-BOX

- Metal corrosion penetration through the weld bead and wall, create a flow pathway.

Degradation of the EBS

Concrete material

- The concrete continues to undergo leaching of calcium, sulfate erosion, and chloride ion intrusion.
- Steel expansion results in fracture and penetrates the disposal vault, forming a connected fracture.

- Localize hydraulic conductivity.
- Localize diffusion coefficient.
- Steel corrosion induced expansion study.

Bentonite material

- Calcification of the sodium-type bentonite.
- The loss of bentonite due to erosion, cause the decreased water barrier performance.

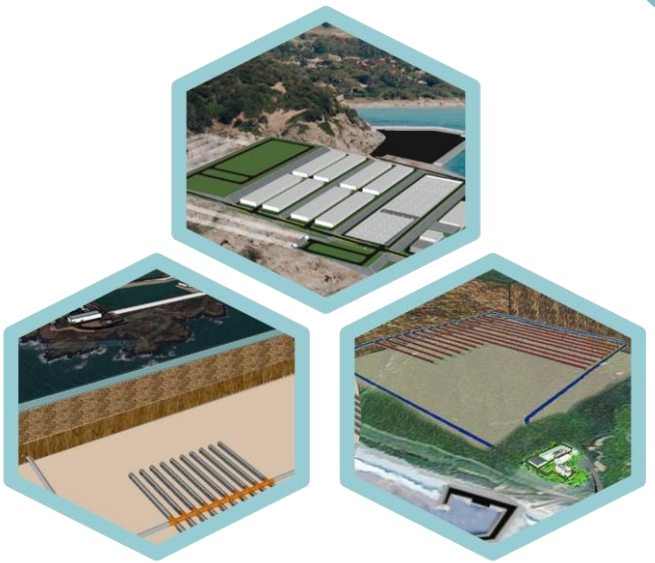
- Localize hydraulic conductivity.
- Localize diffusion coefficient.

T-BOX

- Metal corrosion penetration through the weld bead and wall, create a flow pathway.

- Localize metal corrosion rate.

5 Next Phase of Development.



Future Development

The design of disposal system

- Exploring the mechanism of penetrating cracks in disposal vault
- Study on the long-term deterioration characteristics of T-Box.
- Smart Kd Concept.

The management of disposal plan

- Safety function related parameter verification.
- Clarify model and parameter uncertainties, and develop technology improvement strategies.

Waste Inventory and Container

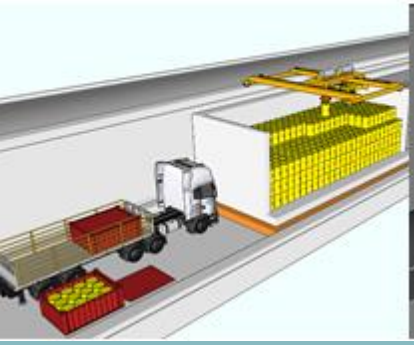
- Update the waste inventory and container according to TPC's plan.

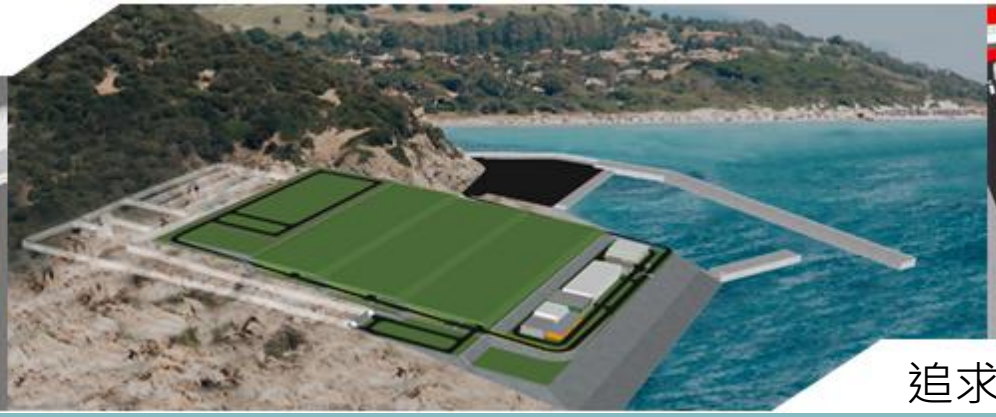
The development of technology

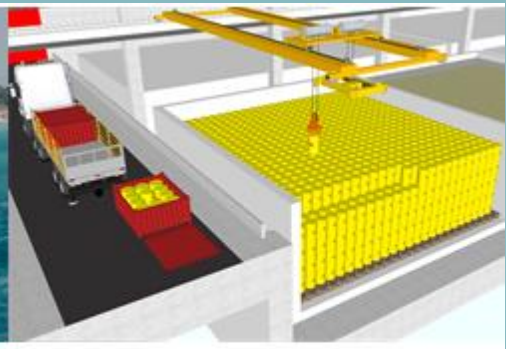
- Further development of near-surface disposal technologies
- The behavior of organic and inorganic C14 in EBS.
- The adsorption of iron oxide.
- Establishing rock mass anisotropy investigation and strength classification assessment methods

Thank You

正派經營、品質保證







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