Document 1-1, the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Installation of New ALPS Treated Water Dilution/ Discharge Facilities and Related Facilities

March 10, 2022

TEPCO

Tokyo Electric Power Company Holdings, Inc.

The Japanese version shall prevail.

Table of Contents

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Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [1]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(1) Discharge Facilities of ALPS Treated Water into the Sea

[3] Methods of seawater intake and discharging ALPS treated water after dilution (including measures to prevent the transfer of radioactive materials within the port into water intake)

- Regarding construction requiring undersea work, including installation work of a partition weir and a discharge outlet caisson, an explanation should be given on measures to suppress swirl-up of seabed soil and its monitoring during the construction period, response if there are significant changes in the monitoring, and the effects in the event of actual swirl-up of seabed soil.

2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-1 Overview of water intake methods and discharge tunnel

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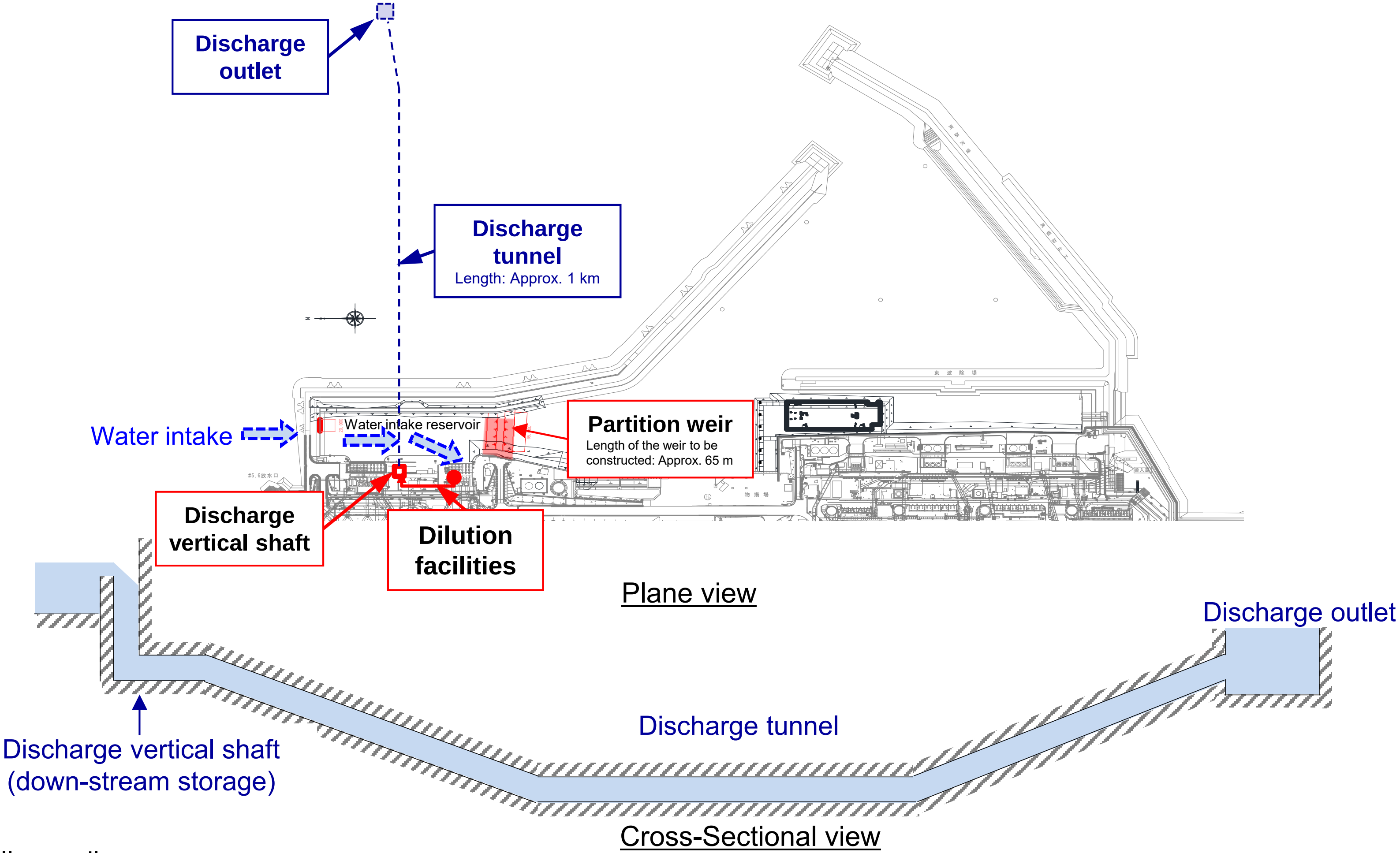
- Intake and Discharge facility
  - Regarding the design of intake facilities, a Units 5-6 intake open-channel will be separated with a partition weir (riprap sloping weir + sheet) from the units 1-4 side port side, and a part of the north breakwater permeation prevention work will be remolded so that the seawater for dilution is taken in from outside the port.
  - Discharge facility is designed so that they can transfer water flowing out over the partition wall in the discharge vertical shaft to the outlet, which is approximately 1 km away, by making use of the head between water in the discharge vertical shaft (down-stream storage) and the sea surface. In addition, friction loss in the Discharge facility and increase in water level are taken into account when designing.



2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-2. Facility overview for ensuring safety

Document 2-1 (repost), the 9th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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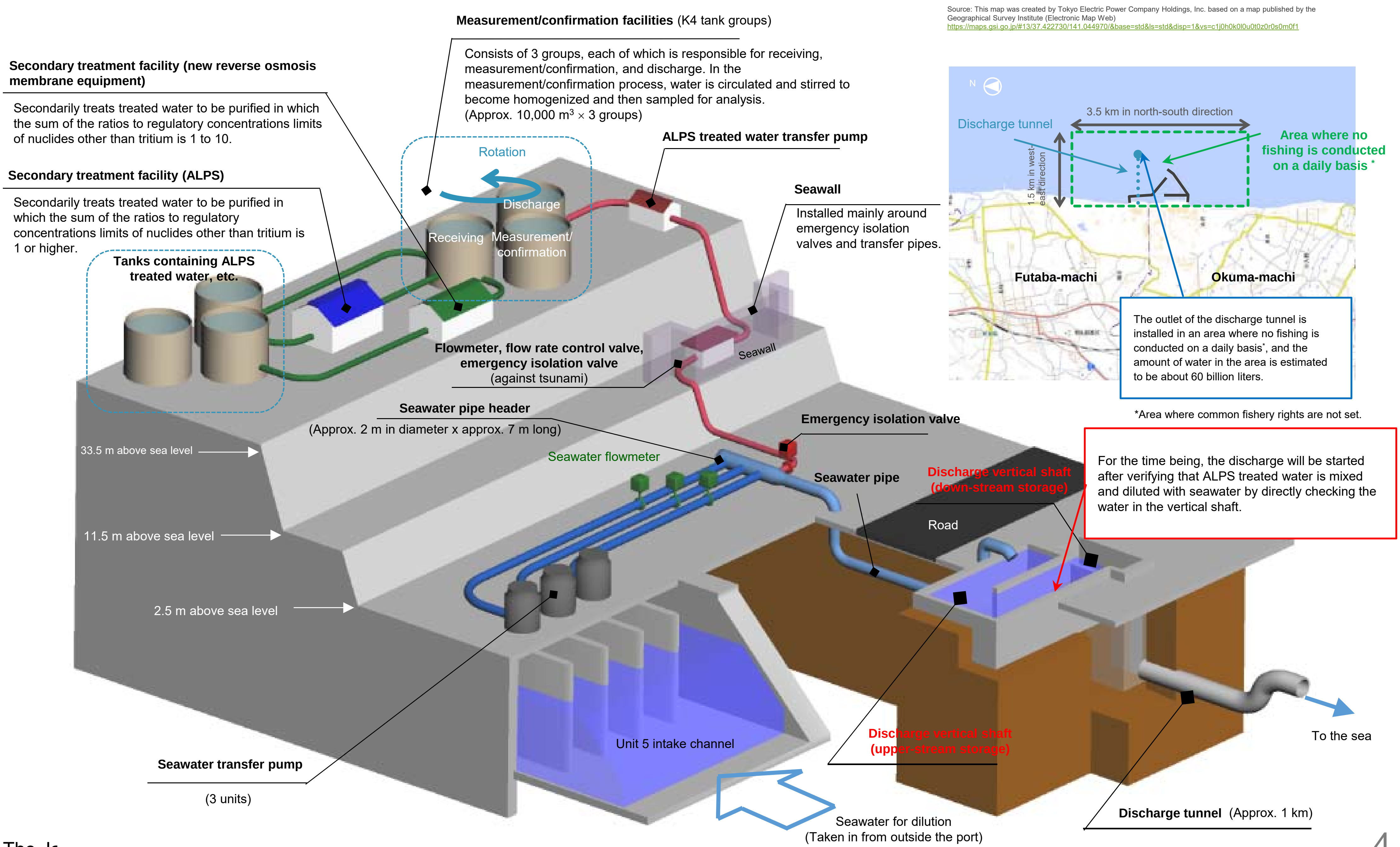


Methods of seawater intake and discharging ALPS treated water after dilution

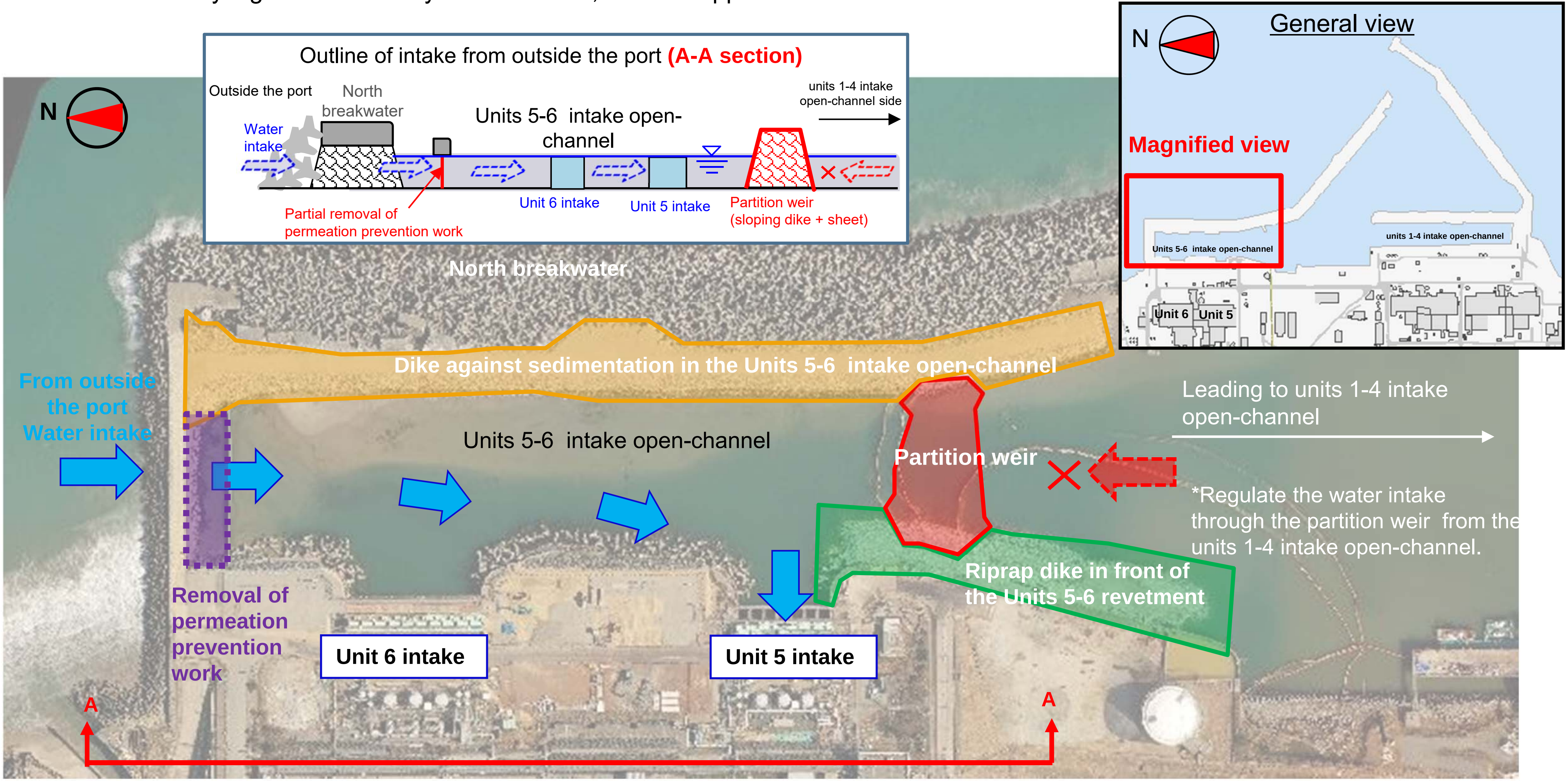
Water intake methods: construction methods

Discharge methods: construction methods

5.1 Enhanced monitoring associated with offshore construction work

2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-3.1 Water intake methods: overall schematic diagram

- Units 5-6 intake open-channel are shut with a partition weir (riprap sloping weir + sheet) from the units 1-4 side port. A part of the north breakwater permeation prevention work is remodeled so that the seawater for dilution is taken in from Discharge Facilities of ALPS Treated Water into the Sea.
- Separation from the port of units 1 -4 side and taking seawater from outside of the port, the seawater intake from within the port, in which relatively higher radioactivity concentration, can be suppressed.

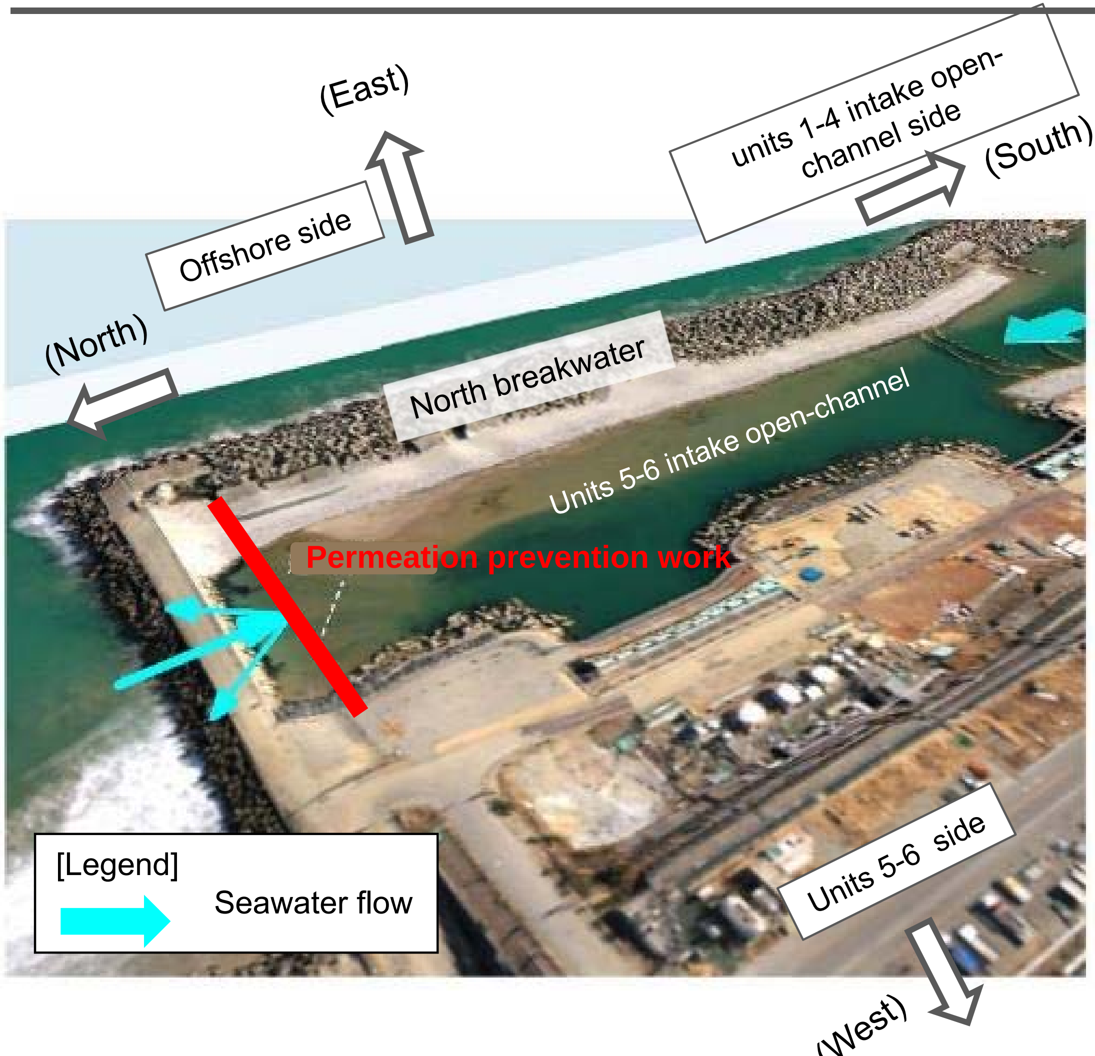


Overview of water intake method

The Japanese version shall prevail.

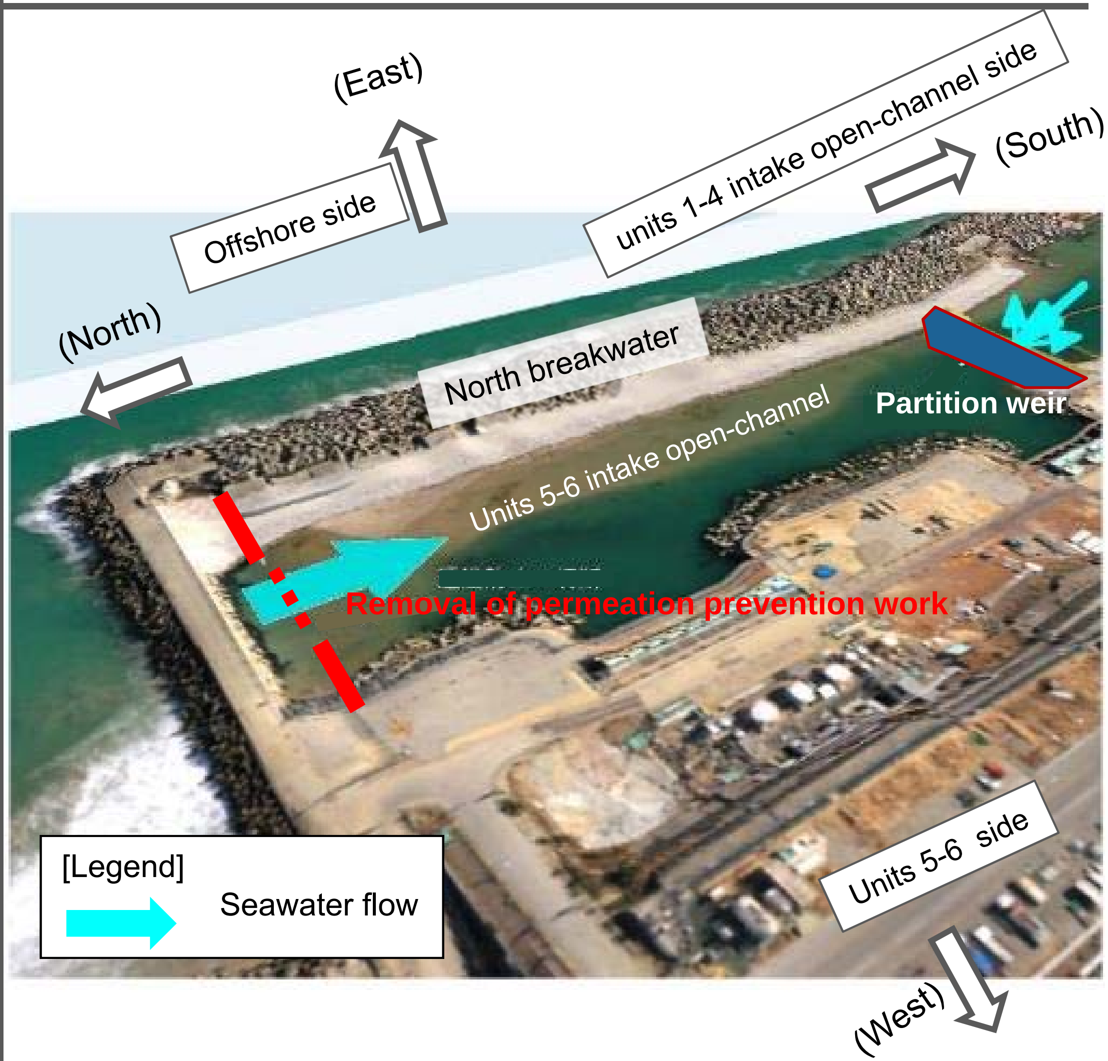
2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[Supplement] Outline of the seawater intake method

Current status



- With the permeation prevention work on the north breakwater, there is no inflow of seawater from the north side outside the port.

After completion of construction



- By removing a part of the permeation prevention work on the north breakwater, the seawater intake from outside the port is enable.
- By constructing a partition weir, the inflow of seawater from the port of units 1-4 intake open-channel is regulated.

The Japanese version shall prevail.

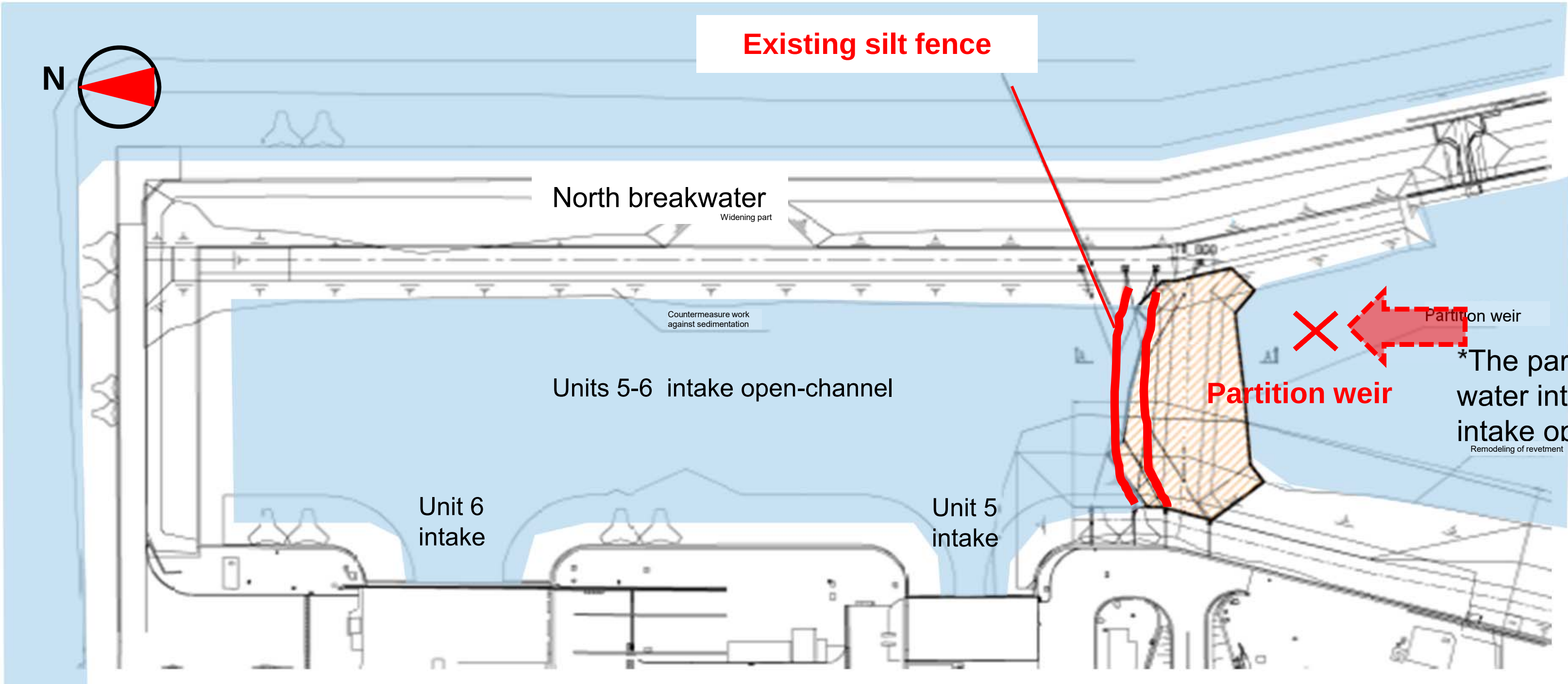
2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-3.2 Water intake methods: positioning of partition weir (1/2))

Current status

- As for the concentration of radioactive materials in the seawater within the port, concentration within units 1-4 intake open-channel is relatively high.
- Regarding the concentration of radioactive materials in seabed soil within the port, concentration on the Units 5-6 side is equivalent to outside the port. Still, concentration on units 1-4 side is relatively high.

Positioning

- In the future, if we continuously take seawater for dilution from unit 5 intake, it is assumed that there will be effects of the seawater and seabed soil on the units 1-4 side with a relatively high concentration of radioactive materials. Therefore, there is a risk of increasing the concentration of radioactive materials in the seawater for dilution.
- For this reason, we will suppress the intake from units 1-4 intake open-channel by building the partition weir.



*The partition weir suppresses water intake from the units 1-4 intake open-channel.

Partition weir position map

2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-3.2 Water intake methods: positioning of partition weir (2/2)

Before constructing the partition weir

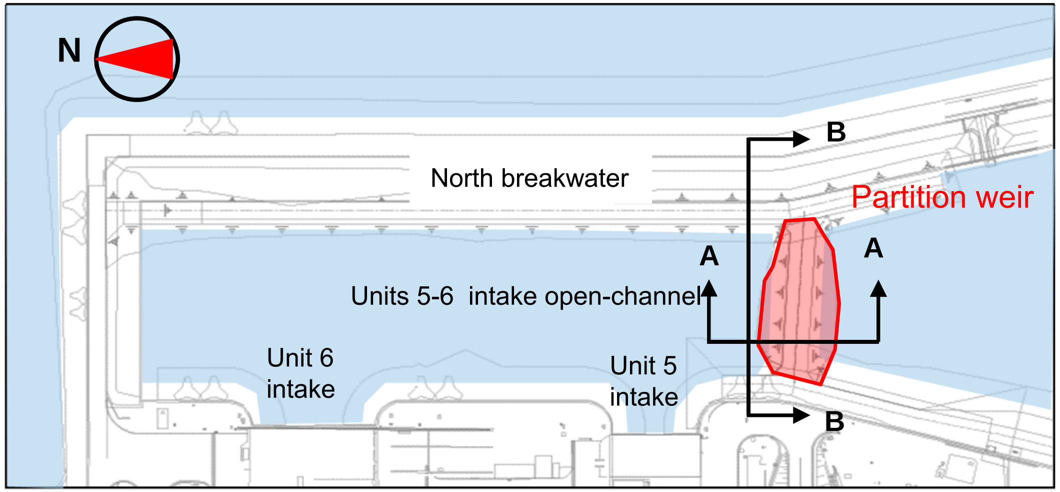
- Units 5-6 intake open-channel and the units 1-4 intake open-channel are separated by two silt fences (two locations).
- Since the silt fences and rope are damaged (wear) due to the influence of the tides and waves by tidal levels, they are replaced every two to three years in addition to periodic maintenance (Performed recently in February 2016, February 2018, and March 2021).
- Due to the impact of tides and waves by tidal levels, the silt fences cannot entirely suppress the drawing in of the seawater with a high concentration of radioactive materials.

After constructing the partition weir

- Installation of sheets on both sides of the partition weir will improve the function and stability as a facility to suppress the intake from the units 1-4 intake open-channel side, compared to the existing silt fences.
- To confirm the suppression effect of the partition weir, after the construction of the partition weir, we will sample the seawater on the Units 5-6 intake open-channel (north) and units 1-4 intake open-channel (south) of the partition weir and compare the concentration of radioactive materials.
- After implementing periodic inspections based on the long-term inspection plan, we will conduct repairs and modifications as necessary.

2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-3.3 Water intake methods: structure of partition weir

- The structural section of the partition weir is shown below:
- The height of the top-end of the partition weir is T.P.+2.2 m, which is higher than the condition of HHWL (the highest sea level in the past: T.P. + 1.15 m), and the inflow of seawater from the units 1-4 side can be avoidable.



Plane view of partition weir

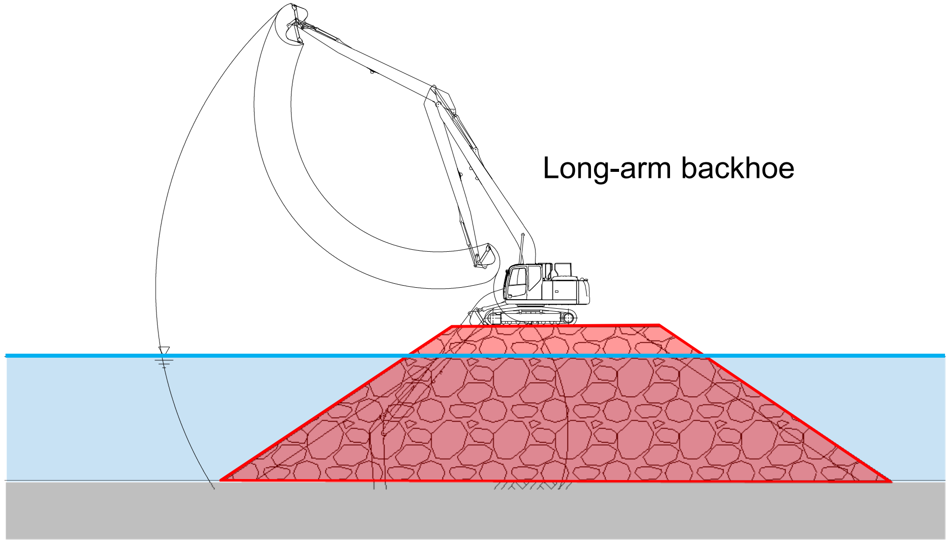
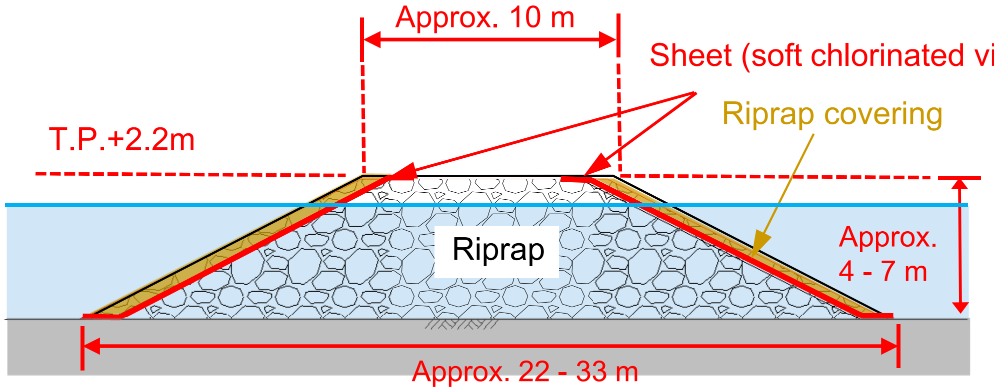
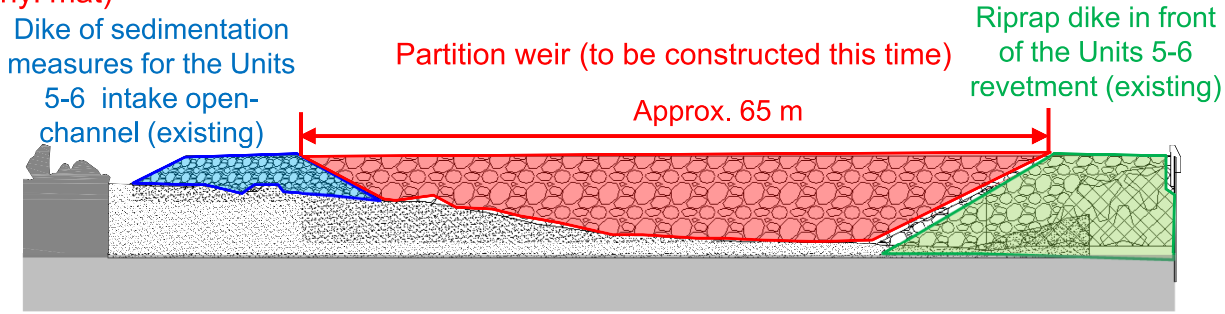


Image drawing of the construction of partition weir



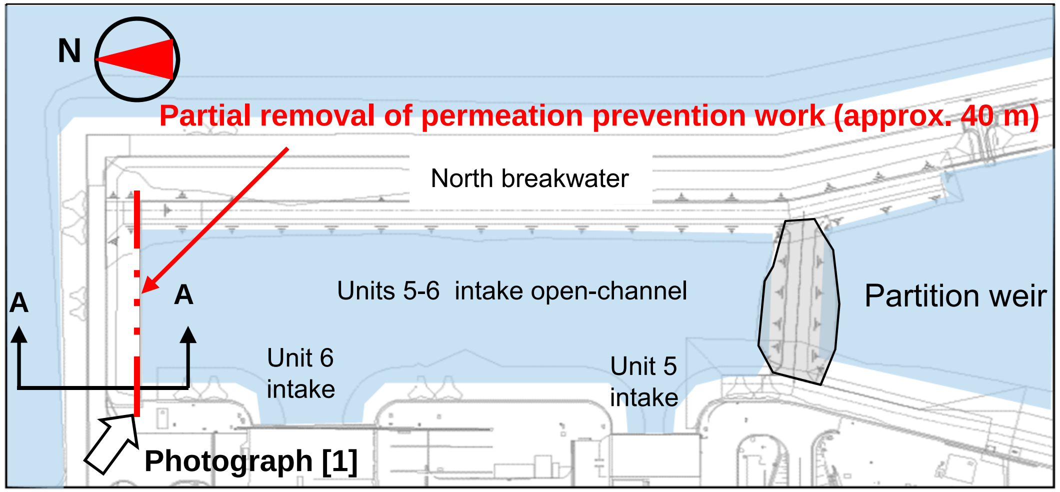
A-A cross-sectional view



B-B cross-sectional view

2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[1]-3.4 Water intake methods: removal of permeation prevention work

- A part of the permeation prevention work (partition wall) located inside the north breakwater (south side) is cut and removed, and seawater for dilution is taken in from outside the port.
- The removed permeation prevention work (concrete and steel sheet pile) is stored as solid waste within the plant site.



Plane view of the partial removal of permeation prevention work

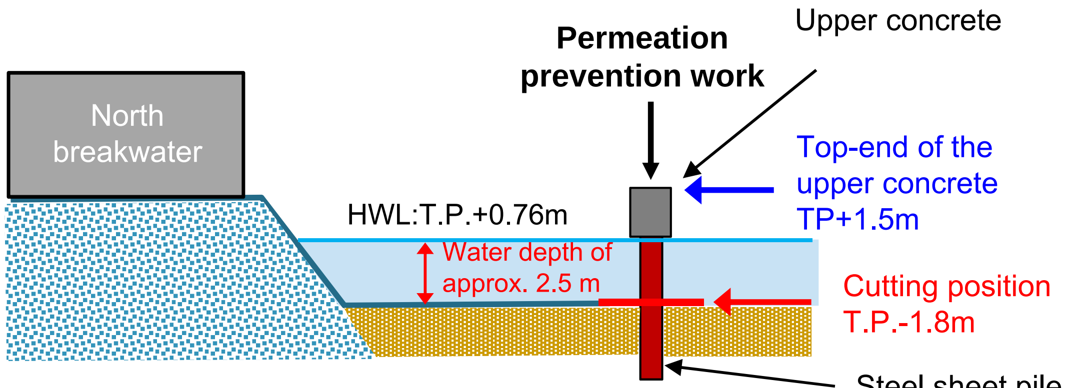
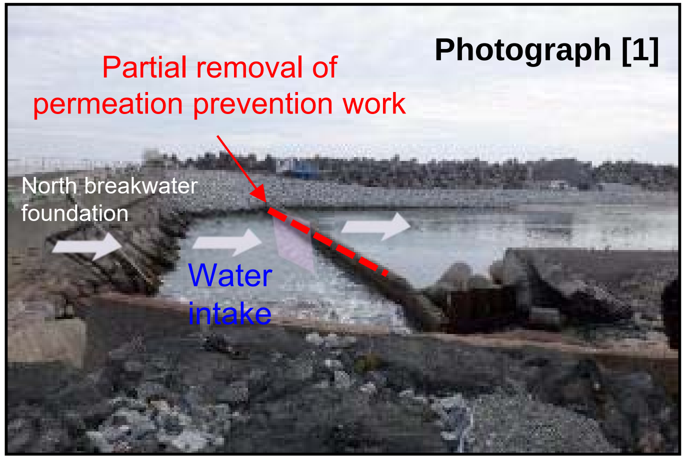


Image drawing of A-A cross-section for permeation prevention work

* In the period between after the construction of the partition weir to the partial removal of the permeation prevention work, there will be almost no supply of seawater from units 1-4 intake open-channel side. However, seawater will be supplied from the side of the north breakwater. Accordingly, there will be no impact on the intake of emergency cooling water (approx. 1.3 m^3/s) for units 5 and 6.



Outline of removal of permeation prevention work

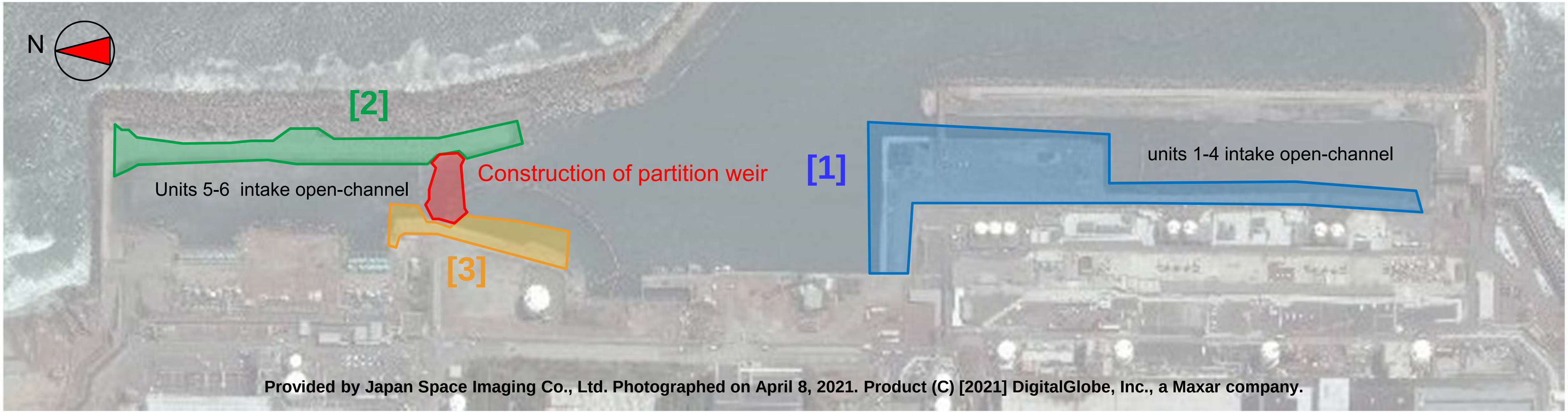
2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution

[1]-3.5 Water intake methods: radioactive material concentration in seawater during the construction of the partition weir (1/3)

- In the last three years, we have experienced pouring materials such as riprap into the sea by using work ships and backhoes within the port.
- During the construction work, we installed the construction fence to prevent contamination, slowed down the work speed, and carefully carried out the work to suppress* the swirling and spread of the seabed earth and sand.
- There was no significant change in the results of monitoring the concentration of radioactive materials in seawater during construction.
- Regarding the construction this time, the method seems no concern and we have determined taking the same method.

*Suppressing the inflow into the Units 5-6 intake and the spread outside the port.

[Construction project name]
[1] Construction for reducing risks such as mega-float tsunami
[2] Construction against sedimentation in front of the Units 5-6 intake
[3] Remodeling work for the Units 5-6 revetment



Construction location map

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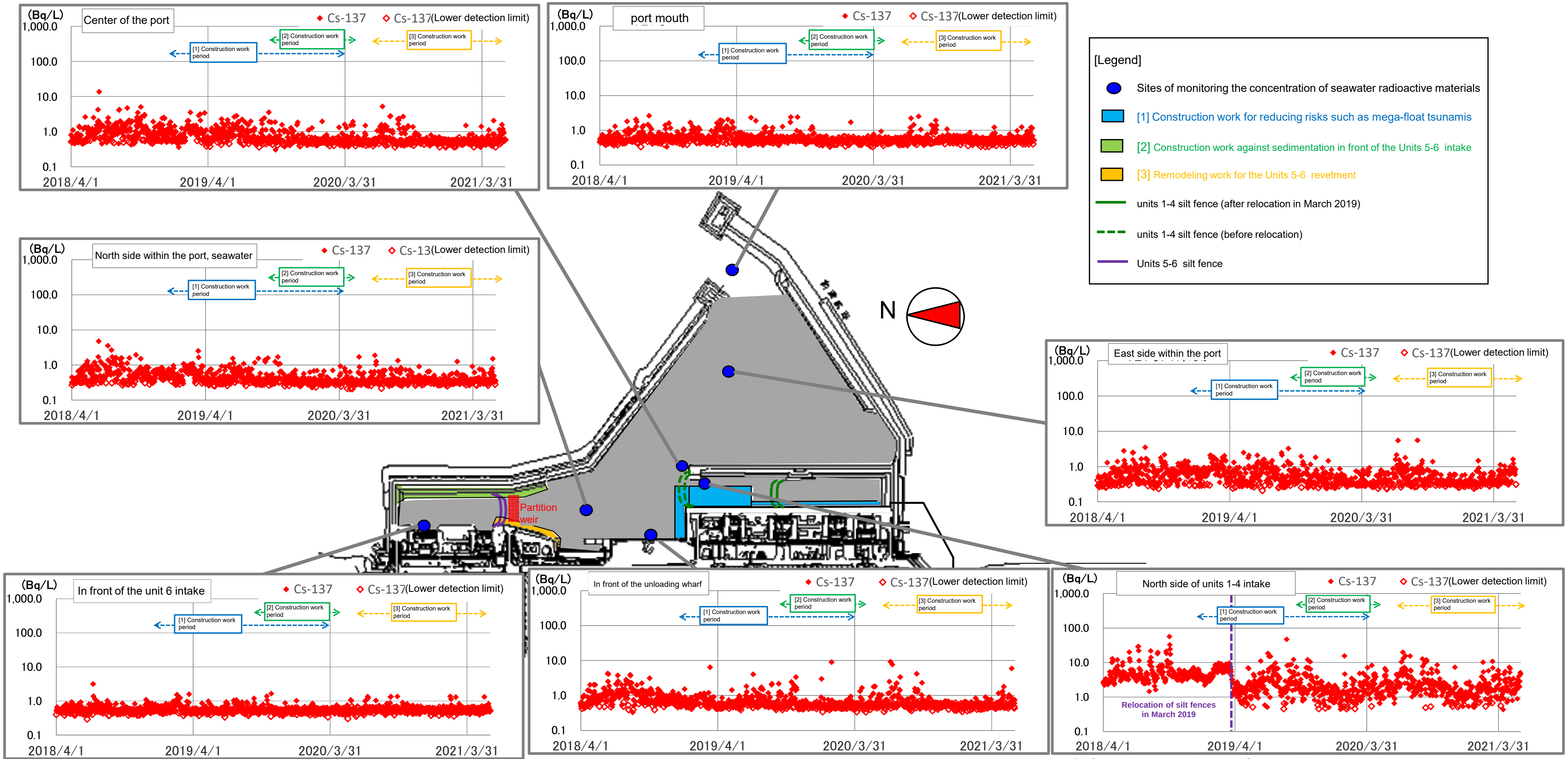
2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution

[1]-3.5 Water intake methods: radioactive material concentration in seawater during the construction of the partition weir (2/3)

- The following shows the results of monitoring on the concentration of seawater radioactive materials (Cs-137) during the construction works within the port in the past three years:
- No significant effects of the construction work found within the port.

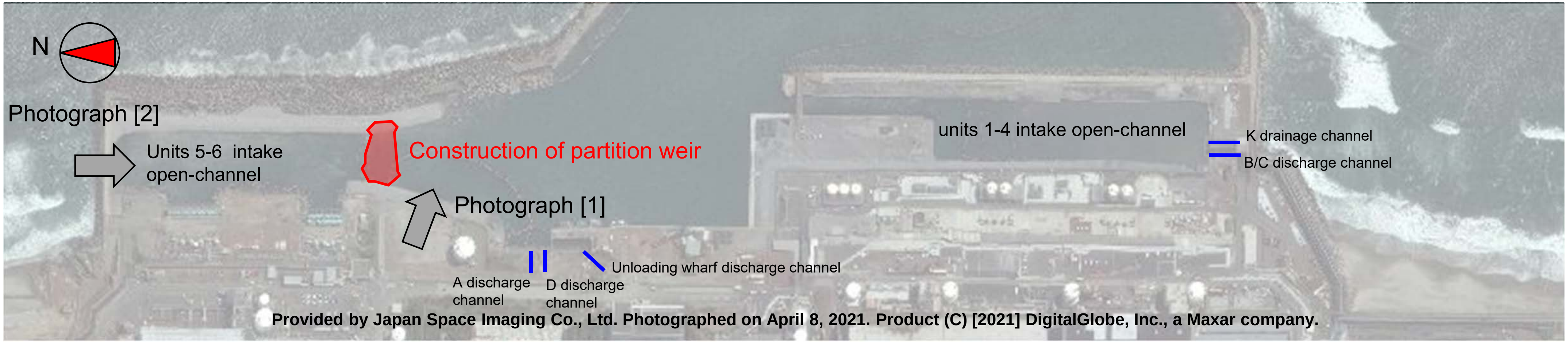


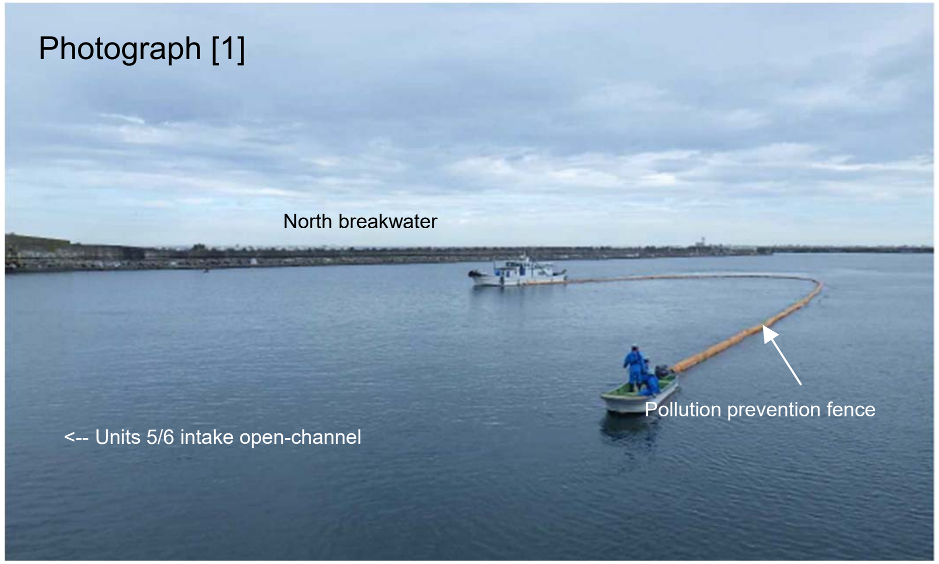
*After relocating the silt fence within the units 1-4 intake open-channel to the south in March 2019, the concentration of radioactive materials in the seawater on the north side inside the units 1-4 intake decreased.

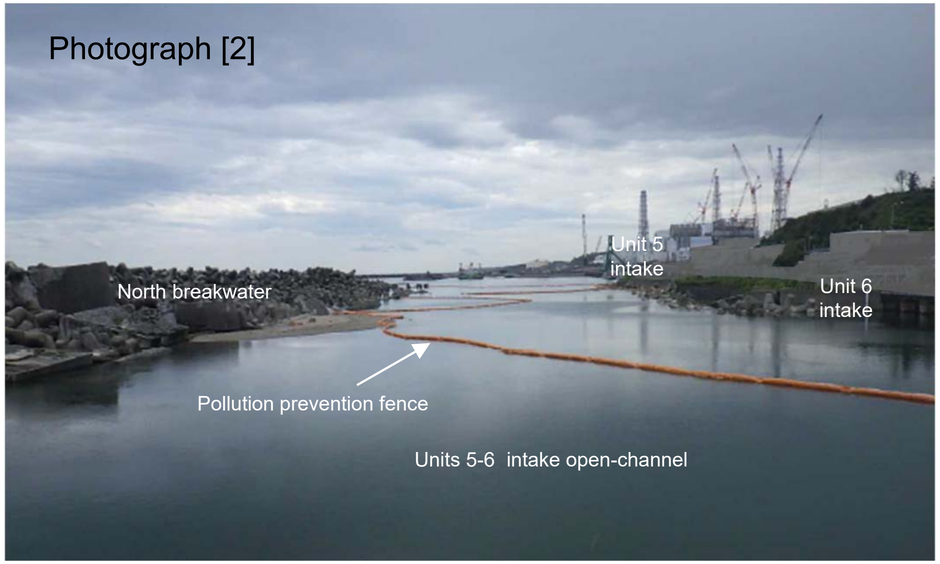
Concentration of seawater radioactive materials during the construction within the port

[1]-3.5 Water intake methods: radioactive material concentration in seawater during the construction of the partition weir (3/3)

- Building the partition weir may cause swirl-up of the seabed for pouring riprap into the sea, silt fences will be placed to prevent underwater pollution.
- Below shows the positions of underwater pollution prevention fence in Units 5-6 intake open-channel construction work.







Results of Pollution prevention fence installation in the Units 5-6 intake open-channel construction work

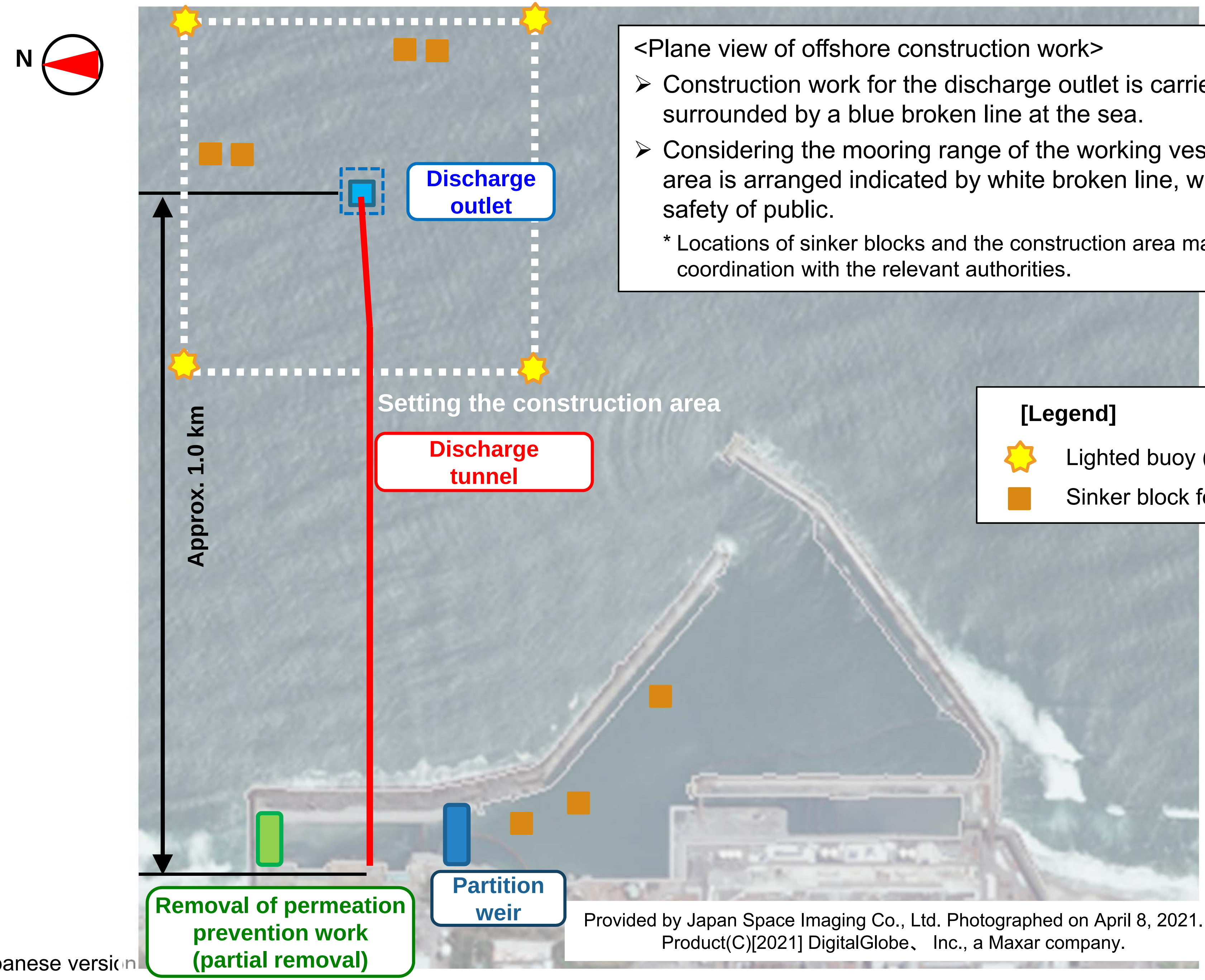
Methods of seawater intake and discharging ALPS treated water after dilution

Water intake methods: construction methods

Discharge methods: construction methods

Enhanced monitoring associated with offshore construction work

[1]-4.1 Discharge methods: plane view of offshore construction work



<Plane view of offshore construction work>

- Construction work for the discharge outlet is carried out within the range surrounded by a blue broken line at the sea.
- Considering the mooring range of the working vessel, the construction area is arranged indicated by white broken line, which allows navigation safety of public.

* Locations of sinker blocks and the construction area may change due to coordination with the relevant authorities.

[Legend]

- Lighted buoy (including sinker block)
- Sinker block for mooring vessels

[1]-4.2 Discharge methods: construction work flow (1/2)

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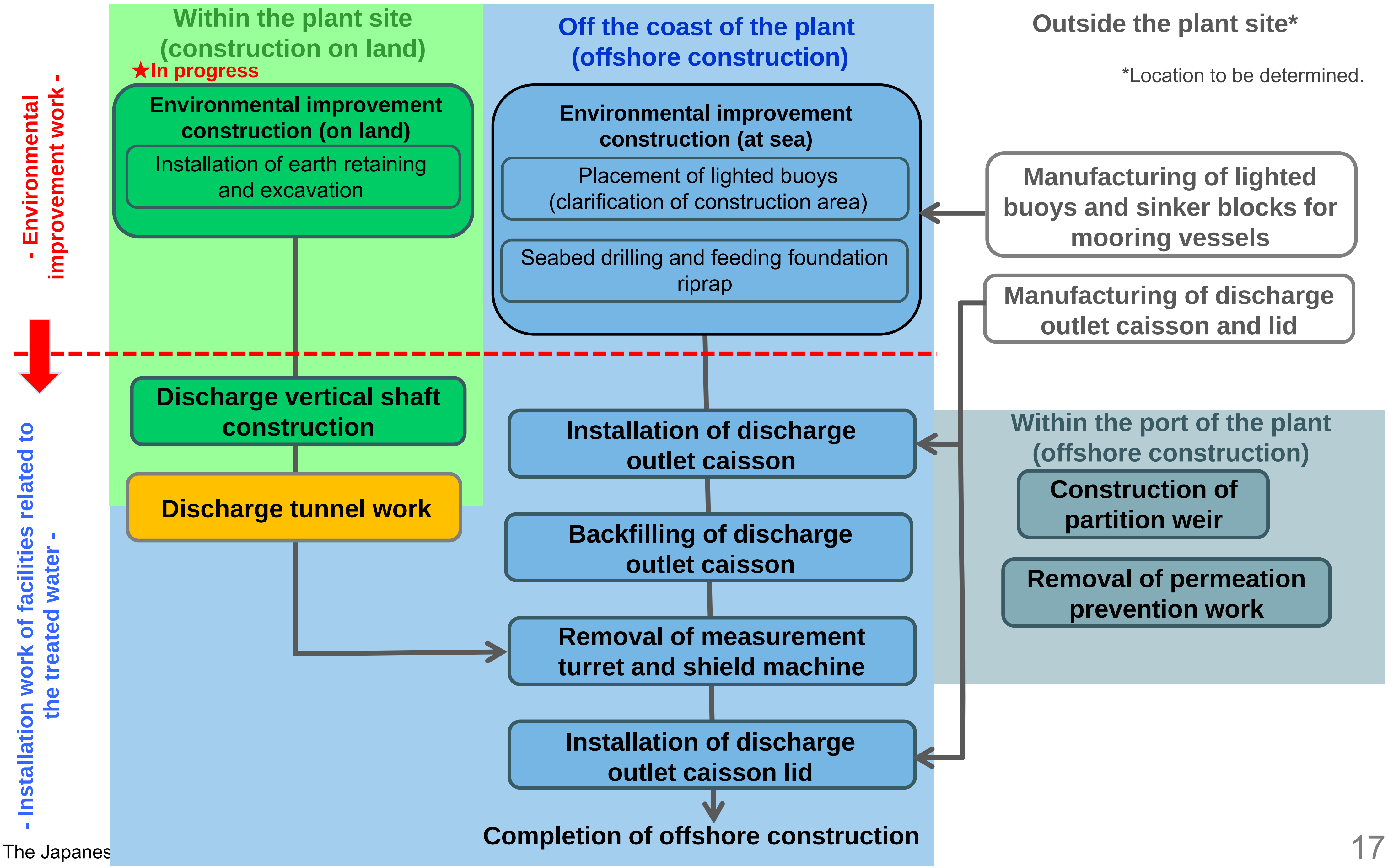

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[1]-4.2 Discharge methods: construction flow (2/2)

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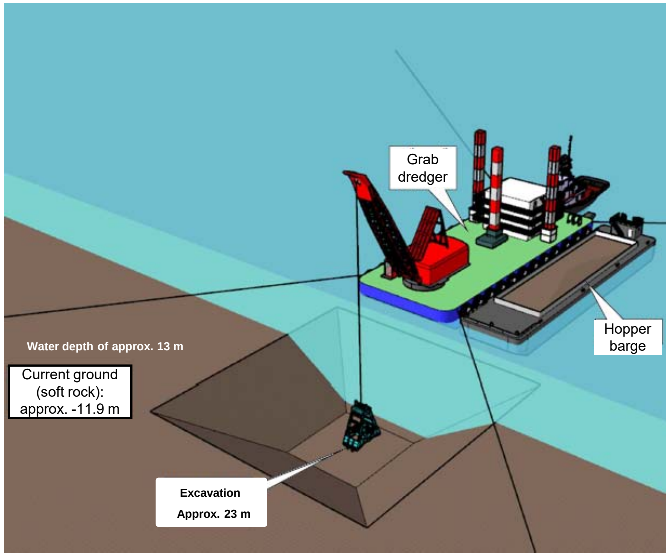
- A grab dredger (drilling ship) excavates the discharge tunnel outlet.
- On the seabed drilled, the discharge outlet caisson made of reinforced concrete will be installed using a large-scale crane barge.
- The shield machine excavating the discharge tunnel will be removed from the discharge outlet caisson with a large floating crane.

- Environmental improvement work -

- Installation work of facilities related to the treated water -

STEP1

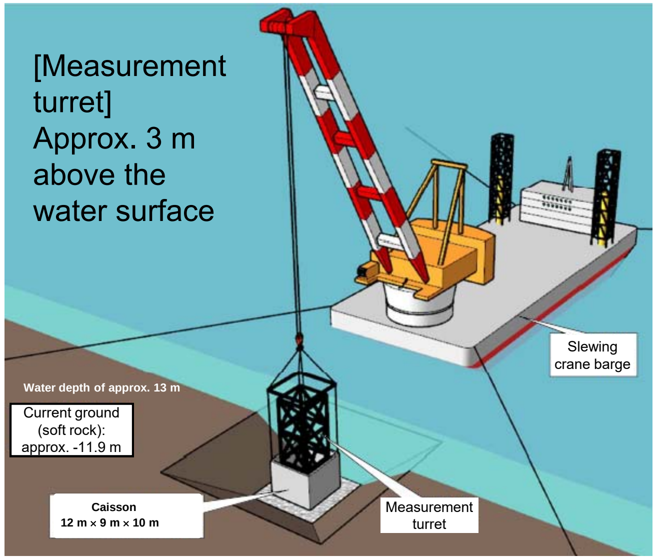


[Drilling bedrock and manufacturing caisson]

1. A grab dredger (drilling ship) excavates Bedrock.
2. Excavated seabed soil is carried into the plant site.
3. While excavating the bedrock, the caisson is manufactured outside the plant site.*

*Location to be determined.

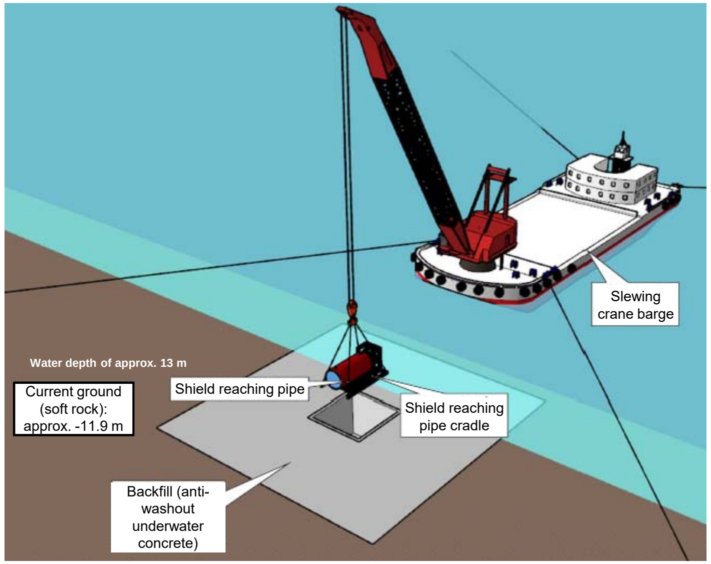
STEP 2



[Installation of caisson]

1. Caisson is transported to sea from outside the plant site and installed using a large-scale crane barge.
2. The periphery of the caisson is backfilled with concrete or the like.
3. For the reaching of the shield machine, a steel measurement turret connected with the caisson manages information about the location of the caisson.

STEP 3



[Shield machine removal and a lid installation]

1. After the shield machine reaches the reaching pipe inside the caisson, the tunnel is filled with seawater.
2. Separating the reaching pipe from the caisson, the shield machine (reaching pipe) is removed using the crane barge.
3. The caisson lid is installed in the end.

*Numbers including depth may change due to future studies.

- To set the construction area at sea, the crane barge places four lighted buoys and four sinker blocks (25 tons each) for mooring the flighted buoys.
- For mooring ships for construction, four sinker blocks (110 tons each) are placed outside the port and three sinker blocks (25 tons, and 40 tons) within the port using the crane barge .

Imape photo of a lighted buoy

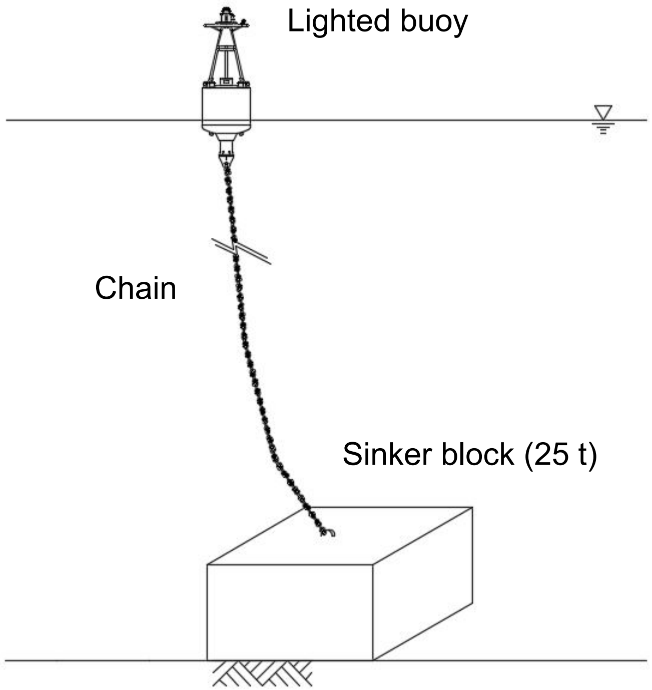


Image drawing of setting a lighted buoy

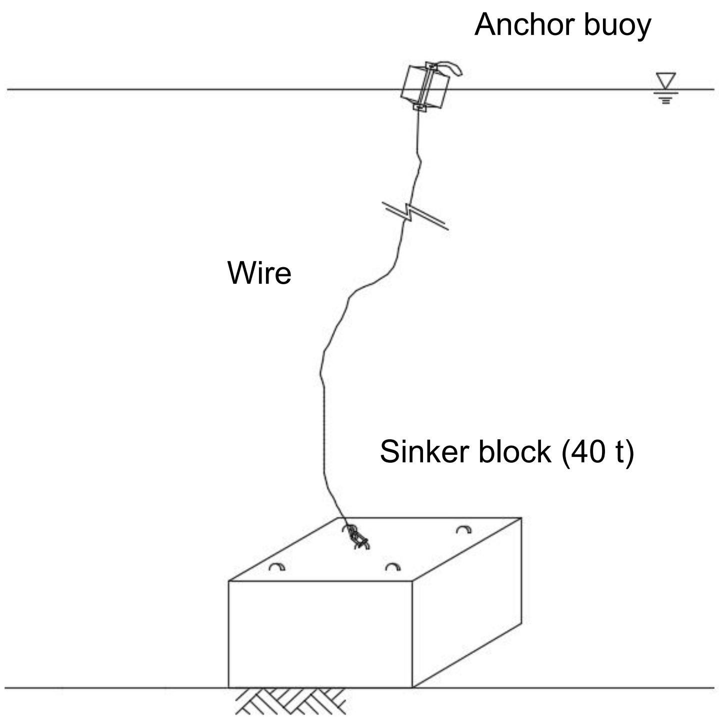


Image drawing of installing sinker blocks for mooring ships

- Sinker blocks are manufactured outside the plant site (*) and loaded onto the crane barge.

*Location to be determined.

[1]-4.4 Drilling at sea

- The grab dredger excavates the seabed surface to install the discharge outlet caisson.
- The seabed soil excavated is transported to the unloading wharf within the port of the plant by the hopper barge. Backhoes unload the earth and sand and carry them to a disposal area within site.

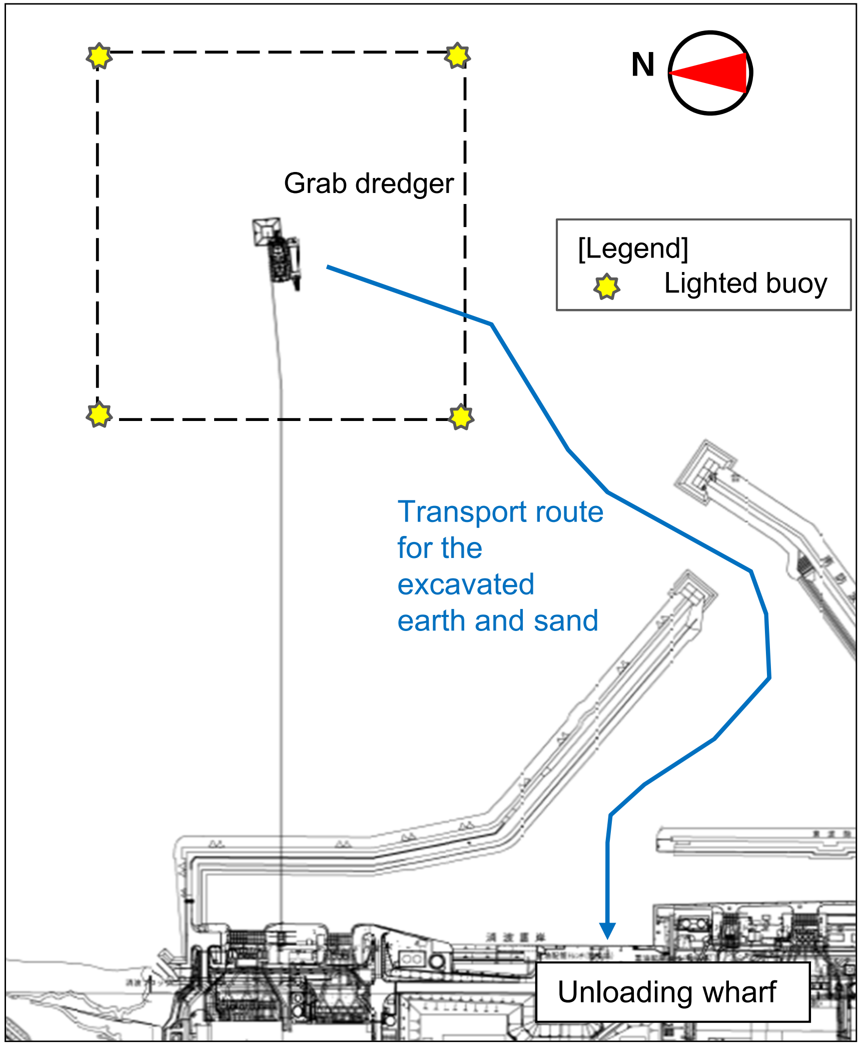


Image drawing of drilling at sea with grab dredger (plane view)

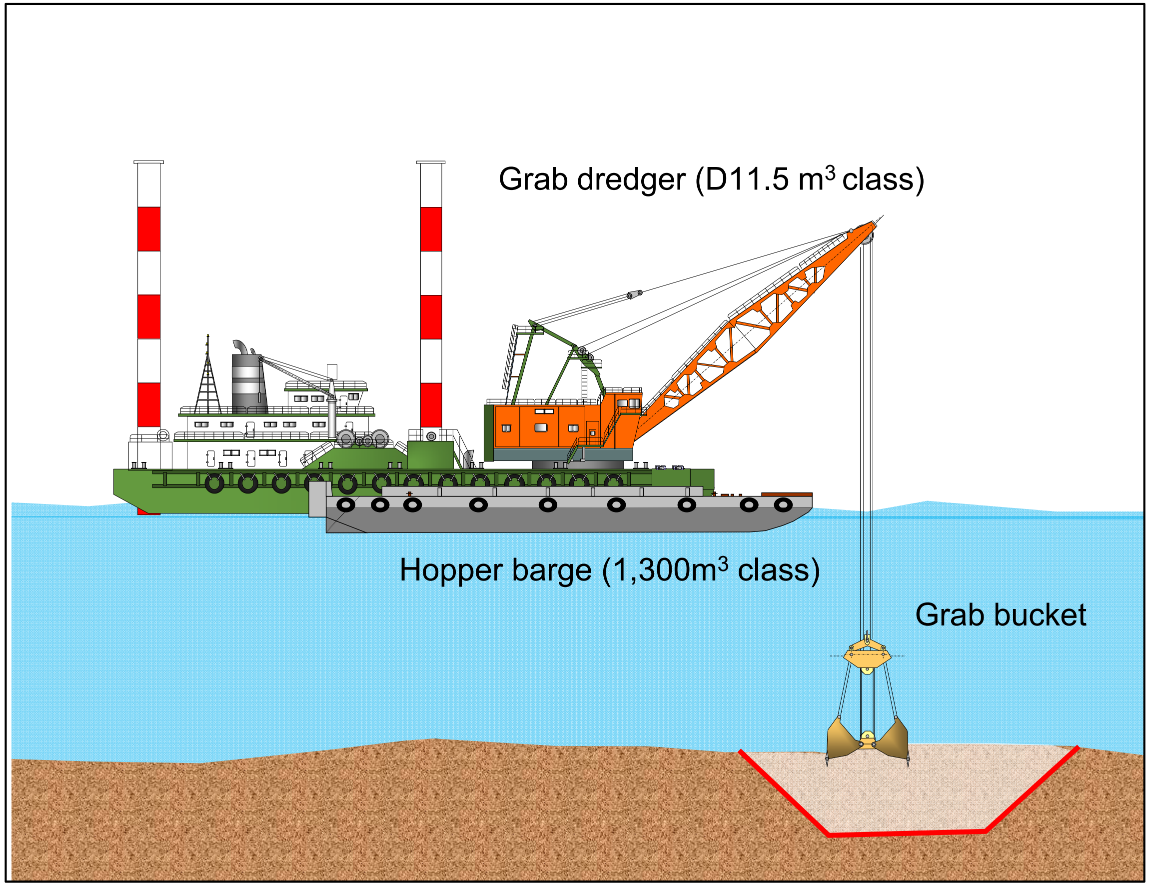


Image drawing of drilling at sea with grab dredger (sectional view)

[1]-4.5 Manufacturing of caisson

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- Discharge outlet caisson will be manufactured outside the plant site(*). *Location to be determined.
- A measurement turret to control the location information for tunnel drilling and the reaching pipe to which the shield machine reaches will be installed inside the caisson in advance.

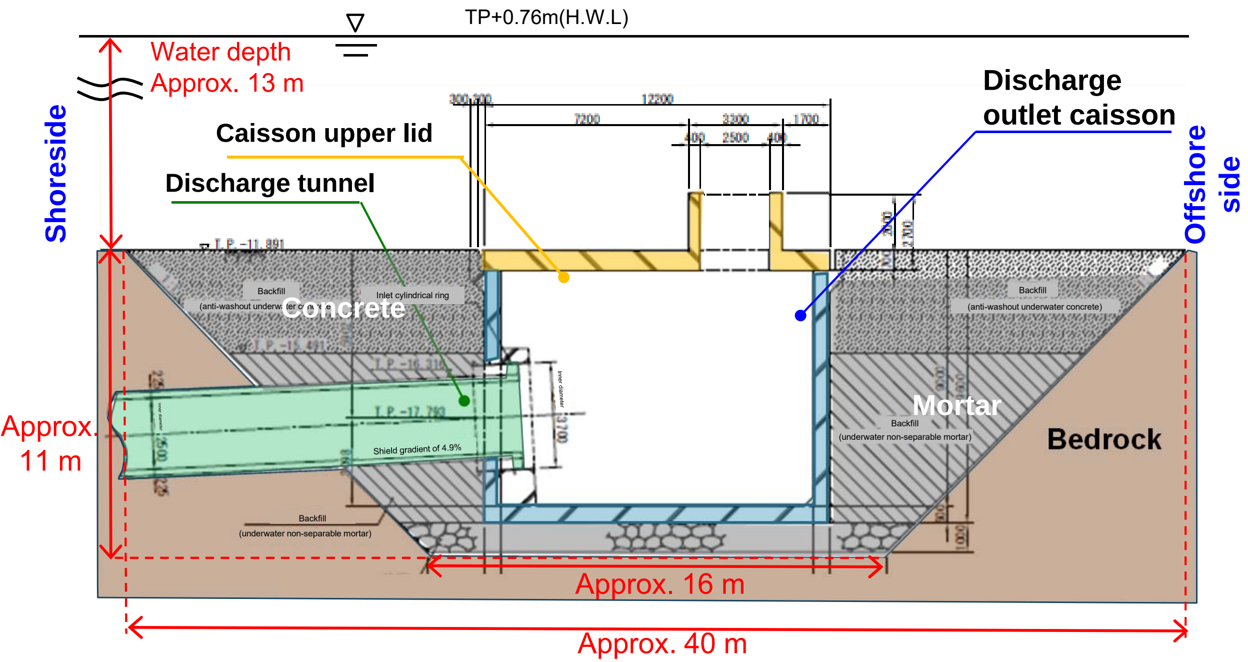


Image drawing of the discharge outlet cross-section

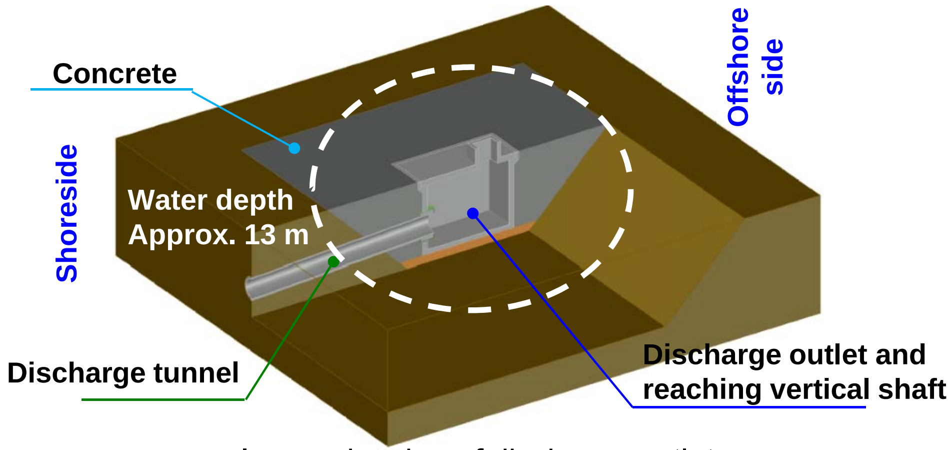


Image drawing of discharge outlet

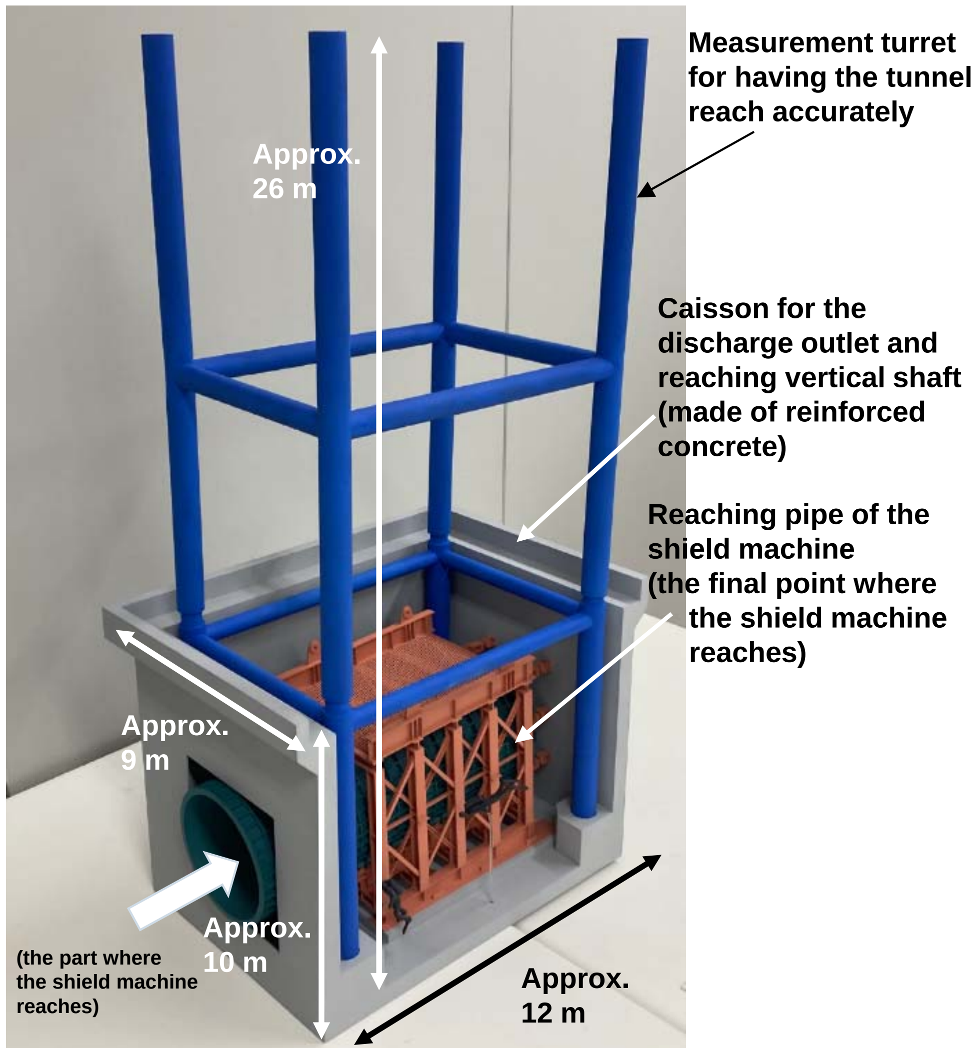


Image drawing of manufacturing discharge outlet caisson

[1] -4.6 Installation of discharge outlet caisson (1/2)

- A large-scale crane barge installs a discharge outlet caisson.
- The crane barge loads the discharge outlet caisson manufactured outside the plant site* and delivers it to the installation location off the coast of the plant.

*Manufacturing site and transporting methods are to be determined.

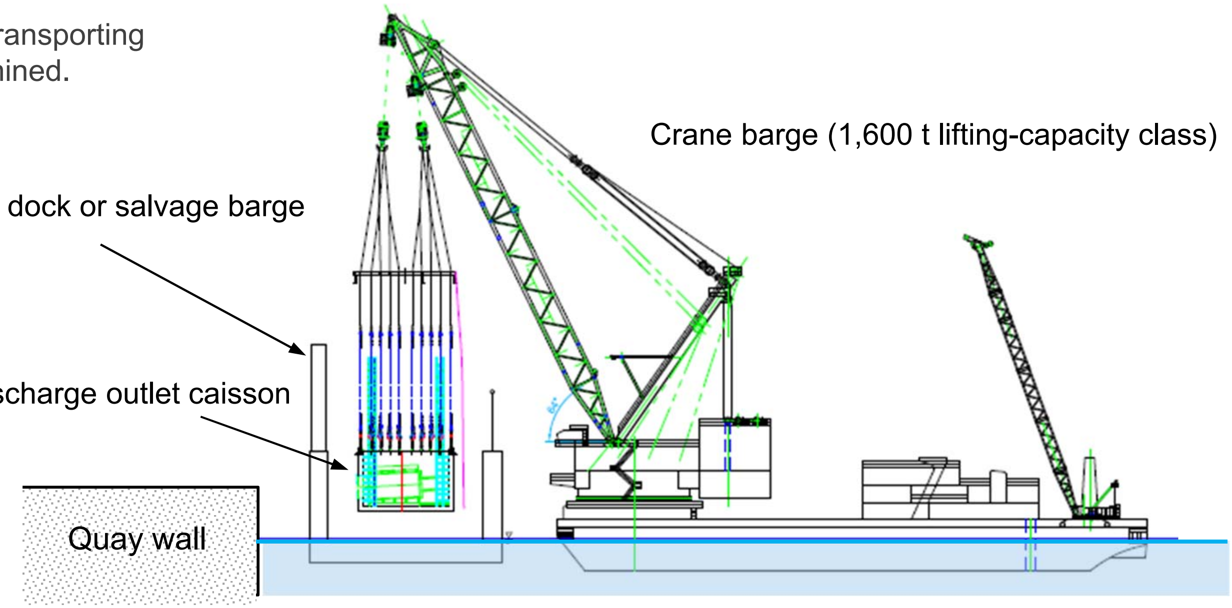


Image drawing of discharge outlet caisson loading

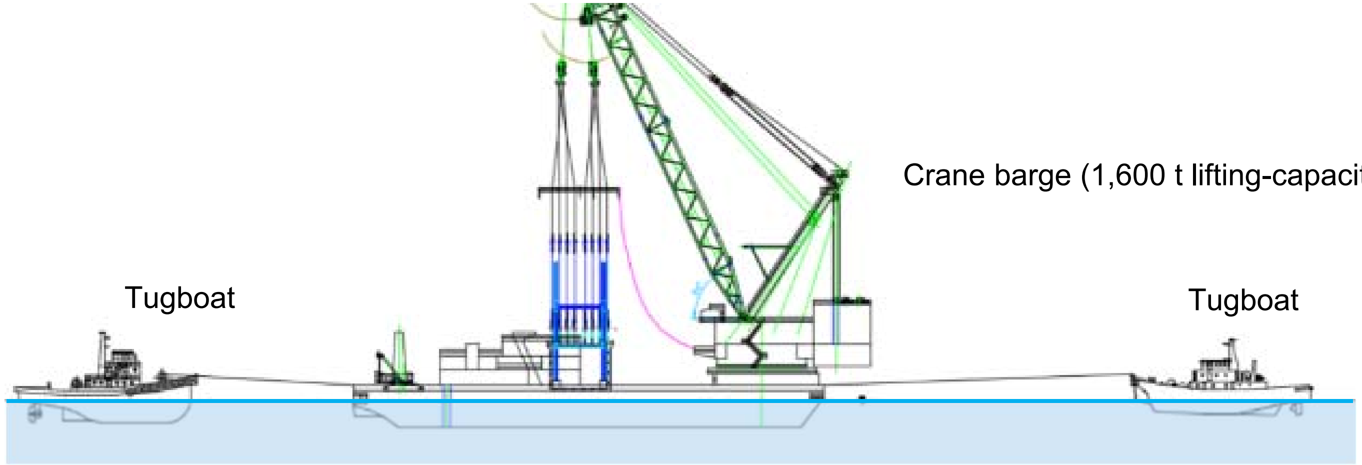


Image drawing of discharge outlet caisson delivery

[1] -4.6 Installation of discharge outlet caisson (2/2)

- Sinker blocks (110 tons each) and anchors, which is placed in advance, fix a large-scaled crane barge using mooring wires. The crane barge moves to the installation location operating mooring wires of the crane barge winch by supplying and rewinding the wires and installs the discharge outlet.
- The crane barge is guided to the installation location by GPS installed on the crane barge and at the measurement turret installed at the caisson measuring from the land side.

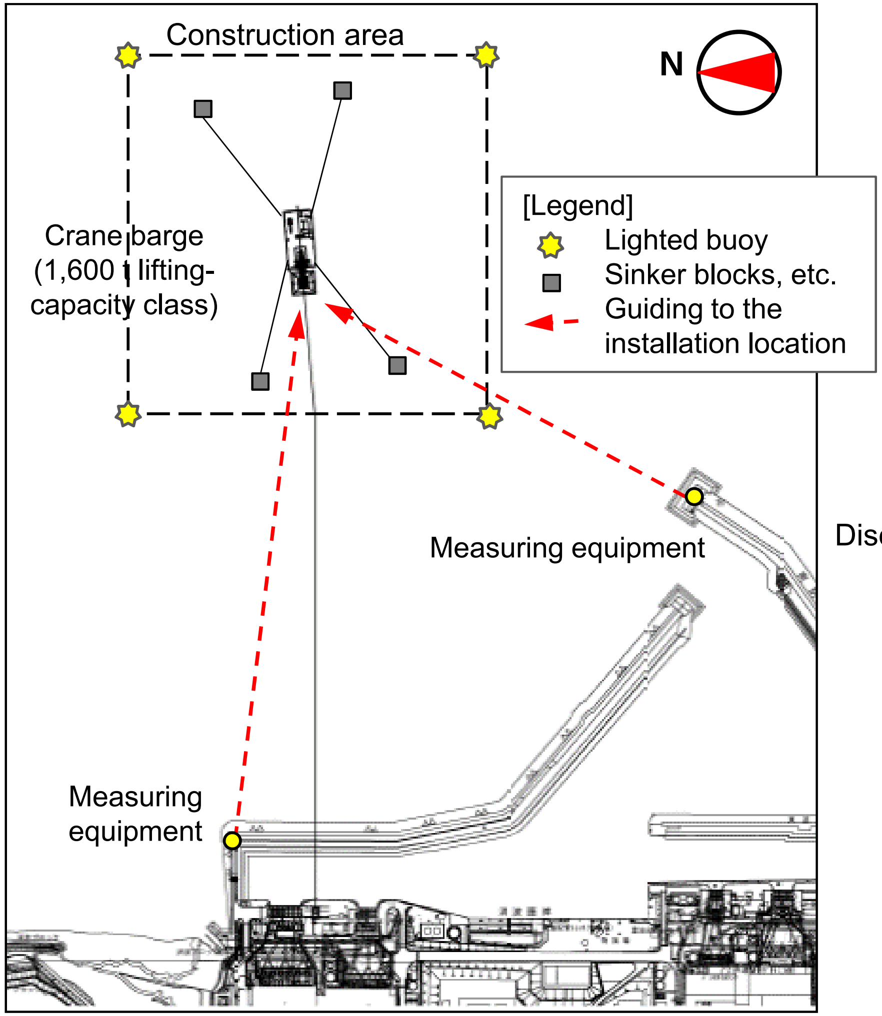


Image drawing of discharge outlet caisson installation
(plane view)

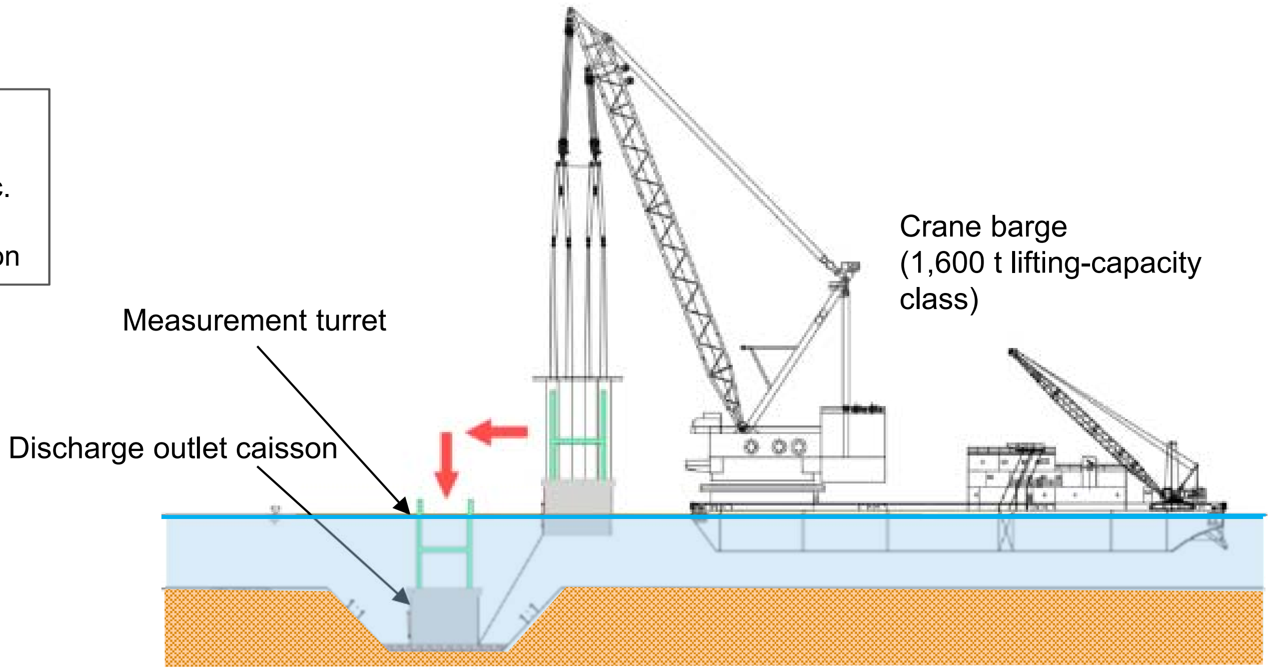


Image drawing of discharge outlet caisson installation
(sectional view)

[1] -4.7 Backfill of discharge outlet caisson

- Around the discharge outlet caisson, underwater non-separable concrete or underwater non-separable mortar will be poured into from a concrete plant vessel for backfill.
- The area from the bottom surface to the part where the shield machine passes through, underwater non-separable mortar will be poured into while underwater non-separable concrete will be poured into the remaining space.

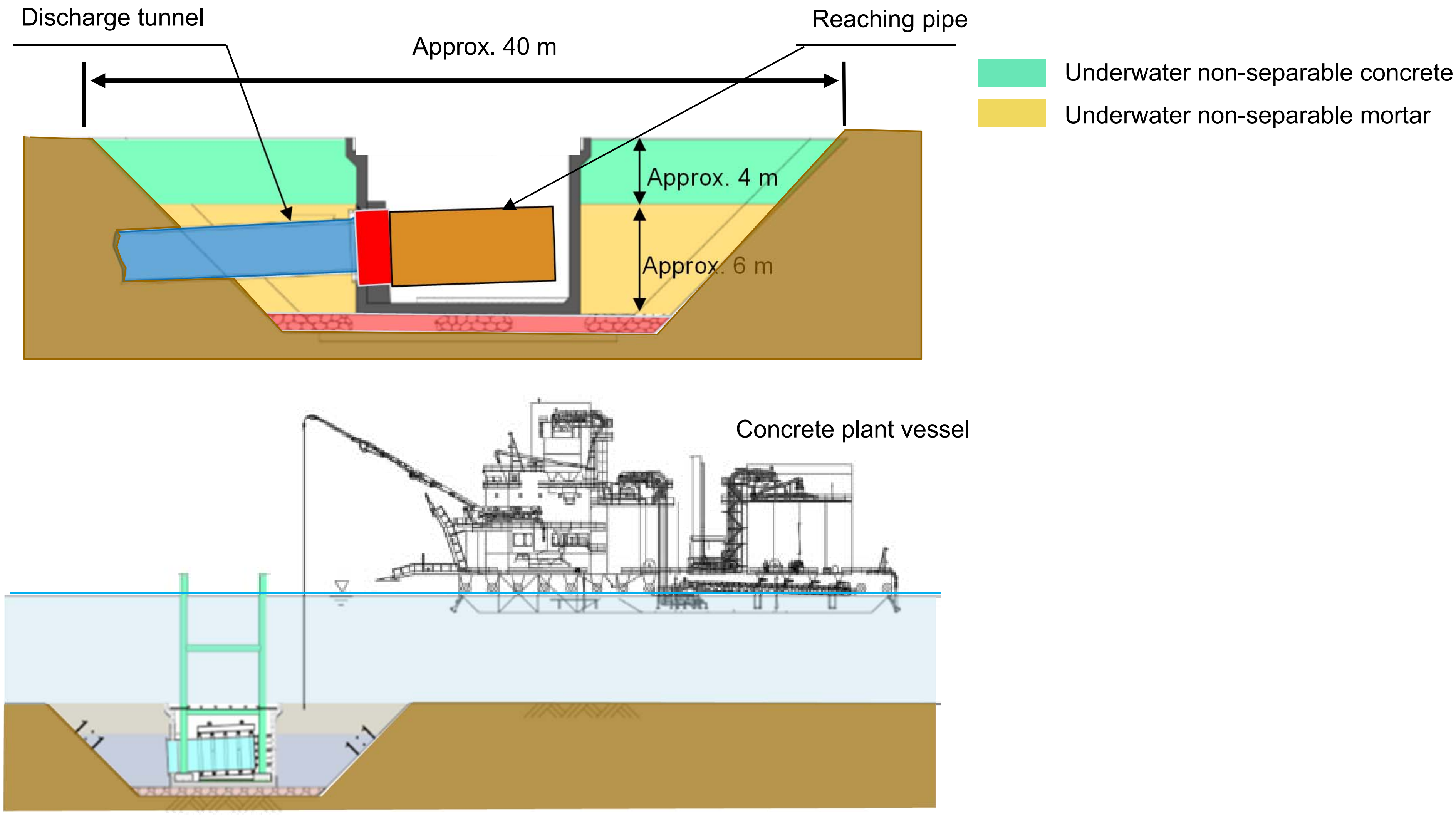


Image drawing of the backfill cross-section

[1]-4.8 Removal of measurement turret and shield machine

- After the shield machine reaches the inside of the reaching pipe of the inner caisson, the measurement turret will be removed using the crane barge.
- After removing the measurement turret, a water injection valve at the reaching pipe will be operated to inject seawater inside the tunnel*.
- After checking that the inside the tunnel is filled with seawater, the reaching pipe will be separated from the connection of the discharge outlet caisson*.
- The crane barge will remove the reaching pipe.

*Regarding the construction work of the connection between the discharge outlet caisson and the discharge tunnel is explaned separately.

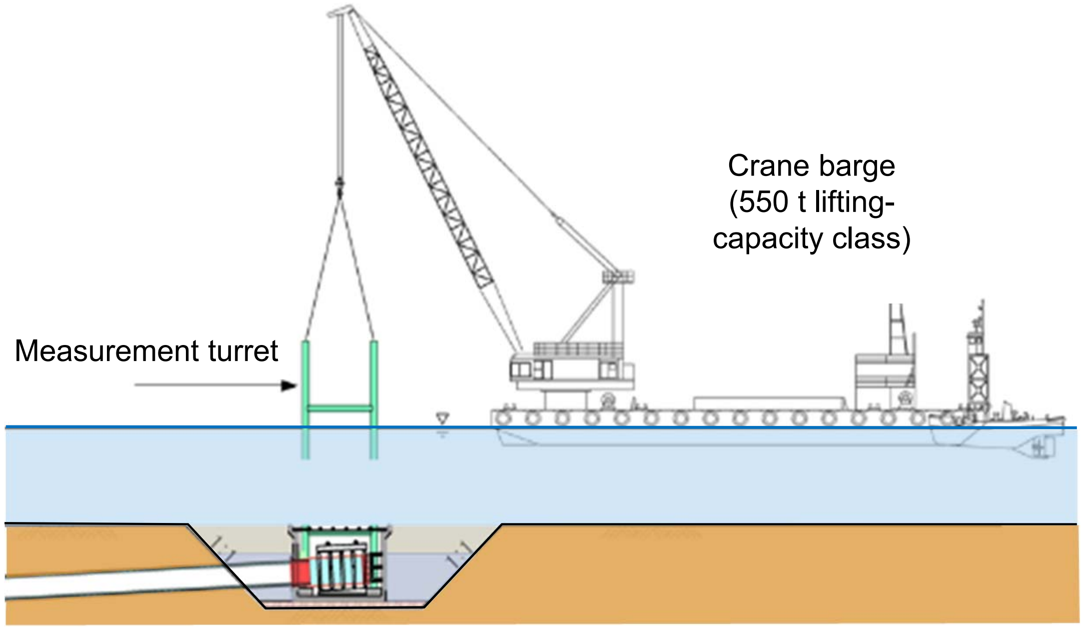


Image drawing of measurement turret removal

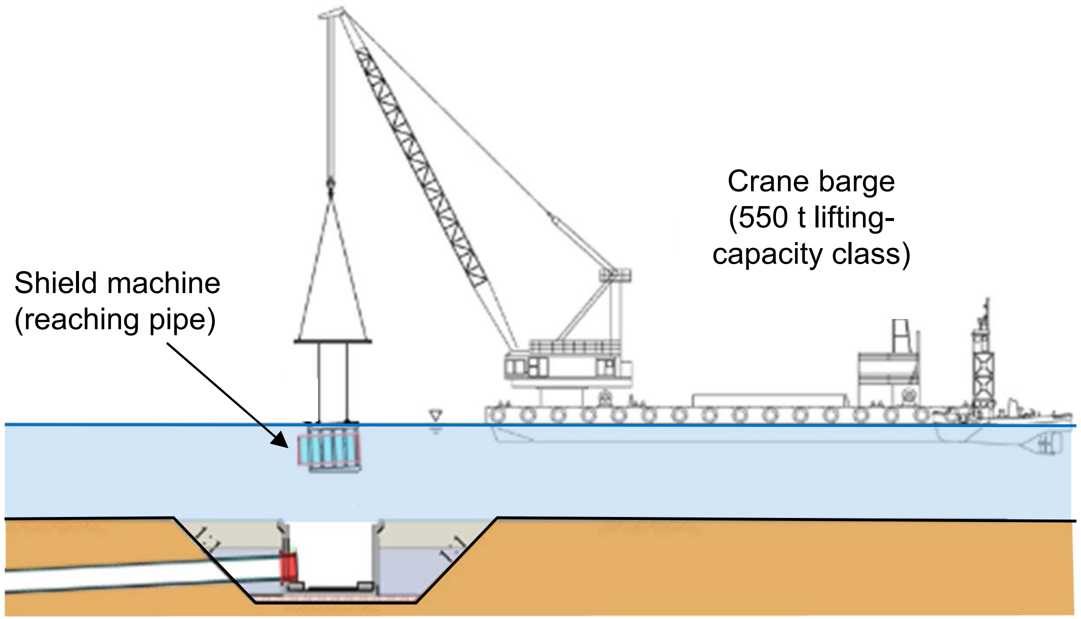


Image drawing of shield machine (reaching pipe) removal

[1] -4.9 Installation of discharge outlet caisson lid

- A discharge outlet lid will be manufactured outside the plant site.*
- The manufactured lid will be loaded onto the crane barge. Then, it will be transported by sea to the installation location off the coast of the plant site and installed at the top-end of the discharge outlet caisson.

*Location to be determined.

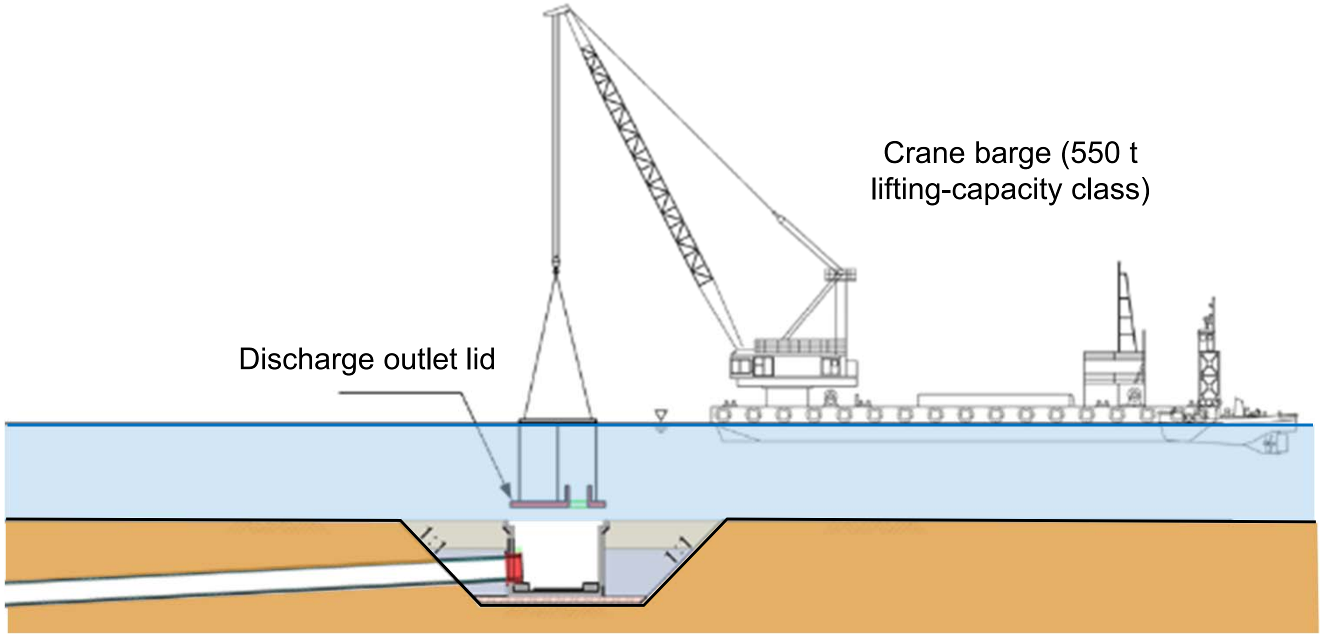


Image drawing of discharge outlet caisson lid installation

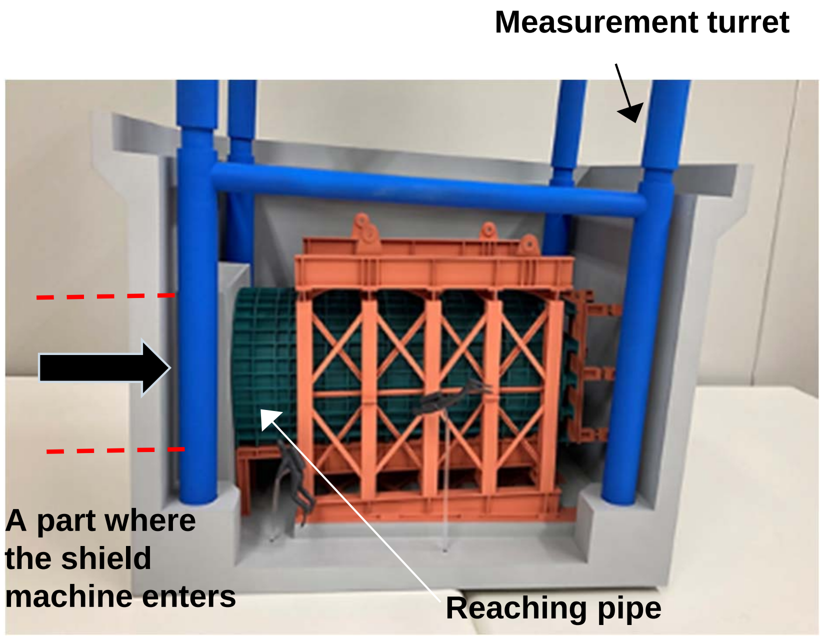
[Reference] Discharge methods (connection): construction overview

- The shield machine will tunnel its way to the reaching pipe installed beforehand inside the discharge outlet caisson and will be connected to the discharge outlet caisson. After that, water will be cut off to prevent water leakage from the surroundings of the tunnel, then remove the equipment and materials inside the tunnel from the starting shaft* on the land side.
- After removing the measurement turret integrated with the discharge outlet caisson, water will be injected inside the tunnel, so that the discharge tunnel will be filled with seawater.
- The reaching pipe that houses the shield machine will be separated from the discharge outlet caisson and be removed using the crane barge.

*Starting shaft will be constructed as a discharge vertical shaft (down-stream storage) after the completion of discharge tunnel installation.

Construction flow

Shield machine reaching
↓
Water cut-off
↓
Removal of measurement turret
↓
Water injection
↓
Removal of reaching pipe



Lateral view of discharge outlet caisson

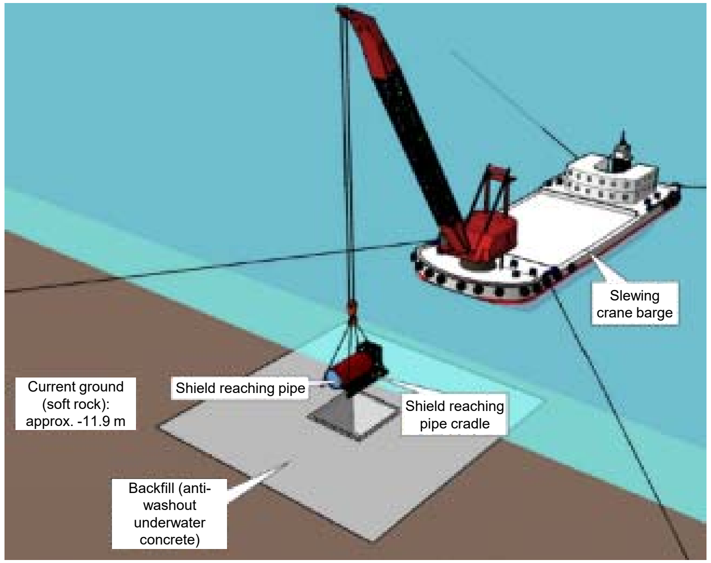


Image drawing of reaching pipe (shield machine) removal

The Japanese version shall prevail.

[Reference] Discharge methods (connection):Condition when the shield machine reaches

- To have the shield machine reach the discharge outlet with high accuracy, reduce the drilling speed of the shield machine just before the mortar portion.

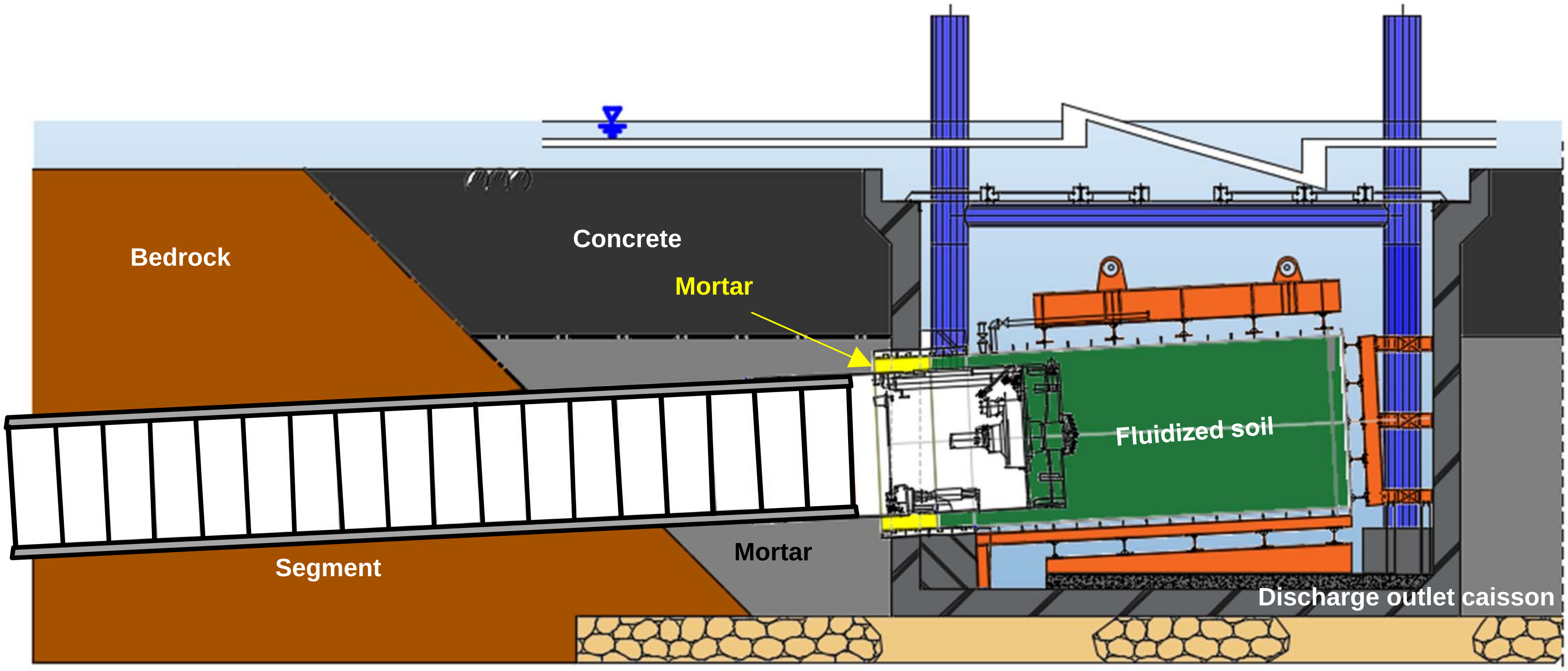


Image drawing of the shield machine reaching

[Reference] Discharge methods (connection): water cut-off methods

TEPCO

- To ensure the work safety, underground water inside the bedrock (water channel [1]) and the underground water at the connection part between the discharge outlet caisson and the concrete and mortar (water channel [2]) will be cut-off.
- The water channel [1], the gap between segments and bedrock in the section from the starting shaft on the land side to the mortar portion, will be cut-off filled with backfilling materials (red line) .
- The water channel [2], assuming the underground water flows through the connection between the discharge outlet caisson and concrete and mortar, will be cut-off the water through chemical injection (green line) from inside the tunnel.

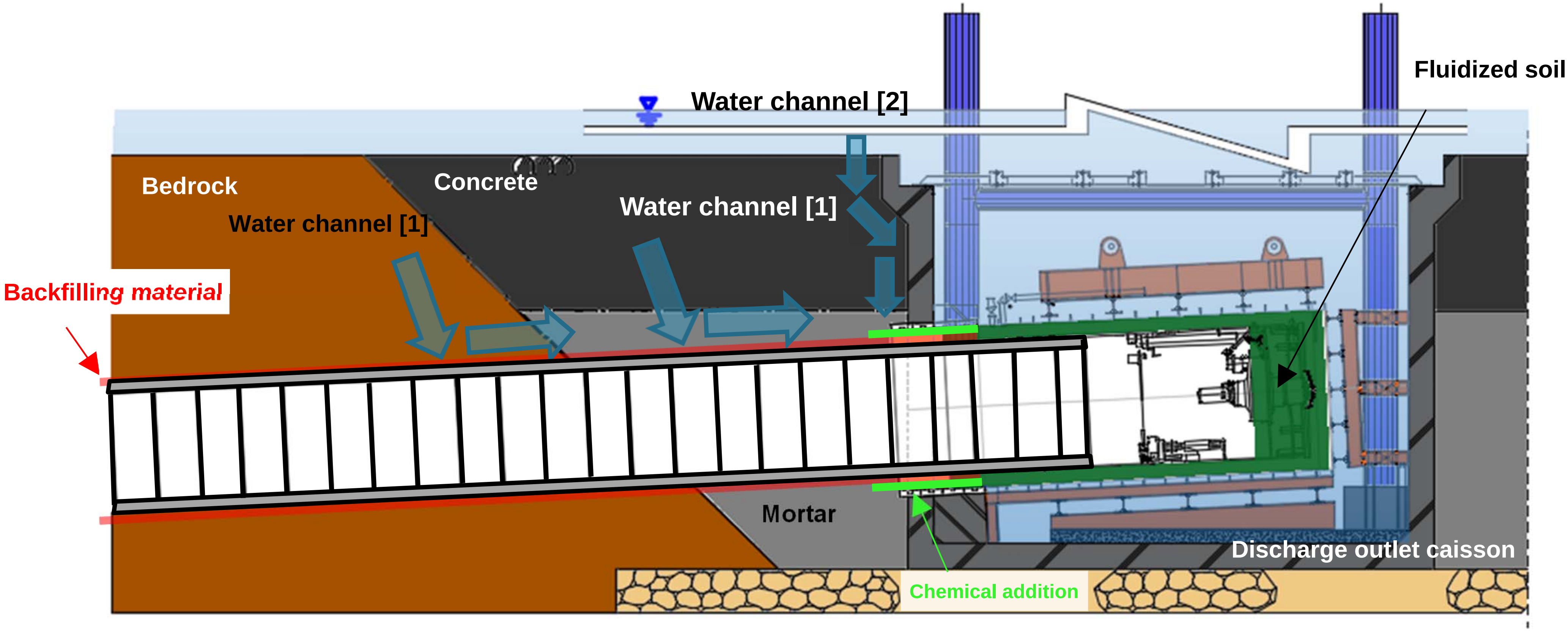


Image drawing of water cut-off for water channels

[Reference] Discharge methods (connection): water cut-off methods (details)

TEPCO

- Remove segments at the water injection section from inside the tunnel. Then remove backfilling materials around the periphery of the tunnel and the fluidized soil will be removed ([1]).
- To stop water from the fluidized soil removed, install a water cut-off ring from inside the tunnel. ([2])
- After completing the water cut-off, remove the measurement turret of the discharge outlet caisson.

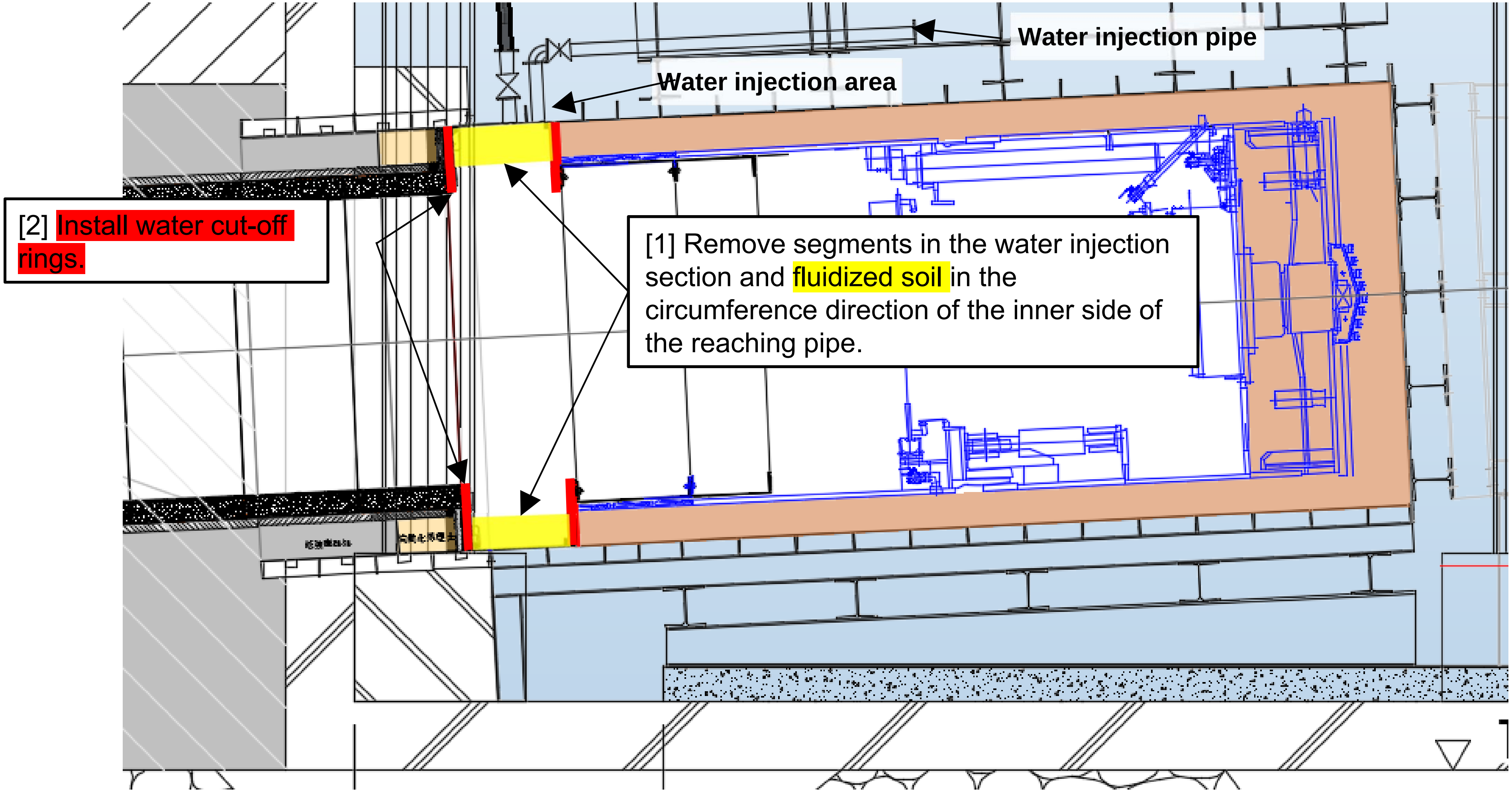


Image drawing of water cut-off (details)

[Reference] Discharge methods (connection): water injection methods

- Install a temporary lid at the connection between the starting shaft and the tunnel to prevent seawater inflow into the starting shaft side (on land side).
- Before injecting seawater, connect an air vent hose by diving operations to create an air passage inside the tunnel.
- Diving operations operate water injection valves that regulate water injection from the water injection pipe to fill the inside of the tunnel with seawater gradually.

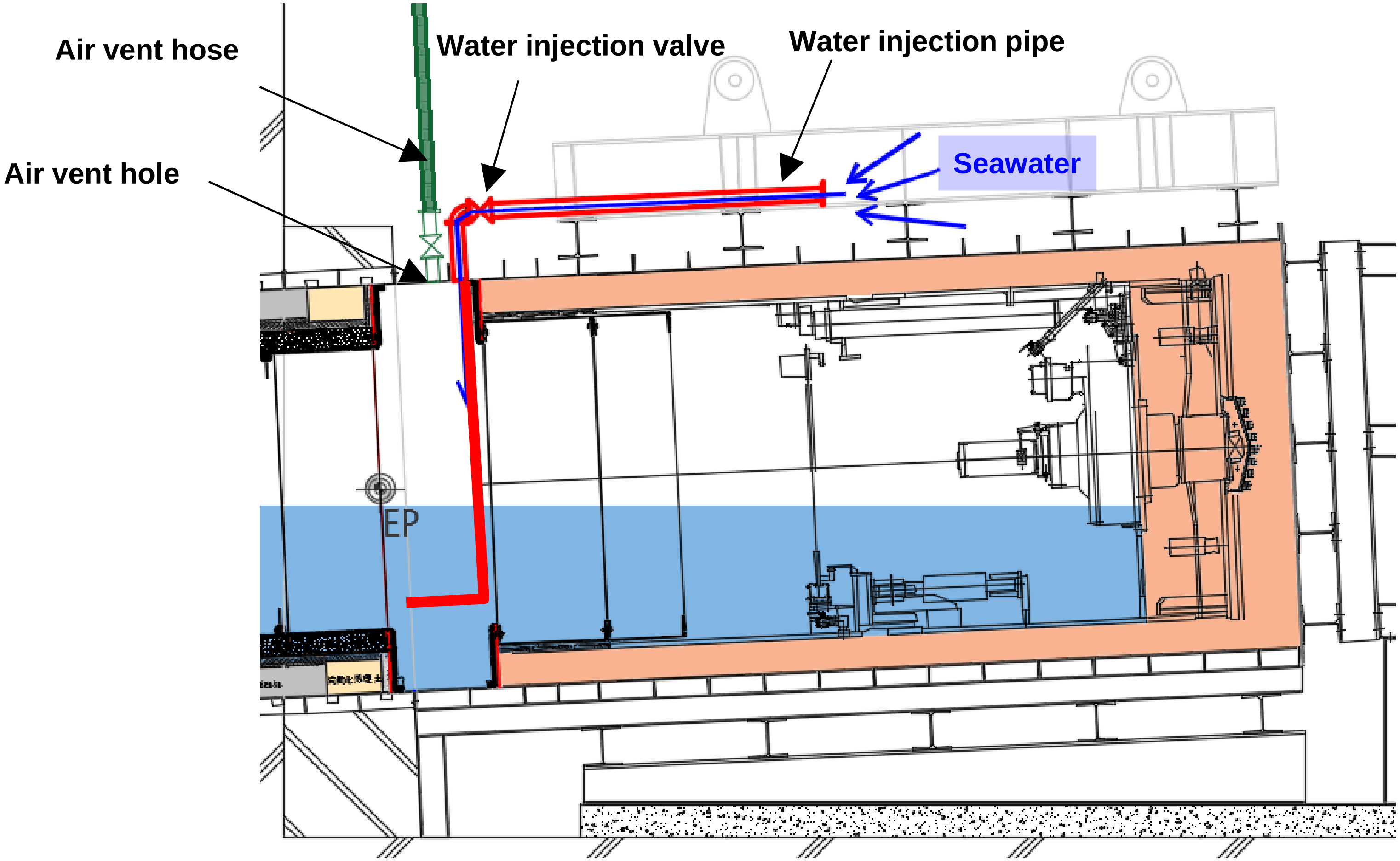


Image drawing of water injection work condition

[Reference]Discharge methods (connection): Removal of the reaches pipe (shield machine)

- After completing the water injection inside the discharge tunnel, remove bolts connecting the discharge outlet caisson with the reaching pipe by the diving operation.
- After slinging work for crane by diving operation, remove the reaching pipe together with the shield machine by the crane barge, Slinging will be carried out to the reaching pipe with the diving operation, and is removed by the crane barge.

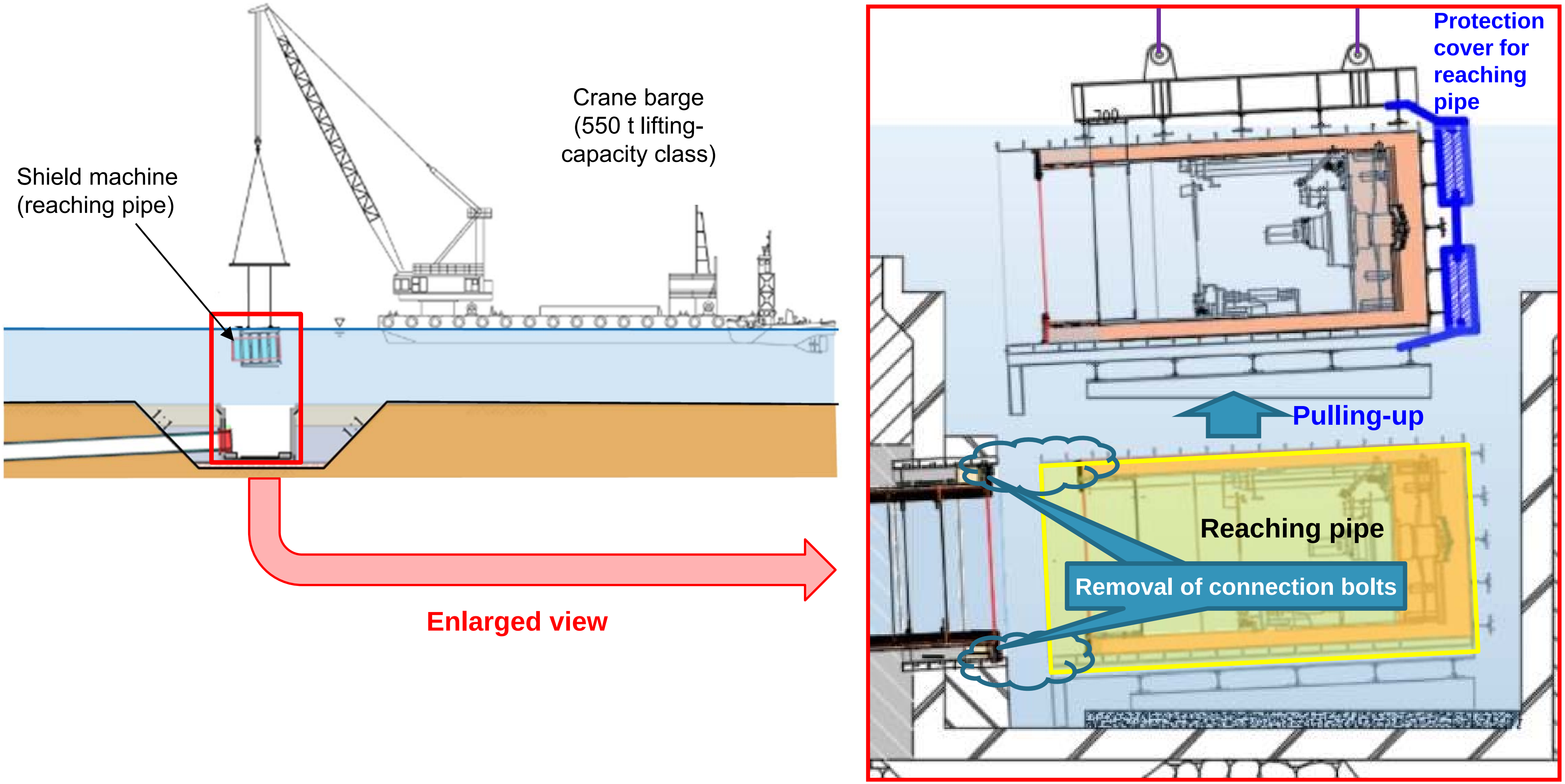


Image drawing of reaching pipe (shield machine) removal

Methods of seawater intake and discharging ALPS treated water after dilution

Water intake methods: construction methods

Discharge methods: construction methods

Enhanced monitoring associated with offshore construction work

[1]-5.1 Enhanced monitoring associated with offshore construction work

- In implementing the offshore construction, the following measures will be taken due to concern over swirl-up of the seabed soil:
  - Seawater monitoring
  - Analysis of earth and sand excavated
  - Measures against turbidity

2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[Supplement] Ongoing marine monitoring

- Current monitoring areas are : seawater and seabed soil of inside the port and surrounding area of the plant, from Souma shore to Onahama shore in Fukushima Prefecture.
- Fishes are monitored as well in the offshore area within 20 km from the plant.

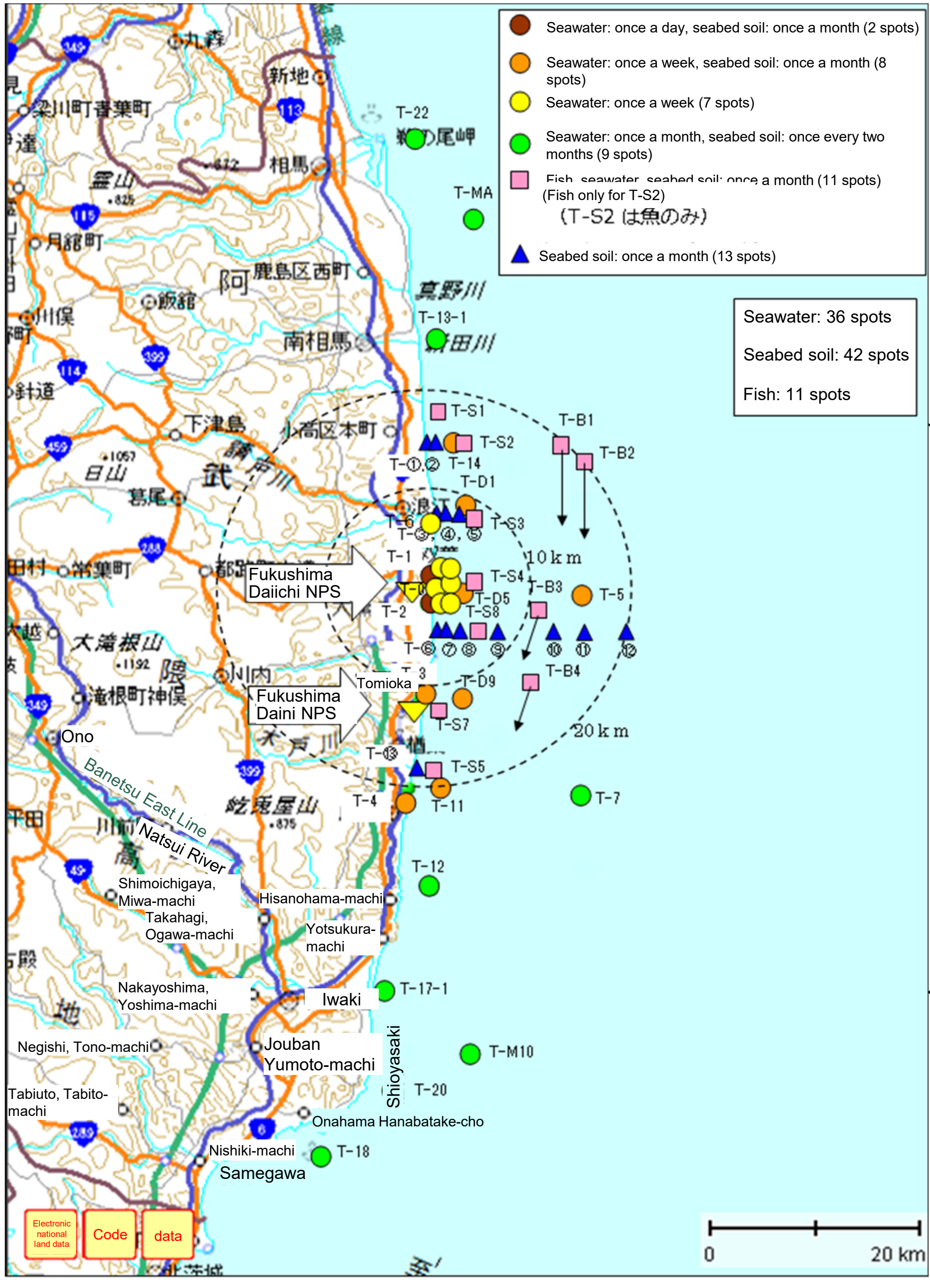


Figure: Location of marine monitoring offshore of Fukushima Prefecture

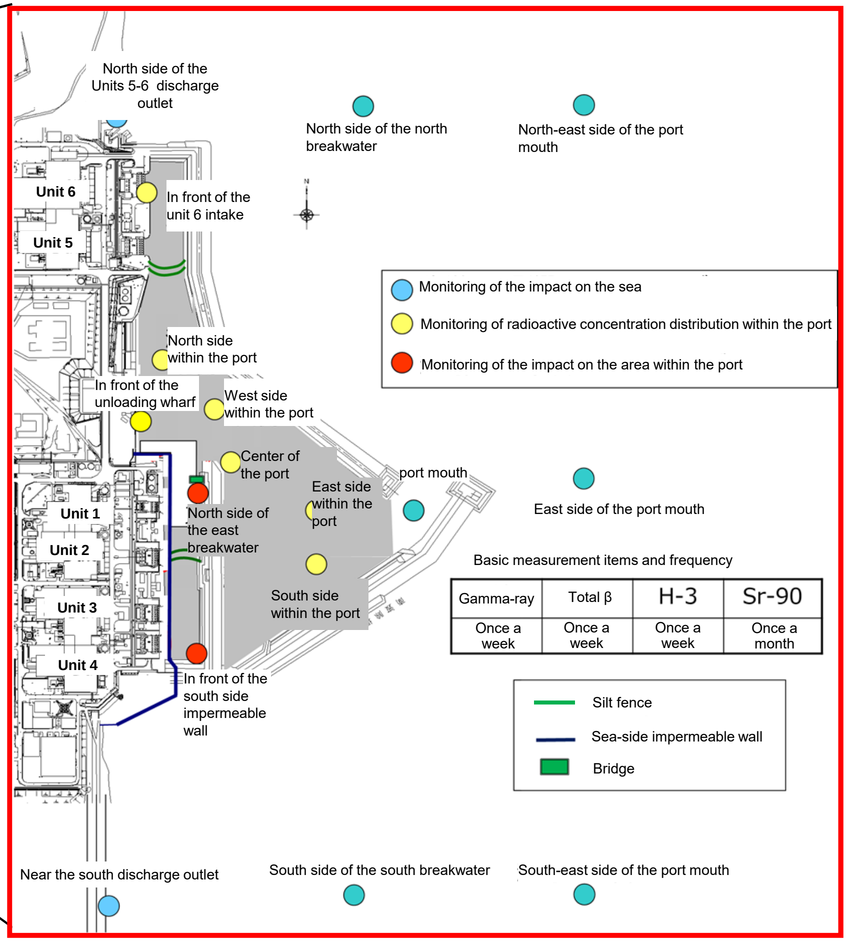


Figure: Location of marine monitoring around the plant

*Seawater is monitored offshore of Ibaraki Prefecture and Miyagi Prefecture in addition to these spots.

The Japanese version shall prevail.

- Items to be implemented
  - During the construction work such as partition weirs within the port of the power plant, measures will be taken to prevent turbidity and the spread of radioactive materials.

- Implementation details
  - Similar to the previous construction work (see 3.5), we will place construction fences during construction work and slow down the work speed to prevent water pollution, and carefully carry out the work to suppress* the swirling and spread of the seabed soil containing radioactive materials.
  - During the construction work, seawater will be constantly monitored.

- Responses when any significant change is detected
  - When any significant rise of the cesium concentration in the seawater or a higher water impurity level is observed, suspend the construction work temporarily.
  - Then, after confirming the cesium concentration level and the water impurity level falls within the allowable levels, resume the construction work.

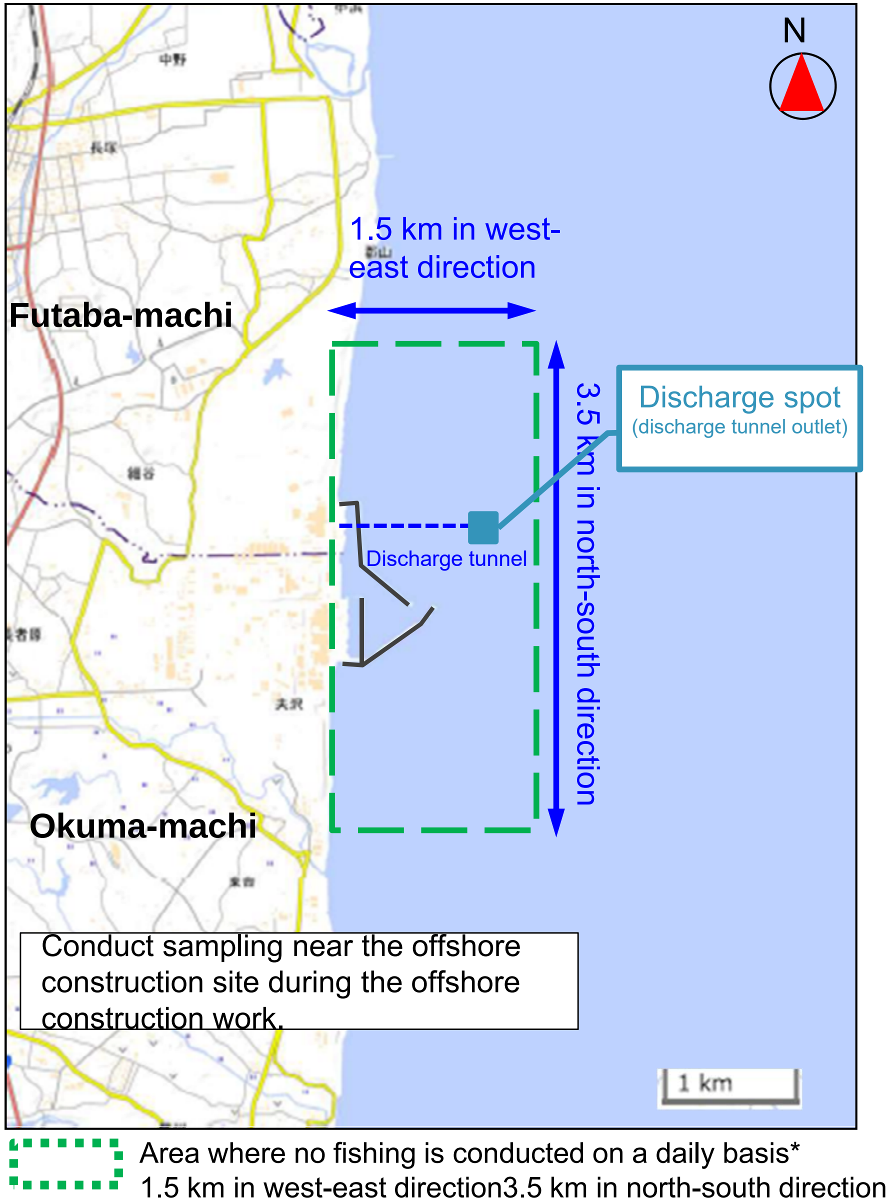
Outline of installation of Pollution prevention fences during the building of partition weir

[1]-5.3 Seawater monitoring plan in the plant offshore area

TEPCO

- Implementation overview
  - During the period of offshore construction work (including drilling, feeding foundation riprap, caisson installation work), conduct sampling seawater at the workplace to check the cesium concentration level, if the work causes any rise.
- Implementation details
  - Period: Before the start of the construction, during the construction work
  - Place: Around the offshore construction site of the power plant
  - Frequency: Every working day

    *To be reviewed according to the status of the construction.
- Responses when any significant change is detected
  - Suspend the construction work, when a significant increase in the cesium concentration caused by the construction work is detected.
  - Then, after confirming the cesium concentration level and the water impurity level falls within the allowable levels, resume the construction work.



*Area where common fishery rights are not set.

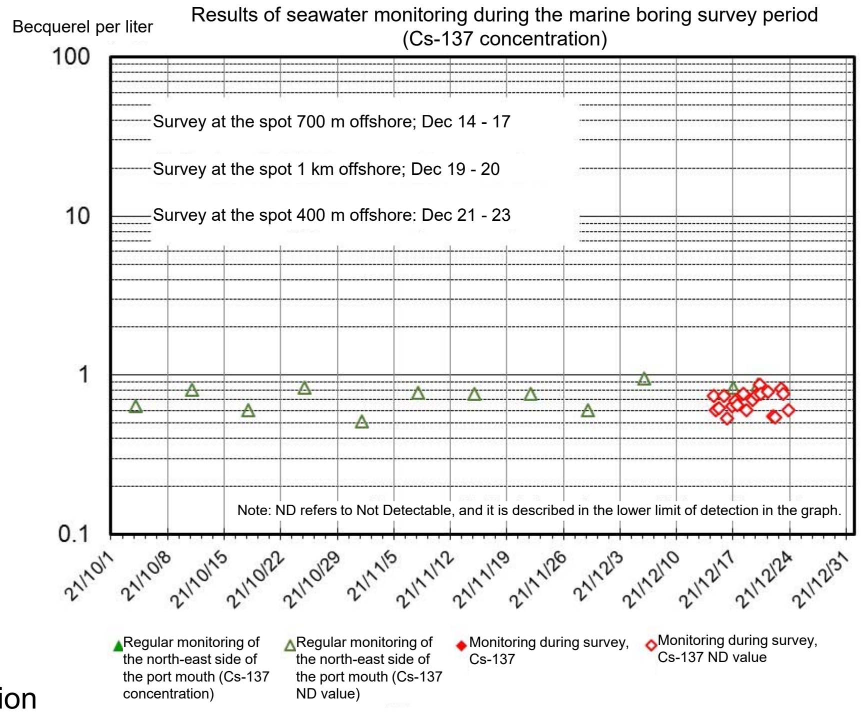
[Reference] Seawater monitoring results during the geological survey (marine boring)

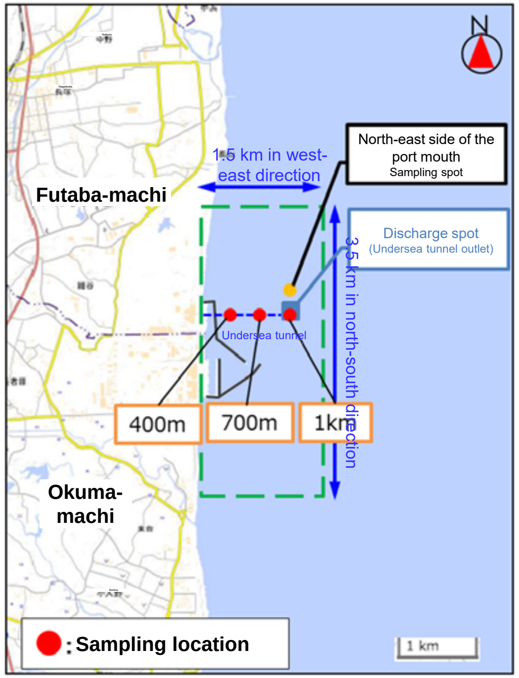
TEPCO

- Implementation overview
  - Daily sweater samplings were conducted in the period of the geological survey (maritime boring), before and after the work in a day in the range of survey to verify the cesium concentration rise in the seawater.

- Implementation details
  - Period: During the marine boring survey
  - Place: Near the worksite
  - Frequency: Every day before and after the work

- Result
  - All the monitoring results were negative, and no significant change was observed from the survey.





Area where no fishing is conducted on a daily basis*
1.5 km in west-east direction3.5 km in north-south direction

*Area where common fishery rights are not set.

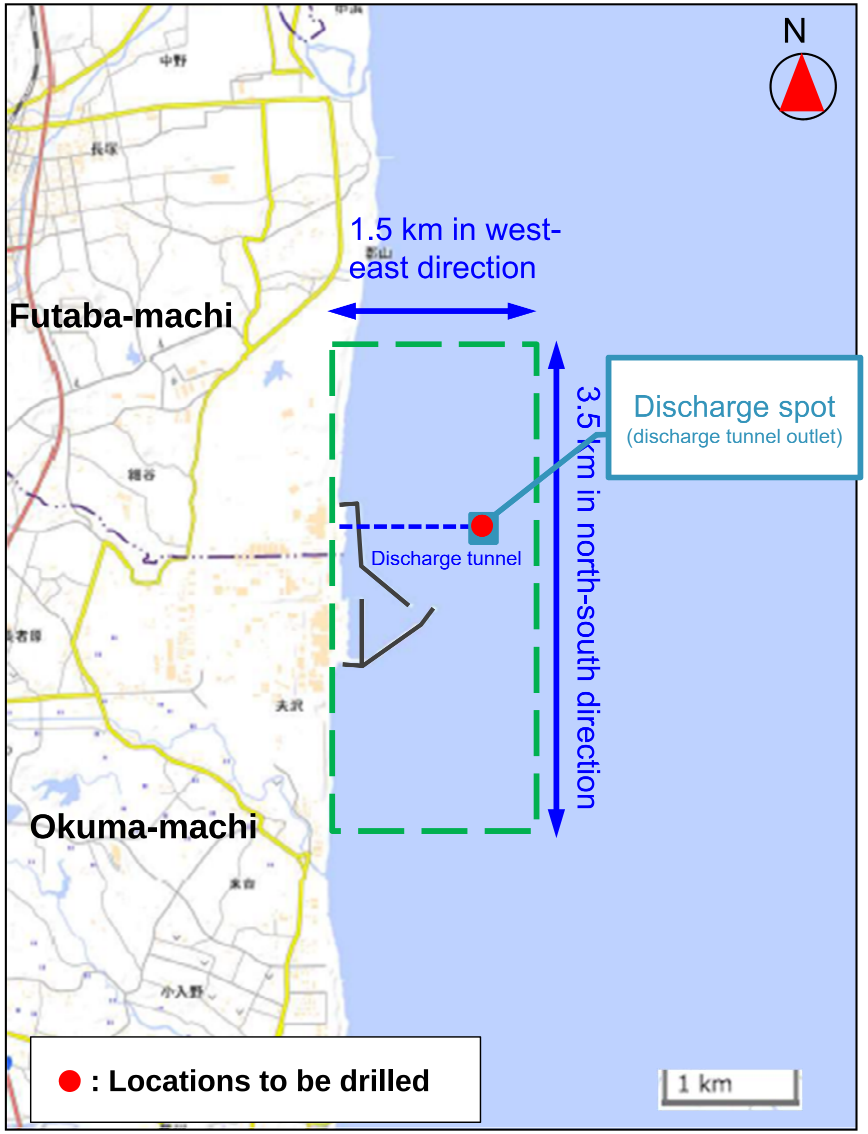
[1]-5.4 Analytical plan for excavated earth and sand

TEPCO

- Implementation overview
  - Conduct sampling from a part of soil and sand excavated offshore in the discharge tunnel outlet, and analyze the cesium concentration in the soil. Lift and transport the soil excavated from the power port to the site and mound in the soil dumping field on site.

- Implementation details
  - Period and frequency: Initial period, middle period, and completion time of the construction
    - *To be reviewed according to the status of the construction.
  - Place: Discharge tunnel outlet

- Responses when any significant change is detected
  - In the analysis assessment of the soil and sand, when a significant rise in the cesium concentration in the soil is detected, they will be boxed into containers and control adequately on site.



Area where no fishing is conducted on a daily basis*
1.5 km in west-east direction3.5 km in north-south direction

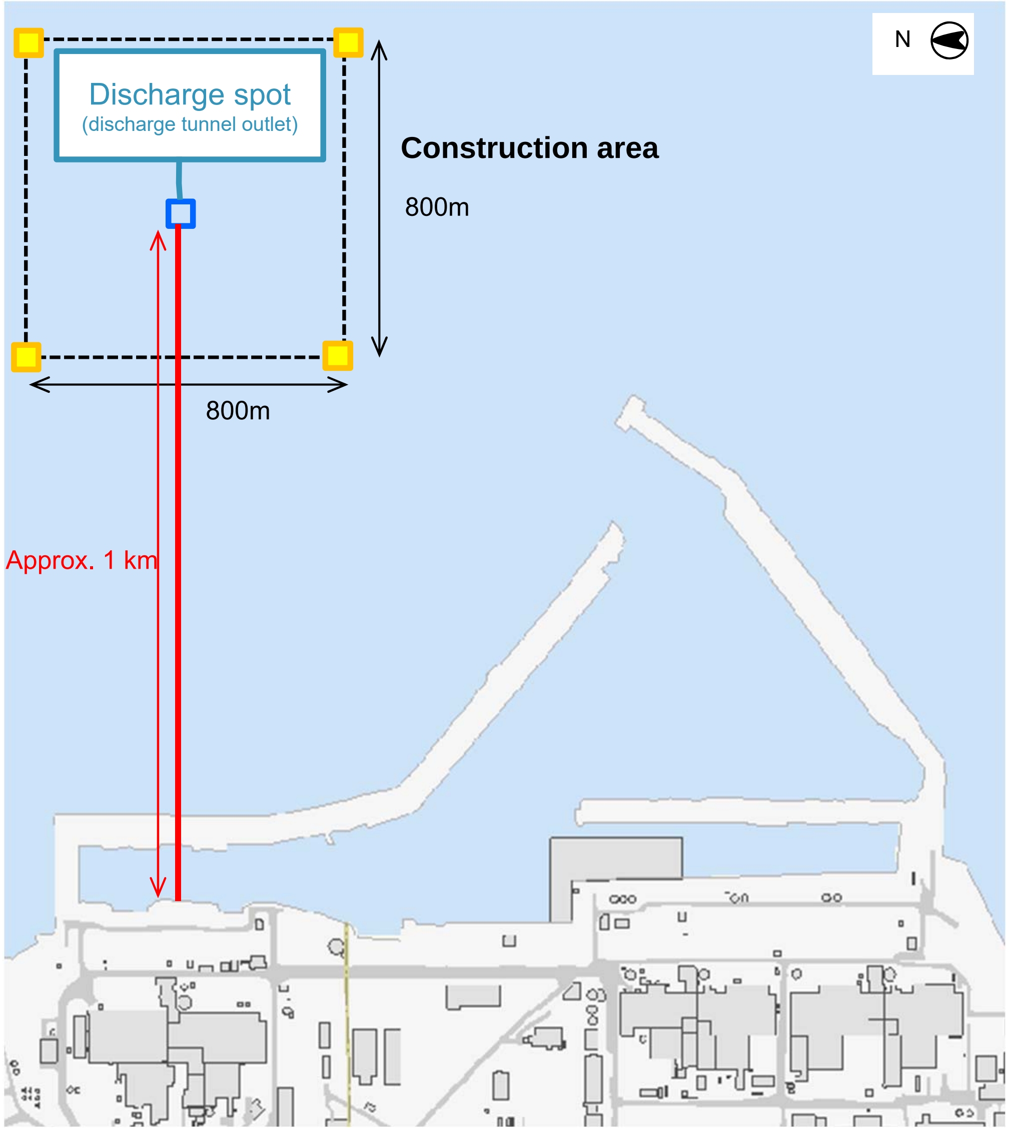
*Area where common fishery rights are not set.

The Japanese version shall prevail.

[1]-5.5 Measures against turbidity offshore the plant

TEPCO

- Items to be implemented
  - During the construction work, such as marine excavation offshore the power plant, conduct measures against turbidity.
- Implementation details
  - At the initial construction period, slow down the work speed and reduce the work per hour to suppress generating of turbidity. The work speed is adjusted depending on the situation.
  - Check the turbidity with visual inspection at the site.
    Using a turbidity meter to check in the construction area boundaries (four locations), and control the turbidity using a SS* indicators.
    Control value: SS: BG+10mg/L
    *SS(suspended solids)
    : Mass of suspended solids (there is a correlation with turbidity)
- Responses when any significant change is detected
  - When a high degree of turbidity was observed, suspend the construction work temporarily.
  - Depending on the degree of turbidity, place like an oil fence (serving as the oil measure) , and consider the use of a sedimentation agent (inorganic flocculant).
  - Then, confirm the degree of turbidity is in allowable level, resume the construction work..



2-1(1) [3] Methods of seawater intake and discharging ALPS treated water after dilution
[Reference] Measures against fish within the port (1/2)

- Items to be implemented

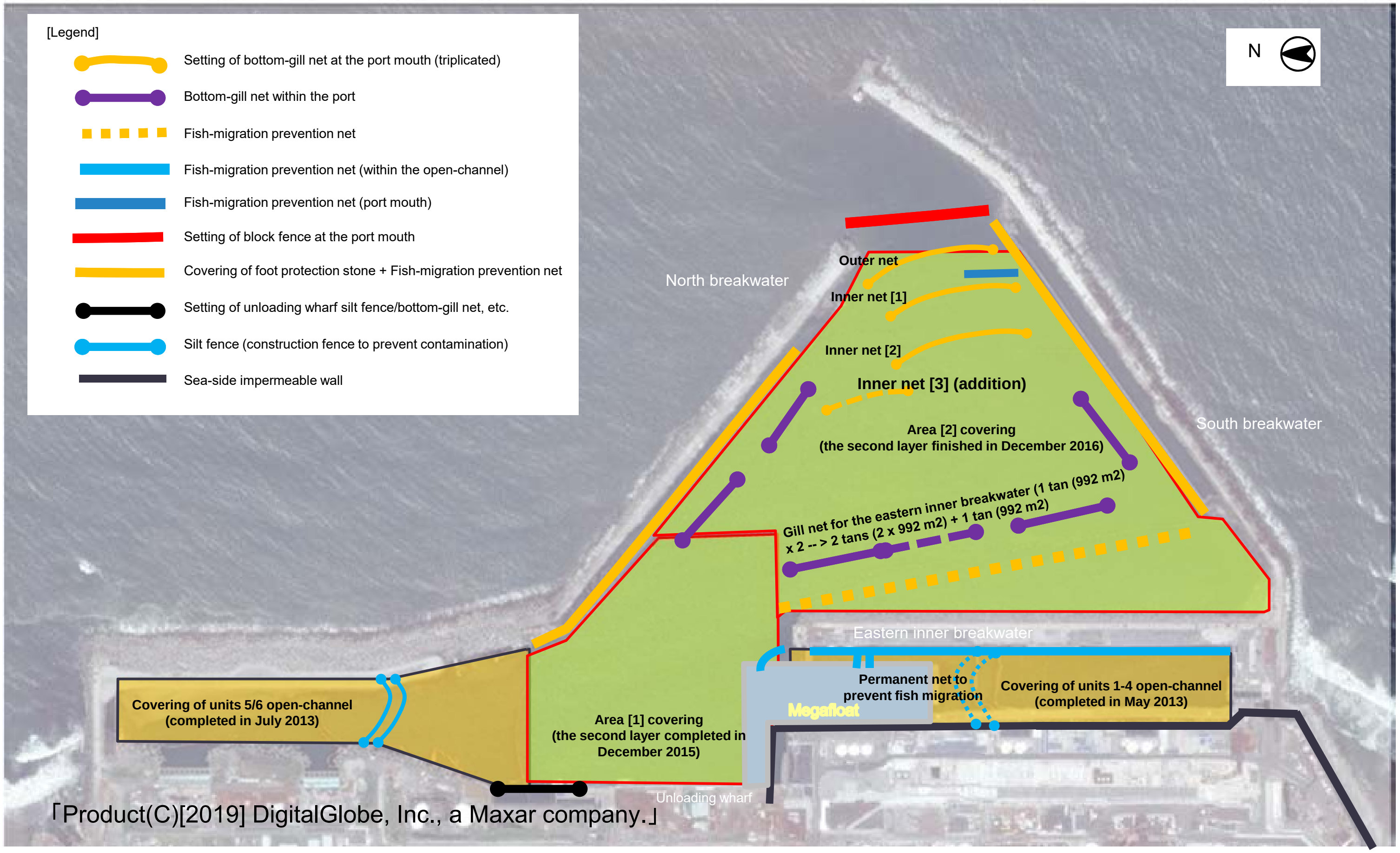
  In response to the fact that radioactive cesium with beyond the permission level of government's criteria has been detected in a fish caught, called jacopevers, gill nets within the power port are reinforced.

- Implementation details

  [1] Of the gill nets at the port mouth, additional gill nets (inner nets [3]) are added to the inner side of the inner nets [2] to prevent migration and enhance the effect of extermination.

  [2] Of two gill nets near the eastern inner breakwater within the port, one gill net is extended for two *tans* (2 x 992 m2) to prevent migration and enhance the effect of extermination.

  [3] Planning a basket net fishing or the like within the port and create drastic measures to get rid of fishes efffectively.



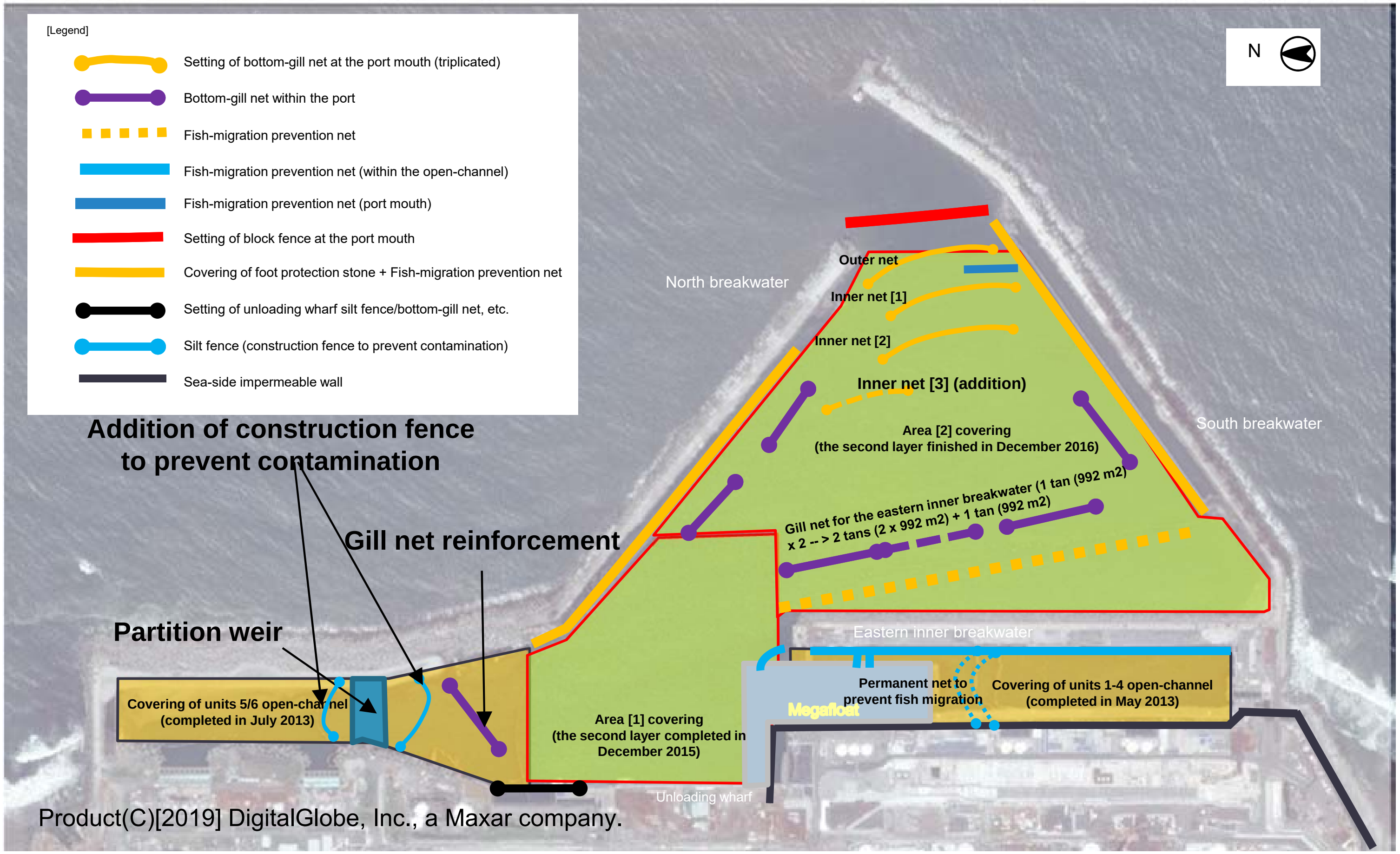
Planned enhancement of measures against fish within the port

The Japanese version shall prevail.

[Reference] Measures against fish within the port (2/2)

- Items to be implemented
  Enhance measures for fish within the power port when building partition weirs.

- Implementation details
  [1] Place construction fences to prevent water pollution when building partition weirs.
  [2] Then, arrange the location of gill nets within the port, and place them in the area near the partition weir.
  [3] Use the existing gill nets and fish-migration prevention nets (see figure below) continuously.



Measures against fish within the port

The Japanese version shall prevail.

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [2]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

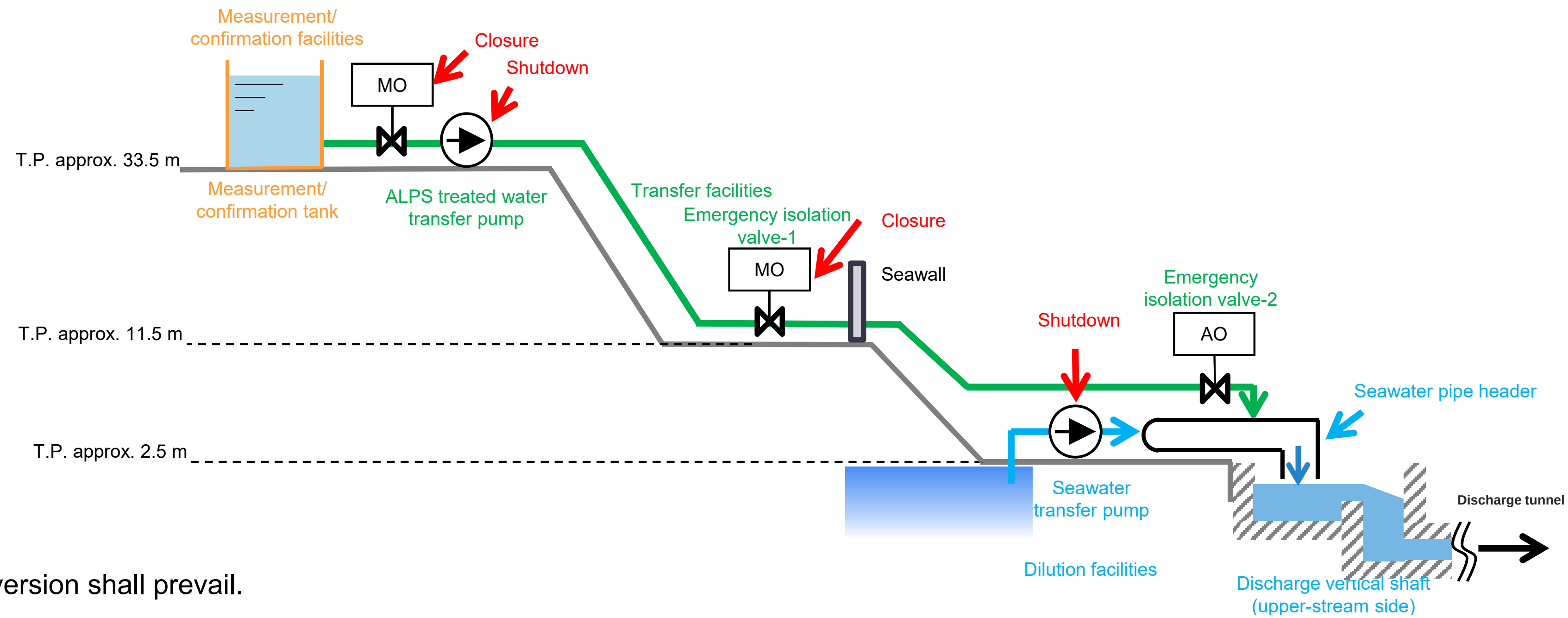
(1) Discharge Facilities of ALPS Treated Water into the Sea

[5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, prevention of misoperation, reliability, etc.

- On the ground of possible physical unavailability of discharge into the sea caused by tsunamis and storm surges, the need to detect abnormalities observing the water level using such as the vertical shaft and tide gauges, and to suspend discharge into the sea should be considered.

- As a design consideration for natural phenomena, when risks are found that facilities may be damaged, the discharge operation will be manually deactivated by the monitoring and control device in the central monitoring room in the seismic isolation building. Specific phenomena assumed are as follows:

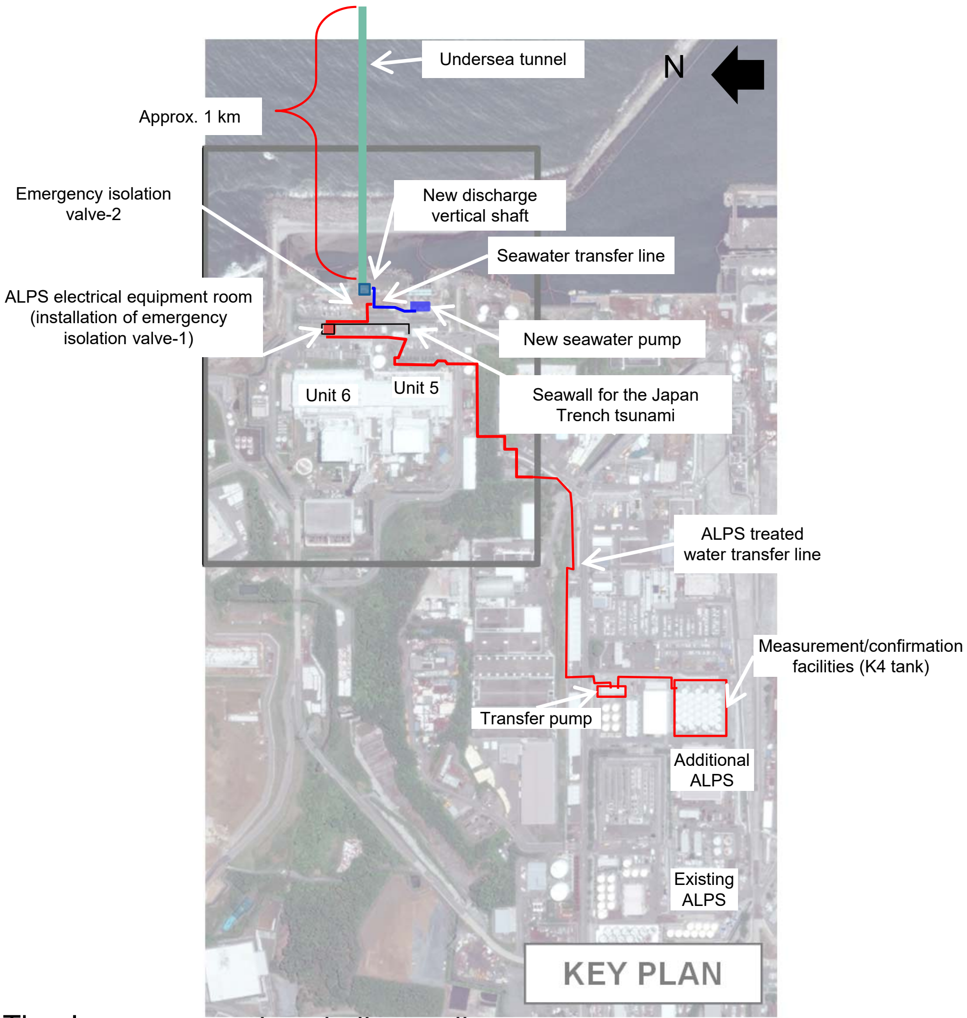
No.	Events that lead to manual shutdown	Reason for shutdown
1	Earthquakes with a seismic intensity of a lower 5 or greater	To minimize the impact of functional loss of the facilities due to earthquakes.
2	Tsunami advisory	There are risks that tsunamis may damage equipment at T.P. 2.5 m.
3	Tornado advisory	There are risks that tornadoes may damage each facility.
4	High tide warning	There are risks that the discharge into the sea by the head pressure cannot be carried out as designed.
5	Others	When there is a sign of abnormality other than above 1 - 4, and if the Shift Manager deems it necessary, the discharge into the sea will be shut down.

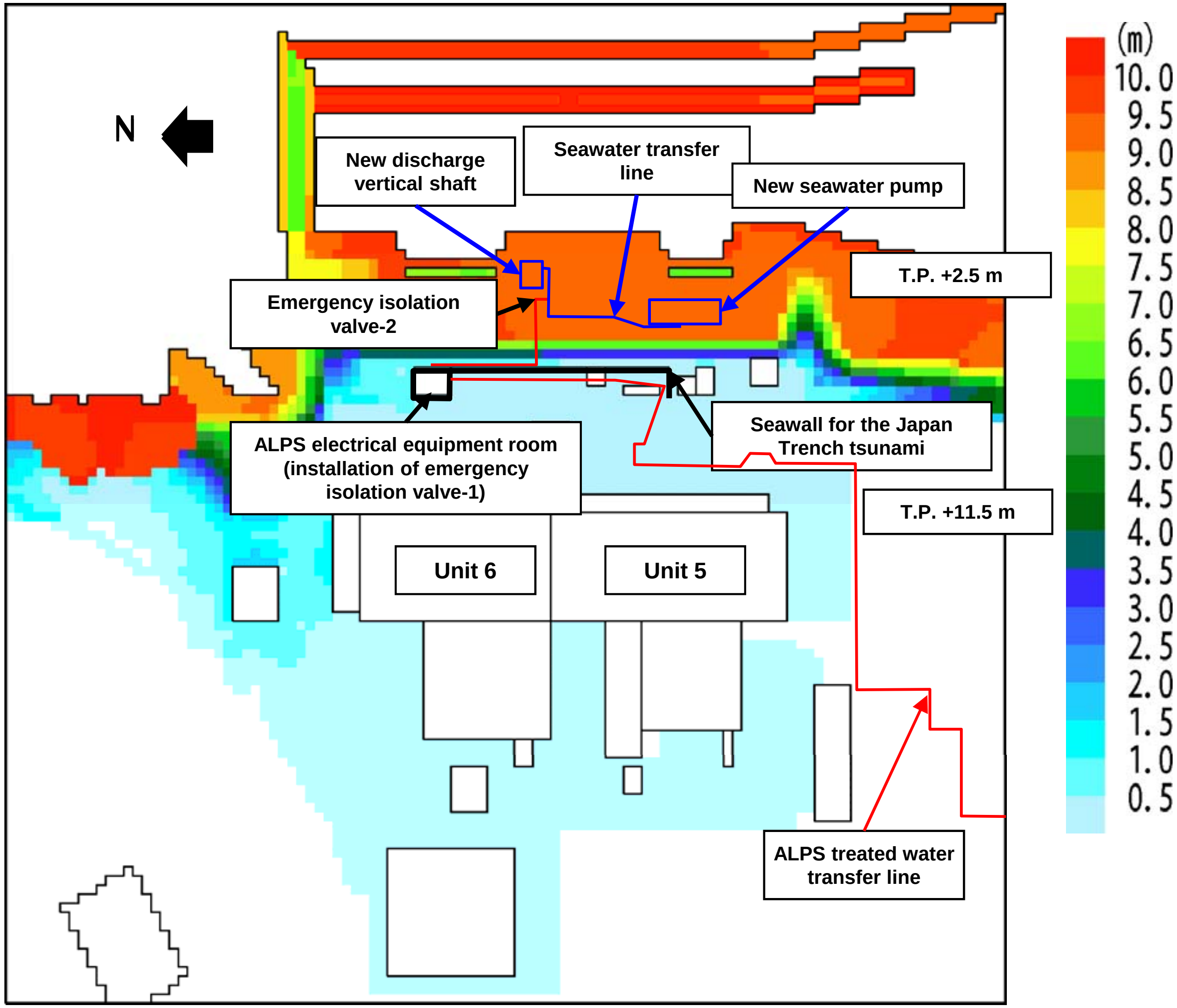


2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis

[Reference] Positional overview between equipment/facilities and seawall

- Based on the analysis results for the Japan Trench Tsunami, the ground at T.P. +2.5 m may be inundated to a depth of 9 meters and equipment such as seawater pumps may be flooded, presumably.
- The emergency isolation valve (1) at T.P. +11.5 m is enclosed by the seawall, and thereby it will not be flooded. The ALPS treated water transfer line will be installed at about 0.3 m to 0.4 m above the ground, with a maximum inundation depth may be less than 0.2 m at all locations there. Therefore, no inundation is presumed.





Maximum inundation distribution map due to the Japan Trench tsunami
(Results of analysis in the same condition as the 83rd Specified Nuclear Facilities Monitoring and Assessment Review Meeting)

2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis

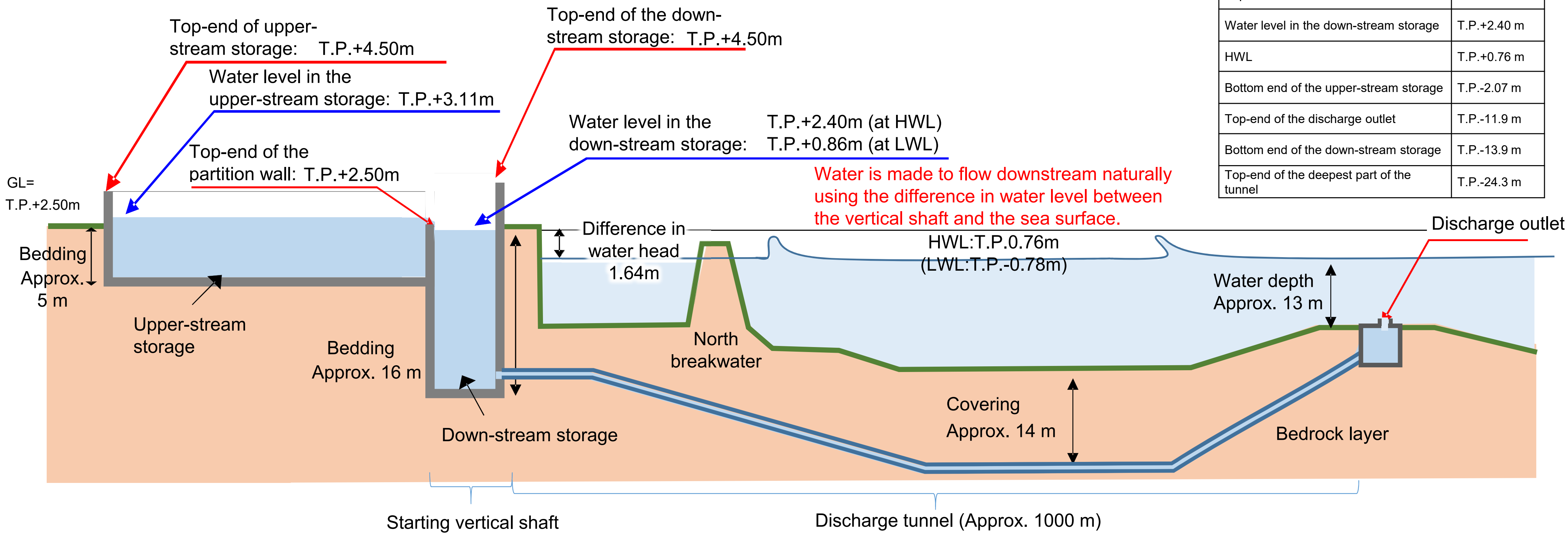
[Reference] Concept of hydraulic design (1/2)

Concept of hydraulic design (when three seawater transfer pumps are operating)

- Pressure is released to the atmosphere from the discharge vertical shaft (down-stream storage) in order to reduce pressure in pipes.
- The structure of the discharge vertical shaft (down-stream storage) is linked to the tide level in the open ocean through the discharge tunnel and the discharge outlet. It was confirmed that even when three seawater transfer pumps are in operation (510,000 m^3/day = 6 m^3/s), gravity flow is possible using the water head difference between the discharge vertical shaft (down-stream storage) and the sea surface (about 1.6 m: total loss from the discharge vertical shaft (down-stream storage) to the discharge outlet).

List of water levels and elevations

Top-end of the upper-stream storage	T.P.+4.50 m
Top-end of the down-stream storage	T.P.+4.50 m
Water level in the upper-stream storage	T.P.+3.11 m
GL	T.P.+2.50 m
Top-end of the weir	T.P.+2.50 m
Water level in the down-stream storage	T.P.+2.40 m
HWL	T.P.+0.76 m
Bottom end of the upper-stream storage	T.P.-2.07 m
Top-end of the discharge outlet	T.P.-11.9 m
Bottom end of the down-stream storage	T.P.-13.9 m
Top-end of the deepest part of the tunnel	T.P.-24.3 m



Conceptual diagram of Discharge facility

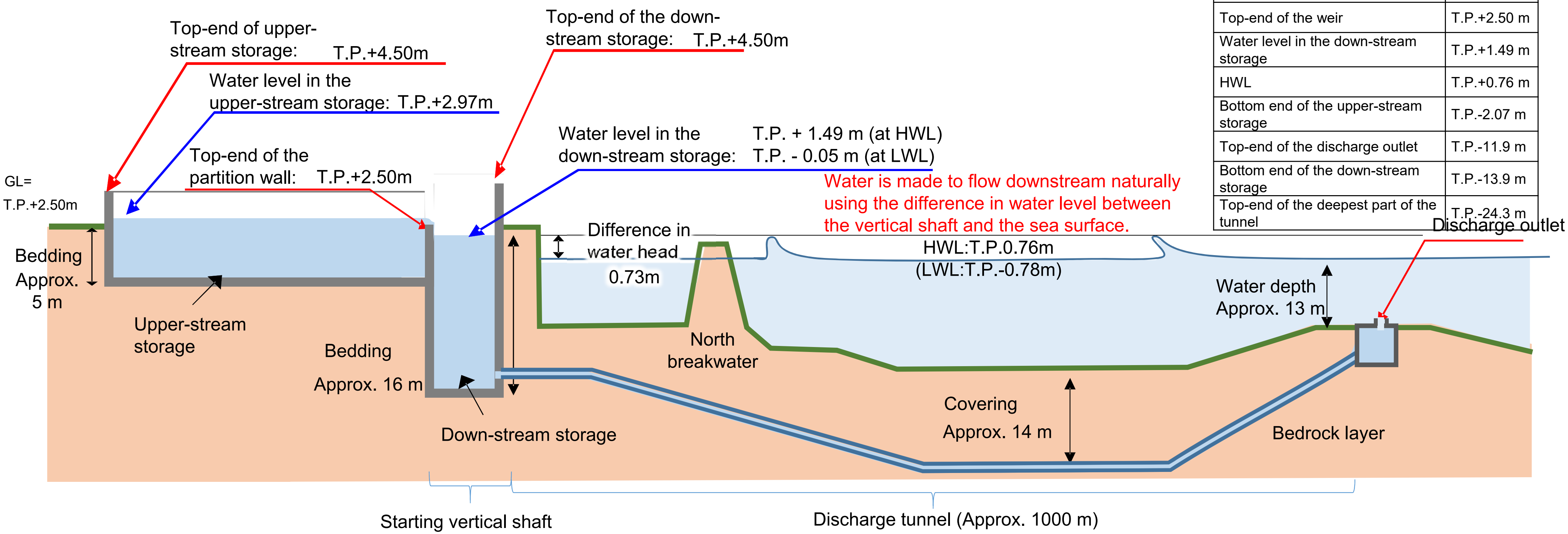
2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis
[Reference] Concept of hydraulic design (2/2)

Concept of hydraulic design (when two seawater transfer pumps are operating)

- Given maintenance such as inspections and responses in the event of one of the pumps shutting down, three pumps are prepared. Usually, two pumps operate, and one pump is on standby.
- Under the condition using 2 seawater transfer pumps (340,000 m^3/day = 4 m^3/s), the natural water flow downward is found due to the height difference between the discharge vertical shaft (down-stream storage) and the sea surface (about 0.7 m: total loss from the discharge vertical shaft (down-stream storage) to the discharge outlet).

List of water levels and elevations

Top-end of the upper-stream storage	T.P.+4.50 m
Top-end of the down-stream storage	T.P.+4.50 m
Water level in the upper-stream storage	T.P.+2.97 m
GL	T.P.+2.50 m
Top-end of the weir	T.P.+2.50 m
Water level in the down-stream storage	T.P.+1.49 m
HWL	T.P.+0.76 m
Bottom end of the upper-stream storage	T.P.-2.07 m
Top-end of the discharge outlet	T.P.-11.9 m
Bottom end of the down-stream storage	T.P.-13.9 m
Top-end of the deepest part of the tunnel	T.P.-24.3 m



Conceptual diagram of Discharge facility

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [3]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(1) Discharge Facilities of ALPS Treated Water into the Sea

[5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, prevention of misoperation, reliability, etc.

- Regarding the main facilities, such as ALPS treated water transfer line, seawater transfer line, and seawater pipe header, the basic specifications including material properties, the main structure, and the structural strength assessment details (those based on applicable standards and criteria other than JSME are included) should be provided.

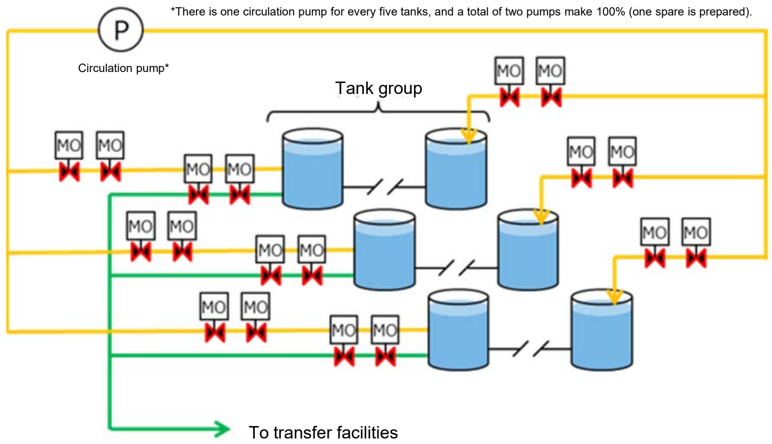
[3]-1 Main equipment of ALPS treated water dilution/discharge facilities

TEPCO

- Basic specifications of the main equipment and instruments of the ALPS treated water dilution/discharge facilities are described below..

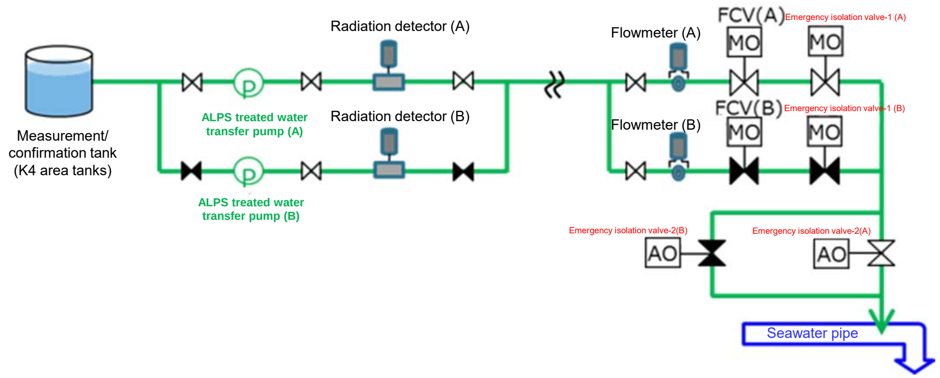
Main equipment

Measurement/ confirmation facility



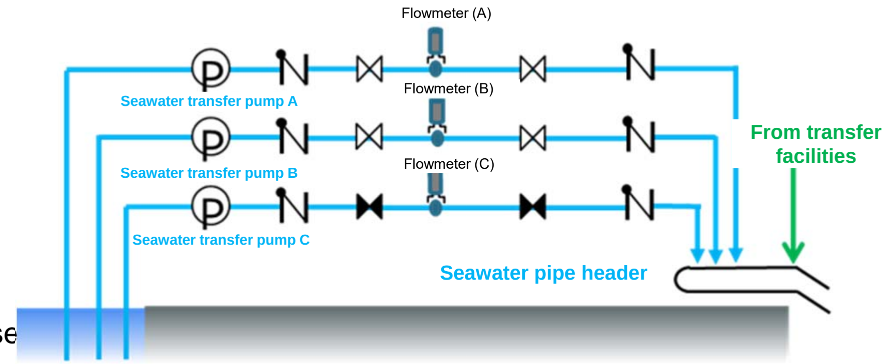
- ✓ Measurement/confirmation tank
- ✓ Circulation pump
- ✓ Circulation pipe

Transfer facility



- ✓ ALPS treated water transfer pump
- ✓ ALPS treated water flowmeter
- ✓ Transfer pipe

Dilution facility

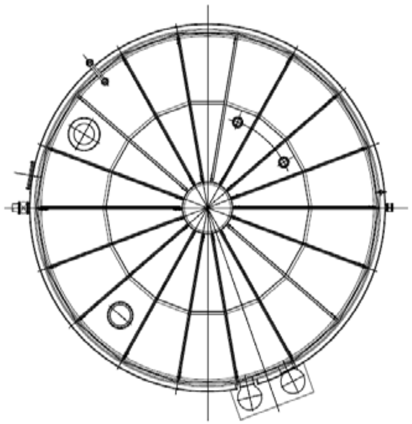


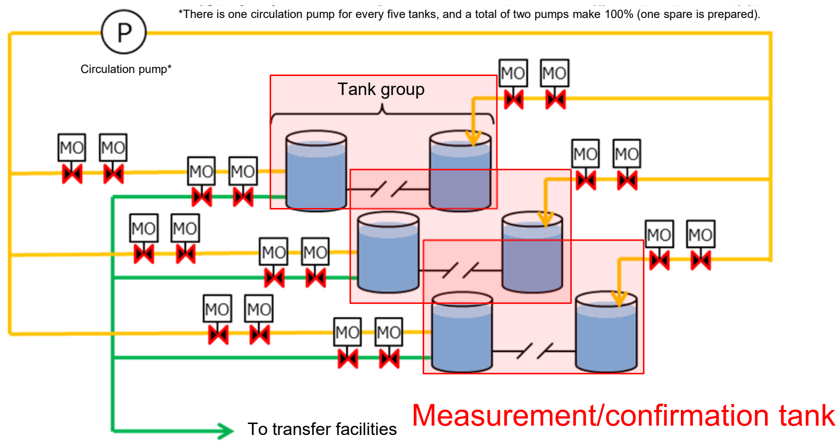
- ✓ Seawater transfer pump
- ✓ Seawater flowmeter
- ✓ Seawater pipe header
- ✓ Seawater pipe

Th nese

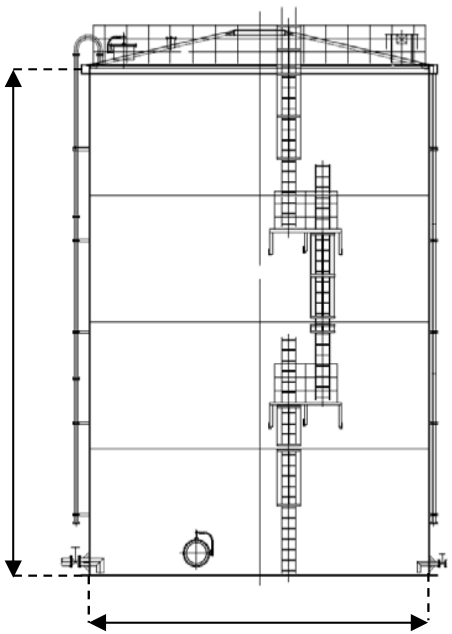
[3]-2 Basic specifications and main structure of the measurement/confirmation tank

TEPCO





Height: 14,565 mm



Inner diameter: 10,000 mm

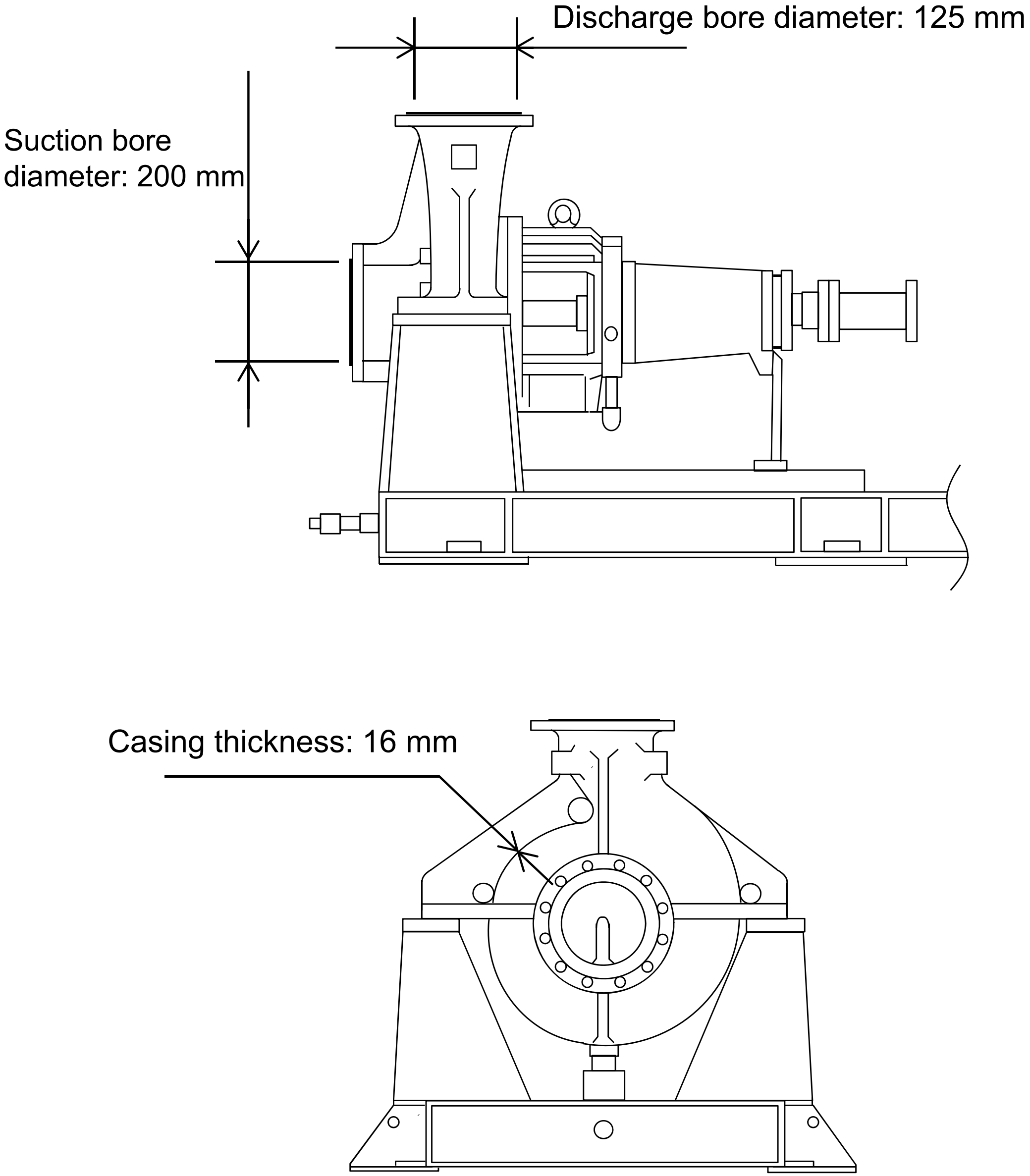
Structural drawing of measurement/confirmation tank

Tank capacity		m^3	1,000
Main dimensions	Inner diameter	mm	10,000
	Thickness of shell plate	mm	15
	Thickness of bottom plate	mm	25
	Height	mm	14,565
Nozzle thickness	100A	mm	8.6
	200A	mm	12.7
	600A	mm	16.0
Material	Shell plate/ Bottom plate	-	SS400
	Nozzle	-	STPT410,SS400

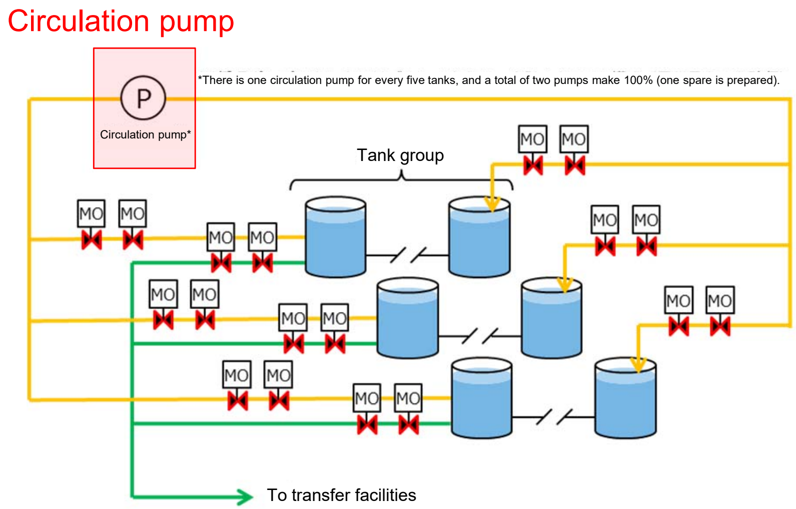
- Design temperature 50 °C

The Japanese version shall prevail.

[3]-3 Basic specifications and main structure of the circulation pump

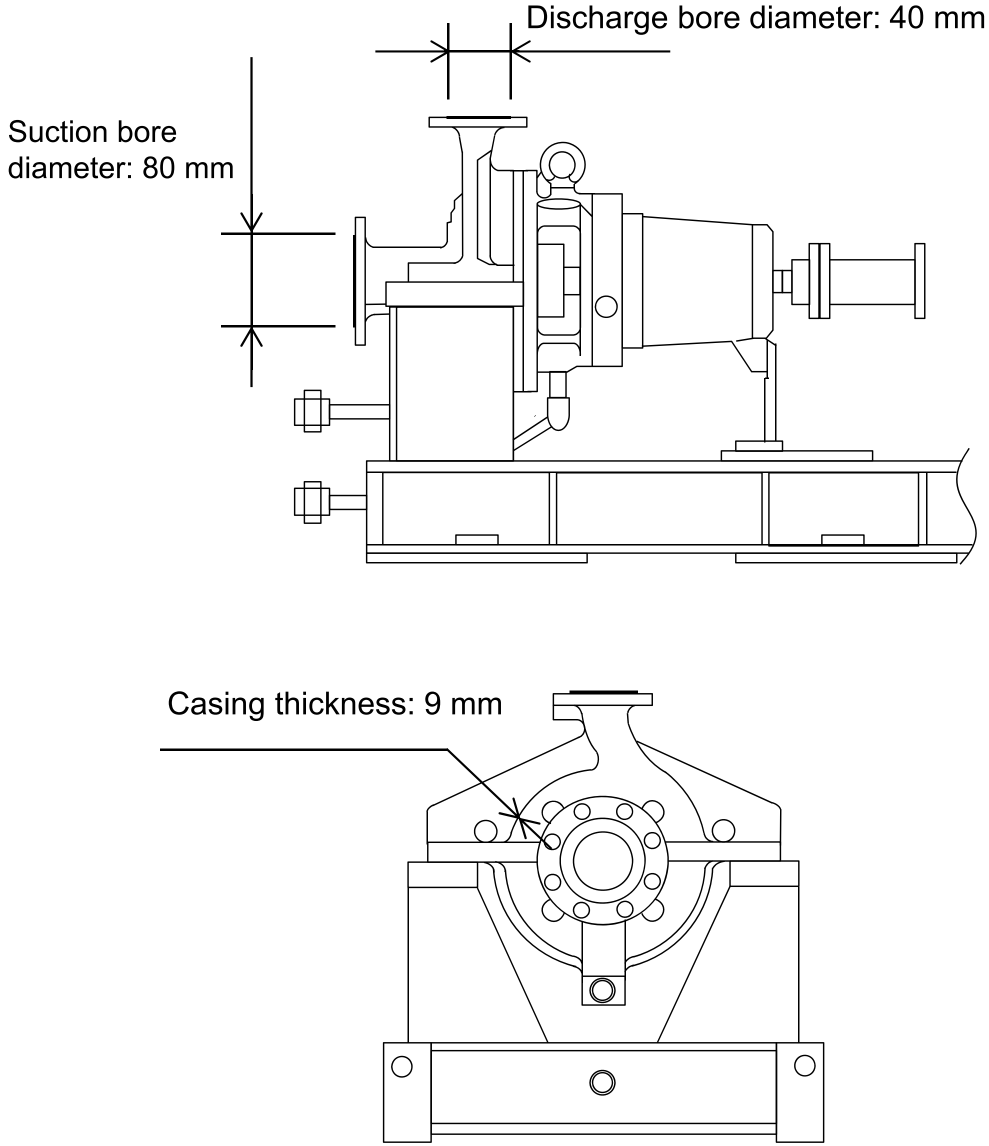


Structural drawing of circulation pump

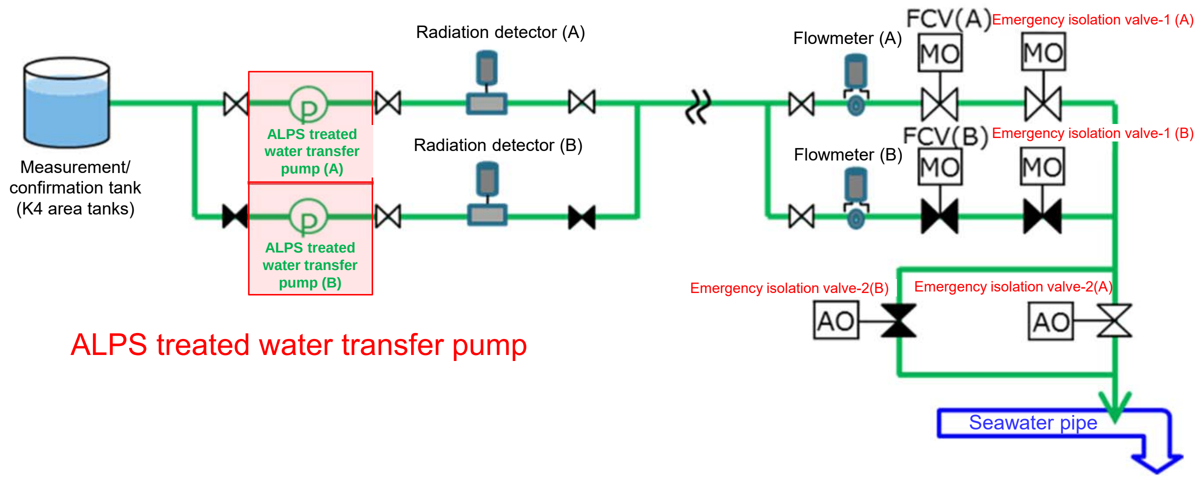


Pump	Type		Horizontal-axis spiral-type
	Rated capacity (m^3/h/unit)		160
	Rated head (m)		41.5
	Main material	Shell	SCS10
		Impeller	SCS10
		Axis	SUS329J4L
	Number of units		2
Motor	Type		Induction motor
	Output (kw/unit)		37
	Number of units		2

[3]-4 Basic specifications and main structure of the ALPS treated water transfer pump



Structural drawing of ALPS treated water transfer pump

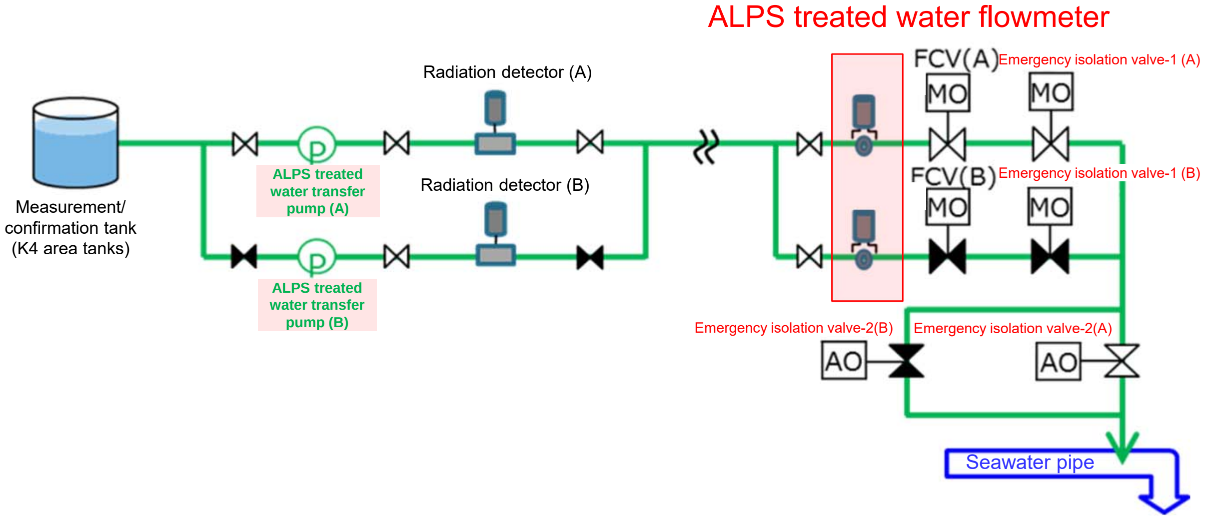


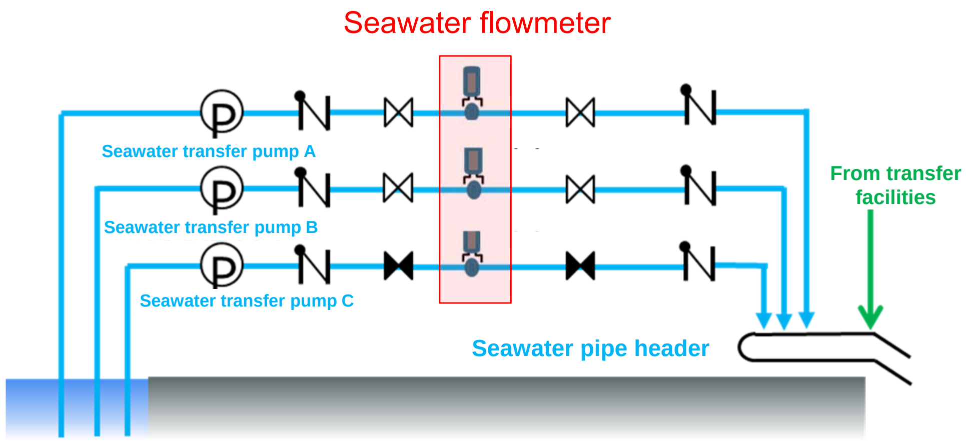
ALPS treated water transfer pump

Pump	Type		Horizontal-axis spiral-type
	Rated capacity (m^3/h/unit)		30
	Rated head (m)		40
	Main material	Shell	SCS10
		Impeller	SCS10
		Axis	SUS329J4L
	Number of units		2
Motor	Type		Induction motor
	Output (kw/unit)		11
	Number of units		2

The Japanese version shall prevail.

2-1(1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis
[3]-5. Basic specifications of ALPS treated water flowmeter and seawater flowmeter





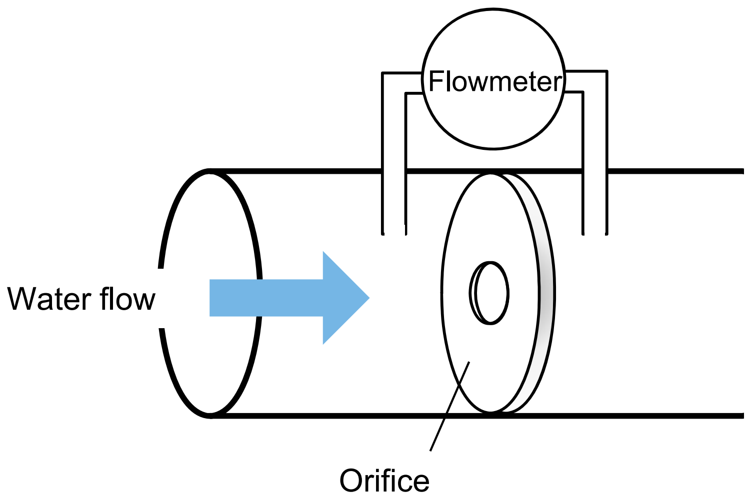
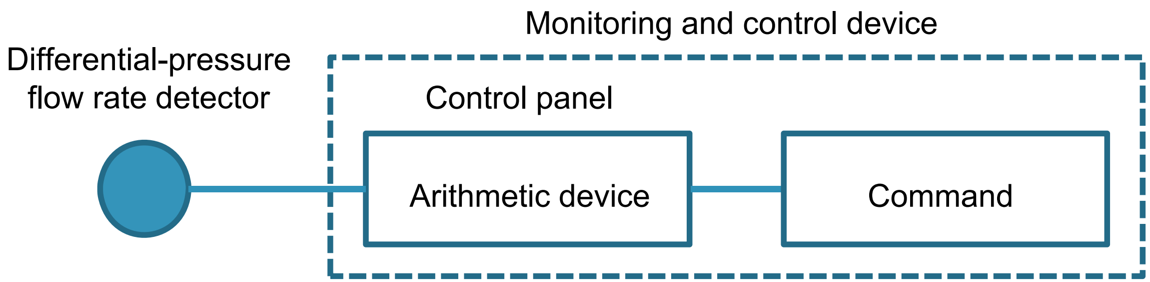


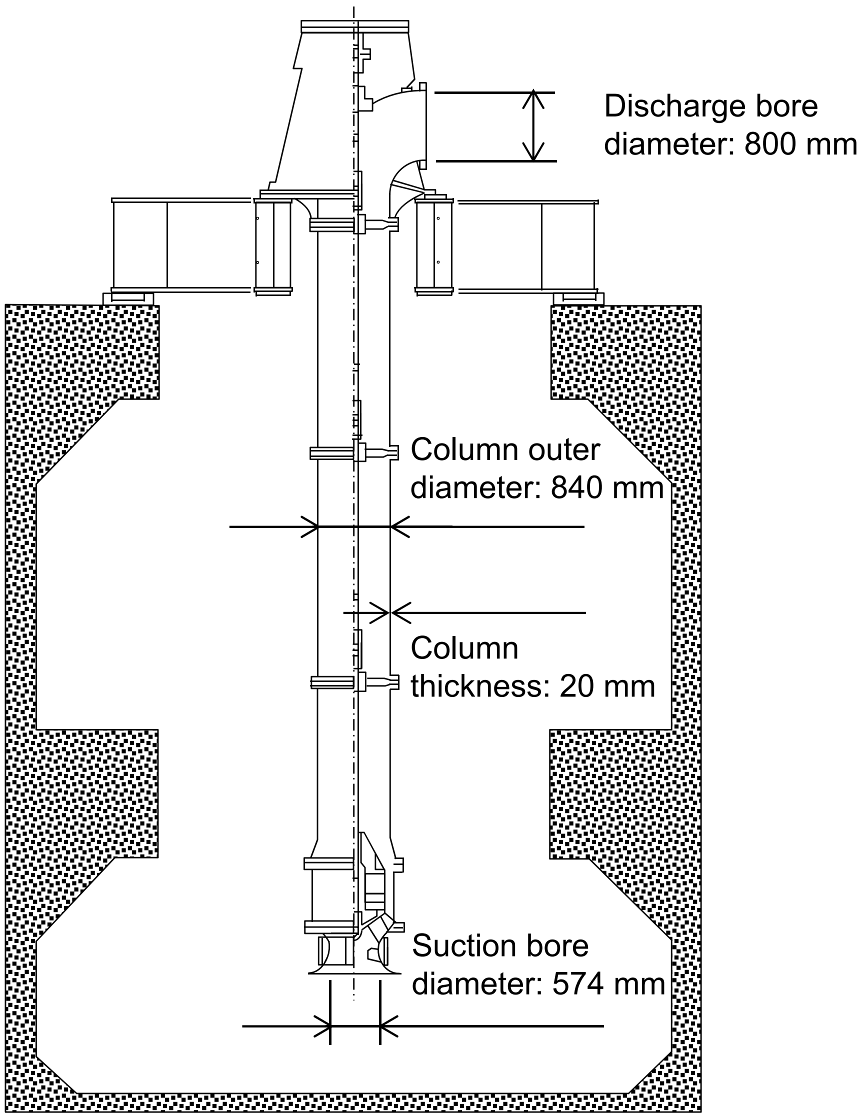
Image drawing of measurement with differential-pressure type flowmeter (orifice)

Measurement method	Differential pressure-type (orifice)
Specifications (orifice)	JIS Z 8762-2*
Measurement area	0 - 40 m^3/h (ALPS treated water) 0 - 10,000 m^3/h (seawater)
Instrumental error	±2.1% FS (ALPS treated water, seawater)

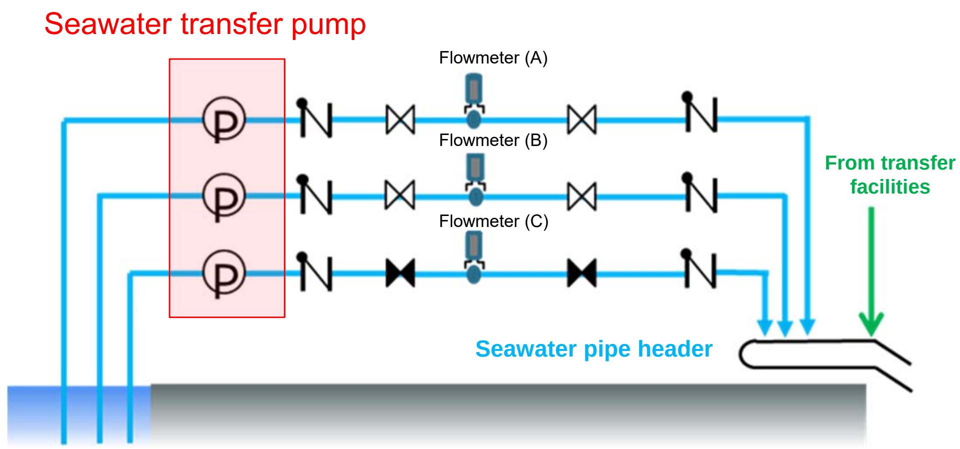
*Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 2: Orifice plates



[3]-6 Basic specifications and main structure of the seawater transfer pump



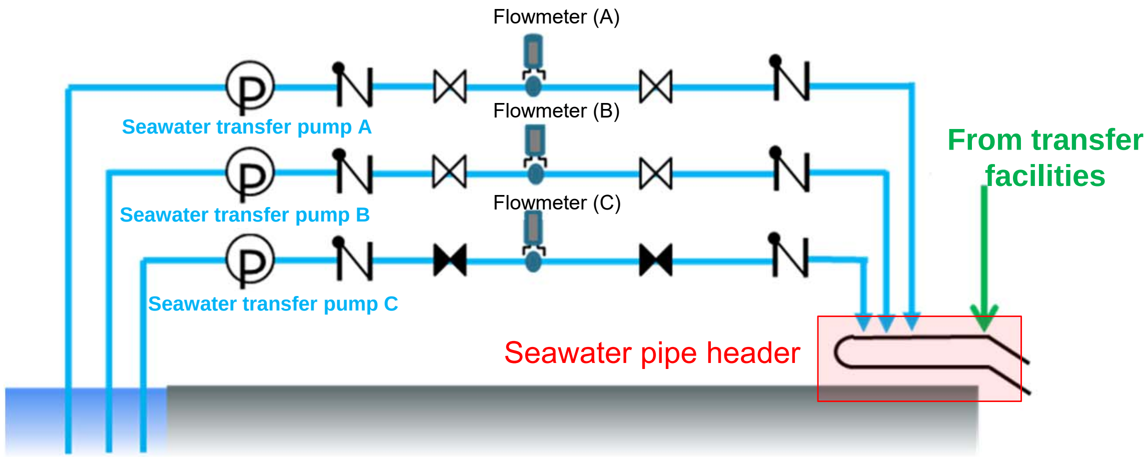
Structural drawing of seawater transfer pump

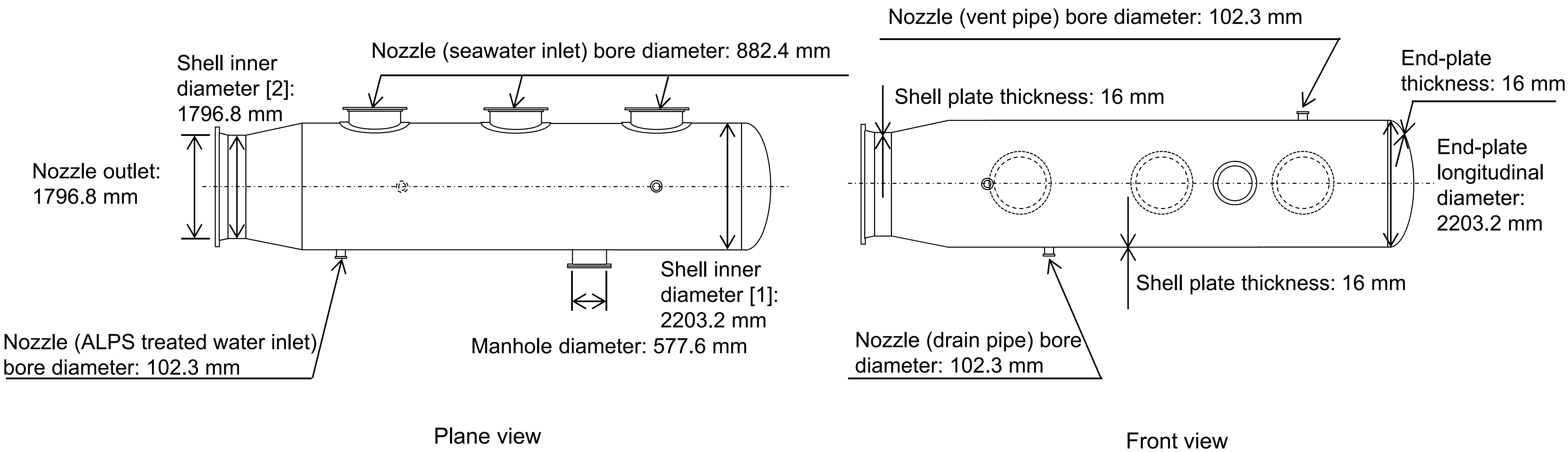


Pump	Type		Vertical-axis, single-stage, and mixed flow-type
	Rated capacity (m^3/h/unit)		7,086
	Rated head (m)		27.1
	Main material	Shell	2%NiFC
		Impeller	SCS14
		Axis	SUS316
	Number of units		3
Motor	Type		Induction motor
	Output (kw/unit)		760
	Number of units		3

The Japanese version shall prevail.

[3]-7 Basic specifications and main structure of the seawater pipe header





Structural drawing of seawater pipe header

The Japanese version shall prevail.

TEPCO

- Assessment method (straight-pipe)
  - We will check whether the minimum thickness of the seawater pipe header (straight-pipe portion) satisfies the required thickness calculated from the PPD-3411 formula (PPD-1.3) in Rules on Design and Construction for Nuclear Power Plants (hereinafter [1]), or Table PPD-3411-1 in Rules on Design and Construction for Nuclear Power Plants PPD-3411(3) (hereinafter [2]).
  - The required thickness of the pipe should be [1] or [2] listed below, whichever is greater.
    - Pipe receiving pressure on the inner surface

The thickness required for calculation of the pipe: $t = \frac{PD_0}{2S\eta + 0.8P} \cdots$ [1]

P : Maximum working pressure (MPa)

D_0 : Pipe outer diameter (mm)

S : Allowable tensile stress of materials at the maximum working temperature (MPa)

η : Efficiency of longitudinal joint

- The minimum thickness required in Rules on Design and Construction for Carbon Steel Pipe: t_r ・・・[2]
--> Value obtained based on Table PPD-3411-1 of Rules on Design and Construction for Nuclear Power Plants PPD-3411(3)

Table-1 Results of structural strength assessment of the seawater pipe header (straight-pipe portion)

Equipment assessed	Outer diameter (mm)	Material property	Maximum working pressure (MPa)	Maximum working temperature (°C)	Required thickness (mm)	Minimum thickness (mm)
Seawater pipe header	2235.2	SM400B	0.60	40	11.14	<u>14.90</u>
	1828.8	SM400B	0.60	40	9.11	<u>14.90</u>

The underlined part was corrected to optimize the description based on Attachment-3, Chapter II 2.50 of the Implementation Plan.

- Assessment method (reducer)
  - We will check whether the minimum thickness of the seawater pipe header (reducer) satisfies the required thickness calculated from the PPD-3415.1 formula (PPD-1.8) in Rules on Design and Construction for Nuclear Power Plants (hereinafter [1]), or the PPD-3415.1 formula (PPD-1.9) in Rules on Design and Construction for Nuclear Power Plants (hereinafter [2]).
  - The required thickness of the reducer should be [1] or [2] listed below, whichever is greater.
    - Required thickness of the circular cone

$$t_1 = \frac{PD_i}{2\cos\theta(S\eta - 0.6P)} \cdot \cdot \cdot [1]$$

- Required thickness of the rounded part of the hem

$$t_2 = \frac{PD_iW}{4\cos\theta(S\eta - 0.1P)} \cdot \cdot \cdot [2]$$

However, $W = \frac{1}{4}\left(3 + \sqrt{\frac{D_i}{2r\cos\theta}}\right)$

P : Maximum working pressure (MPa)

D_i : Inner diameter (mm) of the section that the circular cone is perpendicular to the axis of the portion connecting to the rounded part of the hem

S : Allowable tensile stress of materials at the maximum working temperature (MPa)

η : Efficiency of longitudinal joint

r : Internal radius (mm) of the rounded part of the hem of the circular cone

Table-2 Results of structural strength assessment of the seawater pipe header (reducer)

Equipment assessed	Inner diameter (mm)	Material property	Maximum working pressure (MPa)	Maximum working temperature (°C)	Required thickness (mm)	Minimum thickness (mm)
Seawater pipe header	2203.2	SM400B	0.60	40	11.3	14.90

- Assessment method (end-plate)
  - The seawater pipe header (end-plate) is a dish-formed end-plate. Its outer has a diameter equal to or greater than the radius of the inner surface at the center, the radius of the rounded part of the hem is equal to or greater than three times the thickness, and it is equal to or greater than 0.06 times the outer diameter (50 mm if it is less than 50 mm).
  - We will check that the minimum thickness of the seawater pipe header (end-plate) satisfies the required thickness calculated from the minimum thickness of the dished end-plate (Rules on Design and Construction for Nuclear Power Plants, PPD -3415.2 (PPD -1.12)).

$$t = \frac{PRW}{2S\eta - 0.2P}$$

However, $W = \frac{1}{4}\left(3 + \sqrt{\frac{R}{r}}\right)$

P	: Maximum working pressure (MPa)
R	: Inner radius of the center portion of the end-plate (mm)
W	: Coefficient due to the shape of the dished end-plate (-)
r	: Inner radius of the rounded part of the hem of the dished end-plate (mm)
S	: Allowable tensile stress of materials at the maximum working temperature (MPa)
η	: Efficiency of the joint when produced by joining end-plates

Table-3 Results of structural strength assessment of the seawater pipe header (end-plate)

Equipment assessed	Inner diameter (mm)	Material property	Maximum working pressure (MPa)	Maximum working temperature (°C)	Required thickness (mm)	Minimum thickness (mm)
Seawater pipe header	2203.2	SM400B	0.60	40	10.19	13.40

- Assessment methods (hole reinforcement calculation)
  - A hole provided at the seawater pipe header exceeds 64 mm, beyond the value "d" obtained based on the diagrams PPD-3422-1 and PPD-3422-2. With this, reinforcement calculation for the hole will be carried out.
  - We will check whether the effective gross area of reinforcement for the hole provided at the seawater pipe header (A_0) satisfies the area required for reinforcement (A_r).

$$A_0 = A_1 + A_2 + A_3 + A_4$$

A_1 : Effective area of the main pipe for the reinforcement of the hole

A_2 : Effective area of the nozzle for the reinforcement of the hole

A_3 : Effective area of the main pipe for the reinforcement of the hole

A_4 : Effective area of the stiffener for the reinforcement of the hole

$$A_1 = (\eta t_s - F t_{sr})(2L_A - d)$$

η : When the hole passes through the longitudinal joint of the pipe, it is an efficiency specified in the PVD-3110 Otherwise, it is 1.

F : Value obtained based on the diagram PPD-3424-1

t_s : Thickness of the main pipe

t_{sr} : Required thickness for calculation of the main pipe

L_A : Effective area of reinforcement divided by a straight line parallel to the centerline of the hole

d : Diameter of the hole appearing in the section

$$A_2 = 2(t_n - t_{nr})\, cosec\, \theta\, L_N \frac{S_n}{S_s}$$

t_n : Minimum nozzle thickness

t_{nr} : Thickness required for calculation of the nozzle

θ : Intersection angle between branch pipe centerline and main pipe centerline (degrees)

L_N : Effective area of reinforcement divided by a line parallel to the plane of the main pipe

S_n : Allowable tensile stress of the nozzle material at the maximum working temperature

S_s : Allowable tensile stress of the main pipe material at the maximum working

2-1(1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis
[2]-7 Structural strength assessment of the seawater pipe header (5/8)

TEPCO

$$A_3 = (L_1)^2 sin\theta \frac{S_n}{S_s}$$

(When the stiffener is within the effective area L_A)

$$A_4 = (D_{0e} - D_{0n} cosec\theta) t_e \frac{S_e}{S_s} + (L_2)^2 \frac{S_e}{S_s}$$

(When the stiffener extends to the outside the effective area L_A)

$$A_4 = (2L_A - D_{0n} cosec\theta) t_e \frac{S_e}{S_s}$$

$$A_r = 1.07 d t_{r3} (2 - sin\,\theta)$$

L_1 : Leg length of the fillet of the nozzle or the shorter-side length of the reinforced nozzle portion

S_e : Allowable tensile stress of the stiffener material at the maximum working temperature

D_{0e} : Outer diameter of the stiffener

D_{0n} : Outer diameter of the nozzle

t_e :Minimum thickness of the stiffener

L_2 : Leg length of the fillet surface of the stiffener

t_{r3} : Thickness required by the provisions of PPD-3411 (mm)

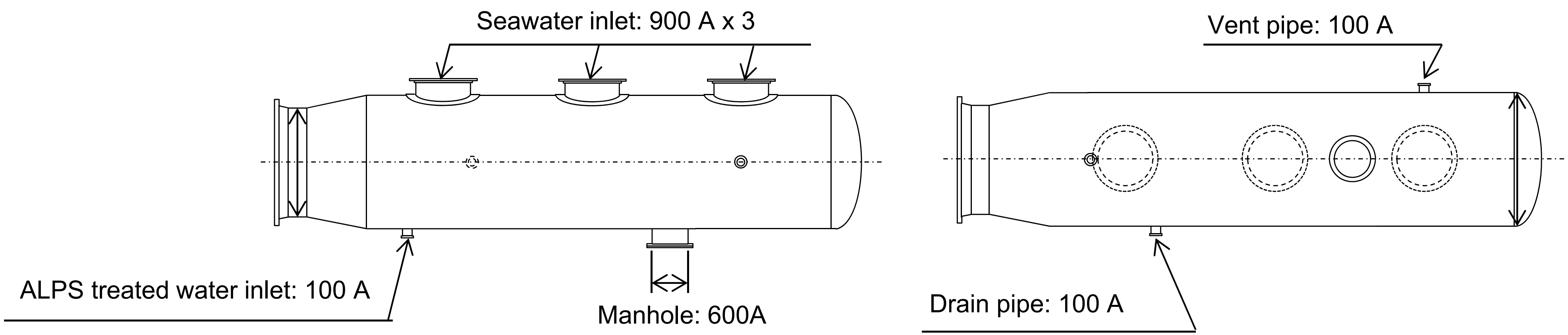
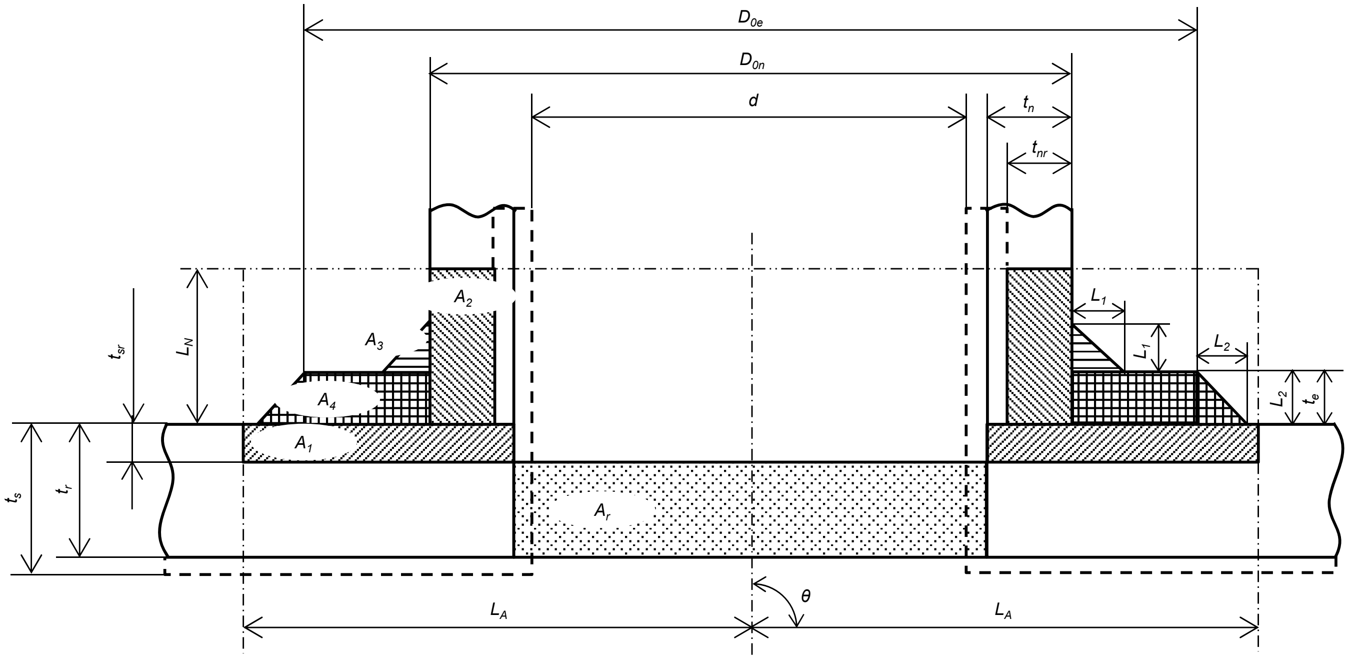


Table-4: Results of structural strength assessment of the seawater pipe header (reinforcement calculation of the hole)

Equipment assessed	Nozzle bore diameter	Area to be assessed	Area required for reinforcement A_r (mm²)	Effective gross area for reinforcement A_0 (mm²)
Seawater pipe header	100A	Nozzle	732.25	1335.66
	600A		4134.36	6800.89
	900A		6316.06	41500.34



Effective area for hole reinforcement (main pipe) A_1

Effective area for hole reinforcement (branch pipe) A_2

Effective area for hole reinforcement (welded part) A_3

Effective area for hole reinforcement (stiffener) A_4

Effective area for hole reinforcement A_r

Diagram of calculation for hole reinforcement

[2]-7 Structural strength assessment of the seawater pipe header (7/8)

TEPCO

- Assessment method (reinforcement calculation of multi-holes)
  - We will perform reinforcement calculation in cases where the effective reinforcement area for two or more holes provided at the seawater pipe header overlaps and verify that the reinforcement is sufficient by meeting the following conditions.
    - Cross-sectional area (A_{so}) of the main pipe between the two holes ≥ the required cross-sectional area (A_{sr}) of the main pipe between the two holes
    - The effective area of reinforcement between two holes (A_{oi}) ≥ 1/2 of the area required for reinforcement of two holes (A_{ri})
    - Center distance of 2 holes (L_s) ≥ 1.5 times the average diameter of 2 holes (L)

$$A_{so} = \left(L_s - \frac{d + d_D}{2}\right) t_r \quad , \quad A_{sr} = 0.7 L_s t_{sr} F$$

$$A_{oi} = \left(L_s - \frac{d+d_D}{2}\right)(t_s - t_{sr}) + \frac{A_2 + A_{2s}}{2} + \frac{A_3 + A_{3s}}{2} + \frac{A_4 + A_{4s}}{2}$$

A_2, A_{2s}, A_3 , A_{3s}, A_4 , and A_{4s} are according to the calculation of one hole.

$$A_{ri} = \frac{A_r + A_{rs}}{2} \quad , \quad L = 1.5\left(\frac{d + d_D}{2}\right)$$

A_r and A_{rs} are according to the calculation of one hole.

d : Diameter of the hole appearing in the section

d_D : Diameter of the adjoining holes appearing in the section

t_s : Thickness of the main pipe

t_{sr} : Required thickness for calculation of the main pipe

F : Value obtained based on the diagram PPD-3424-1

Table-5: Results of structural strength assessment of the seawater pipe header (reinforcement calculation of multiple holes)

Equipment assessed	Nozzle bore diameter	Area to be assessed	Required values	Values assessed
Seawater pipe header	900A	Nozzle	A_{sr} :3512.02 (mm^2)	A_{so} :8963.84 (mm^2)
			A_{ri} :6430.06 (mm^2)	A_{oi} :19535.62(mm^2)
			L :1347.60 (mm)	Ls :1500.00 (mm)

TEPCO

- Assessment method (mounting strength of stiffener)
  - We will verify that the strength of the weld is sufficient by assessing the load (W) to be borne by the weld based on the PPD-3424 (8).

$$W = dt_{sr}S_s - (\eta t_s - Ft_{sr})(2L_A - d)S_s$$

W : Load to be borne by the weld

d : Diameter of the hole appearing in the section

t_s : Thickness of the main pipe

t_{sr} : Required thickness for calculation of the main pipe

S_s : Allowable tensile stress of the main pipe material at the maximum working temperature

η : Efficiency specified in PVD -3110

F : Value obtained based on the diagram PPD-3424-1

L_A : Effective area of reinforcement divided by a straight line parallel to the centerline of the hole

Table-6: Results of structural strength assessment of the seawater pipe header (mounting strength of stiffener)

Equipment assessed	Nozzle bore diameter	Area to be assessed	Load to be borne by the weld W(N)
Seawater pipe header	100A	Nozzle	-4.98×10^{4}*
	600A		-2.81×10^{4}*
	900A		-4.30×10^{5}*

*The load to be borne by the welded section is negative. Therefore, it is not necessary to verify the mounting strength of the welded section.

[2]-8. Structural strength assessment of other equipment (1/2)

- Polyethylene pipes will be assessed as satisfying the required structural strength as long as pipes conforming to ISO or JWWA standards are used within the scope of application. Pressure hoses and expansion joints will be assessed as satisfying the structural strength as long as they are used at pressures and temperatures within the range specified by the manufacturer.

  (Implementation Plan: II-2-50-6)

Applicable range of non-metallic pipes*

		Allowable pressure [Max] (MPa)	Allowable temperature [Max] (°C)
Polyethylene pipe		1.00	40
Pressure hose		0.75	60
Expansion joint	**Circulation pipe Transfer pipe**	1.00	80
	Seawater pipe	0.60	40

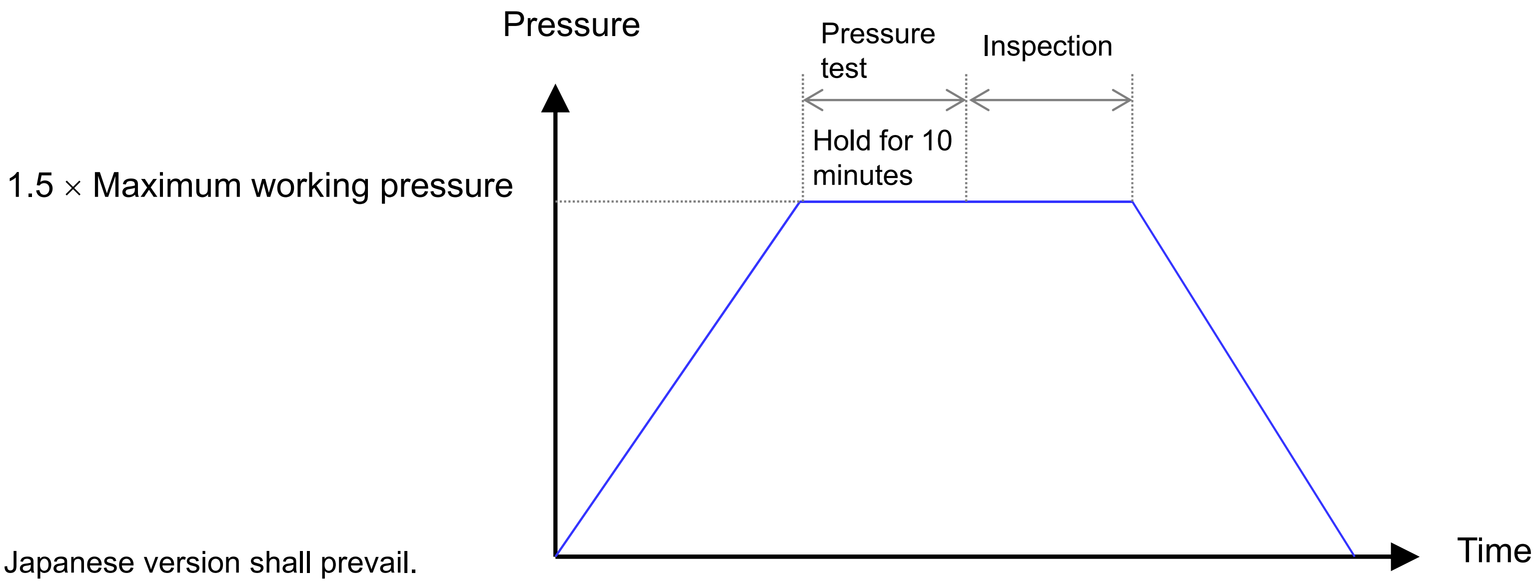
*: Detailed design of some equipment is in progress, and the values are not fixed. However, equipment that meets the maximum working pressure and temperature of the system will be adopted.

- Among pumps for which structural strength is not specified in the Rules on Design and Construction for Nuclear Power Plants, circulation pumps and ALPS treated water transfer pumps that are connected to Class 3 equipment, the hydraulic test specified by JIS* must be performed to ensure that the pressure part of all pressure-holding components, including fasteners, has sufficient strength.

*: JIS B 8307 Technical Specifications for Centrifugal Pumps - Class II

Pump name	Maximum working pressure (MPa)	Pressure test factor	Test pressure (MPa)
Circulation pump	0.98	1.5	1.47
ALPS treated water transfer pump	0.98	1.5	1.47

- The test is performed by the procedures shown below. If leakage is not detected visually after hydraulic pressure is held for at least 10 minutes, the pump will be judged to have sufficient strength.



[Reference] Basic specifications of circulation pipes/transfer pipes

TEPCO

Name	Specifications	
From the outlet of the measurement/ confirmation tank to the inlet of the circulation pump (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	200A/Sch.20S SUS316LTP 0.49MPa 40ºC
(Polyethylene pipe)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 200 A Polyethylene 0.49MPa 40ºC
(Pressure hose)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 200 A Synthetic rubber 0.49MPa 40ºC
(Expansion joint)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 200 A Synthetic rubber 0.49MPa 40ºC
From the outlet of the circulation pump to the inlet of the measurement/ confirmation tank (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	125A/Sch.20S 150A/Sch.20S 200A/Sch.20S SUS316LTP 0.98MPa 40ºC
(Polyethylene pipe)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 150 A Polyethylene 0.98MPa 40ºC
(Expansion joint)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 125 A Synthetic rubber 0.98MPa 40ºC

Name	Specifications	
Between measurement/ confirmation tanks (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	200A/Sch.20S SUS316LTP 0.49MPa 40ºC
(Polyethylene pipe)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 200 A Polyethylene 0.49MPa 40ºC
(Pressure hose)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 200 A Synthetic rubber 0.49MPa 40ºC
From the outlet of the measurement/ confirmation tank to the inlet of the ALPS treated water transfer pump (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	100A/Sch.20S 150A/Sch.20S SUS316LTP 0.49MPa 40ºC
(Polyethylene pipe)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 100 A Equivalent to 150 A Polyethylene 0.49MPa 40ºC
(Expansion joint)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 100 A Synthetic rubber 0.49MPa 40ºC

2-1(1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis
[Reference] Basic specifications of transfer pipes/seawater pipes

Name	Specifications	
From the outlet of the ALPS treated water transfer pump to the seawater pipe header inlet connection (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	100A/Sch.40 STPG370 0.98MPa 40ºC
(Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	65A/Sch.20S 100A/Sch.20S 150A/Sch.20S SUS316LTP 0.98MPa 40ºC
(Polyethylene pipe)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 100 A Polyethylene 0.98MPa 40ºC
(Expansion joint)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 65 A Equivalent to 100 A Synthetic rubber 0.98MPa 40ºC

Name	Specifications	
From the outlet of the seawater transfer pump to the seawater pipe header inlet connection (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	800A/12.7mm 900A/12.7mm STPY400 0.60MPa 40ºC
(Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	900A/Sch.20S SUS329J4LTP 0.60MPa 40ºC
(Expansion joint)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 800A Equivalent to 900 A Synthetic rubber 0.60MPa 40ºC
Seawater pipe header (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	900A/16mm 1800A/16mm 2200A/16mm SM400B 0.60MPa 40ºC
From the outlet of the seawater pipe header to the discharge end (Steel tube)	Nominal diameter/Thickness Material property Maximum working pressure Maximum working temperature	1800A/16mm SM400B 0.60MPa 40ºC
(Expansion joint)	Nominal diameter Material property Maximum working pressure Maximum working temperature	Equivalent to 1800 A Synthetic rubber 0.60MPa 40ºC

The underlined part was corrected to optimize the description based on Chapter II 2.50 of the Implementation Plan.

- Assessment results (Implementation Plan: II-2-50- Attachment 3-5)
  - Table 1 shows the assessment results. Having required thickness, the pipes are evaluated as having sufficient structural strength.

Table-1 Results of structural strength assessment of main pipes (steel pipes)

Equipment assessed*	Outer diameter (mm)	Material property	Maximum working pressure (MPa)	Maximum working temperature (°C)	Required thickness (mm)	Minimum thickness (mm)
Pipe [1]	216.3	SUS316LTP	0.49	40	0.46	5.68
Pipe [2]	139.8	SUS316LTP	0.98	40	0.59	4.37
Pipe [3]	165.2	SUS316LTP	0.98	40	0.69	4.37
Pipe [4]	216.3	SUS316LTP	0.98	40	0.91	5.68
Pipe [5]	165.2	SUS316LTP	0.49	40	0.35	4.37
Pipe [6]	114.3	SUS316LTP	0.49	40	0.24	3.50
Pipe [7]	76.3	SUS316LTP	0.98	40	0.32	3.00
Pipe [8]	114.3	SUS316LTP	0.98	40	0.48	3.50
Pipe [9]	114.3	STPG370	0.98	40	3.40	5.25
Pipe [10]	914.4	SM400B	0.60	40	4.56	14.90
Pipe [11]	2235.2	SM400B	0.60	40	11.14	14.90
Pipe [12]	1828.8	SM400B	0.60	40	9.11	14.90

*: Refer to the following pages for pipe numbers.
The pipes [10] and [11] and part of the pipe [12] make up the seawater pipe header.

The underlined part was corrected to optimize the description based on Attachment-3, Chapter II 2.50 of the Implementation Plan.

- The following figure shows pipes to be evaluated.

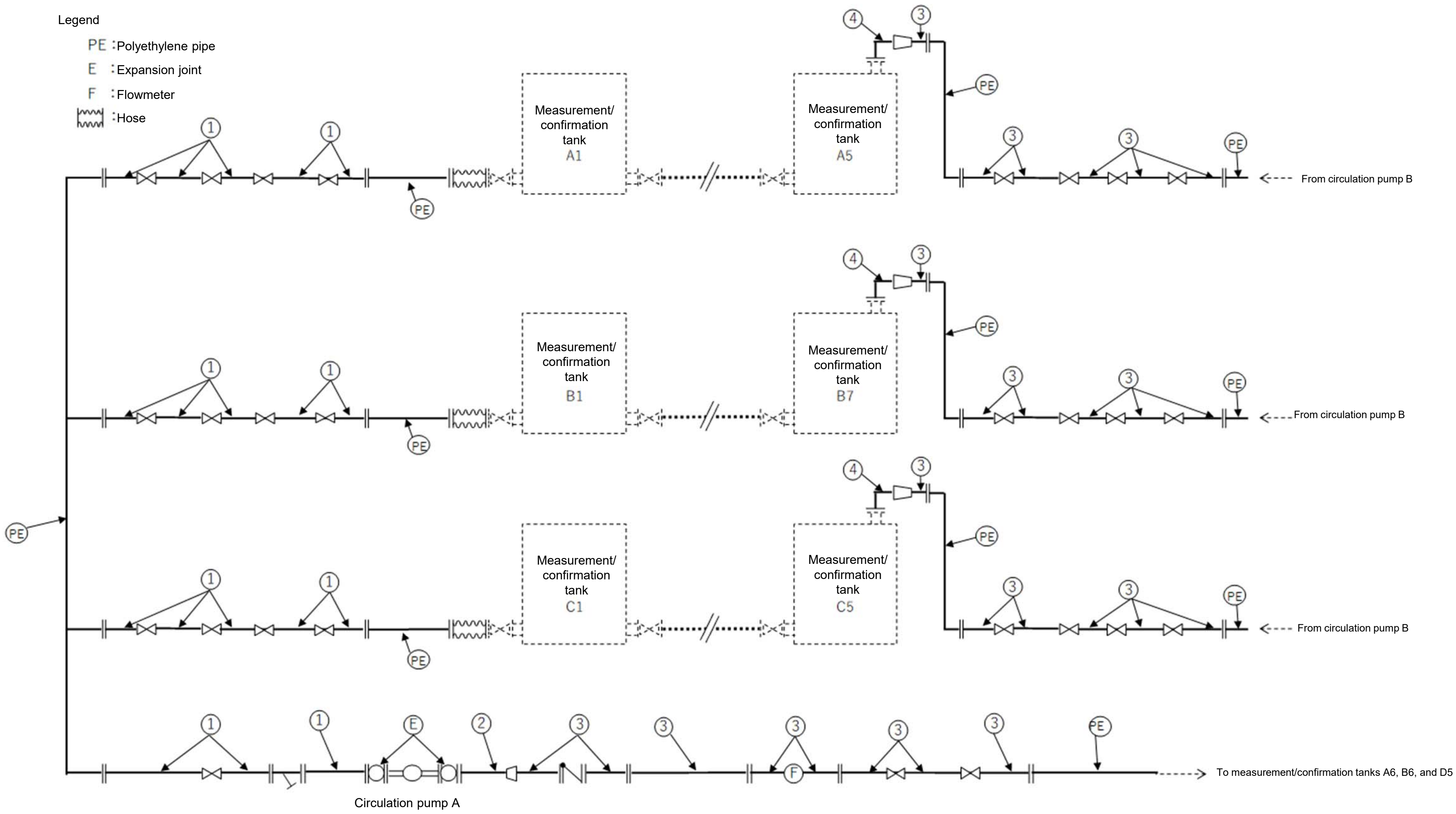


Figure-1 Piping diagram (1/5)

- The following figure shows pipes to be evaluated.

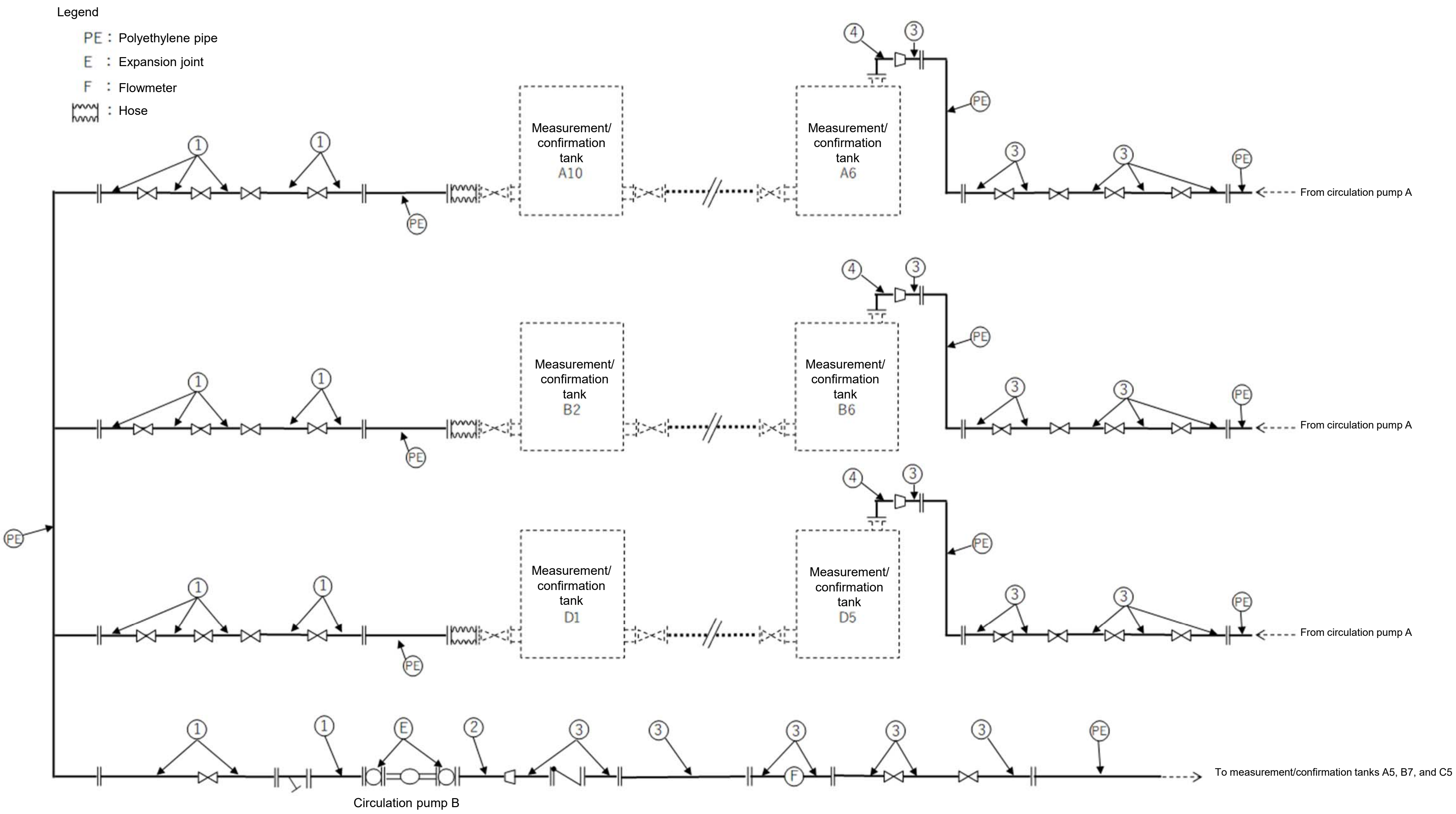


Figure-1 Piping diagram (2/5)

The Japanese version shall prevail.

[Reference] Pipes subject to the structural strength evaluations of ALPS treated water dilution/discharge facilities

- The following figure shows pipes to be evaluated.

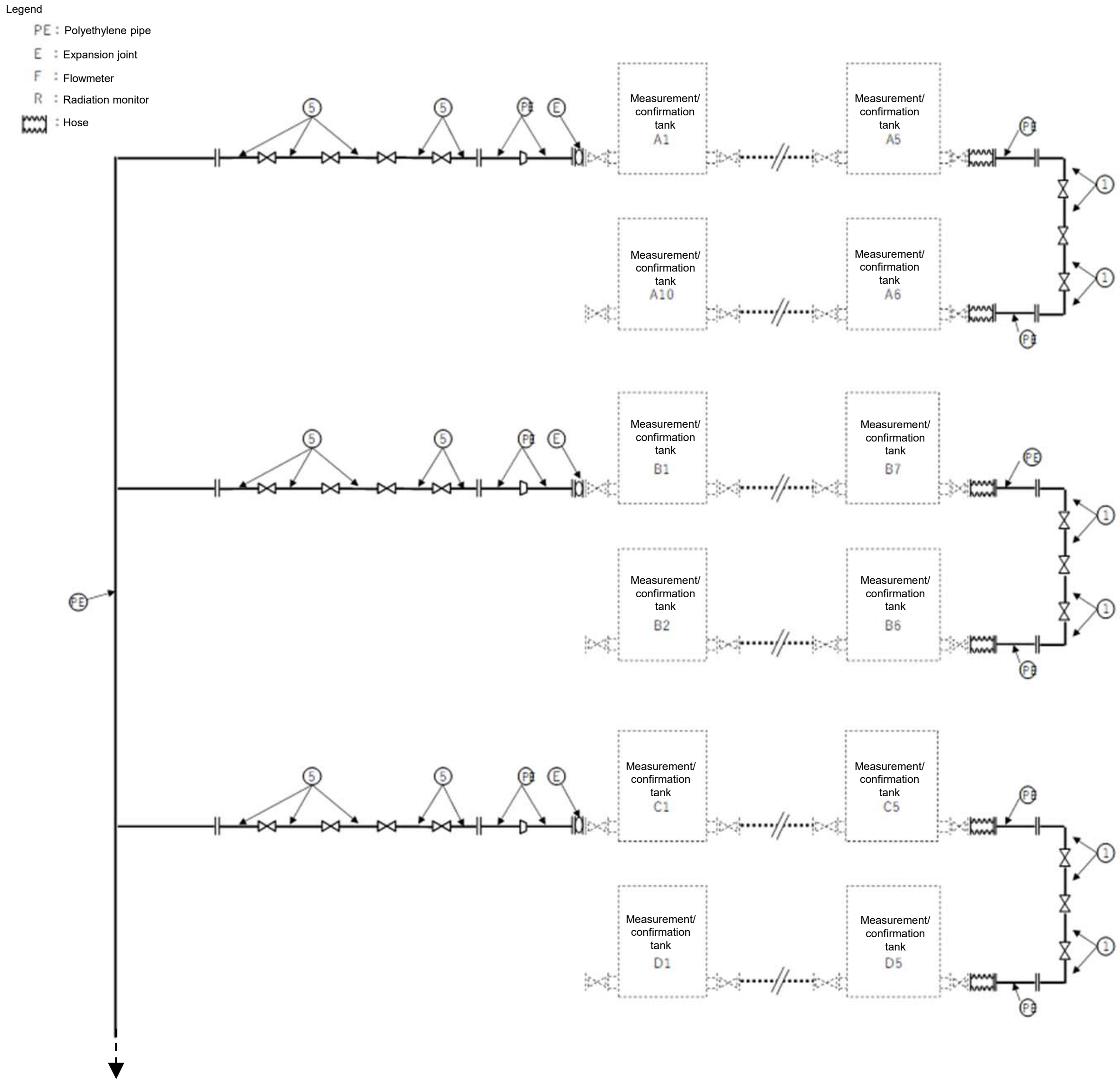


Figure-1 Piping diagram (3/5)

- The following figure shows pipes to be evaluated.

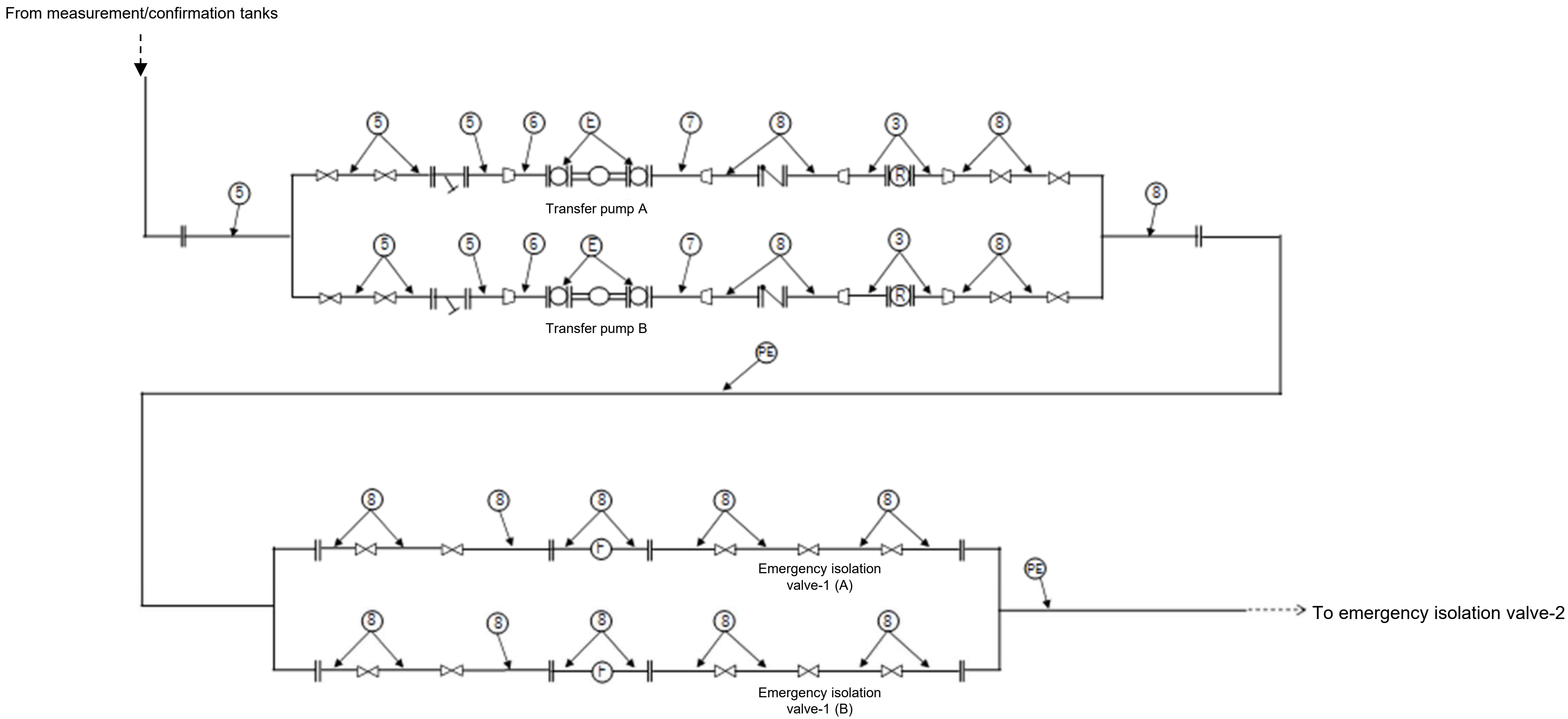


Figure-1 Piping diagram (4/5)

- The following figure shows pipes to be evaluated.

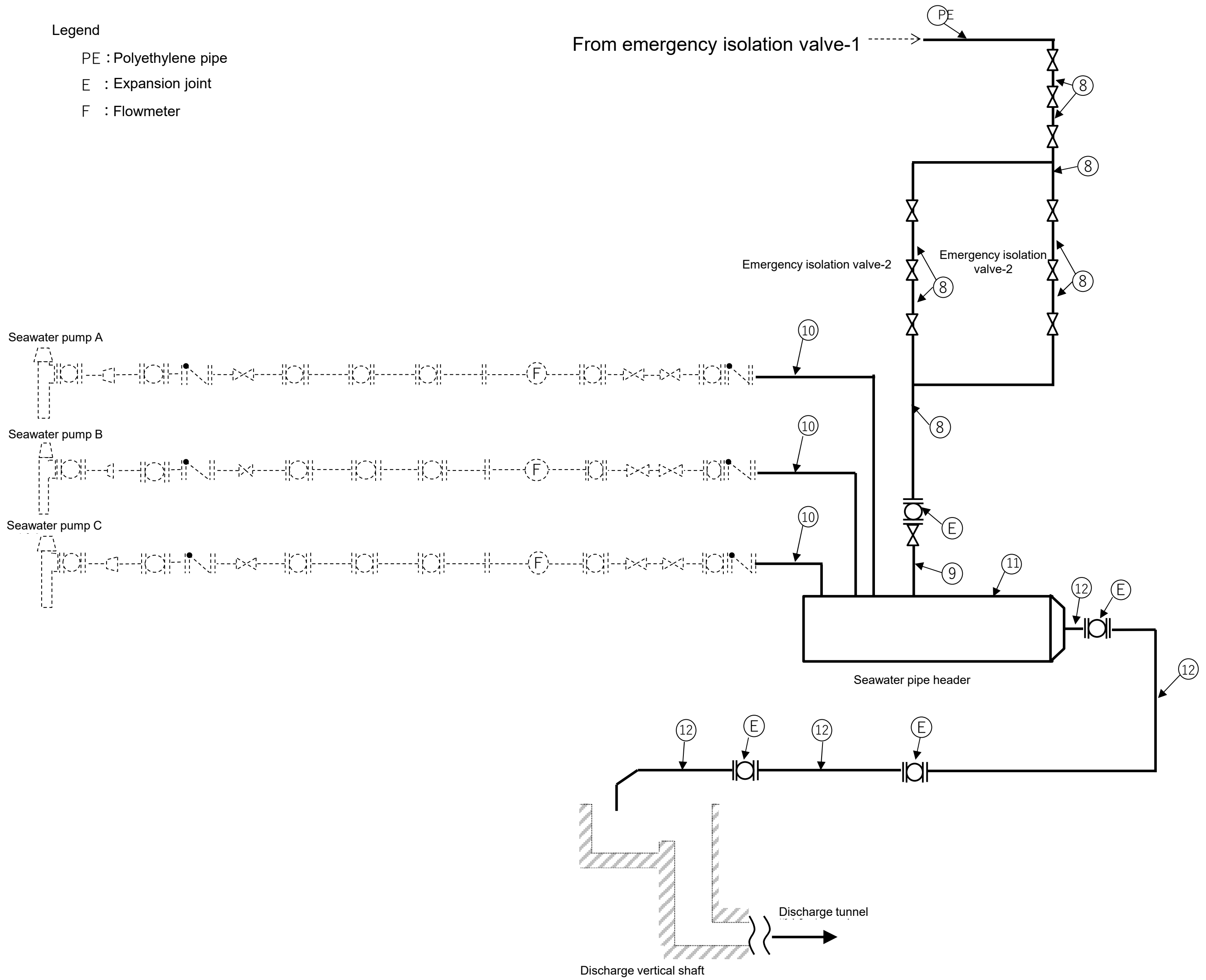


Figure-1 Piping diagram (5/5)

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [4]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(1) Discharge Facilities of ALPS Treated Water into the Sea

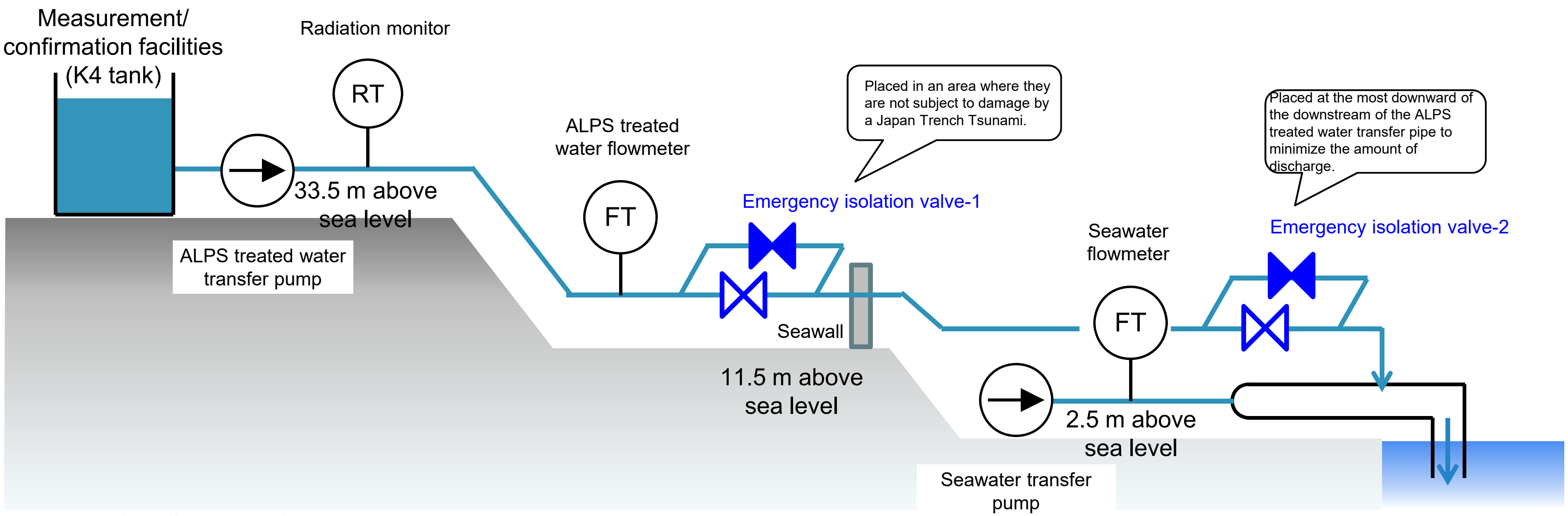
[6] Validity assessment of the facility design in the event of failure

- Explain including entire scope (installation locations of MO valves) and the closing time, because there are many MO valves of the same type as the emergency isolation valve-1 (MO valve).
- In the event of a single failure of the driving source (compressed air), the emergency isolation valve-2 (AO valve) will close, in contrast, water will continue to flow in to the tank through the three-way valve. How to deal with this situation must be explained.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[4]-1. Expected role and design of the emergency isolation valve

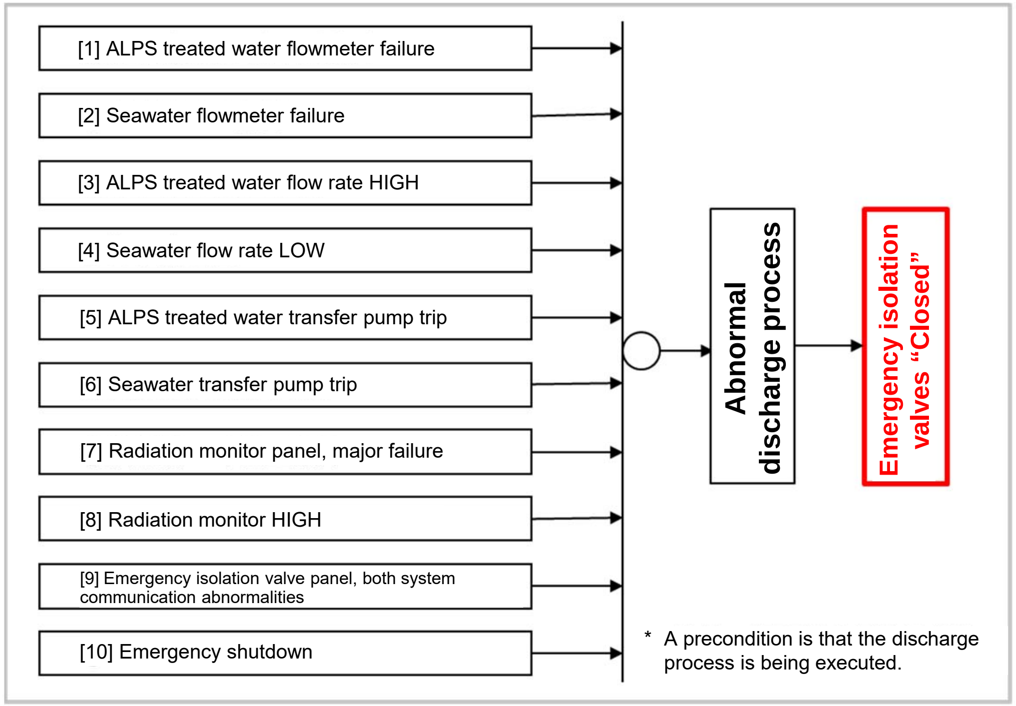
- The emergency isolation valves, which are installed in the ALPS treated water transfer line, have a function to stop the discharge of ALPS treated water into the sea by closing the valves without manual operation in the event of detecting an abnormality that deviates from normal operation.
- The emergency isolation valves has a design of dual-redundant in series. Their installation position, working methods, and design concept are as follows:

Design	Emergency isolation valve-1	Emergency isolation valve-2
Location of installation	Where not subject to damage by tsunami	At the most downward of the downstream of ALPS treated water transfer pipe to minimize the amount of discharge at the valve operation.
Operating system	Motor-operated (The closing motion needs 10 seconds)	Air operated (AO) (The closing motion needs 2 seconds)
Concept of design	Two systems are installed. The system to use can switch by opening or closing the valves the front or rear in the event of failures or maintenance to keep the facility availability.	(Same as on the left)

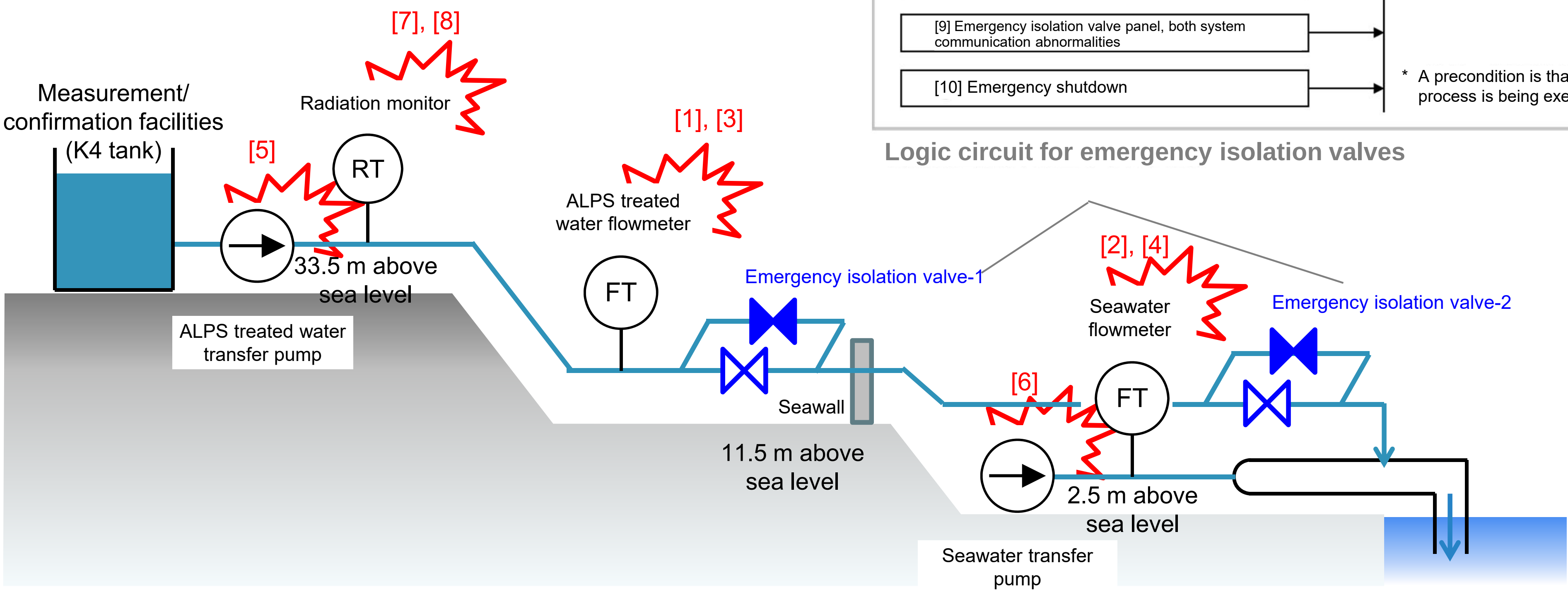


2-1 (1) [6] Validity assessment of the facility design in the event of failure
[4]-2. Operating conditions of the emergency isolation valve

- The operating conditions under which the emergency isolation valve is "closed" are shown in the figure below, designed to prevent "unintentional discharge of ALPS treated water into the sea."
- The logic is that when various kinds of abnormalities are detected, the sound seawater transfer system will continue the operation and dilution as much as possible.



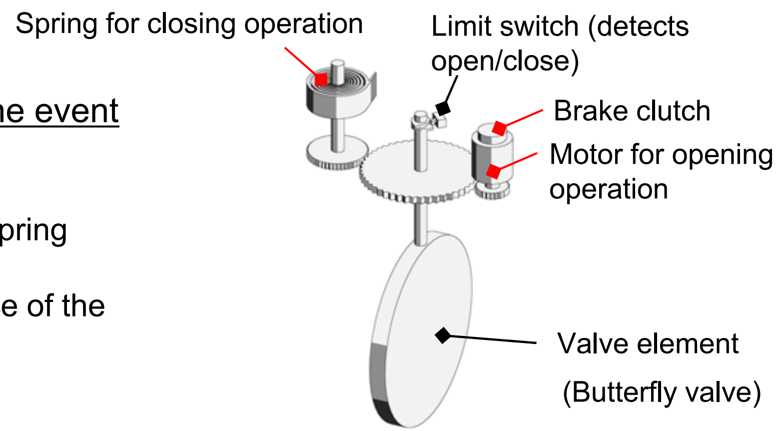
Logic circuit for emergency isolation valves



2-1 (1) [6] Validity assessment of the facility design in the event of failure
[4]-3. Specifications for emergency isolation valves

Emergency isolation valve-1 (MO valve)

- Spring return type motor-operated emergency isolation valve, which closes fully in the event of loss of power
  - To fully open the valve, the motor will start up to wind the spring.
  - Once the valve is opened fully, the built-in brake will be activated to keep the wound-up spring from moving back (under normal operation).
  - With the loss of power, the brake will be released, and the valve will be closed by the force of the spring.
  - Open → Close: within 10 seconds
- Measures against water hammers
  - Measures are taken in the mini-flow line at the ALPS treated water transfer pump outlet.

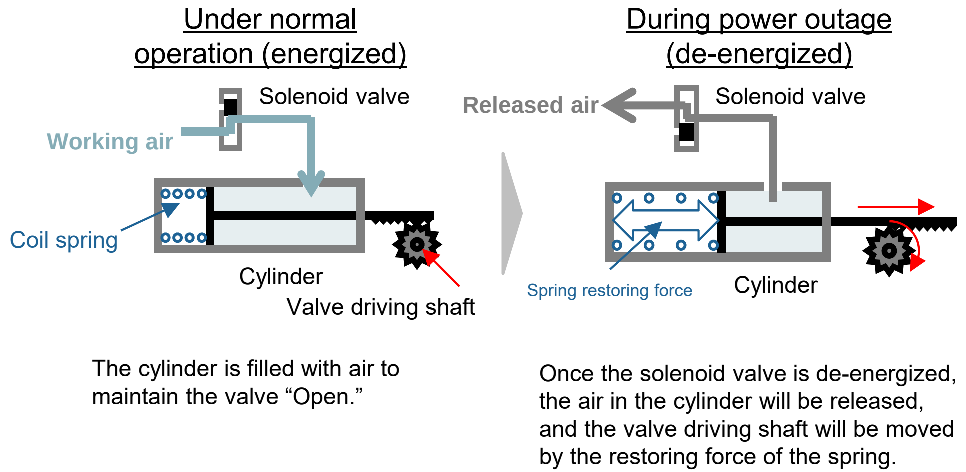


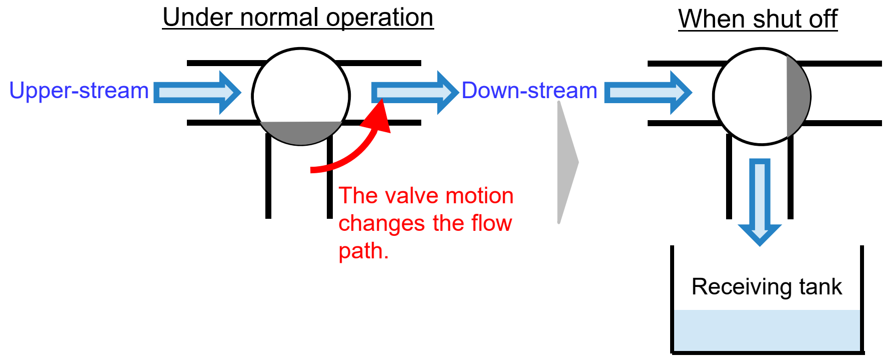
Outline of the structure of emergency isolation valve-1

Emergency isolation valve-2 (AO valve)

- Air-operated emergency isolation valve, which closes fully in the event of loss of power
  - The linear movement of the pressurized piston in the cylinder is converted into rotary motion (valve drive system).
  - This valve has a coil spring in it, and when the solenoid valve of the working air is de-energized at the time of power outage, the air in the cylinder is released to move the piston.
  - Open → Close: about 2 seconds
- Measures against water hammers
  - Since the emergency isolation valve-2 has a design featured to shut off the discharge as quickly as possible, countermeasures against water hammers is required. Therefore, a three-way valve is adopted.

→ The capacity of the receiving tank shall be approximately 1.1 m^3 plus sufficient allowance, that is, the volume larger than the amount of water transferred when the emergency isolation valve-1 is closed and the amount contained in the pipe from the emergency isolation valve-1 to the emergency isolation valve-2.



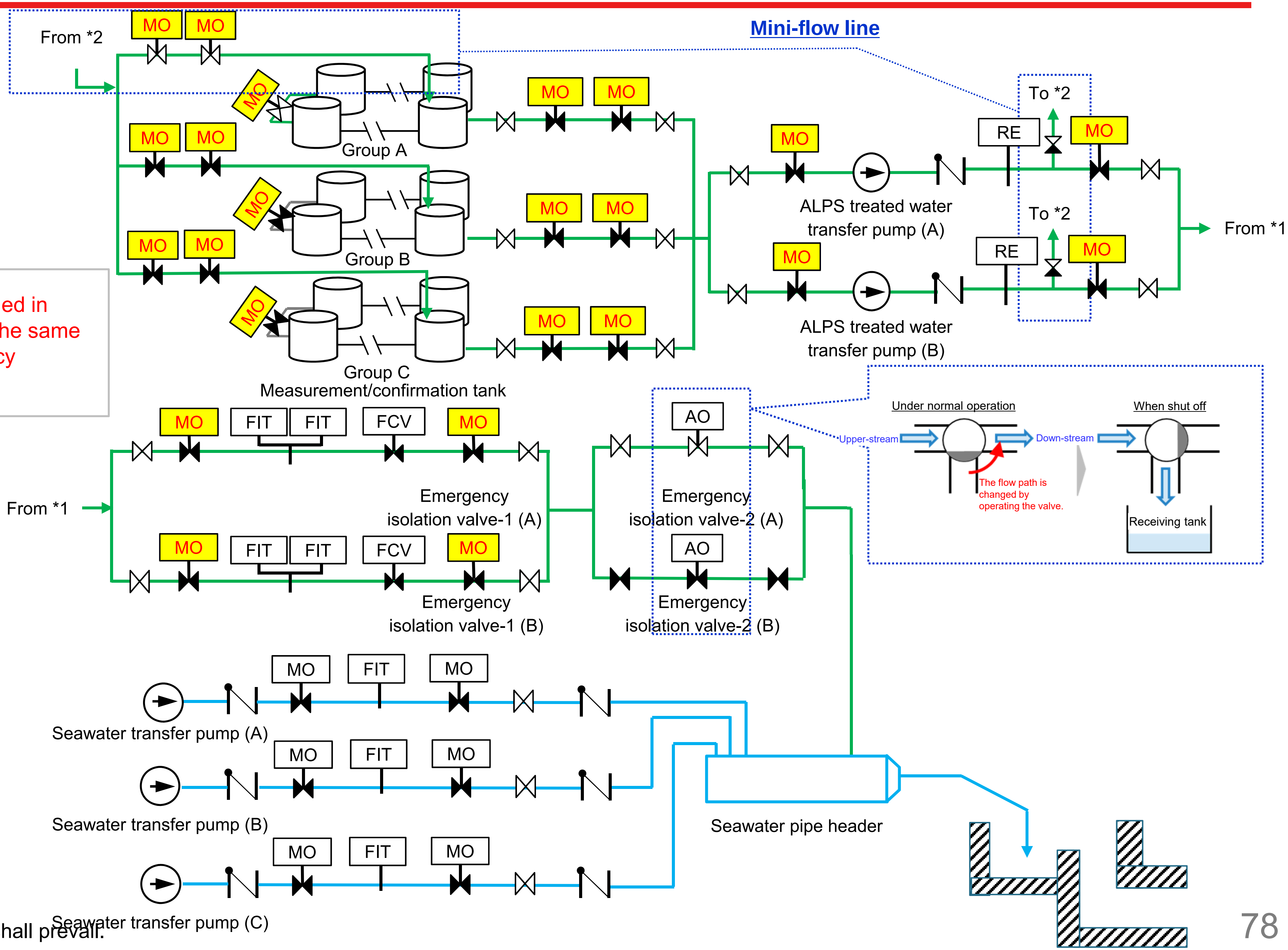


The Japanese version shall prevail.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[Supplement] Fail-close valves in the transfer/dilution facilities

TEPCO

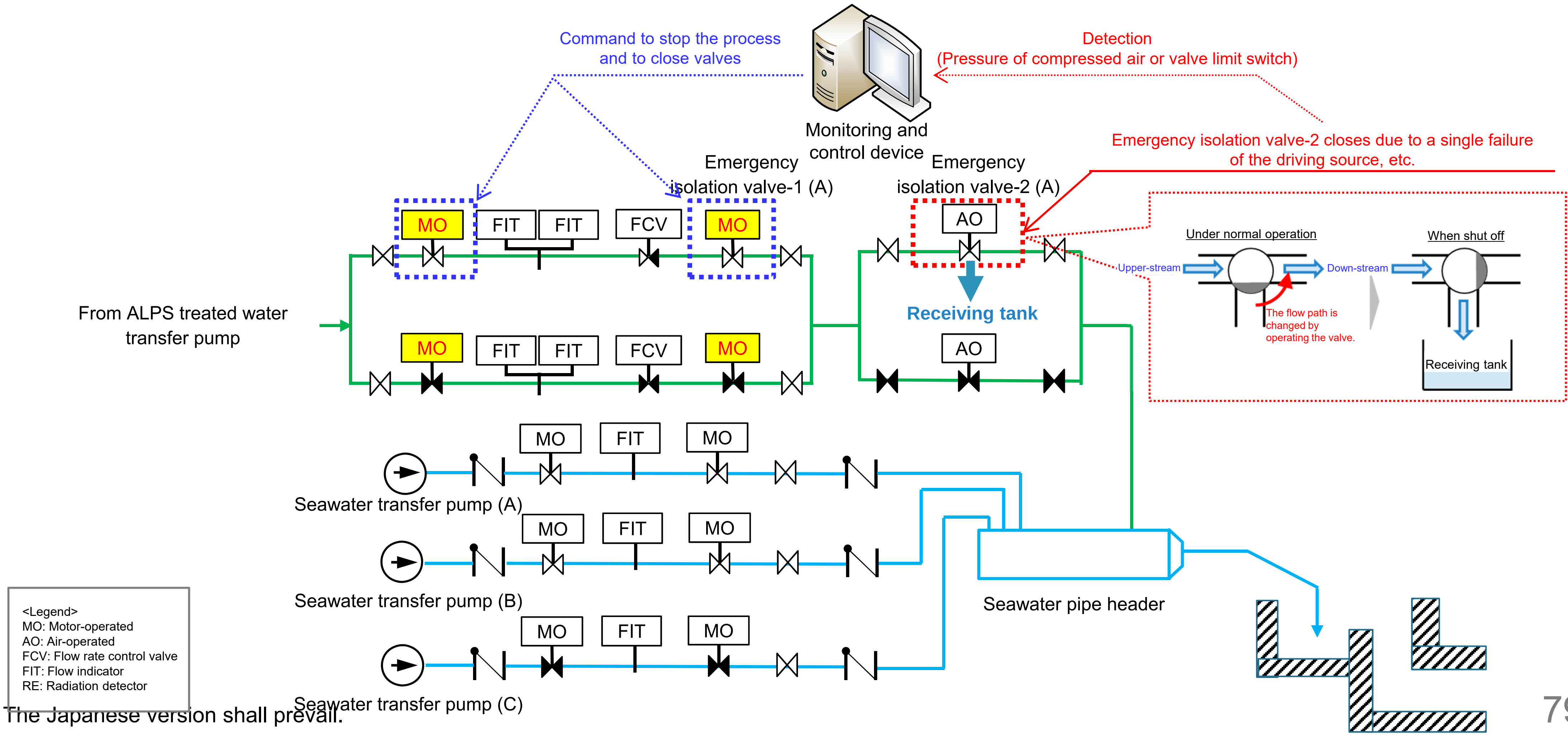
The MO valves hatched in yellow are valves of the same type as the emergency isolation valve-1.



<Legend>
MO: Motor-operated
AO: Air-operated
FCV: Flow rate control valve
FIT: Flow indicator
RE: Radiation detector

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[4]-4. How to deal with failure modes of emergency isolation valve-2

- The emergency isolation valve-2 is a three-way valve, and when it takes a closing motion caused by a single failure of the driving source (compressed air) , or the like, water flows into the receiving tank. Besides, when a single failure of the driving source of the emergency isolation valve-2 occurs, a loss of pressure of the compressed air or a valve limit switch detects a malfunction and activate the alarm at the monitoring/control equipment following stopping the (transfer) process, closing the emergency isolation valve-1 and the other MO valves of the same type.
- This design will prevent ALPS treated water from keeping flowing into the receiving tank. In addition, ensuring leakage prevention, the receiving tank is provided with enough capacity with allowance take into account of such malfunctions.



The Japanese version shall prevail.

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [5]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(2) Safety measures at the time of discharge into the sea

[1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water

- The overall picture of analytical work must be explained, including required resources, details, time and frequency of analyses for conventional routine analyses that have been performed, analyses work of transient situations in emergencies, and the analysis of ALPS treated water, which will be added this time. Then, an explanation should be given on what role and impact the analysis of ALPS treated water will have in the overall analytical work and how the resources are secured.

2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water

[5]-1. Analysis facilities involved

TEPCO

- The [chemical analysis building] will have to deal with an increased number of test samples as the discharge of ALPS treated water. After clarifying the resources required, plans for necessary measures will be developed.
- For liquid sample analyses at the time of trouble on site, such as leakage, will not involved in the chemical analysis building because the property and radioactivity of the liquid are unknown. Therefore, no need to keep resources for responding to troubles.

Environmental management building

preprocessing (preprocessing of fish)

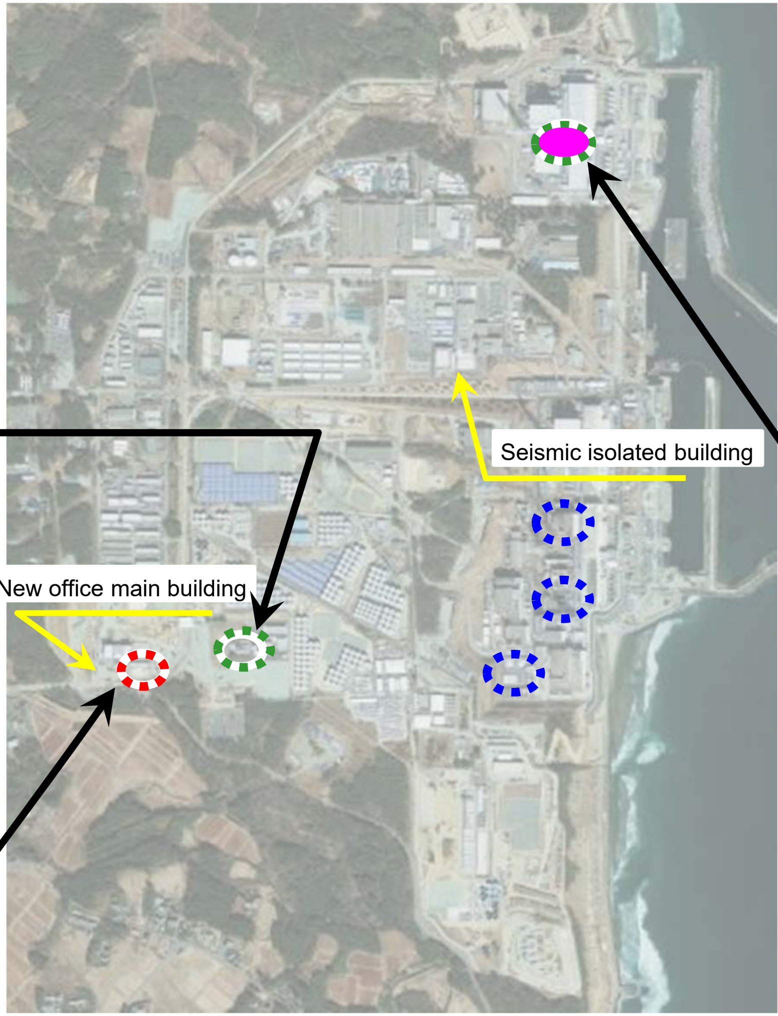
Chemical analysis building

For samples with low activity concentration

Analysis room + Measurement room: 1,000 m^2

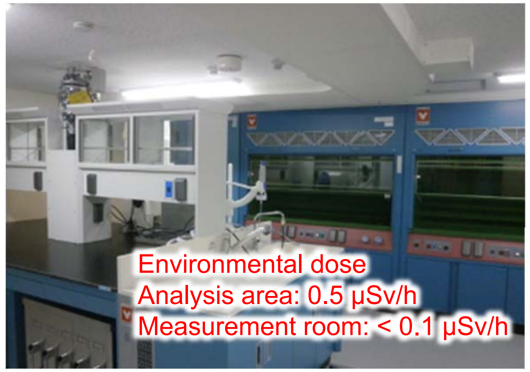
Laboratory table: 15, Fume hood: 35

- This facility was put into use in 2013.



Units 5 and 6 analysis room

For samples with high activity concentration



- Facilities that have been used since before the 3.11 Earthquake
- Facilities that became unusable due to the 3.11 Earthquake
- New facilities that were constructed or put into use after the 3.11 Earthquake
- Existing facilities that were renovated or expanded after the 3.11 Earthquake

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[5]-2. Resource management status

TEPCO

■ Overview of resources (analysts)

- The number of analysts to be allocated is adjusted as necessity depending on the number of test samples to avoid excess or deficiency.
- The maximum number of 34 analysts engage in analyzing concentration levels on low-level radioactive samples in a day-time-shift at the chemical analysis building.
- When even the maximum number of analysts fails to complete the analysis low-level radioactive samples, two analysts of the 5th and 6th analysis room move to the chemical analysis room in the night-time to continue the analyses.
- Since the number of test samples is expected to increase, further efforts will be made to secure and foster analysts.
- A system to have employees living in the Okuma Dormitory for Bachelors work as supervisors during nighttime will be established.

	Affiliation	Number of employees	Daytime on weekdays (Maximum)	Nonbusiness days	Nighttime	Remarks
Analyst	Chemical analysis building	34 analysts	34 analysts	5 analysts	0 analysts	Day shift only
	Units 5 and 6 analysis room	59 analysts	37 analysts	21 analysts*1	2 analysts	Shiftwork and day shift
Supervisor	Chemical Analysis & Evaluation Group	15 analysts	15 analysts	2 analysts	0 analysts (7 analysts*2)	Day shift only

(Arrow from Units 5 and 6 nighttime to Chemical analysis building:) Assigned to chemical analysis building to take over analyses during nighttime

*1: Total number of employees *2: Night shift staff are appointed

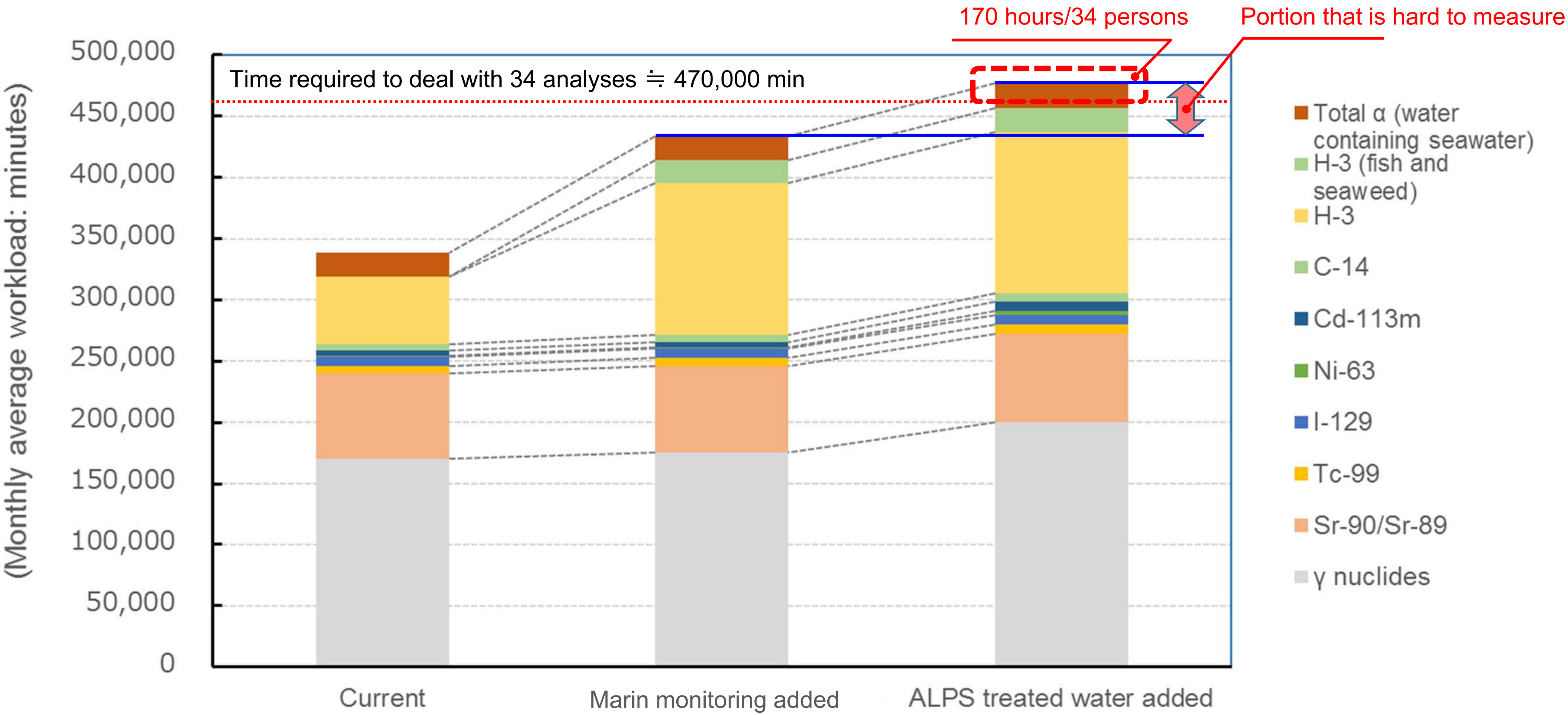
The Japanese version shall prevail.

[5]-3. Prospects of analytical work

TEPCO

- Determining the time required for work

- Working status for analyzing appears by the total number of hours to analyze low-level radioactivity concentrations in total workload, including the measurement time.
- The measurement time includes waiting time, which makes up approximately 30% of the working hours.
- Including measurement of the 64 nuclides in ALPS treated water subject to discharge, there exists a gap of 170 hours a month. These gap can be filled through improvement of the competence of the analysts and organization of simultaneous work before the start of the discharge.



[5]-4. Identifying the competence of workers

TEPCO

Approach to enhance competence

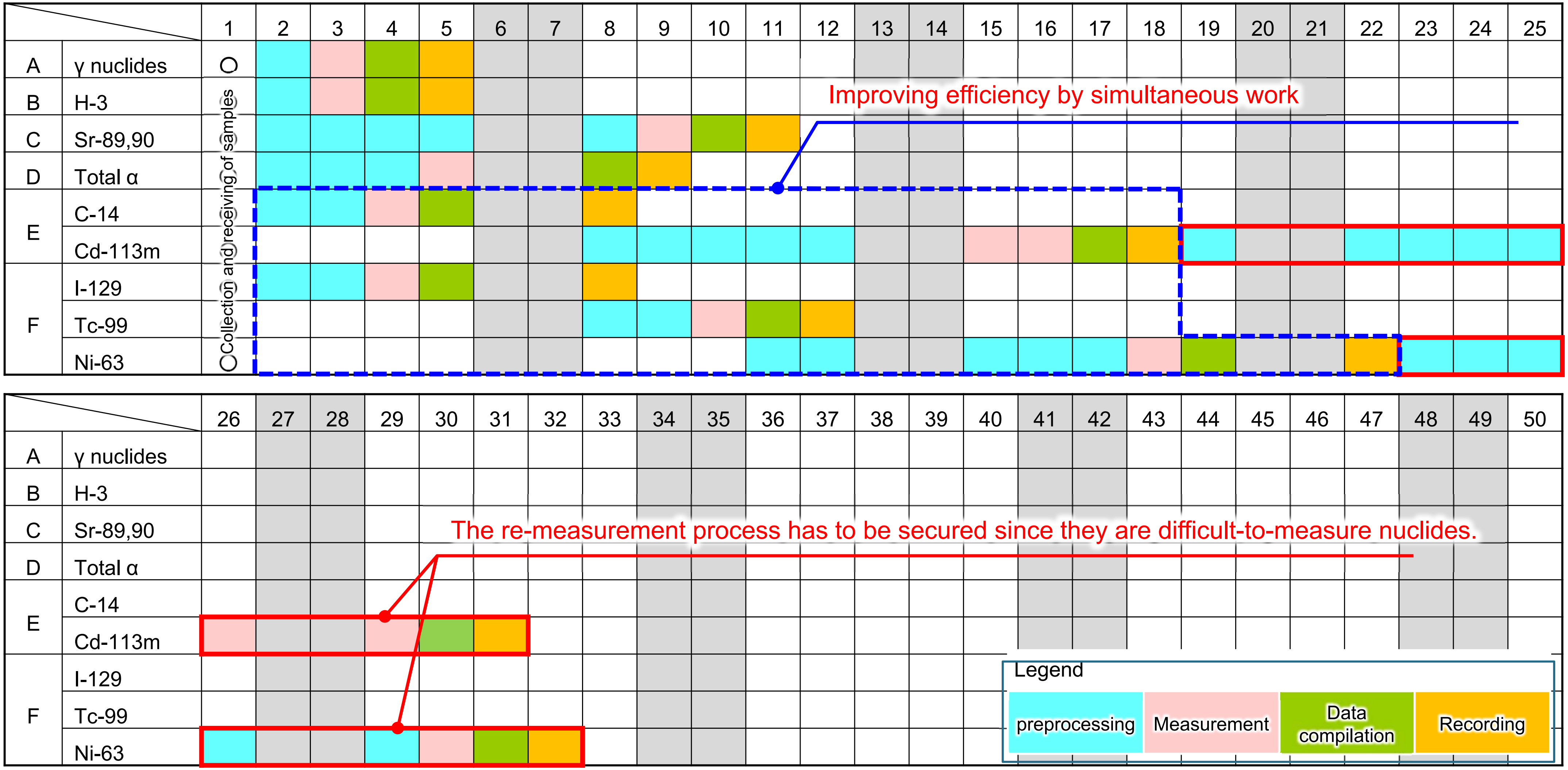
- Visualize the competence of 34 employees working in the chemical analysis building and 2 employees in the units 5 and 6 analysis room.
- The table below shows the visualized competences and the competence rate will have been improved before the discharge of ALPS treated water.

Worker \ Nuclide	Ni-63	Cd-113m	C-14	Tc-99	I-129	Sr-90	Worker \ Nuclide	Ni-63	Cd-113m	C-14	Tc-99	I-129	Sr-90
1	○	○	○	○	○	○	19			○	○	○	
2	○	○	○	○	○	○	20			○			○
3	○	○	○		○	○	21						
4	○	○	○	○	○	○	22						
5	○	○	○	○	○	○	23						○
6	○	○	○	○	○	○	24	○	○				
7	○	○	○	○	○	○	25	○	○	○	○	○	
8	○	○		○	○	○	26	○	○	○	○	○	○
9		○		○	○	○	27			○	○	○	
10	○	○	○		○	○	28		○	○	○	○	
11			○			○	29			○	○	○	
12			○			○	30			○	○	○	
13			○			○	31			○	○	○	
14			○			○	32			○	○	○	
15			○				33			○	○	○	
16			○			○	34			○	○	○	
17			○			○	35	○	○				
18			○				36						○
							Number of competent persons	13	15	28	19	21	20

[5]-5. Identifying the required work

Consideration of simultaneous work

- Studying a highly effective method for simultaneous work to adapt, and allocate analysts to optimize their skills aiming aiming at effective analyses.
- In addition, to shorten the time required to obtain values necessary for making discharge go/no-go decisions, efforts will be made to streamline procedures for off-site transport.



[5]-6. Further Efficiency Promotion

TEPCO

Expansion of the functions of the chemical analysis building

- Equipment in preprocessing and measurement areas is planned to be added with anticipation for an increase in the number of objects to be measured in view. Once the construction of facilities completes, work efficiency will be increased enough to carry out the analyses with the planned workers, leaving excess capacity..

[Preprocessing area]

Target	Measurement target	Expansion scale (Maximum number of samples per year)	preprocessing facility (planned number of units)	
Seawater	H-3	156	Fume hood Rotary evaporator Electrolytic concentrator	4 5 4
	I-129	8	Laboratory table Fume hood	2 7
	C-14	20		
	γ nuclides (including Sn-126)	12	Fume hood Laboratory table	4 2
	α nuclides	12	Laboratory table Fume hood	1 4
	Sr-90	12		
Seabed sediment	Sn-126	20		
Fishes	C-14	1	Fume hood Laboratory table Freezing dryer Electrolytic concentrator H-3 attenuation vessel	6 3 6 6 2
	Sn-126	1		
Seaweeds	C-14	2		
	Sn-126	2		

[Measurement area]

LSC: 11 -> 14 units

Measurement target	Measuring equipment (planned number of units)	
H-3	LSC*1	3
C-14	He-MS*2	2
γ nuclides (including Sn-126)	Ge (LEPS*3)	2

*1: LSC: Low background liquid scintillation counter

*2: He-MS: Noble gas mass spectrometer for the measurement of H-3

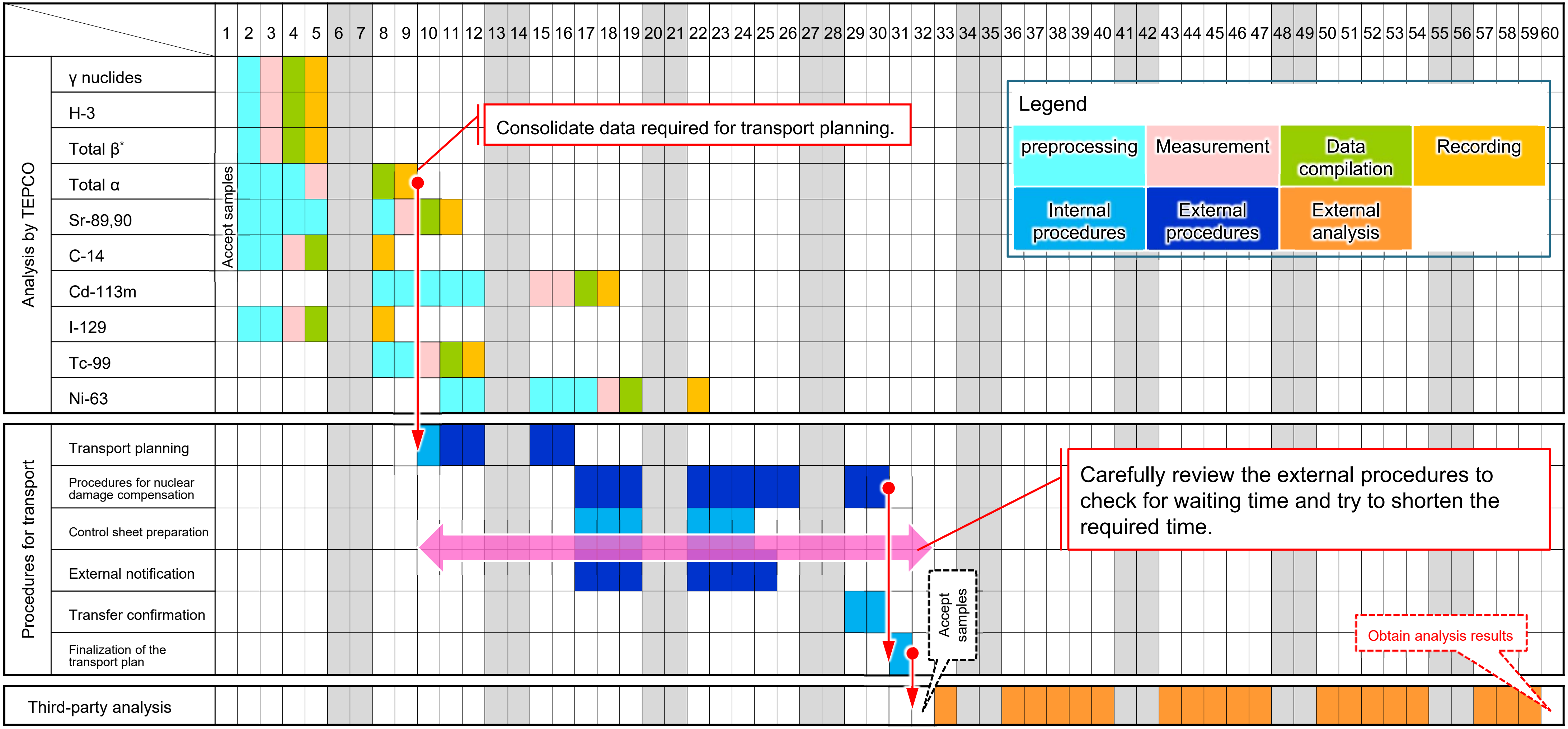
*3: LEPS: High purity Ge semiconductor detector for low energy photons

- The current area of about 1,500 m^2 will be expanded by about 600 m^2 to about 2,100 m^2.
- The number of analyzers needed may change depending on monitoring plans and the detailed design of equipment.
- The completement of the construction work is scheduled by the end of FY 2023.

[5]-6. Further Efficiency Promotion

Time-saving for measurement/confirmation facility

- In the treated water verification process before discharge, analyses by a third-party organization are performed to verify the values measured by TEPCO, which takes about 2 months to obtain the analysis results.
- The process will be reviewed carefully to shorten the required time without affecting the analyses of ALPS treated water to be discharged.



*Not applied to the analyses of drainage water.

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [6]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(2) Safety measures at the time of discharge into the sea

[1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water

- Explane the analytical methods, applicable methods to be adopted this time, reasons and grounds for adopting these methods, etc.

2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water
[6]-1. Application of analysis methods

- The analytical methods to be adopted for the analyses of ALPS treated water are the methods that have been widely used (for γ-ray emitting nuclides, etc.) and those developed by JAEA for determining radio activity concentrations of waste from the power plants and the research facilities, focusing on the change of target nuclides in the cooling water caused by contact the fuel debris emerged after the 3.11 earthquake.
- As regards preprocessing methods that have been changed or newly adopted after the earthquake, it needs to be verified that the analyses are performed in an intended manner and the result obtained are appropriate values.

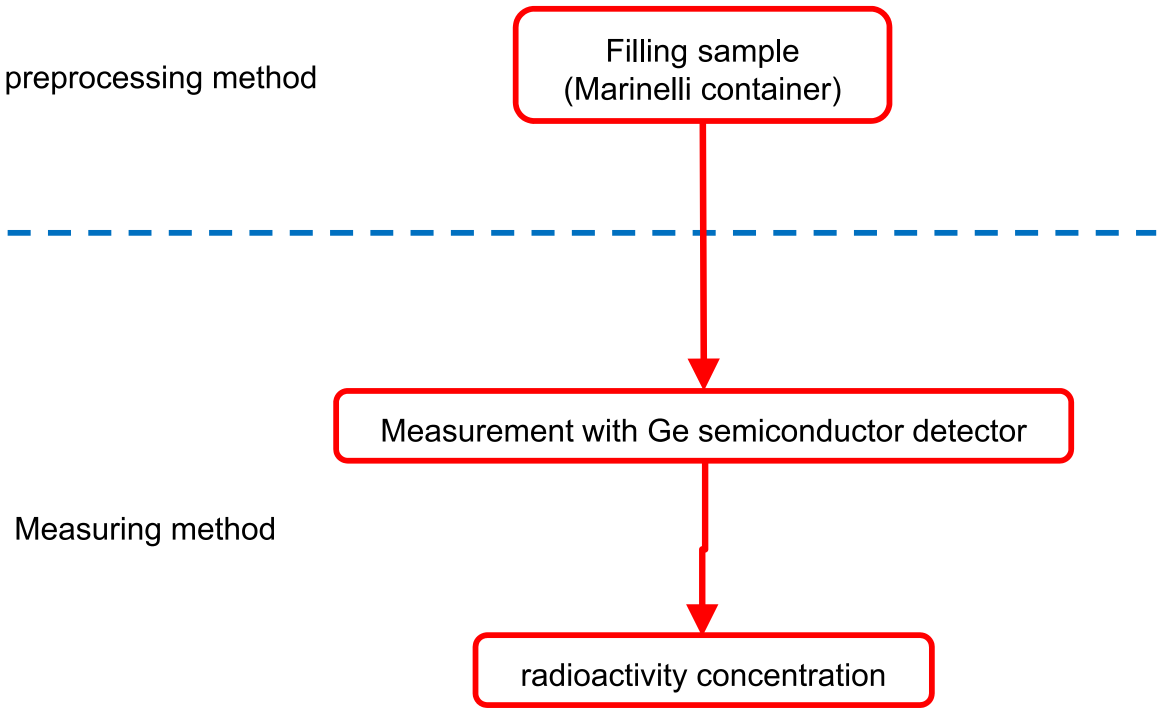
- When changing preprocessing methods or adopting a new method, the source of each method must be carefully examined to verify that the methods are available to the analyses of ALPS treated water.

- Examine if a newly adopted methods can perform preprocessing and has a expected accuracy function using a standard radiation source and from the RI addition test results to ensure that it can perform Pre processing and obtain values of expected accuracy.

[6]-2. Validity evaluation of analytical methods for ALPS treated water (1/9)

TEPCO

Target nuclide	Result of validity evaluation
γ-ray emitting nuclides	Conforming [The Series of Environmental Radioactivity Measuring Methods No.7 (Gamma-ray Spectrometry using Germanium Detector)].



Grounds for the selection

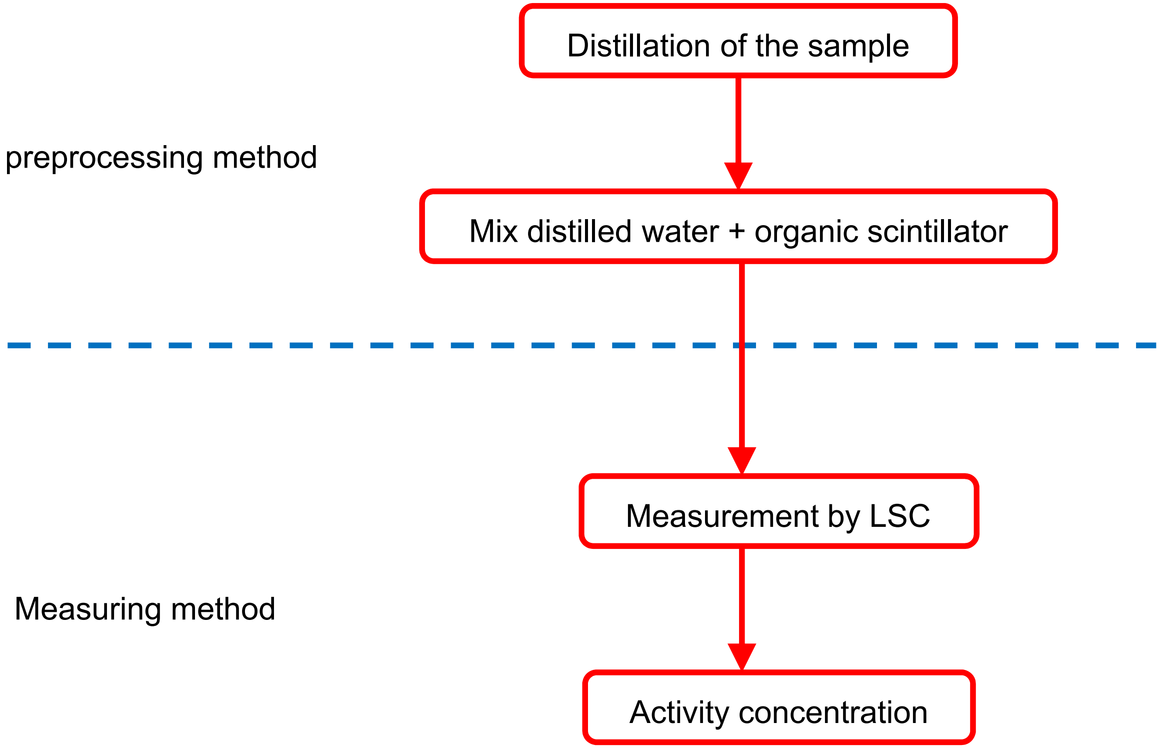
Since the radioactivity concentration is low, it is unnecessary to consider methods that deviate from conventional methods.

Verification of validity

- Compare records with third-party organizations for groundwater bypass and sub-drain purification water analyses.
- Quantitatively verify the validity through the IAEA proficiency tests.

2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water
[6]-2. Validity evaluation of analytical methods for ALPS treated water (2/9)

Target nuclide	Result of validity evaluation
H-3	It comforms [The Series of Environmental Radioactivity Measuring Methods No.9 (Tritium Analysis)].



Grounds for the selection

The low background liquid scintillation counter (LSC) maintains linearity in counting. Therefore, the conventional method can be applied as it is.

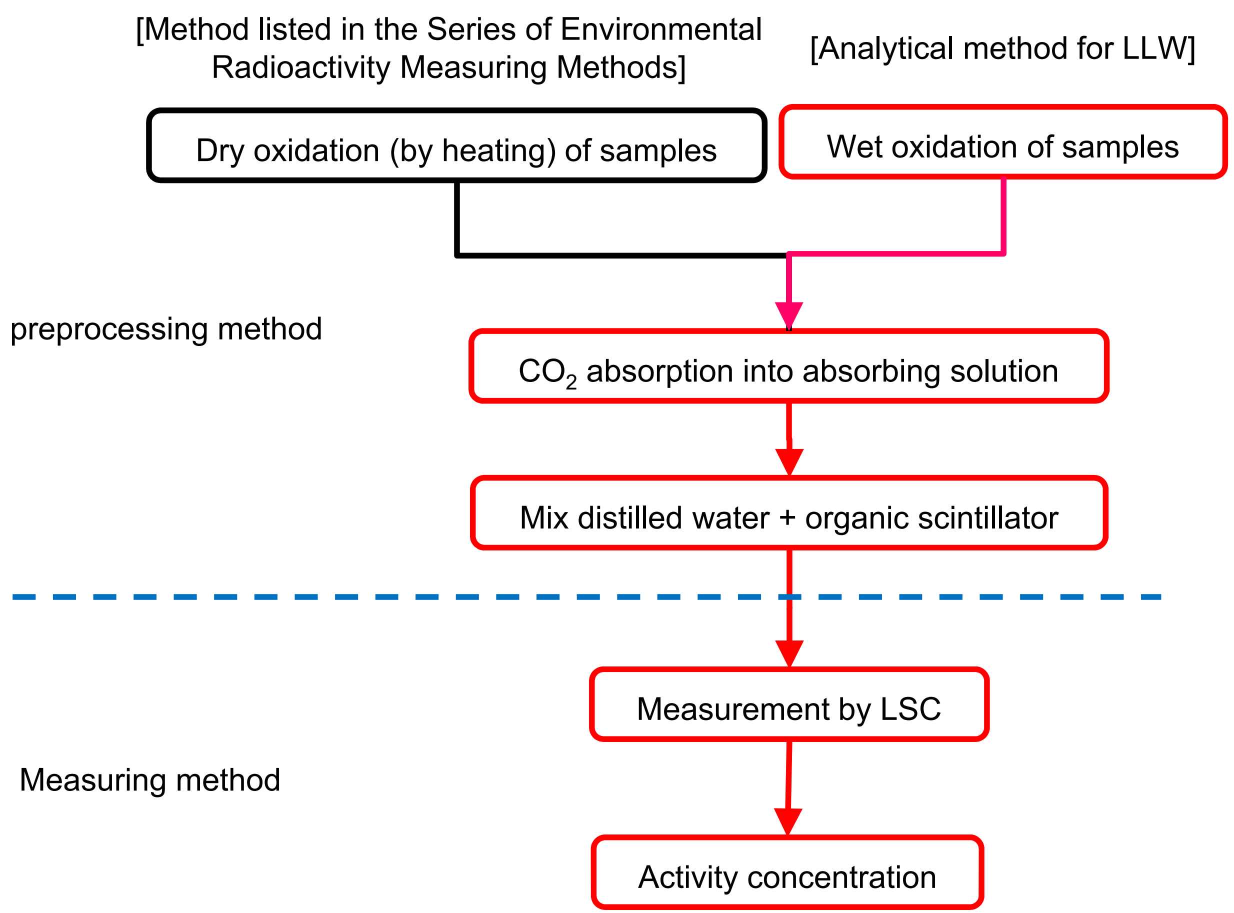
Verification of validity

- Compare records with third-party organizations for groundwater bypass and sub-drain purification water analyses.
- Quantitatively verify the validity through the IAEA proficiency tests.

[6]-2. Validity evaluation of analytical methods for ALPS treated water (3/9)

TEPCO

Target nuclide	Result of validity evaluation
C-14	• It conforms [Pre processing method for low-level radioactive waste samples (Analytical method for LLW)*1]. • It conforms [The Series of Environmental Radioactivity Measuring Methods No.25 (Radiocarbon Analysis)].



Grounds for the selection

The analytical method for LLW has a good track record of measuring low-level radioactive concentrations. Therefore, it can be applied to ALPS treated water as it is.

Verification of validity

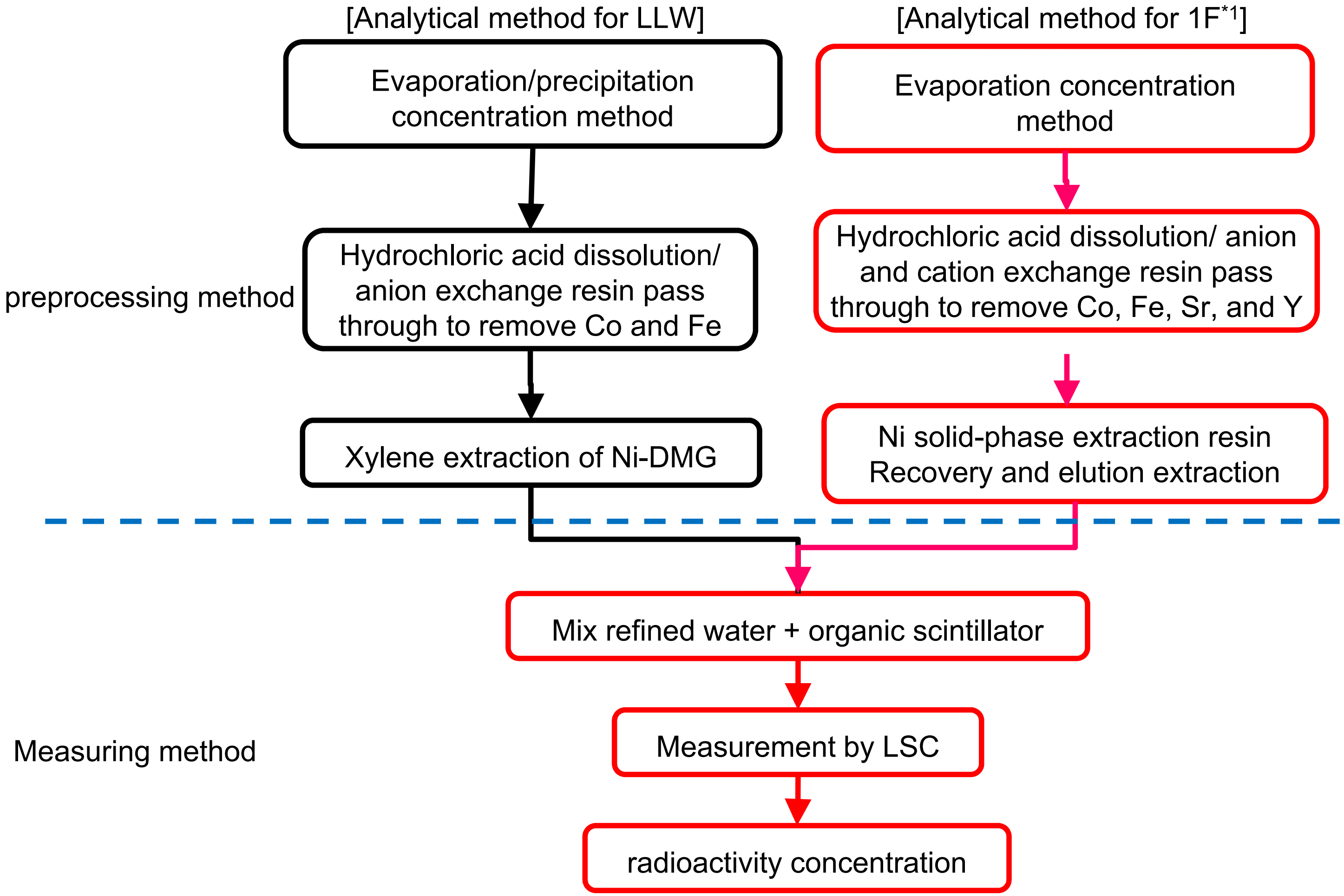
This method has been proved to measure concentrations to the detection limit that is sufficiently below the regulatory concentration limit (2,000 Bq/L).

*1: Approved at the 7th Waste Materials WG_the Radioactive Waste Safety Technical Advisory Council.

[6]-2. Validity evaluation of analytical methods for ALPS treated water (4/9)

TEPCO

Target nuclide	Result of validity evaluation
Ni-63	• It conforms [Pre processing method for low-level radioactive waste samples (Analytical method for LLW)]. • Pre processing method adopted in the analytical method for 1F is [Simple and Rapid Determination Methods for Low-Level Radioactive Wastes Generated from Nuclear Research Facilities (Guidelines for Determination of Radioactive Waste Samples)].



Grounds for the selection

Method improved and streamlined by JAEA based on the analytical method for LLW*1.

Verification of validity

- The recovery rate of stable Ni was checked, and a reasonable recovery rate was achieved.
- This method has been proved to measure concentrations to the detection limit that is sufficiently below the regulatory concentration limit (6,000 Bq/L).

*1: [1] Simple and Rapid Determination Methods for Low-Level Radioactive Wastes Generated from Nuclear Research Facilities (Guidelines for Determination of Radioactive Waste Samples), JAEA-Technology 2009-051

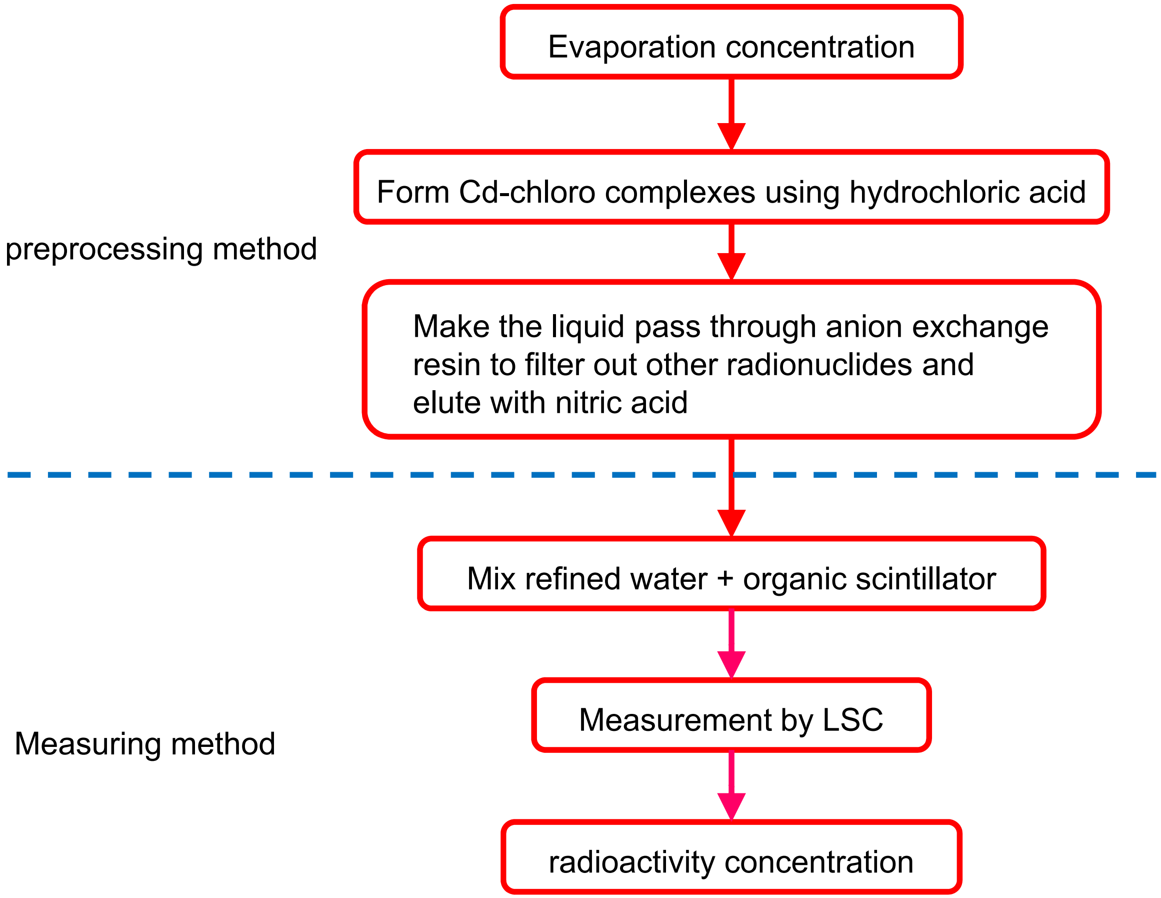
[2] "Systematic analysis method for radioactive wastes generated from nuclear research facilities", Transactions of the Atomic Energy Society of Japan, Vol. 10, No. 3, p. 216 -225 (2011)

2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water
[6]-2. Validity evaluation of analytical methods for ALPS treated water (5/9)

TEPCO

Target nuclide	Result of validity evaluation
Cd-113m	It complies with [the Determination method using liquid scintillation counter for ^{113m}Cd in wastewater in Fukushima-1 Nuclear Power Plant].

[Analytical method for 1F*1]



Grounds for the selection

- A method was developed for 1F as no existing method.
- A determination method that combines a preprocessing method based on a publicly known Cd concentration determination method adopted for pollution analyses and the radioactivity measurement using LSC.

Verification of validity

- Having a reasonable stable Cd recovery rate, this method can be applied to the analyses of ALPS treated water.
- Since obtaining a Cd-113m source is difficult, the radioactivity concentration is calculated using the C-14 counting efficiency, which is lower in energy than Cd-113 m (conservative evaluation).

*1: "Determination method using liquid scintillation counter for ^{113m}Cd in wastewater in Fukushima-1 Nuclear Power Plant]
BUNSEKI KAGAKU Vol.63 No.4 pp.345-350 (2014)

[6]-2. Validity evaluation of analytical methods for ALPS treated water (6/9)

TEPCO

Target nuclide	Result of validity evaluation
I-129	It complies with [The Series of Environmental Radioactivity Measuring Methods No.32 (Rapid Analytical Method for Iodine 129 in Environmental Samples)].

[Method listed in the Series of Environmental Radioactivity Measuring Methods]

preprocessing method

Dispense and dilute the sample

↓

Measuring method

Measurement by ICP-MS

↓

Activity concentration

Grounds for the selection

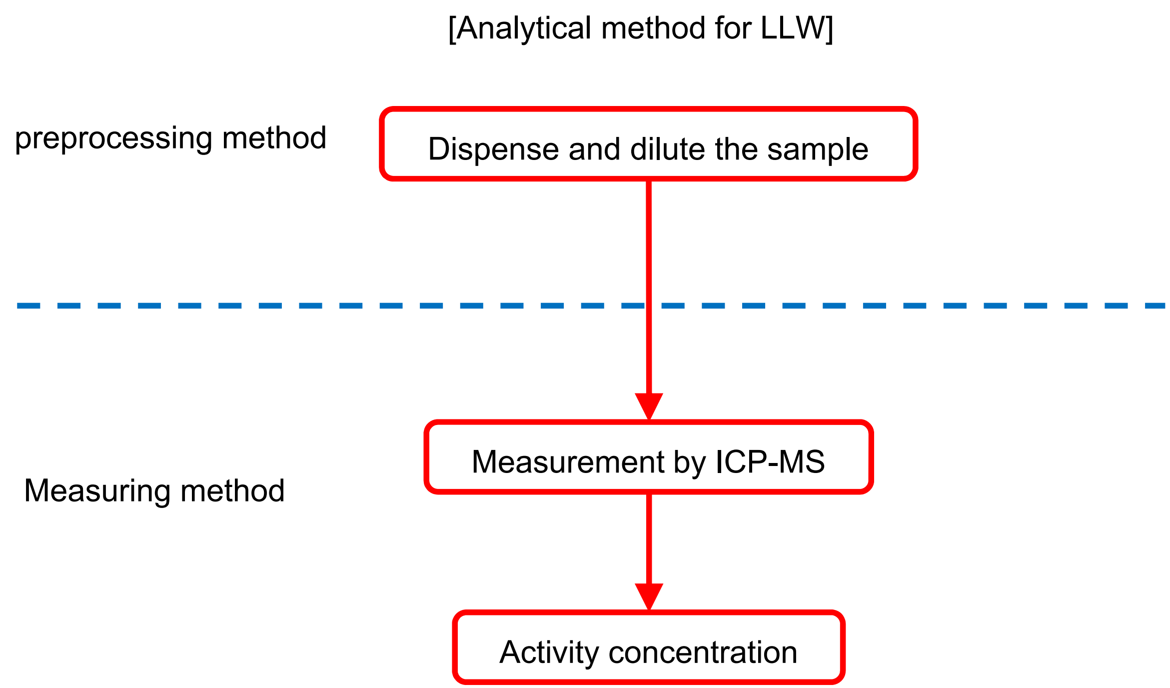
- It is a method listed in the Series of Environmental Radioactivity Measuring Methods.
- The recent improvements in the function of coupled plasma spectrometers (ICP-MS) eliminates the need for concentration in the preprocessing.

Verification of validity

It has been confirmed that an increase in the background due to Xe-129 contained in Ar gas can be restricted satisfactorily without concentration.

2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water
[6]-2. Validity evaluation of analytical methods for ALPS treated water (7/9)

Target nuclide	Result of validity evaluation
Tc-99	It complies with [the Analytical method for LLW].



Grounds for the selection

The analytical method for LLW has a good track record of measuring low-level radioactive concentrations. Therefore, it can be applied to ALPS treated water as it is.

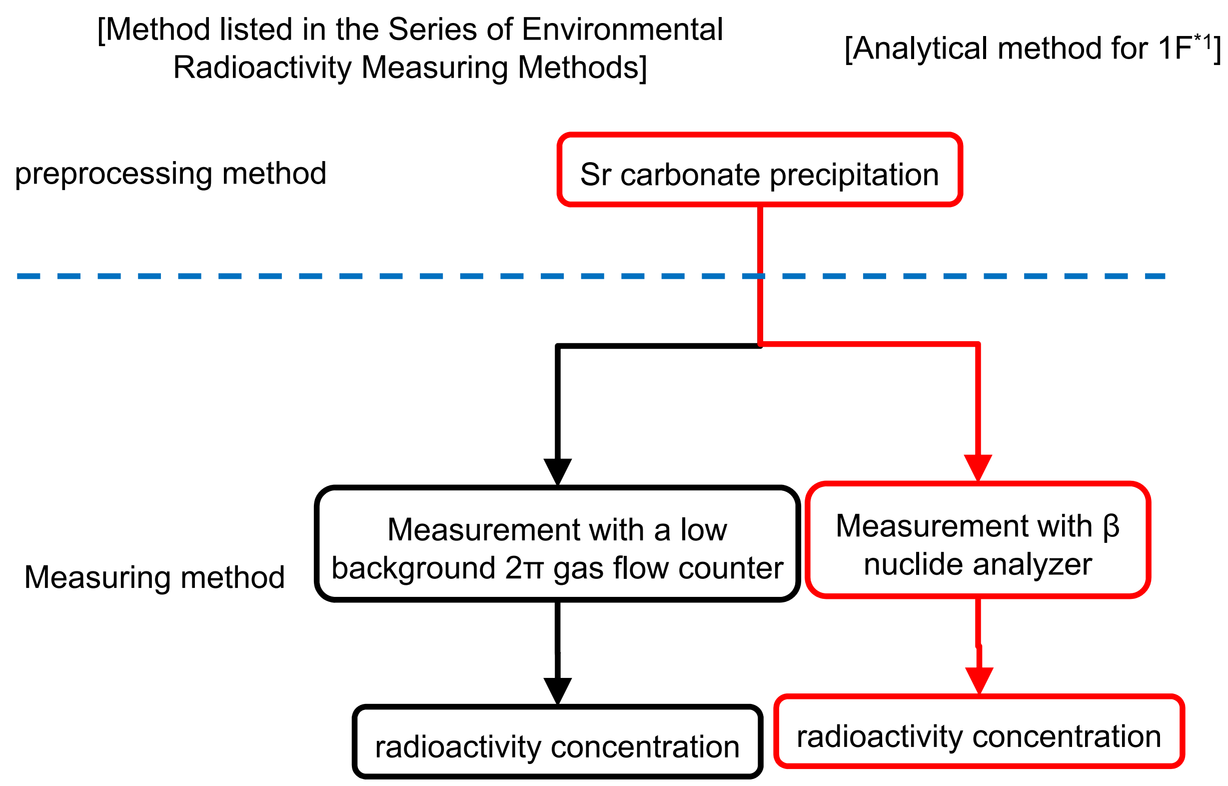
Verification of validity

This method has been proved to measure concentrations to the detection limit that is sufficiently below the regulatory concentration limit (1,000 Bq/L).

[6]-2. Validity evaluation of analytical methods for ALPS treated water (8/9)

TEPCO

Target nuclide	Result of validity evaluation
Sr-89, Sr-90	• The Sr resin concentration is adopted as Sr pre-concentration method. • Pre processing method (Sr carbonate precipitation) complies with [The Series of Environmental Radioactivity Measuring Methods No.2 (Radio-strontium Analysis)]. • A measurement method listed in the [Nuclear Safety Commission Guidelines] was adopted.



Grounds for the selection

The method has a good track record of measuring Sr-89 and 90 in drainage water from power plants and in seawater. Therefore, it can be applied to ALPS treated water as it is.

Verification of validity

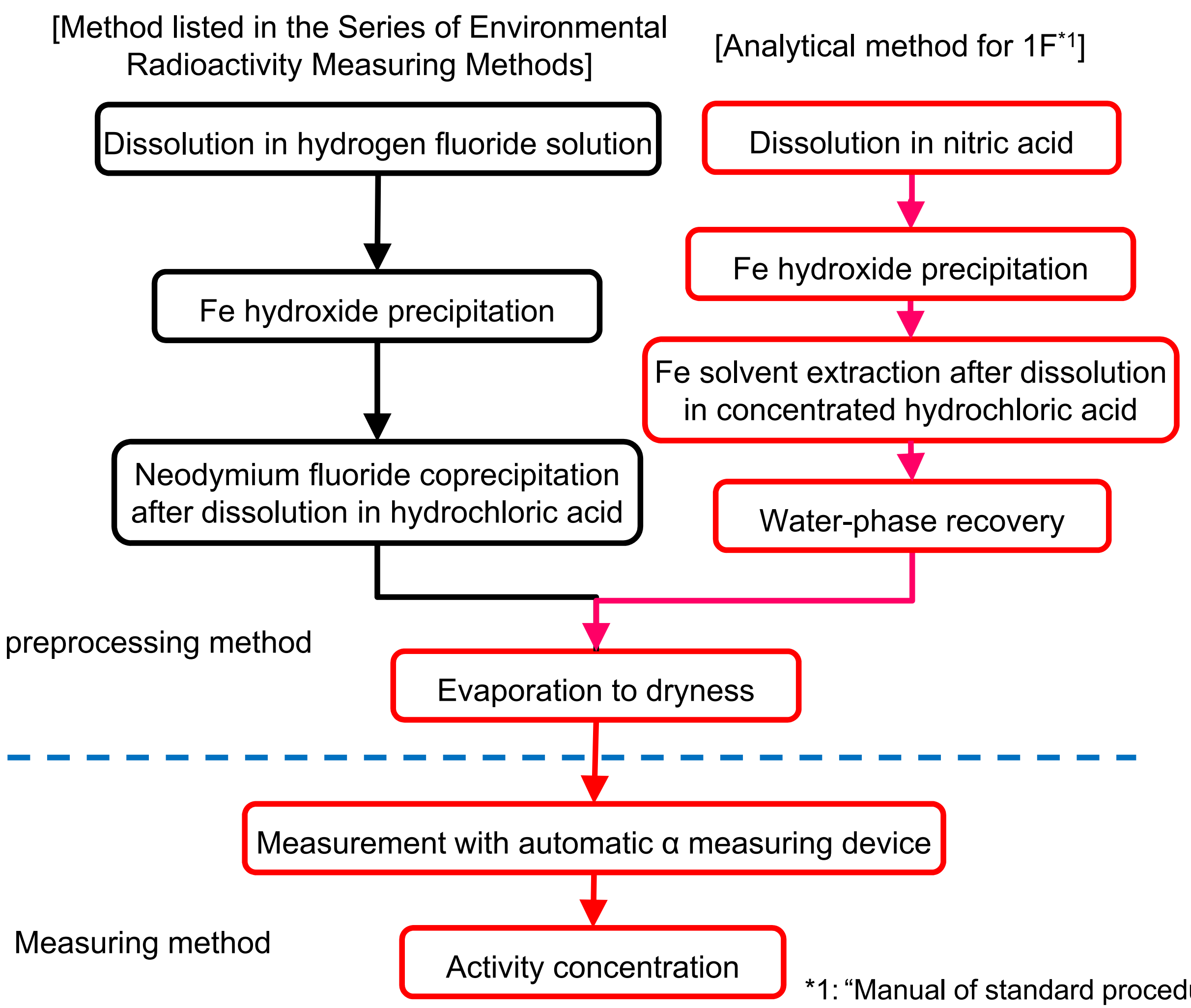
- Having been proved to achieve a reasonable recovery rate of stable Sr, the Sr resin concentration can be applied to the analyses of ALPS treated water.
- The measurement method was verified using a standard source at the time of delivery by the equipment manufacturer and proved to be capable of measuring concentrations to the detection limits that are sufficiently below the regulatory concentration limits (Sr-89: 300 Bq/L, Sr-90: 30 Bq/L).

*1: "Determination of ^{89}Sr and ^{90}Sr by β-ray spectrometry"RADIOISOTOPES Vo1.29, No.11 pp.24-27(1980)

[6]-2. Validity evaluation of analytical methods for ALPS treated water (9/9)

TEPCO

Target nuclide	Result of validity evaluation
Total α	• The separation method complies with the [Manual of standard procedures for analysis of radioactive effluents and gases from Tokai Works of Power Reactor and Nuclear Fuel Development Corporation]. • The measurement method complies with [The Series of Environmental Radioactivity Measuring Methods No. 31 (Rapid Measurement of Gross Alpha Radioactivity in Environmental Samples)].



Grounds for the selection

JAEA and JNFL have used this method to determine the radioactivity of total α in high-salinity drainage water.

Verification of validity

The recovery rate of Am-243, which was added to ALPS treated water, was evaluated in an in-house verification test to verify the validity of the current total α recovery rate.

Remarks

The “hydrogen fluoride solution” used in the Series of Environmental Radioactivity Measuring Methods is considered to be avoided for the following reasons.

- Highly toxic chemical agents
- Deterioration of analytical facilities

*1: “Manual of standard procedures for analysis of radioactive effluents and gases from Tokai Works of Power Reactor and Nuclear Fuel Development Corporation”PNC-TN8520-93-003

The Japanese version shall prevail.

Responses to issues pointed out* at the review meeting, etc.

*: Documents 2-2, Attachment 2 for (the 97th) Specified Nuclear Facility Monitoring and Assessment Review Meeting

Issues pointed out [7]

(2-1 Major issues to be reviewed based on the Nuclear Reactor Regulation Act)

(2) Safety measures at the time of discharge into the sea

[1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water

- Uncertainties in analysis results must be clearly defined, and the approach used in the uncertainty assessment must be explained, including the concept.

[7]-1. Application of uncertainty assessment

- The analytical methods to be adopted for the analyses of ALPS treated water are the methods that have been widely used (for γ-ray emitting nuclides, etc.) and those developed by JAEA for determining radioactivity concentrations of waste from the power plants and the research facilities, focusing on the change of target nuclides in the cooling water caused by contact the fuel debris emerged after the 3.11 earthquake.
- As regards preprocessing methods that have been changed or newly adopted after the earthquake, it needs to be verified that the analyses are performed in an intended manner and the result obtained are appropriate values.

- Values obtained through the analyses of ALPS treated water will serve as information to control the discharge operation of treated water and assess impacts to the environment. Therefore, to clarify the degree of variation among the analysis values is necessary before they are used for the control and assessment.
- The degree of variation is generally quantified as “expanded uncertainty,” in which various characteristics of the analysis process, such as sample dispensing volume, calibration and working environment of analysis devices and equipment, and preprocessing, are identified and assessed in numerical values (error bar).

Process to assess uncertainties of measurements*1

Step 1) Develop a measurement model.

Clarify the relationship between the measured amount (activity concentration) and its input quantities (count, sample quantity, correction coefficient, etc.) on which the measured depends.

Step 2) Identify uncertainty sources.

Clarify the measurement procedure and create a list of possible uncertainty sources (fishbone diagram and source summary table).

Step 3) Quantify uncertainty components.

Estimate the magnitude of uncertainty components associated with the identified potential sources using budget sheets.

Step 4) Calculate combined standard uncertainty.

Express the magnitude of the contribution of each source to the uncertainty in the standard deviation, and calculate the combined standard uncertainty according to general rules.

Step 5) Calculate expanded uncertainty.

Calculate the expanded uncertainty by multiplying the combined standard uncertainty by the coverage factor k and adding it to the measured results.

*1: Refer to Quantifying Uncertainty in Analytical Measurement translated by Chushiro YONEZAWA (Maruzen).
Original book: Quantifying Uncertainty in Analytical Measurement (Third Edition); EURACHEM/CITAC Guide CG4

Step 1) Develop a measurement model.

Clarify the relationship between the measured (activity concentration) and input quantities (count, sample quantity, correction coefficient, etc.) on which the measured depends.

In the measurement of γ-ray emitting nuclides using a Ge semiconductor detector, the activity concentration is expressed by the function of the following input quantities.

$$C_\gamma = f(x_1, x_2 \dots) = f(X, Y, Z, E, V) = \frac{X \times Z}{(E/100) \times (Y/100) \times V}$$

$f(x_1, x_2 \dots)$: function for determining the activity concentration
X, Y, Z, E, V: input quantities required to determine the activity concentration

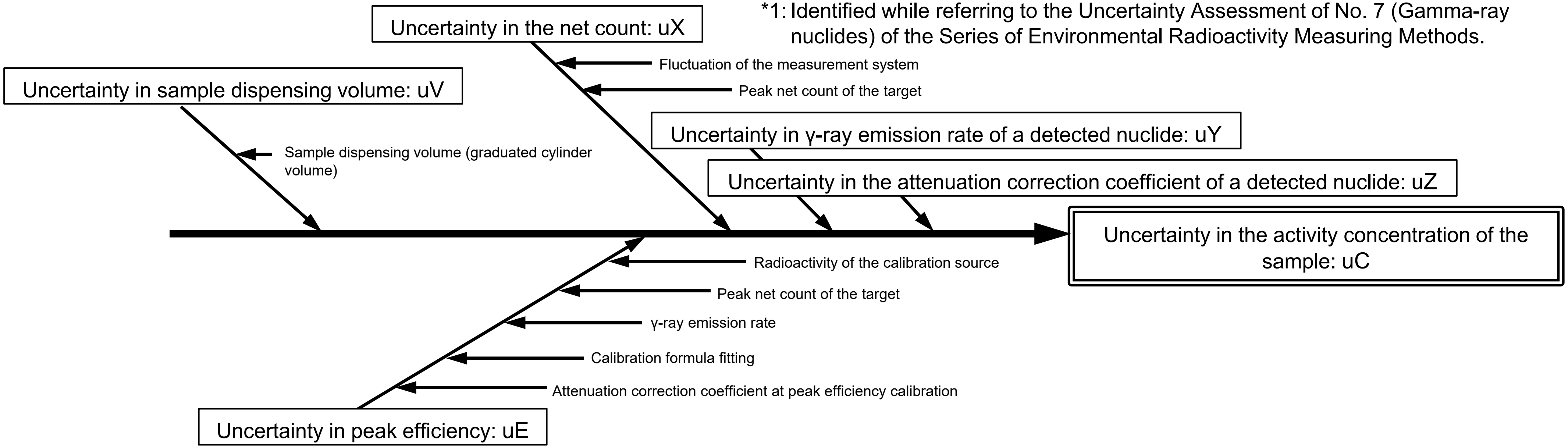
C_γ	;	Activity concentration of γ-ray emitting nuclides (Bq/L)	E	;	Peak efficiency of γ-ray of the relevant energy (%)
X	;	The net counting rate of the sample of the relevant peak (cps)	Y	;	The emission rate of γ-ray of the relevant energy (%) of the nuclide
Z	;	Half-life correction coefficient (-)	V	;	Sample dispensing volume (L)

[7]-2. Process to assess uncertainties of measurements

Step 2) Identify uncertainty sources.

Clarify the measurement procedure and create a list of possible uncertainty sources (fishbone diagram*1 and summary table).

*1: Identified while referring to the Uncertainty Assessment of No. 7 (Gamma-ray nuclides) of the Series of Environmental Radioactivity Measuring Methods.



Major sources	Symbol	Breakdown of sources
Sample dispensing volume	uV	Sample dispensing volume (graduated cylinder volume)
Peak efficiency	uE	Radioactivity of the calibration source, peak net count of the calibration source, γ-ray emission rate of the calibration source Calibration formula fitting, attenuation correction coefficient at peak efficiency calibration
Net count	uX	Fluctuation of the measurement system, peak net count of the target
γ-ray emission rate	uY	γ-ray emission rate of the detected nuclide
Attenuation correction coefficient	uZ	Half-life

"u" refers to the standard uncertainty (standard deviation) of each source.

Step 3) Quantify uncertainty components.

Quantitatively evaluate the identified uncertainty source using Type A and Type B methods.

Type A: A method in which measurements are performed repeatedly to actually obtain data, and the standard deviation is determined from the variation of the data.

Type B: A method of determining the standard deviation using an approach other than Type A.
- Determine the standard deviation from available information, such as literature, the standard value specified by the manufacturer, calibration certificate, etc.

(Example) Uncertainty of sample dispensing volume: u_V

The uncertainty of sample dispensing volume is calculated by two evaluation methods: Type A, a method of repetitive measurement, and Type B, a method based on the standard value specified by the manufacturer.

Major sources	Uncertainty source	Uncertainty abbreviation	Type	Method to assess uncertainties
Uncertainty in sample dispensing volume		u_V	-	$u_V = \sqrt{u_{V1}^2 + u_{V2}^2}$
	Dispensing volume of the test sample (Graduated cylinder) measured value	u_{V1}	B	Calculated based on specifications by the manufacturer.
		u_{V2}	A	Standard deviation of repeated measurements.

The Japanese version shall prevail.

Step 4) Calculate combined standard uncertainty.

The standard uncertainties obtained in steps up to 3 are combined by the law of propagation of uncertainties to determine the standard uncertainty of a measured result.

<Law of propagation of uncertainties>

$$u_c = \sqrt{\sum_{i-1}^{n} \left\{ \frac{\partial f}{\partial x_i} u(x_i) \right\}^2}$$

u_c: Combined standard uncertainty of activity concentration
$u(x_i)$: Standard uncertainties of input quantities $x_1, x_2, \cdots, x_n$

- For example, the standard uncertainties obtained in steps up to 3 are combined by the law of propagation of uncertainties to evaluate γ-ray emitting nuclides.
- The combined standard uncertainty is calculated as follows.

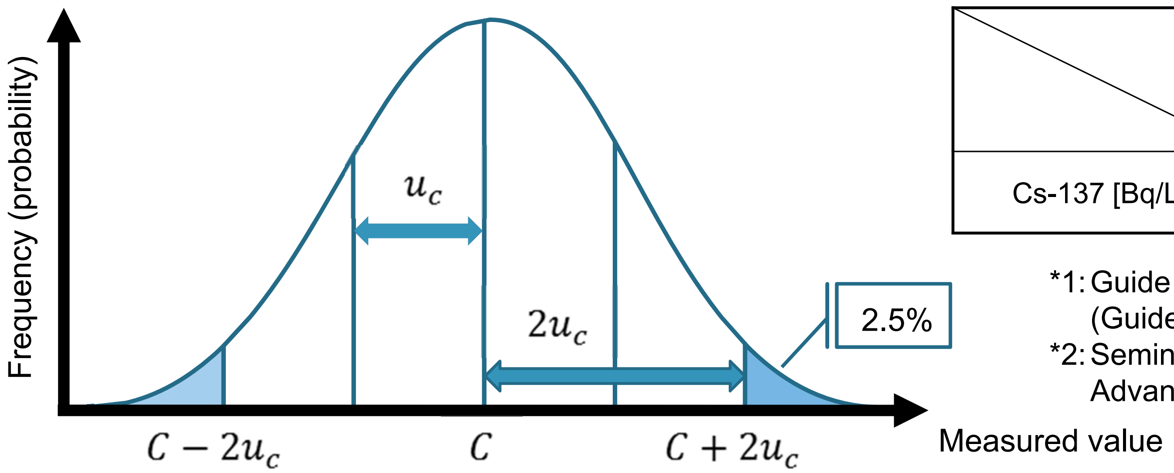
$$u_\gamma = \sqrt{\left(\frac{\partial f}{\partial V} u_V\right)^2 + \left(\frac{\partial f}{\partial E} u_E\right)^2 + \left(\frac{\partial f}{\partial X} u_X\right)^2 + \left(\frac{\partial f}{\partial Y} u_Y\right)^2 + \left(\frac{\partial f}{\partial Z} u_Z\right)^2}$$

u_γ: Combined standard uncertainty of activity concentration of γ-ray emitting nuclides

Step 5) Calculate expanded uncertainty.

Multiply the combined standard uncertainty by the coverage factor “k” to determine the expanded uncertainty, and add it to the measured results (UC = k×u_c).

- The coverage factor is a factor reflecting the confidence level. If there is no specific requirement regarding the level of confidence, k = 2 is used, and if so, an appropriate coverage factor is used (GUM[*1]).
- When a measured result is assumed to follow a normal distribution and k = 2 is used, the confidence probability is about 95%. (Results of controlled measurements generally follow a normal distribution.[*2])
- When a measured result is C and an expanded uncertainty of UC = 2u_c is obtained, the result potentially varies within the interval from C-U to C+U at a probability of about 95% (confidence level of about 68% where k = 1, and about 99.7% where k = 3).
- When k is 1, the confidence level is low, about 68%. Therefore, the expanded uncertainty is reported using “k = 2,” a generally adopted value.



	Measurement result: C	Combined standard uncertainty: uC	Expanded uncertainty (k = 2)
Cs-137 [Bq/L]	1.85E-01	2.04E-02	4.1E-02

*1: Guide to the Expression of Uncertainty in Measurement (Guide to the Expression of Uncertainty in Measurement)
*2: Seminar on Uncertainties for Beginners, Hideyuki TANAKA (National Institute of Advanced Industrial Science and Technology)

Method to assess uncertainties of analytical methods for ALPS treated water

- The uncertainty sources identified regarding analytical methods for ALPS treated water and assessment results are shown on the following pages.
- Uncertainties in radioactivity measurements (Ge semiconductor detector, LSC, α automatic measuring device, etc.) were assessed while referring to the Uncertainties Assessed of No.7 (Gamma-ray nuclides) of the Series of Environmental Radioactivity Measuring Methods.
- The uncertainties of measurements by ICP-MS (I-129, Tc-99) were assessed while referring to the assessment of uncertainties of analytical methods using ICP-MS calibration curves for general metals[*1].

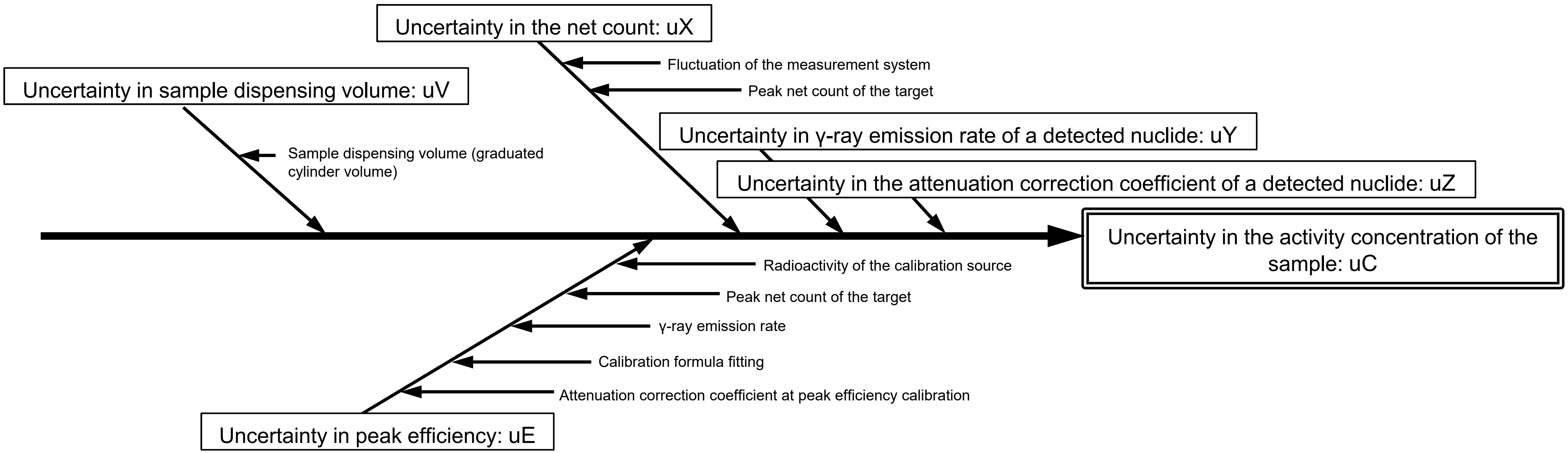
Assessment of uncertainties in the measurements of undetected nuclides

- Measured or evaluated values of undetected nuclides are smaller than the detection lower limits (between 0 and detection lower limit). Therefore, the measured values were assumed to be close to the detection limit to control the discharge conservatively.
- The assessment was performed with the detection lower limit.

*1: JNLA Guidelines for Estimation of Uncertainties Registration Category: Leaching Performance Test First Edition (National Institute of Technology and Evaluation)

[7]-3.1. Method to assess uncertainties (1/10)

- Sources of uncertainty in the measurement of γ-ray emitting nuclides with Ge semiconductor detector



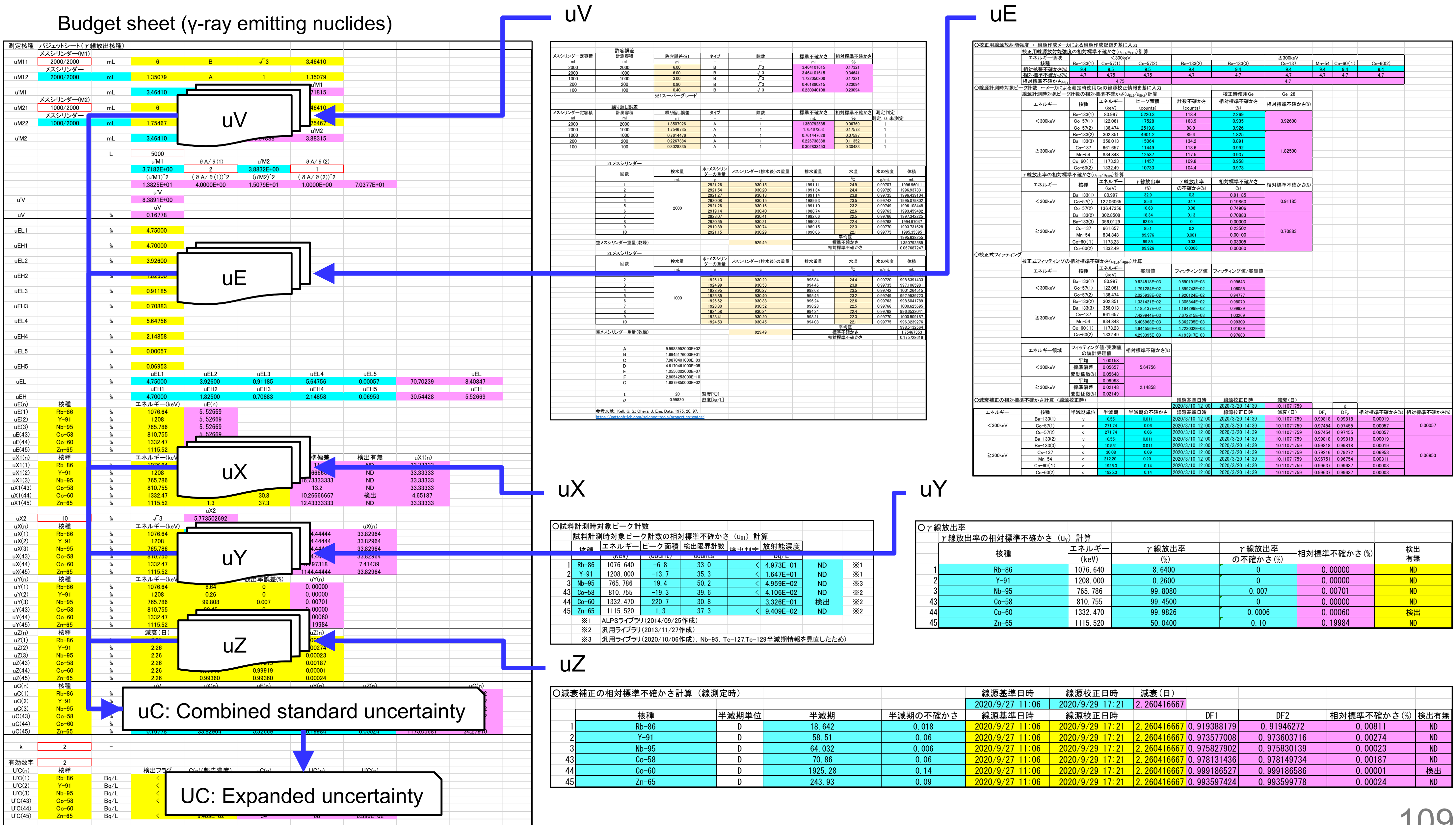
Major sources	Symbol	Breakdown of sources
Sample dispensing volume	uV	Sample dispensing volume (graduated cylinder volume)
Peak efficiency	uE	Radioactivity of the calibration source, peak net count of the calibration source, γ-ray emission rate of the calibration source Calibration formula fitting, attenuation correction coefficient at peak efficiency calibration
Net count	uX	Fluctuation of the measurement system, peak net count of the target
γ-ray emission rate	uY	γ-ray emission rate of the detected nuclide
Attenuation correction coefficient	uZ	Half-life

2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water
[7]-3.1. Method to assess uncertainties (2/10)

TEPCO

- Example budget sheet created on the measurement of γ-ray emitting nuclide with a Ge semiconductor detector

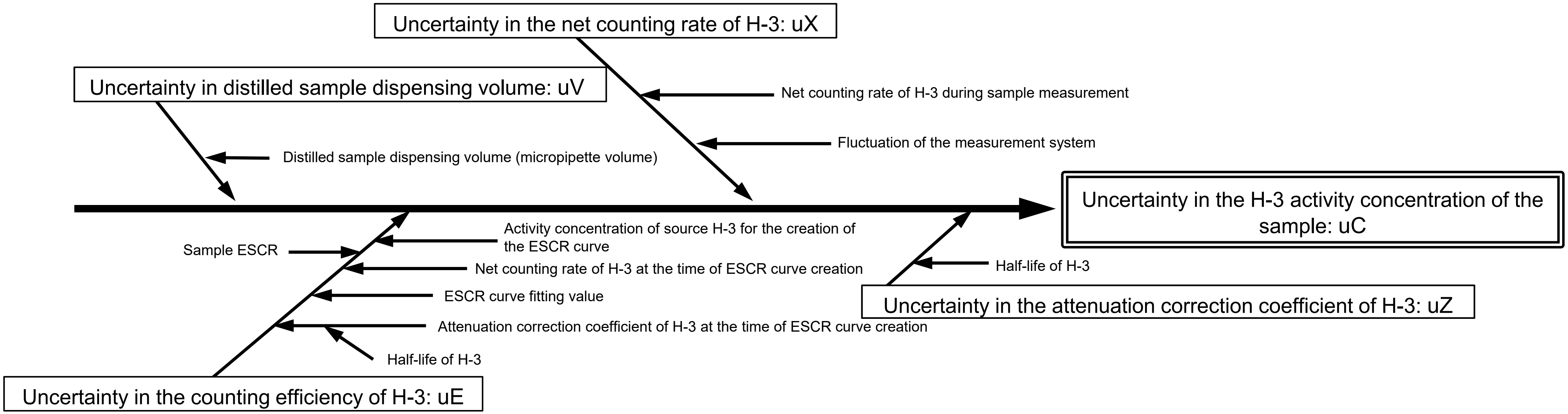
Budget sheet (γ-ray emitting nuclides)



The Japanese version shall prevail.

[7]-3.1. Method to assess uncertainties (3/10)

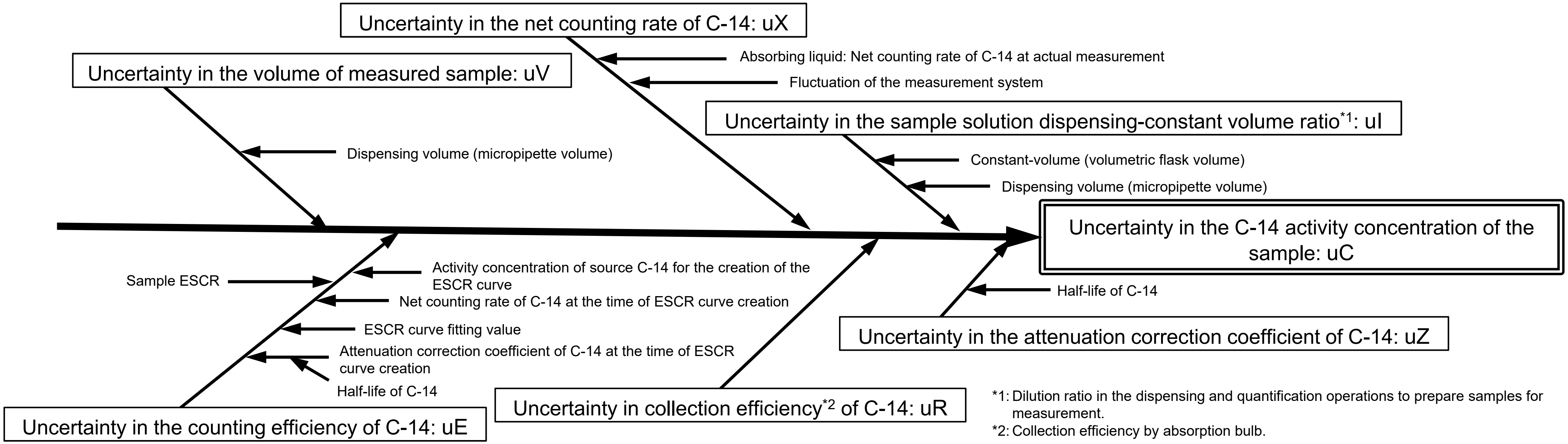
- Sources of uncertainty in the measurement of tritium activity concentration by LSC



Major sources	Symbol	Breakdown of sources
Distilled sample dispensing volume	uV	Distilled sample dispensing volume (micropipette volume)
Counting efficiency of H-3	uE	Activity concentration and net count of H-3, curve fitting value (at the time of ESCR curve creation) Attenuation correction of H-3
Net counting rate of H-3	uX	Fluctuation of the measurement system, net count of H3
Attenuation correction coefficient of H-3	uZ	Half-life

TEPCO

➢ Sources of uncertainty in the measurement of C-14 activity concentration by LSC



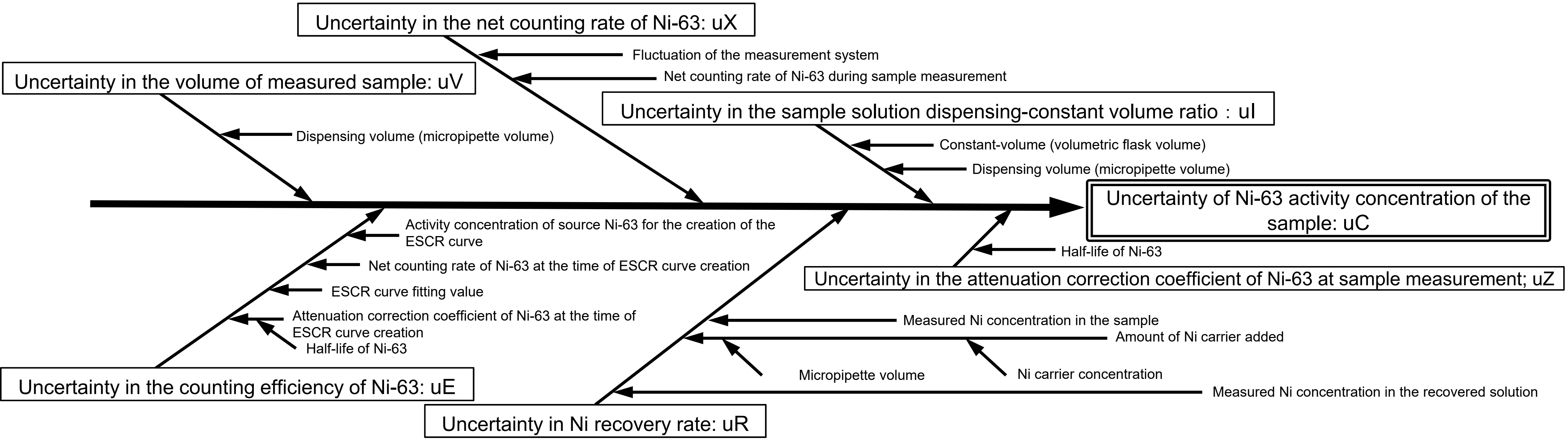
*1: Dilution ratio in the dispensing and quantification operations to prepare samples for measurement.
*2: Collection efficiency by absorption bulb.

Major sources	Symbol	Breakdown of sources
Sample volume to be measured	uV	Dispensing volume (micropipette volume)
Counting efficiency of C-14	uE	Activity concentration and net count of C-14, curve fitting value (at the time of ESCR curve creation) Attenuation correction of C-14
Net counting rate of C-14	uX	Fluctuation of the measurement system, net count of C-14
Collection efficiency of C-14	uR	Net counting rate of C-14 (collection bottle 1, collection bottle 2)
Sample solution dispensing-constant volume ratio	uI	Dispensing volume (micropipette volume), constant-volume (volumetric flask volume)
Attenuation correction coefficient of C-14	uZ	Half-life

[7]-3.1. Method to assess uncertainties (5/10)

TEPCO

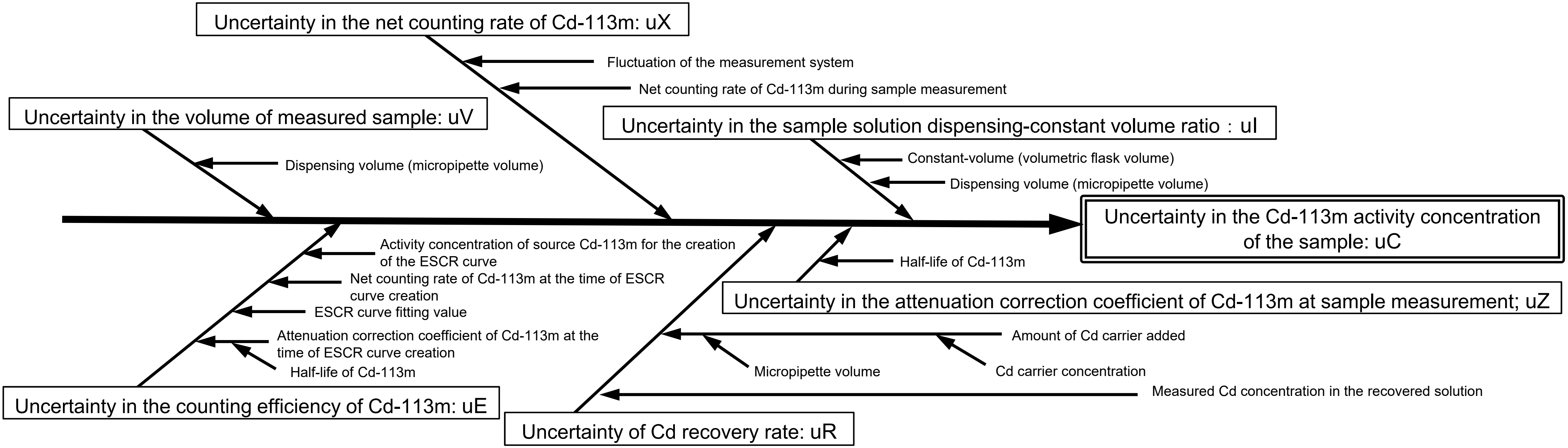
- Sources of uncertainty in the measurement of Ni-63 activity concentration by LSC



Major sources	Symbol	Breakdown of sources
Sample volume to be measured	uV	Dispensing volume (micropipette volume)
Ni-63 counting efficiency	uE	Activity concentration and net count of Ni-63 (at the time of ESCR curve creation) Curve fitting value, attenuation correction of Ni-63
Net counting rate of Ni-63	uX	Fluctuation of the measurement system, net count of Ni-63
Ni recovery rate	uR	Ni concentration in the recovered solution, amount of Ni carrier added, Ni concentration in the sample
Sample solution dispensing-constant volume ratio	uI	Dispensing volume (micropipette volume), constant-volume (volumetric flask volume)
Attenuation correction coefficient of Ni-63	uZ	Half-life

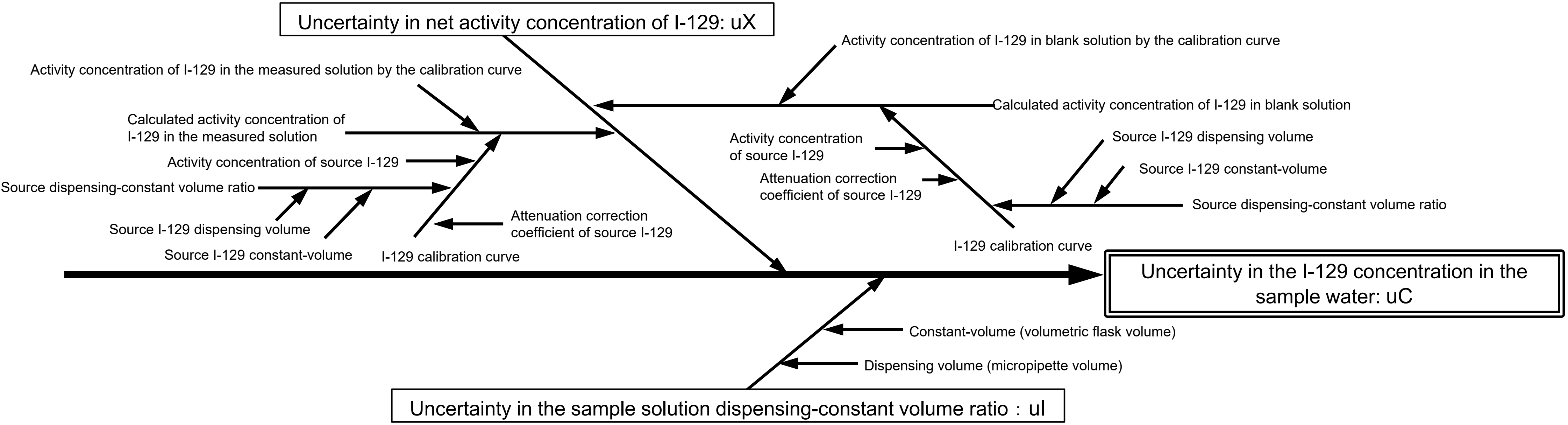
[7]-3.1. Method to assess uncertainties (6/10)

- Sources of uncertainty in the measurement of Cd-113m activity concentration by LSC



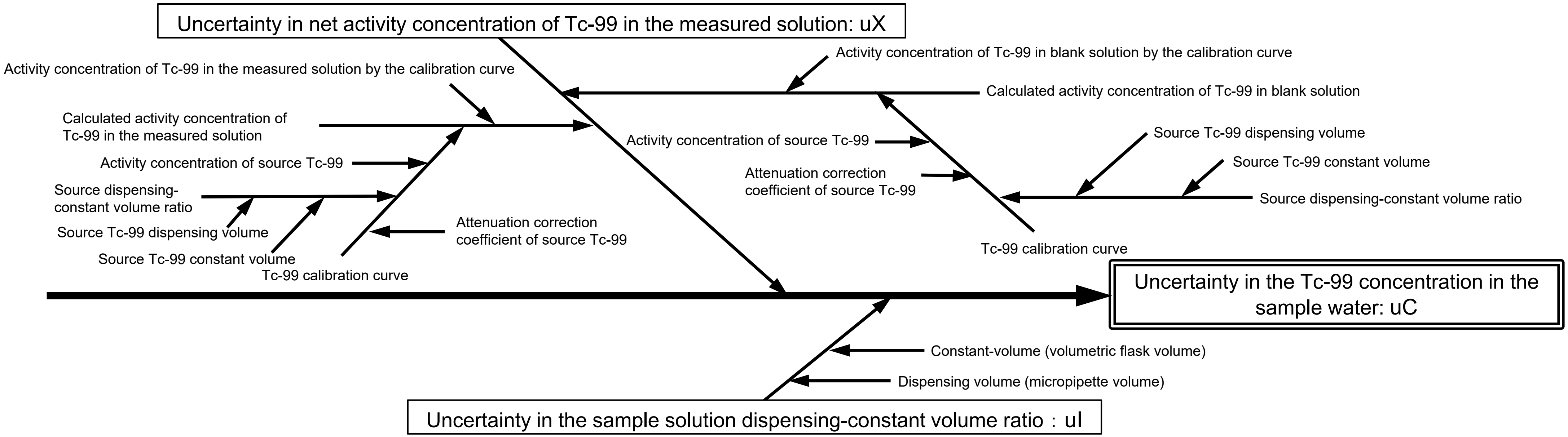
Major sources	Symbol	Breakdown of sources
Sample volume to be measured	uV	Dispensing volume (micropipette volume)
Cd-113m counting efficiency	uE	Activity concentration and net count of C-14, curve fitting value (at the time of ESCR curve creation) Attenuation correction of C-14 (estimation with an alternative to Cd-113m calibration source)
Net counting rate of Cd-113m	uX	Fluctuation of the measurement system, net count of Cd-113m
Cd recovery rate	uR	Cd concentration in the recovered solution, amount of Cd carrier added
Sample solution dispensing-constant volume ratio	uI	Dispensing volume (micropipette volume), constant-volume (volumetric flask volume)
Attenuation correction coefficient of Cd-113m	uZ	Half-life

- Sources of uncertainty in the measurement of I-129 activity concentration by ICP-MS



Major sources	Symbol	Breakdown of sources
T-129 net activity concentration in test solution	uX	Calculated I-129 activity concentration in blank solution, calculated I-129 activity concentration in the test solution
Sample solution dispensing-constant volume ratio	uI	Dispensing volume (micropipette volume), constant-volume (volumetric flask volume)

- Sources of uncertainty in the measurement of Tc-99 activity concentration by ICP-MS

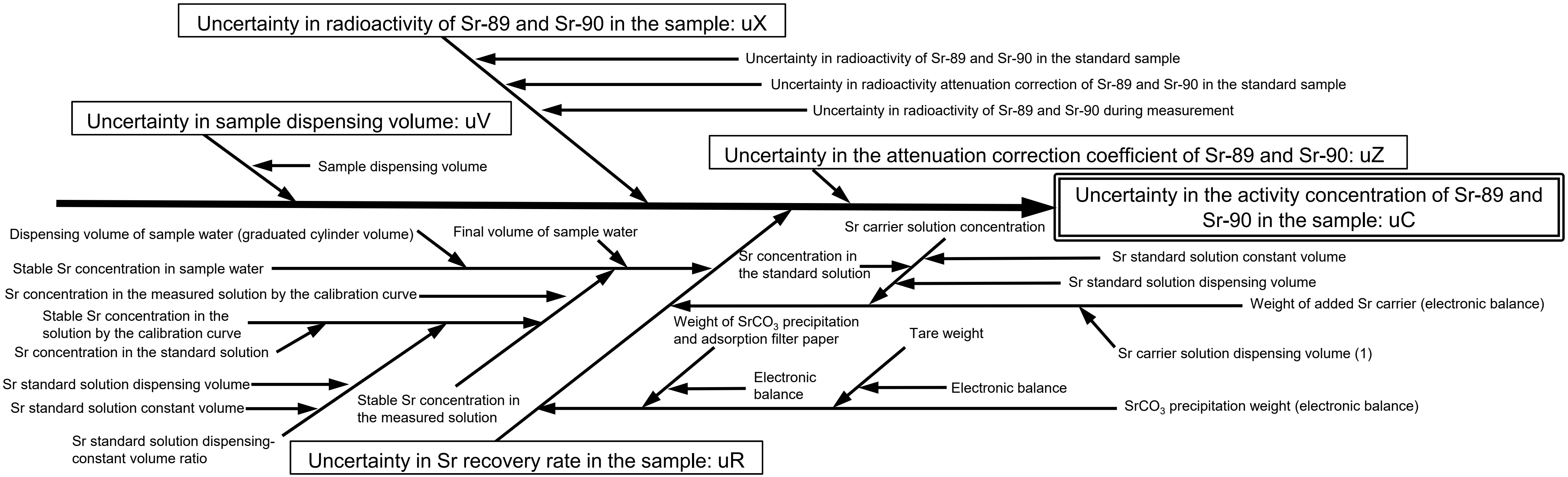


Major sources	Symbol	Breakdown of sources
Net activity concentration of Tc-99 in the measured solution	uX	Calculated Tc-99 activity concentration in blank solution, calculated Tc-99 activity concentration in the test solution
Sample solution dispensing-constant volume ratio	uI	Dispensing volume (micropipette volume), constant-volume (volumetric flask volume)

[7]-3.1. Method to assess uncertainties (9/10)

TEPCO

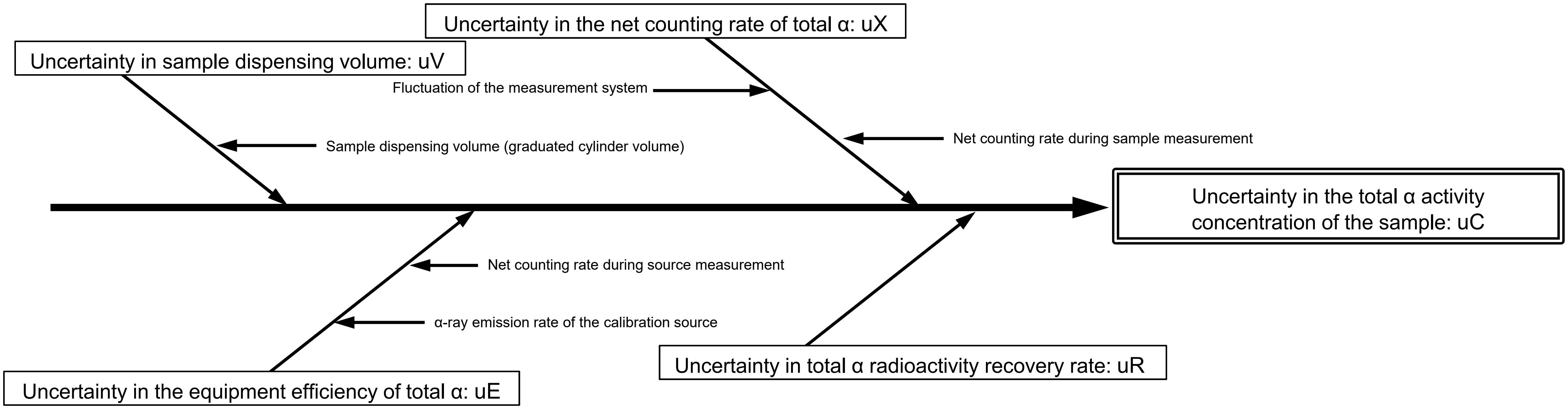
- Sources of uncertainties in the measurement of Sr-89 and Sr-90 activity concentrations with β nuclide analyzer



Major sources	Symbol	Breakdown of sources
Sample dispensing volume	uV	Sample dispensing volume (graduated cylinder volume)
Sr-89 and Sr-90 activity intensity in the sample	uX	Sr-89, Sr-90 activity intensity in standard sample, Sr-89, Sr-90 activity attenuation correction, Sr-89, Sr-90 activity intensity at measurement
Sr recovery rate of the sample	uR	Weight of SrCO3 precipitates, concentration of stable Sr in sample water, amount of Sr carrier added
Attenuation correction coefficient of Sr-89 and Sr-90	uZ	Half-life

[7]-3.1. Method to assess uncertainties (10/10)

- Sources of uncertainty in the measurement of activity concentrations of α-ray emitting nuclides with α automatic measuring device



Major sources	Symbol	Breakdown of sources
Sample dispensing volume	uV	Sample dispensing volume (graduated cylinder volume)
Total α equipment efficiency	uE	Net counting rate at measurement of the source, α-ray emission rate from the calibration source
Net count of total α	uX	Fluctuation of the measurement system, net counting rate at sample measurement
Recovery rate of total α radioactivity	uR	-

[7]-3.2. Uncertainty assessment result (1/3)

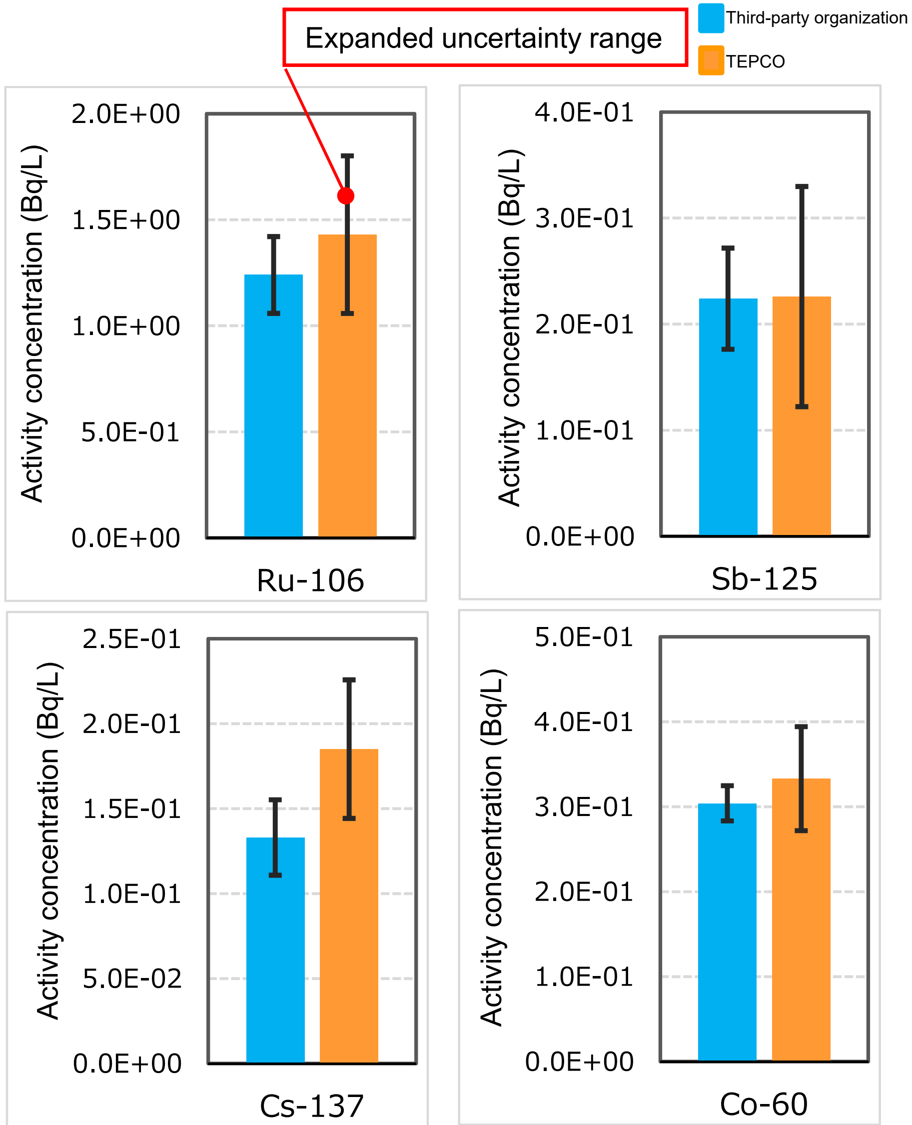
TEPCO

- Expanded uncertainty in the measurement of γ-ray emitting nuclides with Ge semiconductor detector (UC [Bq/L]) *Coverage factor k = 2

Nuclide	Measured result: C	Expanded uncertainty: UC
Rb-86	< 4.97E-01	3.4E-01
Y-91	< 1.65E+01	1.1E+01
Nb-95	< 4.96E-02	3.4E-02
Ru-103	< 5.27E-02	3.6E-02
Ru-106	1.43E+00	3.7E-01
Rh-103m	-	-
Rh-106	-	-
Ag-110m	< 4.26E-02	2.9E-02
Cd-115m	< 2.70E+00	2.6E+00
Sn-119m	-	-
Sn-123	< 6.59E+00	4.5E+00
Sn-126	< 2.92E-01	2.0E-01
Sb-124	< 9.67E-02	6.6E-02
Sb-125	2.26E-01	1.0E-01
Te-123m	< 9.19E-02	6.4E-02
Te-125m	-	-
Te-127	< 4.69E+00	3.5E+00
Te-127m	-	-
Te-129	< 6.15E-01	4.3E-01
Te-129m	< 1.37E+00	1.1E+00
Cs-134	< 7.60E-02	5.2E-02
Cs-135	-	-
Cs-136	< 4.68E-02	3.2E-02
Cs-137	1.85E-01	4.1E-02
Ba-137m	-	-

Nuclide	Measured result: C	Expanded uncertainty: UC
Ba-140	< 2.02E-01	1.4E-01
Ce-141	< 2.62E-01	1.8E-01
Ce-144	< 5.69E-01	4.0E-01
Pr-144	-	-
Pr-144m	-	-
Pm-146	< 6.66E-02	4.5E-02
Pm-147	-	-
Pm-148	< 2.33E-01	1.6E-01
Pm-148m	< 4.84E-02	3.3E-02
Sm-151	-	-
Eu-152	< 2.84E-01	1.9E-01
Eu-154	< 1.14E-01	7.7E-02
Eu-155	< 3.36E-01	2.3E-01
Gd-153	< 2.64E-01	1.8E-01
Tb-160	< 1.43E-01	9.7E-02
Mn-54	< 3.83E-02	2.6E-02
Fe-59	< 8.66E-02	5.9E-02
Co-58	< 4.11E-02	2.8E-02
Co-60	3.33E-01	6.1E-02
Zn-65	< 9.41E-02	6.4E-02

Results of analysis by TEPCO



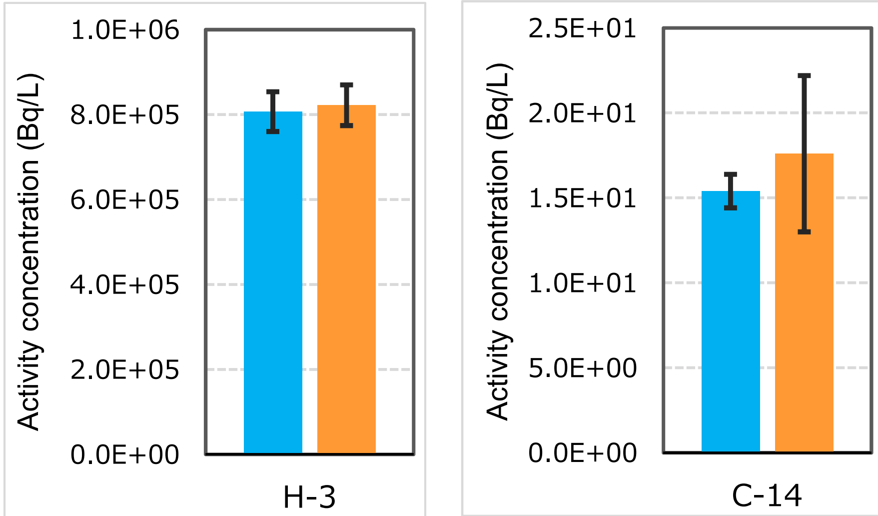
Comparison of values obtained through analysis by a third-party organization and those through analysis by TEPCO

[7]-3.2. Uncertainty assessment result (2/3)

- Expanded uncertainty in the measurement of activity concentrations by LSC (UC [Bq/L]) *Coverage factor k = 2

	Measurement result: C	Expanded uncertainty: UC
H-3	8.22E+05	4.8E+04
C-14	1.76E+01	4.6E+00
Ni-63	< 8.45E+00	3.7E-01
Cd-113m	< 8.52E-02	3.8E-03

Results of analysis by TEPCO

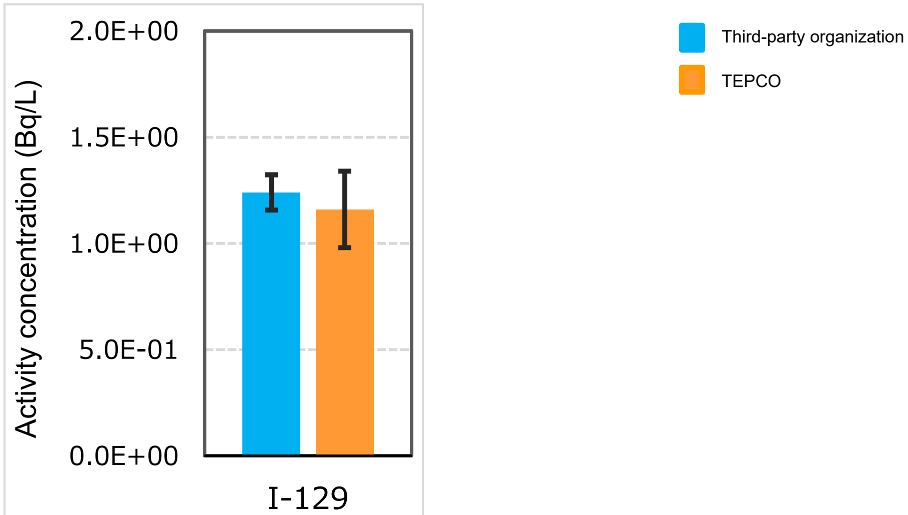


Comparison of values obtained through analysis by a third-party organization and those through analysis by TEPCO

- Expanded uncertainty in the measurement of activity concentrations by ICP-MS (UC [Bq/L]) *Coverage factor k = 2

	Measurement result: C	Expanded uncertainty: UC
I-129	1.16E+00	1.8E-01
Tc-99	< 1.23E+00	1.6E-02

Results of analysis by TEPCO

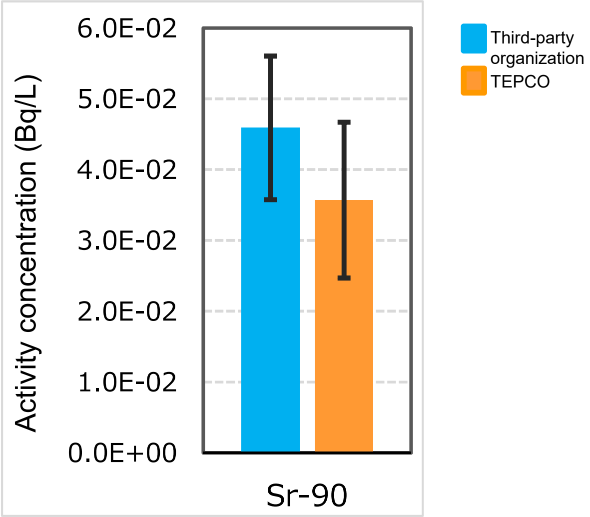


Comparison of values obtained through analysis by a third-party organization and those through analysis by TEPCO

- Expanded uncertainty in the measurement of Sr-89 and Sr-90 activity concentrations with β nuclide analyzer (UC [Bq/L]) *Coverage factor k = 2

	Measurement result: C	Expanded uncertainty: UC
Sr-89	< 5.36E-02	9.7E-03
Sr-90	3.57E-02	1.1E-02

Results of analysis by TEPCO



Comparison of values obtained through analysis by a third-party organization and those through analysis by TEPCO

- Expanded uncertainty in the measurement of total α activity concentrations with α automatic measuring device (UC [Bq/L]) *Coverage factor k = 2

	Measurement result: C	Expanded uncertainty: UC
Total α radioactivity	< 3.25E-02	6.4E-03

Results of analysis by TEPCO

Not compared