Document 1-1, the 13th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Installation of New ALPS Treated Water Dilution/Discharge facilities and Related Facility

March 18, 2022

Tokyo Electric Power Company Holdings, Inc.

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Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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Issues pointed out [1]

(Reference) Overall policy

- When and how much area can be secured by dismantling and removing tanks should be indicated. An explanation should also be given on the prospect of construction of new facilities, including the time and scale of construction, corresponding to the gradual process of dismantling.

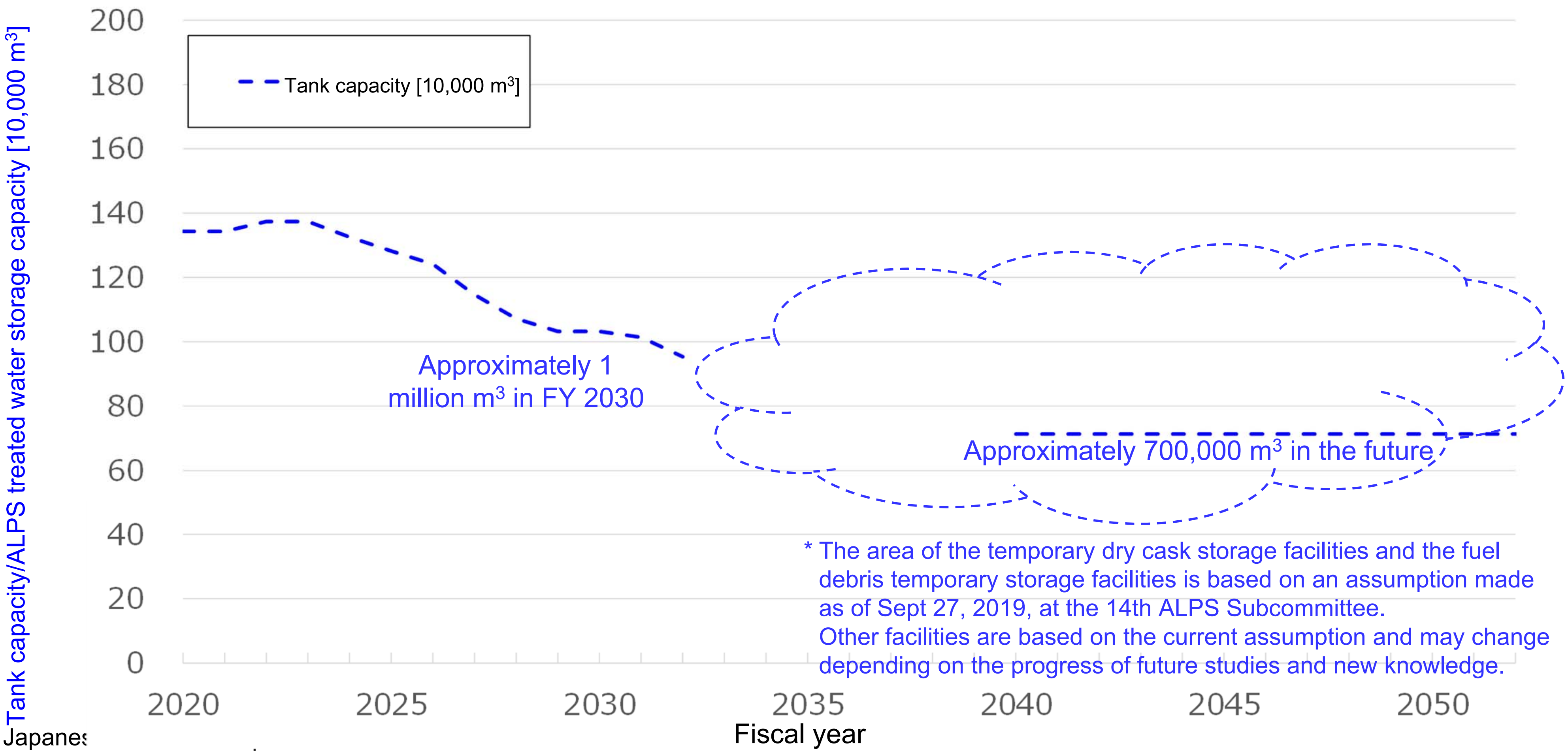
[1]-1. Feasibility of facilities installation by dismantling and removing tanks

- ALPS treated water dilution/discharge facilities and the related facility are intended to be used for safe and steady decommissioning work, such as fuel debris and spent fuel retrieval, through discharging ALPS treated water stored in the tanks into the sea. The steady discharge is needed for a long time.
- With the discharge of the ALPS treated water stored in the tanks, we will achieve the overall construction process according to the medium- to long-term roadmap and implement risk reduction measures according to the risk map.
- Therefore, in developing the discharge plan for the next fiscal year, the annual discharge amount (m^3/year) of ALPS treated water stored in the tanks will be determined so that the future site use plan (area and timing required) can be achieved. To satisfy the discharge amount of 22 trillion Bq/year, including the amount generated daily, water with lower tritium concentration is the first place in the discharge order.

(Reference) Overall policy

[1]-2. Feasibility of facilities installation by dismantling and removing tanks

- Depending on the tank area, the area of the inner weir per 10,000 m^3 of capacity varies from about 1,200 -2,800 m^2. About 50,000- 110,000 m^2 of land will be secured by discharging about 400,000 m^3 of ALPS treated water into the sea by around FY 2030. In the future, about 80,000- 200,000 m^2 of land will be secured by discharging ALPS treated water of approximately 700,000 m^3 into the sea. (excerpts from the tank capacity graphs of slides 32 and 33 of the materials at the 11th Review Meeting).
- With this, temporary dry cask storage facilities (for common pool, approx. 16000 m^2*) that will be required in the 2030s and temporary storage facilities for fuel debris (maximum 60,000 m^2*) that will be needed in the future are expected to be installed.



* The area of the temporary dry cask storage facilities and the fuel debris temporary storage facilities is based on an assumption made as of Sept 27, 2019, at the 14th ALPS Subcommittee. Other facilities are based on the current assumption and may change depending on the progress of future studies and new knowledge.

[Reference] Feasibility of facilities installation by dismantling and removing tanks

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- Considering the results of dismantling flange tanks in the past, the dismantling and removal of the tanks before the start of construction work shown in the table below will take several years, depending on the size of the area.
- Therefore, with regard to the facilities that are scheduled to begin construction in the first half of the 2020s, the Fukushima Daiichi NPS site will be effectively used, such as by building solid waste storage facilities on the north side of the site.

Start of use	Around the 2020s	Around the 2030s	Around the 2040s
Scheduled start of construction	**Around the first half of the 2020s**	**Around the second half of the 2020s**	**2030s and beyond**
Example of necessary facilities	· Facilities necessary to reduce the risk of fuel debris		
	Related to the gradual expansion of the retrieval scale	Related to the further expansion of the retrieval scale	
	✓ Retrieval device maintenance facility ✓ Fuel debris storage facility ✓ Training facility ✓ Fuel debris and waste transfer system, etc.		
	· Facilities necessary to reduce the risk of spent fuel pools (SFP)		-
	✓ Dry cask temporary storage facility (for unit 1 - 6 SFPs) ✓ Storage facilities for high-dose equipment inside SFPs, etc.	✓ Dry cask temporary storage facility (for common pools), etc.	
	· Facilities necessary to reduce the risk of radioactive waste		
	✓ Solid waste storage ✓ Large waste storage ✓ Solid waste volume reduction facility ✓ Recycling facilities, etc.	✓ Storage and volume reduction facilities for high-dose solid waste generated from debris retrieval	
	· Other facilities necessary for risk reduction		

* Not all facilities shall be built in the area where tanks are removed.
This is an assumption as of now and may change depending on the progress of future studies and new knowledge.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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Issues pointed out [2]

(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

- In the relation between the analysis operation procedure and the operation procedure of transfer/Dilution facility, explain organized at which stage of the tritium concentration is checked.

2-1 (2) Safety measures at the time of discharge into the sea
[2]-1. Confirmation of tritium concentration in ALPS treated water

- When ALPS treated water is released into the sea, two timings fined to check the tritium (H-3) concentration.
  - [1] For planning the amount of tritium discharge for each year, "B. ALPS treated water, etc. stored in the tanks" will be discharged at a level below 22 trillion Bq/year while releasing "A. ALPS treated water to be generated daily." The tritium concentration of each annual plan will be verified when planning. (see the next slide).
  - [2] H-3 and radioactive materials other than H-3 will be analyzed in the measurement/confirmation facilities before discharge into the sea to confirm that radioactive materials other than H-3 satisfy the discharge criteria. Further, to reduce the concentration of H-3, it will be drained after being diluted with seawater in the Dilution facility (Implementation plan: III -3 -2 -1 -2).

- As described above, the plan is to check whether the radioactive materials other than H-3 meet the release criteria before the discharge into the sea (measurement/confirmation and analysis processes), use H-3 for adjusting flowrate for seawater dilution, and for comparing the actual result with the one at the time of discharge planning.

Discharge planning → **Measurement/ confirmation process Analytical process** → **Discharge process**

[H-3 concentration (at planning)*]

"A. ALPS treated water to be generated daily"

"B. ALPS treated water, etc. stored in the tanks"

Comparison ⇔

[H-3 concentration (before discharge)]

"Tritium concentration of ALPS treated water in the measurement/confirmation tank"

Input by mechanical means, such as scanner →

Registration to a monitoring and control device

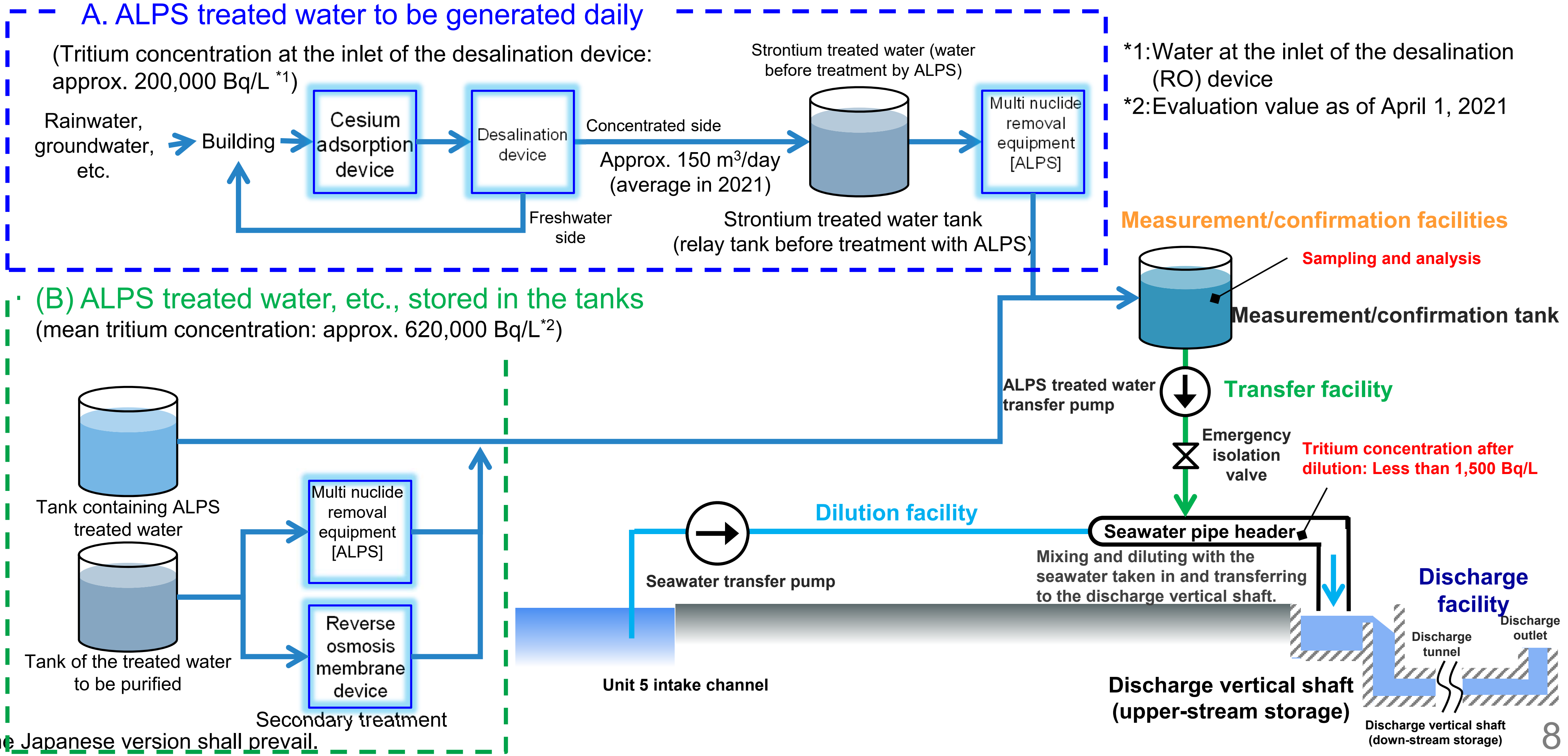
Adjustment of the ALPS treated water flow rate during discharge into the sea

* The basic policy is to release ALPS treated water in order of lower tritium concentration.

The Japanese version shall prevail.

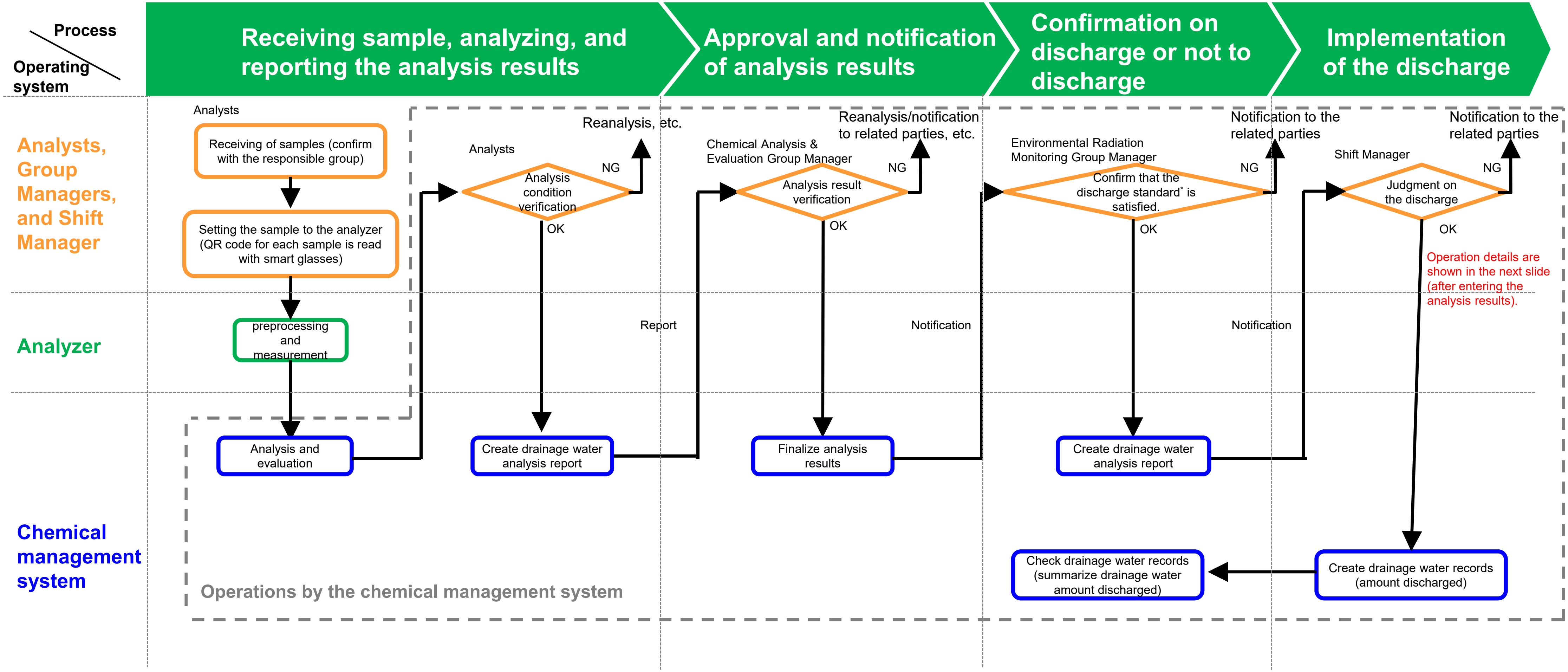
2-1 (2) Safety measures at the time of discharge into the sea
[Reference] Basic policy of discharge plan

- The ALPS treated water to be discharged in the future includes "(A) ALPS treated water to be generated daily" and "(B) ALPS treated water, etc., stored in the tanks."
- The basic policy is to discharge ALPS treated water in order of lower tritium concentration. The amount of water in "(B)" that falls below the tritium concentration in "(A)" is limited (refer to slide 31); accordingly, "(A)" and "(B)" will be discharged alternately.



2-1 (2) Safety measures at the time of discharge into the sea
[Reference] Analysis procedures

- The post-sampling operating procedures for the measurement/confirmation facilities are as follows:
  - After measurement by the analyzer, confirmation/approval work is carried out by the core system (hereinafter referred to as "chemical management system") (There is no manual calculation or transcription).
  - All actions performed by the chemical management system are designed to be recorded.

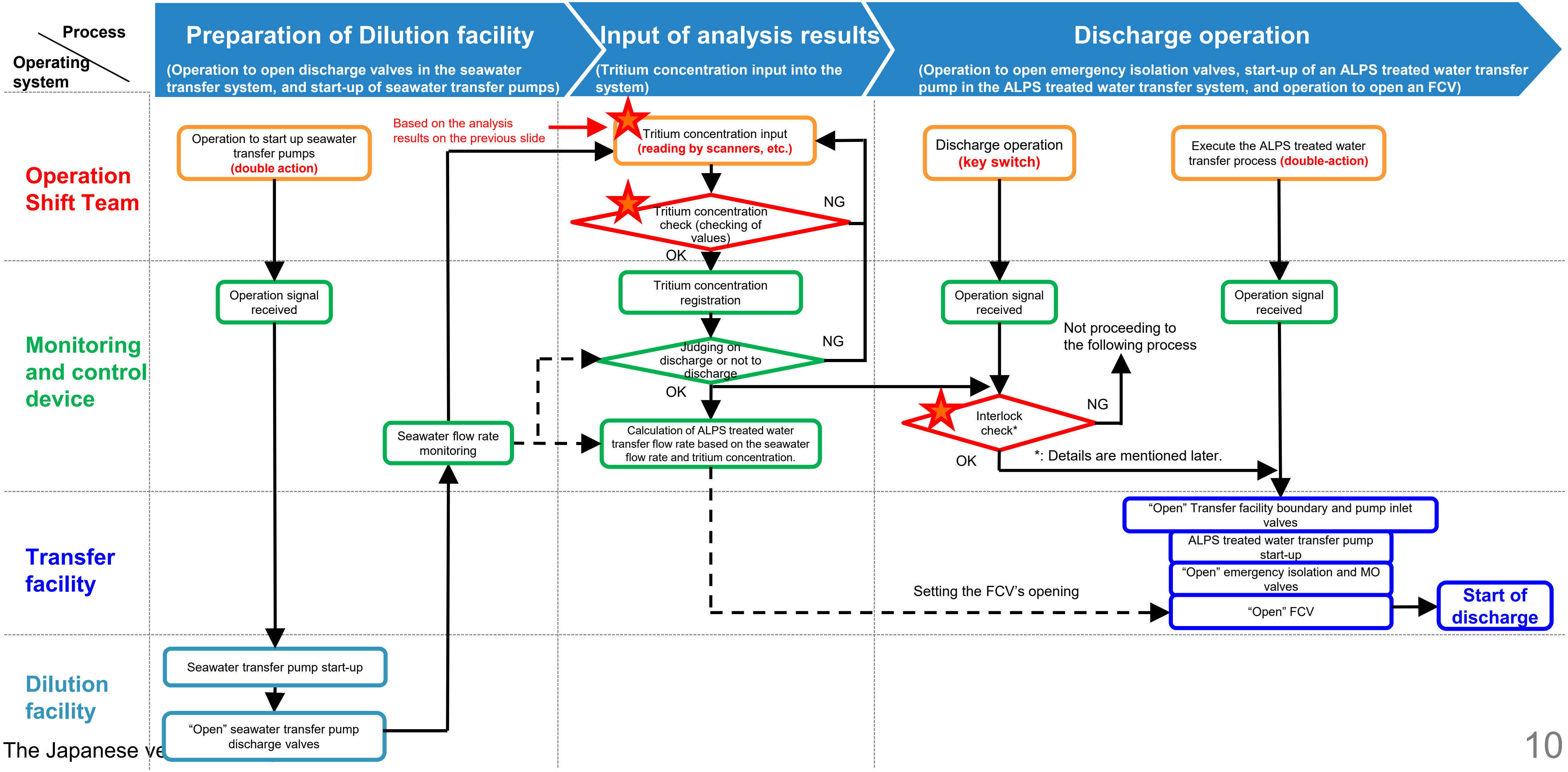


* Ensure that the ALPS treated water in the tank group subject to discharge is being measured.
Ensure that the sum of the ratios to regulatory concentration limits of radionuclides other than tritium in the target water is less than 1.

The Japanese version shall prevail.

2-1 (2) Safety measures at the time of discharge into the sea
[Reference] Operating procedures for Transfer/Dilution facility

- The operating procedures for discharging ALPS treated water are as follows.
  - To prevent human error, the tritium concentrations should be mechanically imported to the monitoring and control device, such as by scanners (several people will check if the entered values are correct).
  - To prevent accidental discharge, the monitoring and control device is provided with an interlock to check that selected tank groups have completed the measurement/confirmation process and that the boundary valves of other tank groups are fully closed.



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Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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Issues pointed out [3]

(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 method and system for activity concentration of nuclides in ALPS treated water

- In the analysis of ALPS treated water, an explanation should be given on what and when each analyst does. Grounds should also be provided that necessary resources will be secured before the discharge by estimating the training period required for the analysts to acquire the prescribed competence.
- An explanation should be given whether or not securing time for training to ensure competence will impact the existing analytical work.
- It should be indicated that parallel analytical work is possible by securing the necessary measurement equipment and analysts based on the increasing number of tritium analyses. In addition, whether each analyst is competent for tritium analysis should also be clarified.

2-1 (2) [1] Analysis method and system for activity concentration of nuclides in ALPS treated water
[3]-1. Analysis facilities involved

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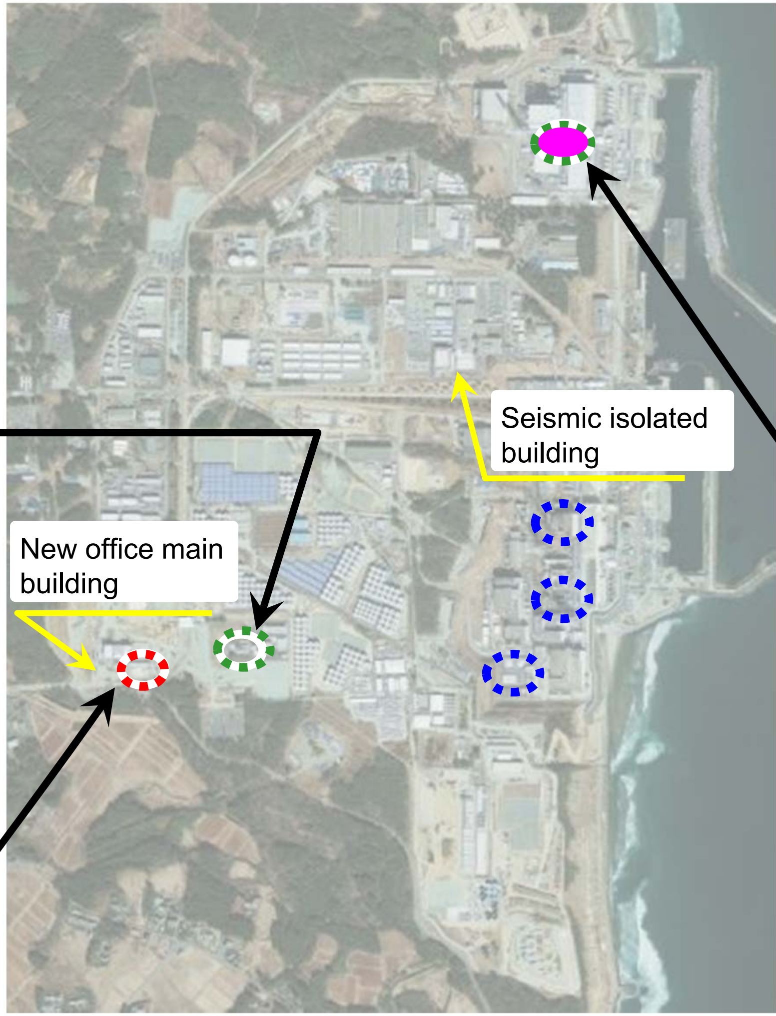
- The [chemical analysis building] will have to deal with an increased number of test samples as the discharge of ALPS treated water. After clarifying the resources required, plans for necessary measures will be developed.
- If trouble, such as leakage of ALPS treated water system, etc., requires urgent analysis of samples with a low radioactivity concentration, an analysis will be performed in the chemical analysis building. However, analysis of leaked water, etc., whose radioactivity concentration cannot be ascertained, will not be handled.

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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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.
- As many as 35 analysts engage in the analyses of low-level radioactive concentration samples during daytime in the chemical analysis building.
- When even the maximum number of analysts fails to complete the analysis low-level radioactive samples, 2 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)	Non-business days	Nighttime	Remarks
Analysts	Chemical analysis building	35 persons	35 persons	5 persons	0 persons	Day shift only
	Units 5 and 6 analysis room	59 persons	37 persons	21 persons*1	2 persons *2	Shiftwork and day shift
Supervisor	Chemical Analysis & Evaluation Group	16 persons	16 persons	2 persons	0 persons (9 persons*3)	Day shift only

Assigned to chemical analysis building to take over analyses during nighttime

*1: Total number of employees *2: 2 out of 9 selected response persons *3: Night shift staff are appointed

2-1 (2) [1] Analysis method and system for activity concentration of nuclides in ALPS treated water
[3]-3. Prospects of analytical work

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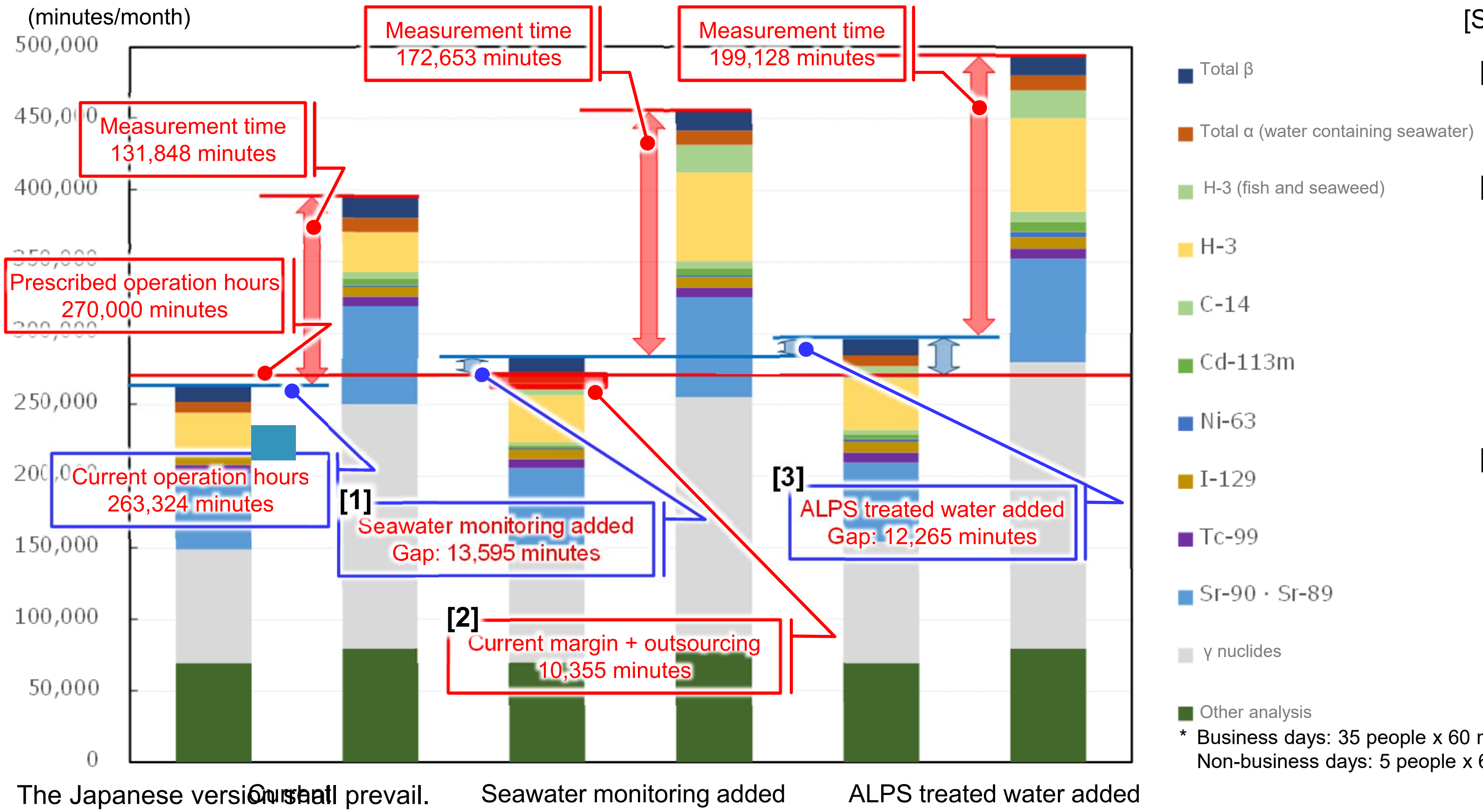
Clarifying the time required for work

- Calculate [operation hours] and [operation hours + measurement time] for the current status and future addition of monitoring items.
- Visualize the gap between the prescribed operation hours* for 35 people working in the chemical analysis building.
- For the analysis of drainage water from ALPS treated water, secure a new outsourcing company to ensure the time to invest for improving competence equivalent to the gap (1) generated by additional marine monitoring --> by comparing with the prescribed operation hours, a margin of about 10000 minutes:(2).
- Endeavor to improve work efficiency for the gap (3) created by adding ALPS treated water (actual gap: approximately 2,000 minutes) and build a framework to ensure analysis of drainage water of ALPS treated water.



[Specific actions]

[1] Outsource the work that exceeds prescribed working hours to offsite.

[2] Improve work efficiency equivalent to the gap (3) (actual condition: about 2,000 minutes) caused by additional ALPS treated water within FY 2022 by making the ratio of the person competent for tritium analysis 100%.

[3] In the future, by expanding the function of the chemical analysis building (construction to be completed within FY 2023), the chemical analysis building will be able to deal with the marine monitoring to be outsourced.

* Business days: 35 people x 60 minutes/hour x 6 hours/day x 20 days/month
Non-business days: 5 people x 60 minutes/hour x 6 hours/day x 10 days/month

The Japanese version shall prevail.

[3]-4. Ascertaining the competence of workers

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Efforts to enhance competence

- Visualization of the competence of 35 employees working in the chemical analysis building and 9 employees in the 5th and 6th analysis room.
- Visualize competence, and make the rate of competent persons 100% by the end of FY 2022 for tritium analysis as there has been a marked increase in samples.
- Increase the rate of competent persons to improve work efficiency even for difficult-to-measure nuclides.

Worker \ Nuclide	γ	H-3	Total α	Ni-63	Cd-113m	C-14	Tc-99	I-129	Sr-90	Total β (Reference)
1	○	○	○							○
2	○	○	○							○
3	○	○				○			○	○
4	○	○	○			○			○	○
5	○					○	○	○		○
6	○			○	○	○	○	○		○
7	○			○	○				○	○
8	○			○	○	○	○	○	○	○
9	○								○	○
10	○			○	○					○
11	○			○	○	○	○	○	○	○
12	○	○				○			○	○
13	○	○				○				○
14	○	○				○			○	○
15	○	○	○							○
16	○	○							○	○
17	○	○								○
18	○	○		○	○	○	○	○	○	○
19	○					○	○	○		○
20	○					○	○	○		○
21	○				○	○	○	○		○
22	○	○	○							○
23	○	○								○
24	○	○	○							○
25	○	○								○
26	○	○								○
27	○	○								○
28	○									○
29										○
30										○
31	○									○
32	○									○
33	○									○
34										
35										
36	○	○								○
37	○	○								○
38	○	○								○
39	○	○								○
40	○	○								○
41	○	○								○
42	○	○								○
43	○	○								○
44	○	○								○
Number of competen	40	26	6	6	7	13	8	8	10	42

Workers 28–30: New analytical workers (Plan to achieve competence for γ and H-3 analysis)

Workers 31–35: General pollutant analysts: 5 persons (Plan to achieve competence for γ, total β, and H -3 analysis)

Workers 36–44: 5th and 6 analysis room workers: 9 persons (Only γ, total β, and H -3 required for emergency analysis)

2-1 (2) [1] Analysis method and system for activity concentration of nuclides in ALPS treated water
[3]-5. Efforts to ensure competence

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■ Efforts to enhance competence (e.g., Sr -90)

➢ Establish training plans based on skills required to acquire competence for each analysis item.

	Training name	Target	Training period Days/times	Training venue	Acquisition of competence Period	Development plan 2022	Development plan 2023
1	Basic knowledge training	New analyst	20	TFTC	-	Training at the time of joining the site	Training at the time of joining the site
2	γ nuclides (Ge detector)	New analyst Person for expanding competence	2	Chemical analysis building	1 month	24	24
3	Tritium	Person for expanding competence	2	Chemical analysis building TFTC	1 month	24	24
9	Tc-99	Person for expanding competence	5	Chemical analysis building TFTC	2 months	6	6
10	I-129	Person for expanding competence	5	Chemical analysis building TFTC	2 months	6	6
11	Sr-90 (Resin method)	Person for expanding competence	5	Chemical analysis building	2 months	6	6

➢ Analysts receive an induction on analytical techniques at an off-site training facility* in the vicinity of the power plant. After taking on-the-job training at the chemical analysis building, they are certified as competent as they meet the standard value in the qualification test.

* Accreditation criteria: In the same sample, they should satisfy the requirements of analytical value difference (± 20%) and competence test items (80% or more) compared to the expert.

➢ Work can be started in as little as 3.5 months, including induction, with competence accreditation.
Those already working in the chemical analysis building will start with basic training: It takes about 2.5 months to become competent.

Induction* Basic knowledge training 20 days → Basic training Sr-90 5 days → Practical training On-the-job training at the site 2 months → Competence check Accreditation 5 days → Accreditation Acquisition of competence

*TFTC: TPT Fukushima Technical Center

2-1 (2) [1] Analysis method and system for activity concentration of nuclides in ALPS treated water
[3]-5. Efforts to ensure competence

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- In OJT, a trainee is engaged in actual work with a competent person in the chemical analysis by analysis item.
- Multiple training courses can be taken simultaneously by using “spare time” for OJT on different analysis items.

Major process	Intermediate process	Small process	Number of workers	Operation hours (Minutes)
Strontium analysis work	Preparation	Handover, etc.		
		Preparation of Sr reporting		
		Moving and entry		
	Analysis	Preparation of analysis		
		Sr analysis (fuming nitric acid method/resin method)		
		Subject of OJT training: Participants in basic training		
		Moving and leaving		
	Break	-		
	Preparation	Work report, consolidation of results, PM schedule check		
		Moving and entry		
	Analysis	Sr analysis (resin method), measurement		
		Subject of OJT training: Participants in basic training		
		Moving and leaving		
		Reporting		

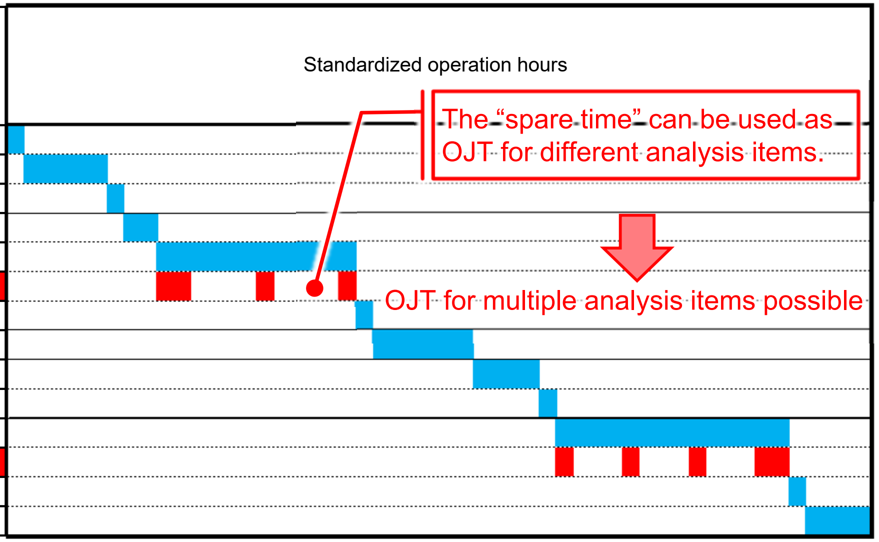
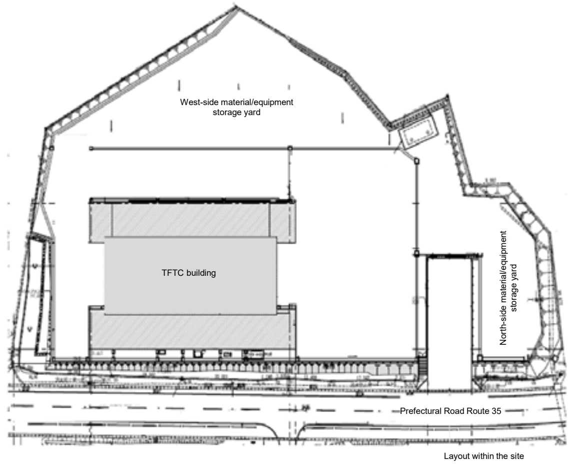
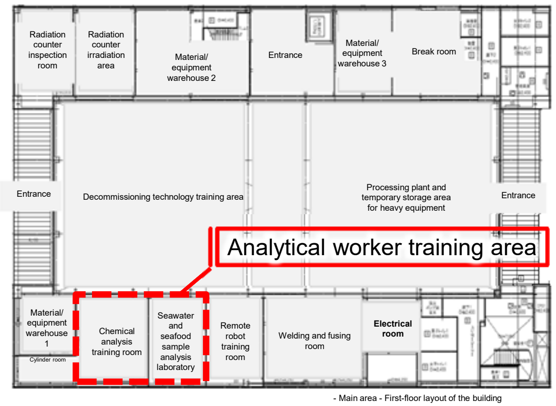


Table. Strontium analysis work (for competent persons and trainees)

	Devices and facilities	Remarks
1	Fume hood	Total beta pretreatment, etc.
2	Low background liquid scintillation counter	H-3, C-14, etc.
3	Inductively coupled plasma mass spectrometer	I-129,Tc-99
4	Lyophilizer	preprocessing of marine organisms: H-3
5	Combustion apparatus	preprocessing of marine organisms: H-3
6	Spectrophotometer	preprocessing of marine organisms: H-3 Water quality analysis
7	pH meter	Water quality analysis
8	Conductivity meter	Water quality analysis
9	Ge semiconductor detector	(Scheduled to be delivered during FY 2022)
10	Gas Chromatograph mass spectrometer	General pollutant

Table. Equipment available at TFTC





[Training facilities]
TFTC: TPT Fukushima Technical Center

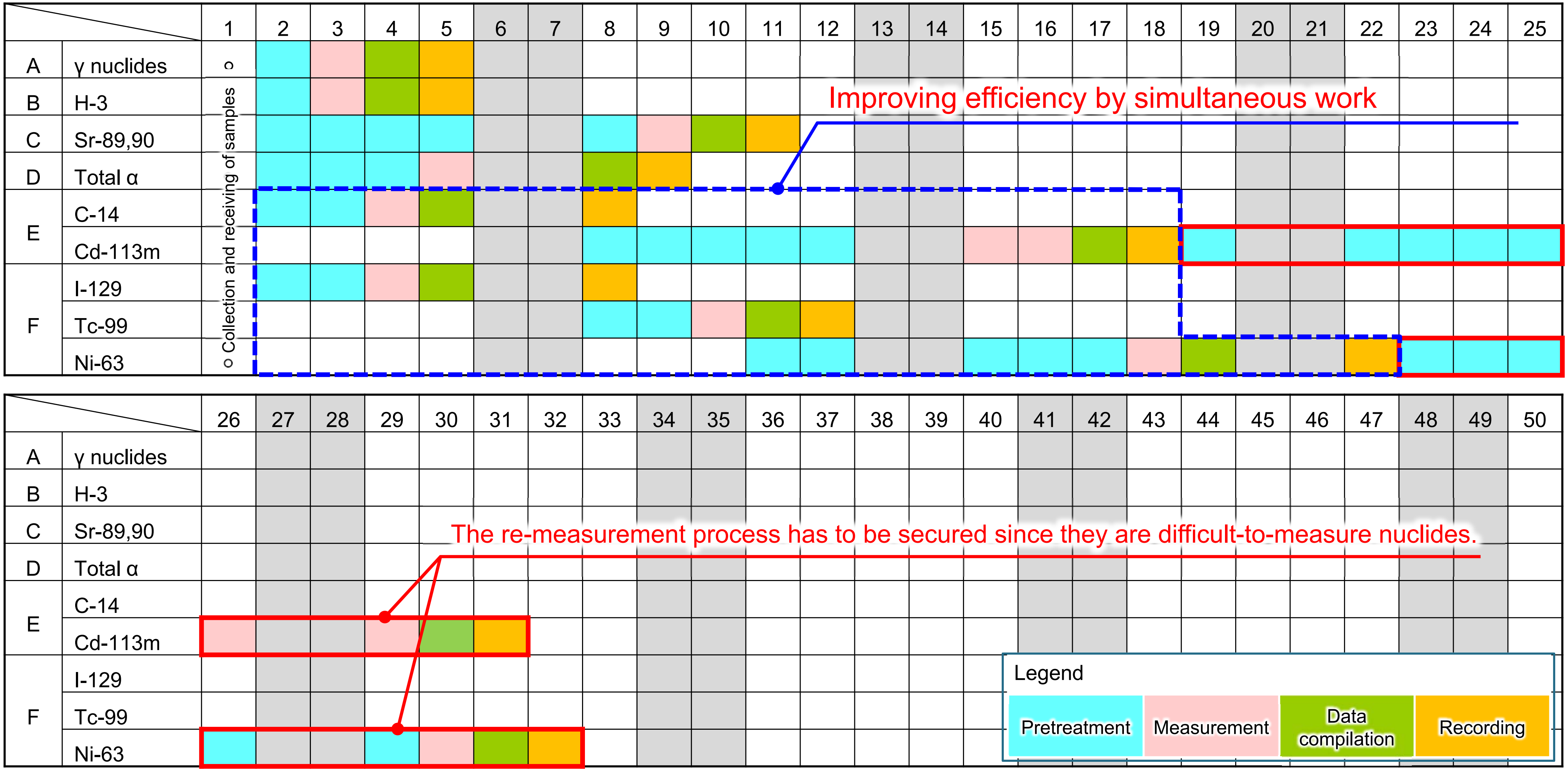
- Total floor area: 2,500 m^2
- Training area for analytical workers: approx. 110 m^2

The Japanese version shall prevail.

2-1 (2) [1] Analysis method and system for activity concentration of nuclides in ALPS treated water
[3]-6. Measures for simultaneous work

TEPCO

- A highly effective method for simultaneous work will be studied and adopted, and analysts will be allocated in an optimized manner to improve the efficiency of 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.



[3]-7 Expansion of the functions of the chemical analysis building

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- 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 equipment (planned number of units)	
Seawater	H-3	156	Fume hood Rotary evaporator Electrolytic condenser	4 5 4
	I-129	8	Experimental table Fume hood	2 7
	C-14	20		
	γ nuclides (including Sn-126)	12	Draft chamber Experimental table	4 2
	α nuclides	12	Experimental table Fume hood	1 4
	Sr-90	12		
Seabed sediment	Sn-126	20		
Fishes	C-14	1	Draft chamber Experimental table Lyophilizer Electrolytic condenser 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

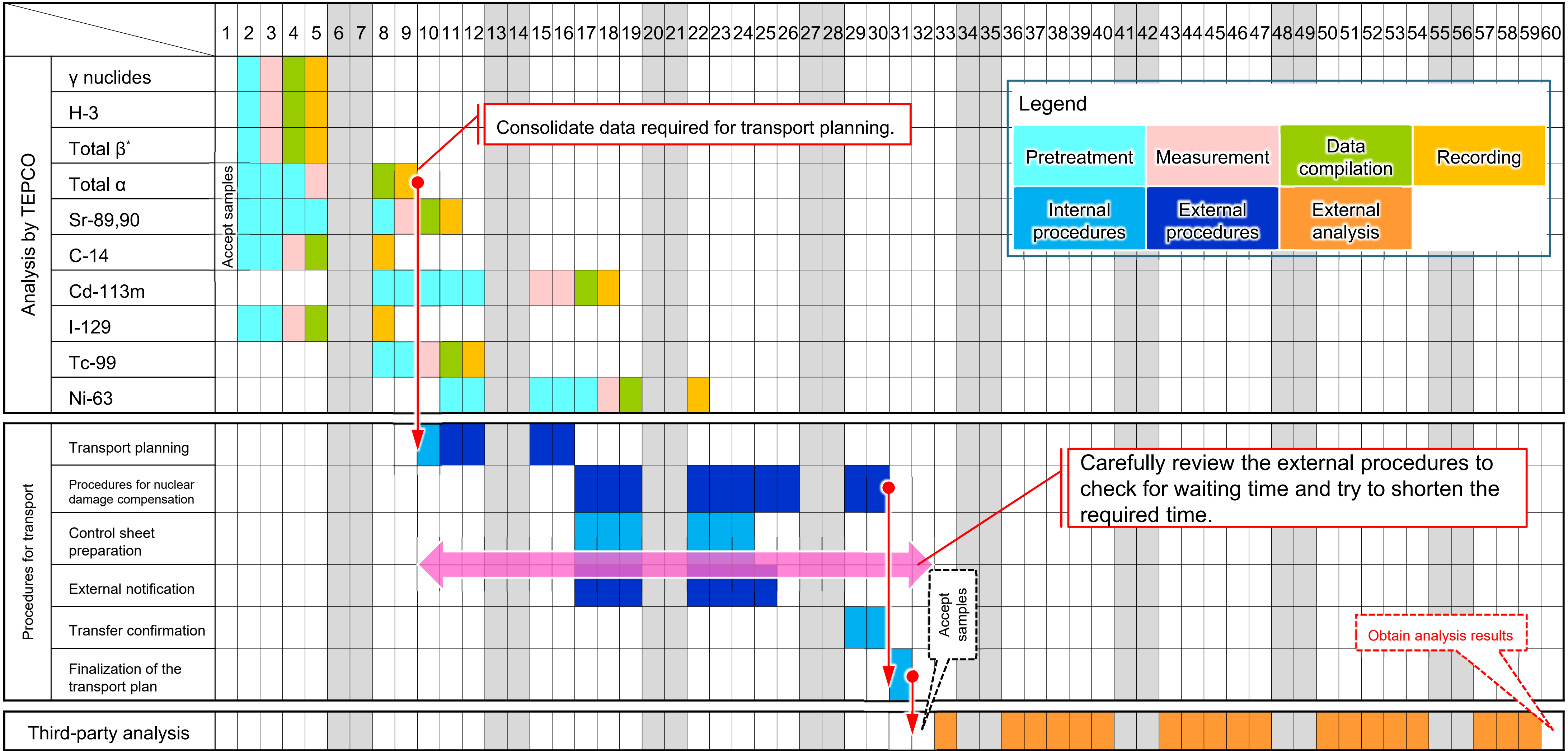
*2: He-MS: Noble gas mass spectrometer for the measurement of H-3

*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 may increase or decrease depending on monitoring plans and the detailed design of facilities to be determined.
- The construction work is scheduled to be completed by the end of FY 2023.

[3]-8. Shortening the measurement and verification process

- Time-saving for measurement/confirmation facilities
  - 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 on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [4]

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

(1) Facilities for discharging into the sea

[1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater

- For the reanalysis of the mixing/dilution simulation after the shape change of the seawater pipe, the concept of the analytical conditions (ALPS treated water flow rate, tritium concentration, etc.) and the impact of these uncertainties should be explained.
- When setting tritium concentration (operational value) after dilution with seawater, it is stipulated that 1,500 Bq/L should be set with a sufficient margin. However, the upper limit of the set point should be evaluated in advance with anticipation for an event that more ALPS treated water is discharged than planned transiently due to trouble, etc.

[2] Homogenization of the radioactive concentration of ALPS treated water in tanks before discharging into the sea

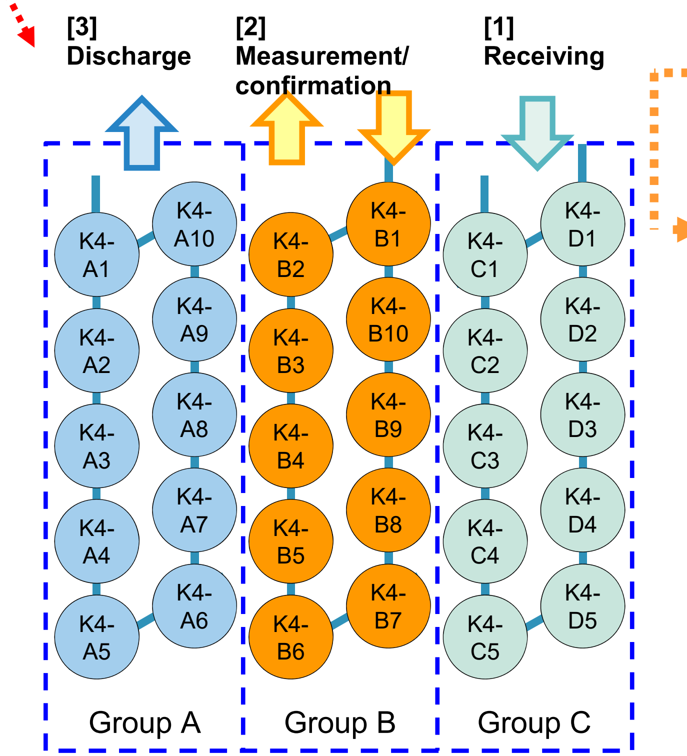
- Regarding variation in the circulation and agitation demonstration test results using tertiary sodium phosphate, how to incorporate the variations into the design or operation should be explained by considering the test conditions (flow velocity of the circulation pump, etc.).

[4]-1. Uncertainty and variability in discharging ALPS treated water into the sea (1/2)

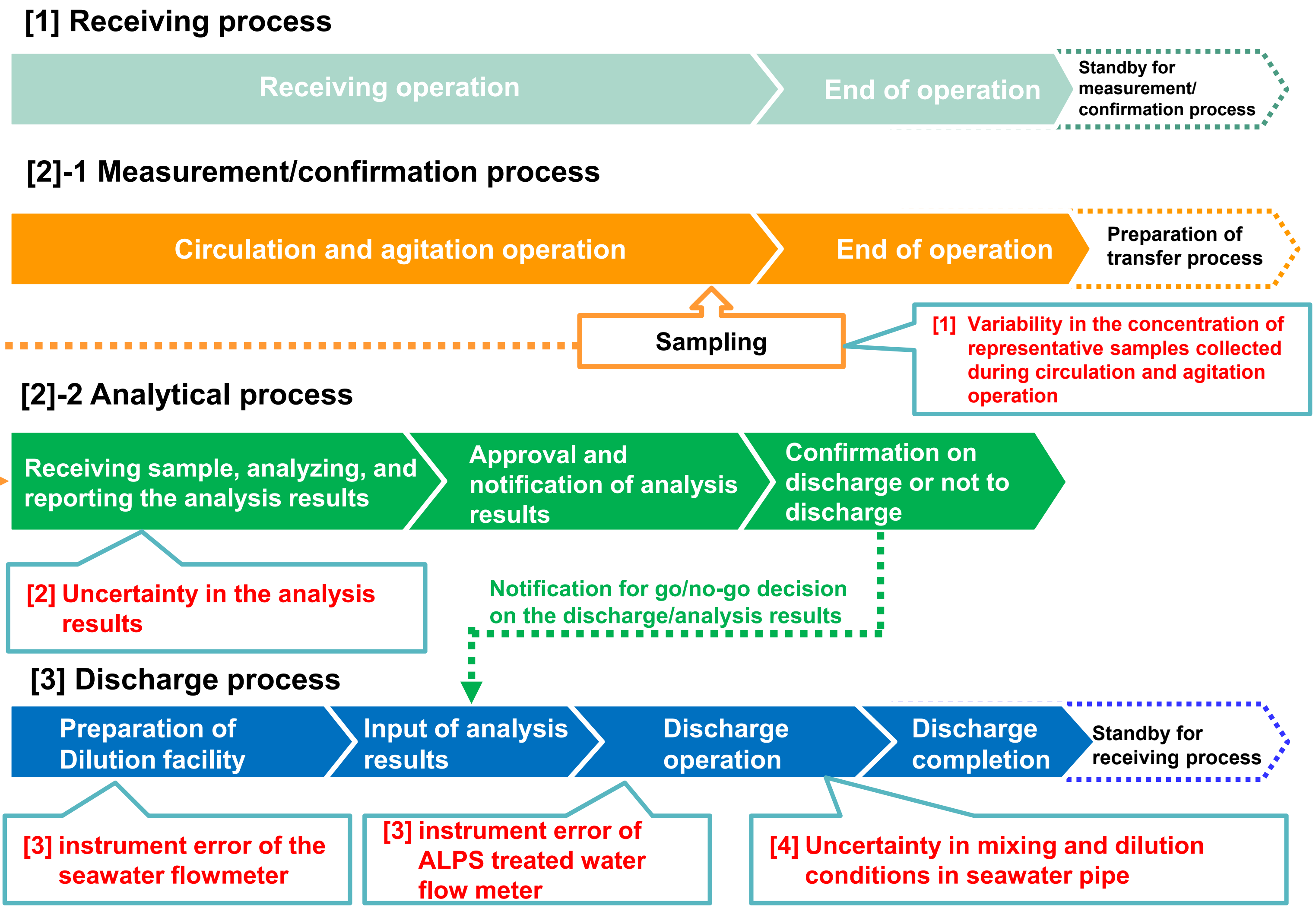
TEPCO

- When considering the whole process of discharging ALPS treated water into the sea, the processes thought to have uncertainties and variability are below.

	Group A	Group B	Group C
1st cycle	Receiving	-	-
2nd cycle	Measurement/ confirmation	Receiving	-
3rd cycle	Discharge	Measurement/ confirmation	Receiving
4th cycle	Receiving	Discharge	Measurement/ confirmation
...	Measurement/ confirmation	Receiving	Discharge



3 groups of measurement / confirmation tanks



The Japanese version shall prevail.

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater [4]-1. Uncertainty and variability in discharging ALPS treated water into the sea (2/2)

TEPCO

- Items with uncertainties and variability extracted in the previous slides are summarized as shown in the table below.

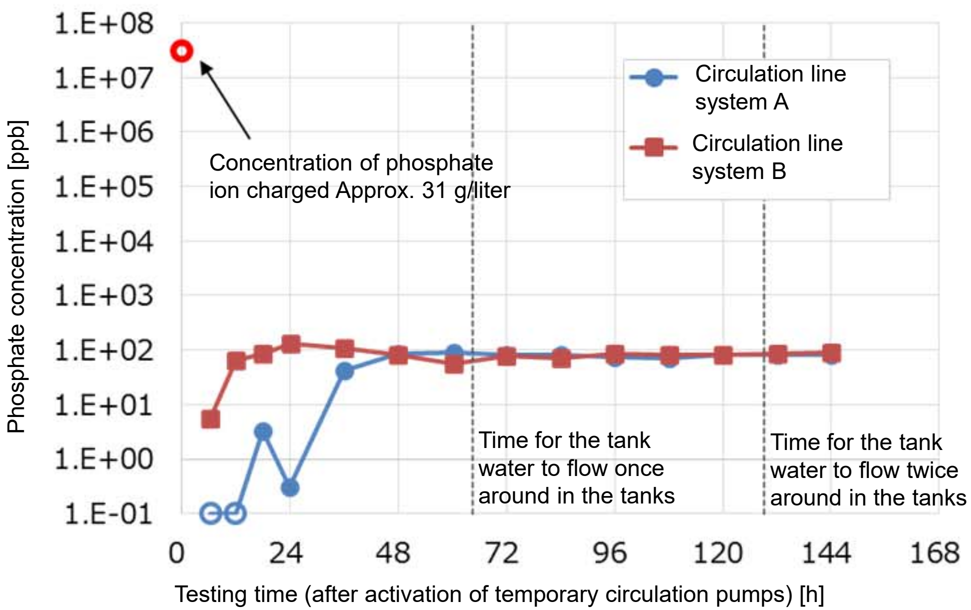
No.	Process	Item	Degree of uncertainty or variability	Remarks
1	Measurement/ confirmation Process	Variability in the concentration of representative samples collected during circulation and agitation operation	[Sampling line] Phosphoric acid: The mean concentration after the time for the tank water to flow once around in the tanks is the same as the theoretical value of 80 ppb. The relative standard deviation is 6.25%. [Inside the tank] Phosphoric acid: The overall mean in the tank is a standard deviation of 9 ppb from the theoretical value of 80 ppb. The relative standard deviation is 10.5%. Tritium: Before the test, an average of 1.61 E + 05 Bq/L and a relative standard deviation of 8.3% were obtained in the middle layer of the tank. After the test, an average of 1.51 E + 05 Bq/L and a relative standard deviation of 3.8% (average of 1.50 E + 05 Bq/L, a relative standard deviation of 2.2% in the tank middle layer) were obtained in the whole tank.	An explanation was given at the 10th Review Meeting.
2	Analytical process	Uncertainty in the analysis results	There is uncertainty about radioactive concentration in the analysis results. -> ± 10% (provisional) for tritium.	An explanation was given at the 9th and 12th Review Meetings.
3	Discharge process	Instrument accuracy of the ALPS treated water flowmeter	There is an instrument error of ± 2.1% F.S. for a measurement range of 0-40 m^3/h.	An explanation was given at the 10th Review Meeting.
		Instrument accuracy of the seawater flowmeter	There is an instrument error of ± 2.1% F.S. for a measurement range of 0-10000 m^3/h.	
4		Uncertainty in mixing and dilution conditions in seawater pipe	In the seawater pipe with ALPS treated water flow rate of 500 m^3/day, and seawater flow rate of 340,000 m^3/day, there is a variation of up to 0.23% of theoretical mass concentration of 0.14% at the outlet of the current analytical model.	An explanation was given at the 5th and 11th Review Meetings.

- As indicated above, taking into account the uncertainty of the overall system for the discharge of ALPS treated water into the sea, it is planned to adjust the mixing and dilution ratio of ALPS treated water with seawater.

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater
[Reference] Results of the circulation and agitation demonstration test (1/3)

TEPCO

Phosphate ion concentration in samples



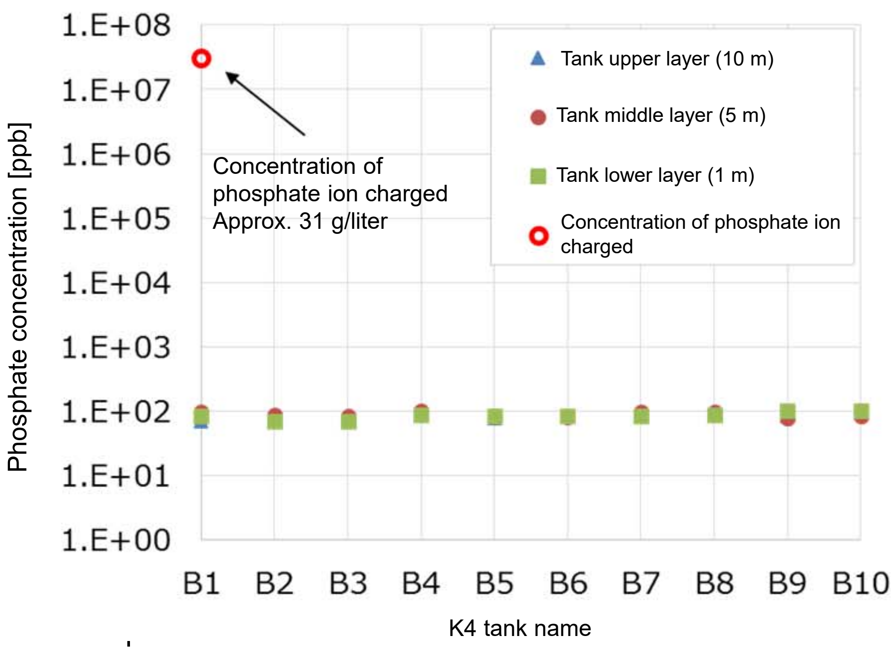
Testing time (h)	Phosphate ion concentration [System A]	Phosphate ion concentration [System B]
6.4	0.1	5.4
12	0.1	65
18	3.3	85
24	0.3	131
36	43	109
48	84	82
60	91	56
72	81	77
84	80	72
96	73	84
108	71	82
120	83	82
132	82	84
144	82	90

1 round (6.4–60 h)

2nd round (72–144 h)

*: Unit (ppb)

Phosphate ion concentration in tanks after the test



Tank name	Tank upper layer (10 m)	Tank middle layer (5 m)	Tank lower layer (1 m)	Mean value
K4-B1	69.0	98.0	84.0	83.7
K4-B2	82.0	88.0	69.0	79.7
K4-B3	68.0	85.0	71.0	74.7
K4-B4	85.0	101.0	87.0	91.0
K4-B5	79.0	82.0	85.0	82.0
K4-B6	84.0	82.0	85.0	83.7
K4-B7	82.0	99.0	85.0	88.7
K4-B8	89.0	98.0	88.0	91.7
K4-B9	83.0	77.0	102.0	87.3
K4-B10	95.0	85.0	101.0	93.7

Overall mean: 86 ppb
Standard deviation: 9 ppb
Relative standard deviation: 10.5%

*: Unit (ppb)

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater
[Reference] Results of the circulation and agitation demonstration test (2/3)

TEPCO

Tritium concentration distribution in tanks after the test

Tank name	* Tritium concentration ($\times 10^5$) before the test* [Bq/L]	Tritium concentration in the tank lower layer after the test ($\times 10^5$) [Bq/L]	Tritium concentration in the tank middle layer after the test ($\times 10^5$) [Bq/liter]	Tritium concentration in the tank upper layer after the test ($\times 10^5$) [Bq/L]	Mean tritium concentration in tanks after the test ($\times 10^5$) [Bq/L]
K4-B1	1.94	1.53	1.51	1.54	1.53
K4-B2	1.63	1.51	1.42	1.50	1.48
K4-B3	1.49	1.51	1.53	1.48	1.50
K4-B4	1.54	1.53	1.48	1.51	1.51
K4-B5	1.67	1.53	1.47	1.55	1.52
K4-B6	1.69	1.52	1.51	1.52	1.52
K4-B7	1.58	1.45	1.53	1.49	1.49
K4-B8	1.50	1.49	1.50	1.48	1.49
K4-B9	1.44	1.50	1.52	1.54	1.52
K4-B10	1.61	1.51	1.54	1.55	1.53
Mean	**1.61**	**1.51**			-
Standard deviation σ	**0.13**	**0.029**			-
Relative standard deviation	**8.1 %**	**1.9 %**			-

*: Sampling from the K4-B1 tank was performed on May 22, 2020, and from K4-B2 to B10 tanks from June 9 to 22 of 2021 in the middle layer of the tanks.

- Based on the results of the circulation and agitation demonstration test this time, we concluded that the circulation and agitation operation enables the collection of representative samples.
  - This test was started in a very conservative initial state, in which the entire amount of tribasic sodium phosphate was charged into one tank (K4-B6) before the start of the test. Even so, after the tank water flowed twice around in the tanks, the mean phosphate concentration in the water sampled from the circulation line sampling points (A) and (B) was 84.5 ppb, which is approximately equal to the theoretical value of 80 ppb.
  - Due to the conservative initial conditions, the mean phosphate concentration in the water collected from the tanks was 86 ppb with a standard deviation of 9 ppb, and a slight variation was observed. On the other hand, the mean tritium concentration in the tanks was 1.51 $\times 10^5$ Bq/L with a standard deviation of 0.029 $\times 10^5$ Bq/L, which means that the circulation and agitation operation has a homogenization effect.

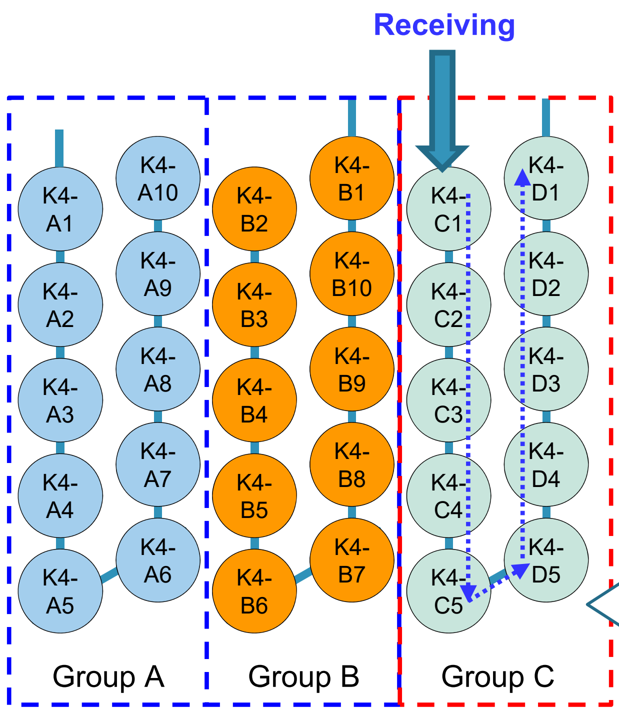
[Reference] Results of the circulation and agitation demonstration test (3/3)

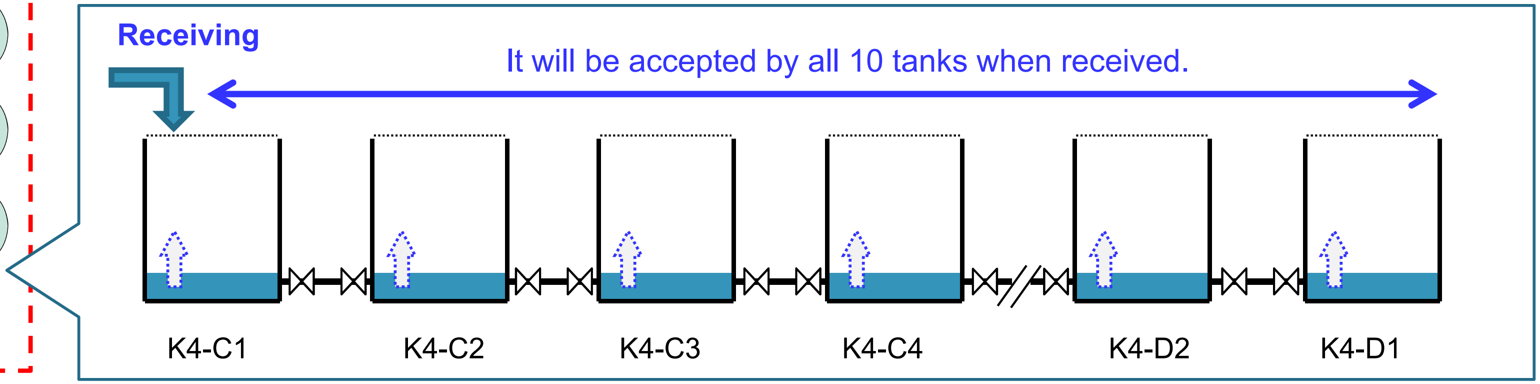
TEPCO

- In the receiving process, the following operations are carried out. Therefore, it is unlikely that there will be a significant difference in tritium concentration in a tank group.
  - When receiving, it should be received by all of the tanks in the receiving tank groups (10 tanks).
  - When receiving "A. ALPS treated water to be generated daily," the change in concentration should be gradual.
  - When receiving "B. ALPS treated water, etc., stored in the tanks," the basic policy of the discharge plan is to discharge ALPS treated water in order of lower tritium concentration. In the phosphoric acid test, even if the concentration difference was 1.0 E + 05 times, the sample collected at the sampling line was almost equal to the theoretical value of 80 ppb. In comparison, the actual concentration difference of tritium was about 2.0 E + 01 times. Therefore, the effect of the tritium concentration difference is considered small.

<Reference: ALPS treated water, etc., and strontium treated water (water before ALPS treatment) stored as of April 2021>

Tritium concentration [becquerels per liter]	to 300,000	300,000 - 600,000	600,000 - 1,200,000	1,200,000 - 1,800,000	1,800,000 - 2,400,000	Assumed as 450,000
Water storage capacity	Approx. 1,219,000 m^3	Approx. 391,000 m^3	Approx. 473,000 m^3	Approx. 50,000 m^3	Approx. 24,000 m^3	Estimated as of December 2020 Approx. 96,000 m^3





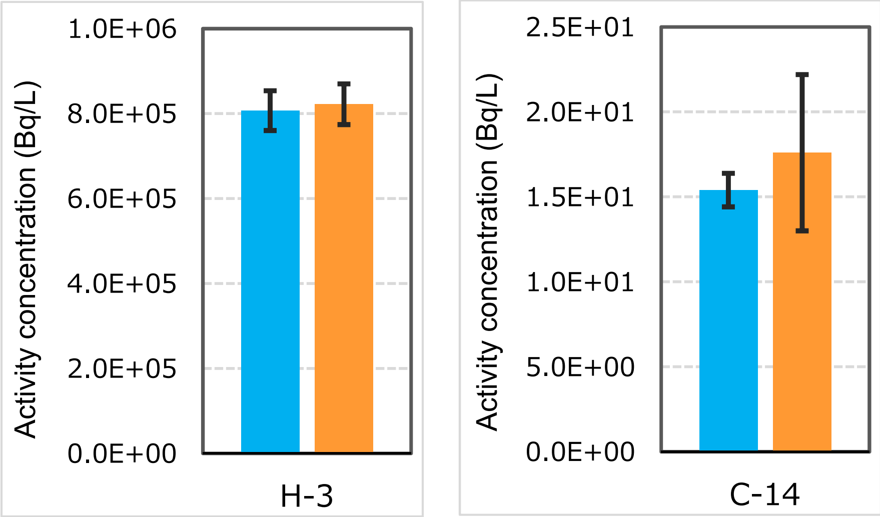
3 groups of measurement/confirmation tanks

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater
[Reference] Uncertainty in the analysis results

➢ 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

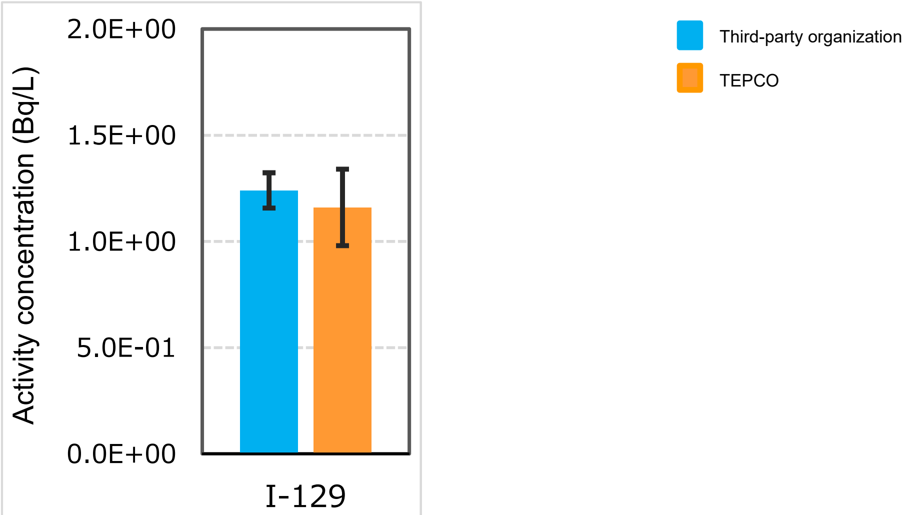


Comparison of values obtained through analysis by a third-party organization and those through analysis by TEPCO

➢ 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

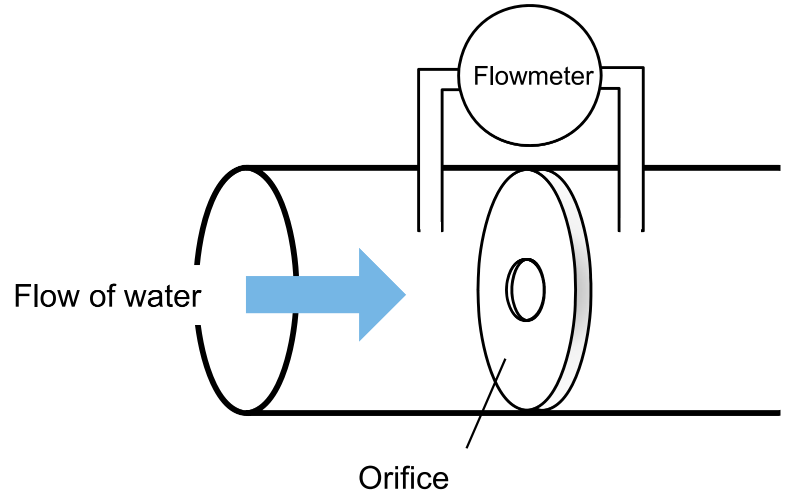


Comparison of values obtained through analysis by a third-party organization and those through analysis by TEPCO

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater [Reference] instrument error of the flowmeter

- In the ALPS treated water dilution/discharge facilities, ALPS treated water and seawater flow rates will be measured with "differential pressure-type flowmeters (orifice)."*1
- Each flowmeter consists of a detector, a computation element (including the indicator), and the specifications and configuration are as follows:
- When setting the flow rate of ALPS treated water and assessing the tritium concentration after dilution with seawater to ensure that the tritium concentration after dilution with seawater is below 1,500 Bq/L, the instrument error is taken into account to obtain a conservative result.

*1: A measurement system in which an orifice (throttle valve) is installed in the flow path, and the difference (differential pressure) in pressure between the front and back of the orifice is detected and converted to a flow rate.

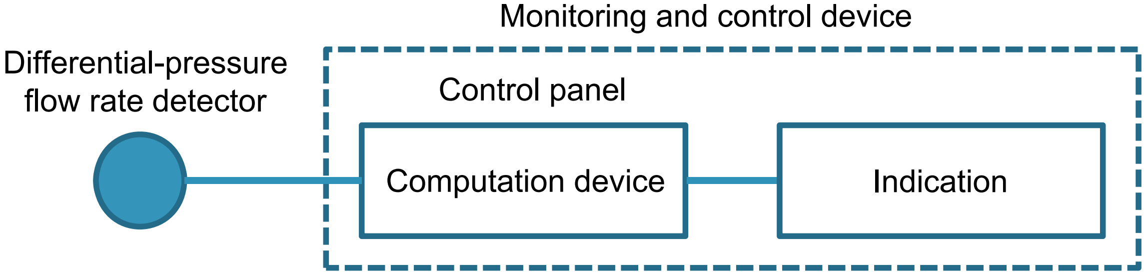


Measurement image using a differential pressure flowmeter (orifice)

Flowmeter specifications

Measurement method	Differential pressure-type (Orifice)
Specifications (orifice)	JIS Z 8762-2*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)

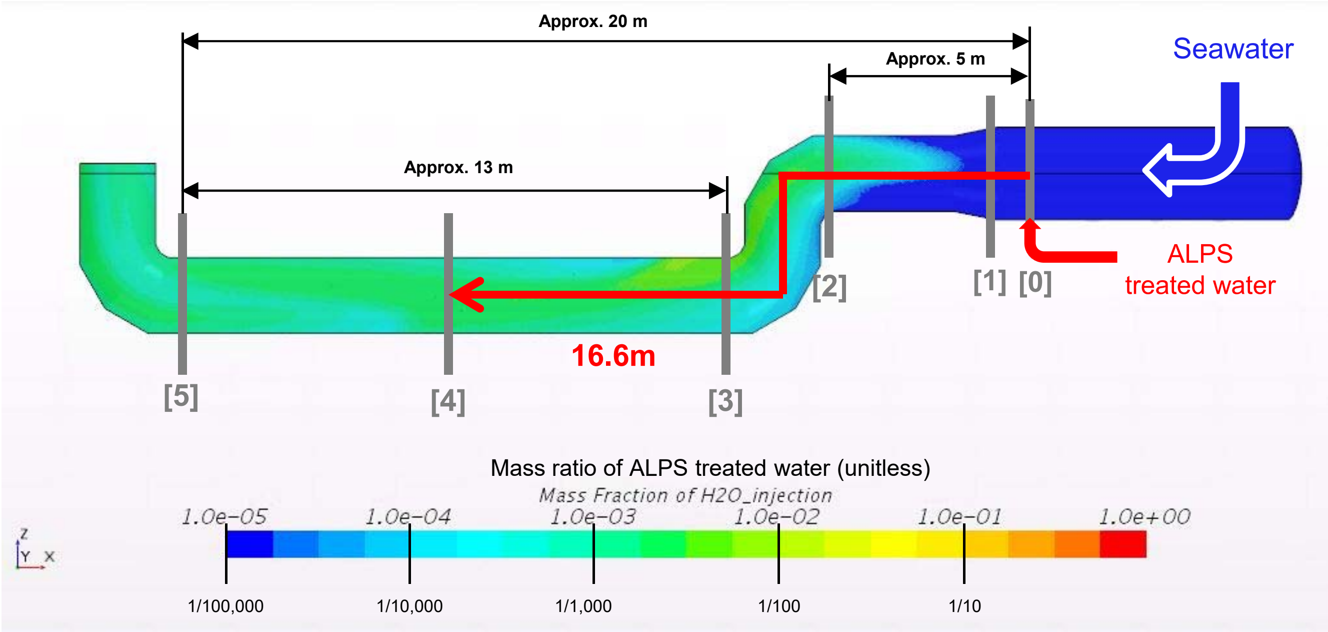
*2: Measurement of fluid flow using pressure differential devices inserted in circular cross-section conduits running full−Part 2: Orifice plates

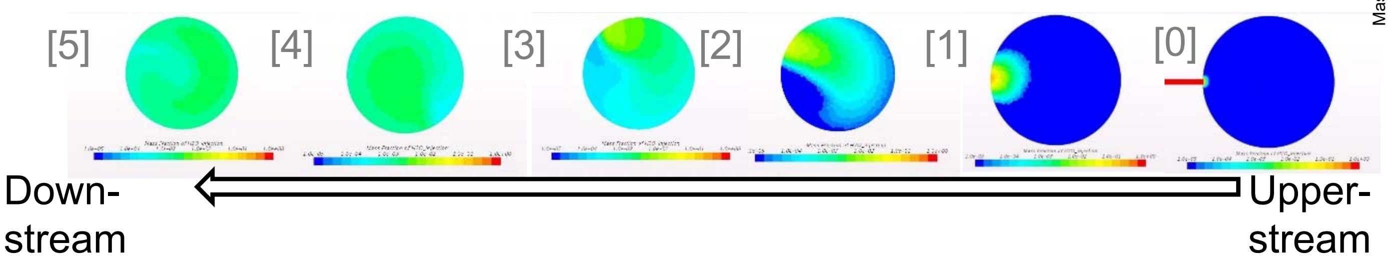


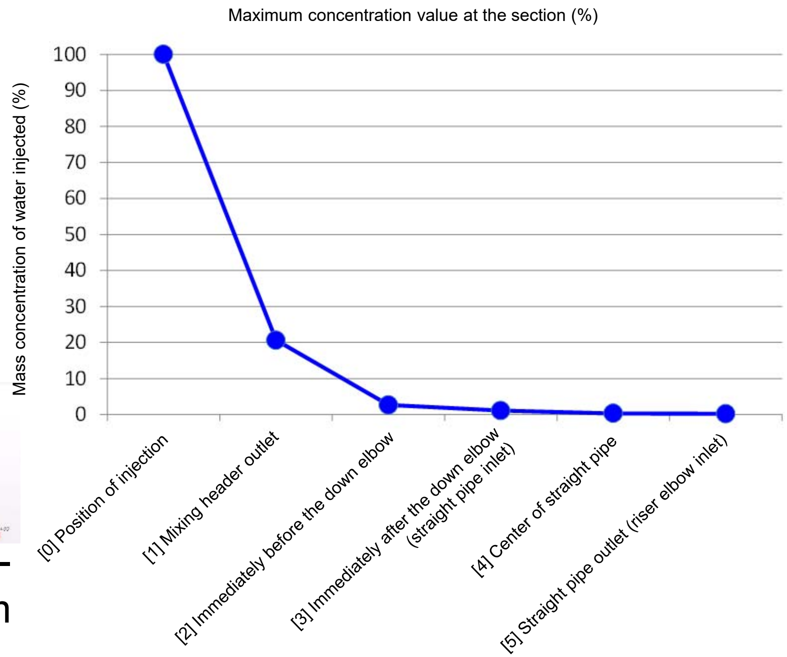
2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater [Reference] Uncertainty in mixing and dilution in seawater pipe (1/2)

- Fluid analysis calculated the mass concentration of ALPS treated water injected at sections inside the seawater pipe. 1.64 times (provisional)
  - In evaluating the seawater flow rate of 340,000 m^3/day, and ALPS treated water flow rate of 500 m^3/day, the theoretical mass concentration was 0.14%.
- Based on the maximum mass concentration of ALPS treated water on the respective sections, the status under which mixing/dilution progress was evaluated.
  - [4] After the center of the straight pipe, the maximum mass concentration of the ALPS treated water was below 1%, and it was determined that the mixing/dilution had progressed on the whole.

Name	Maximum concentration value at the section (%)
[0] Position of injection	100
[1] Mixing header outlet	20.6
[2] Immediately before the down elbow	2.65
[3] Immediately after the down elbow (straight pipe inlet)	1.10
[4] Center of straight pipe	0.30
[5] Straight pipe outlet (riser elbow inlet)	0.23



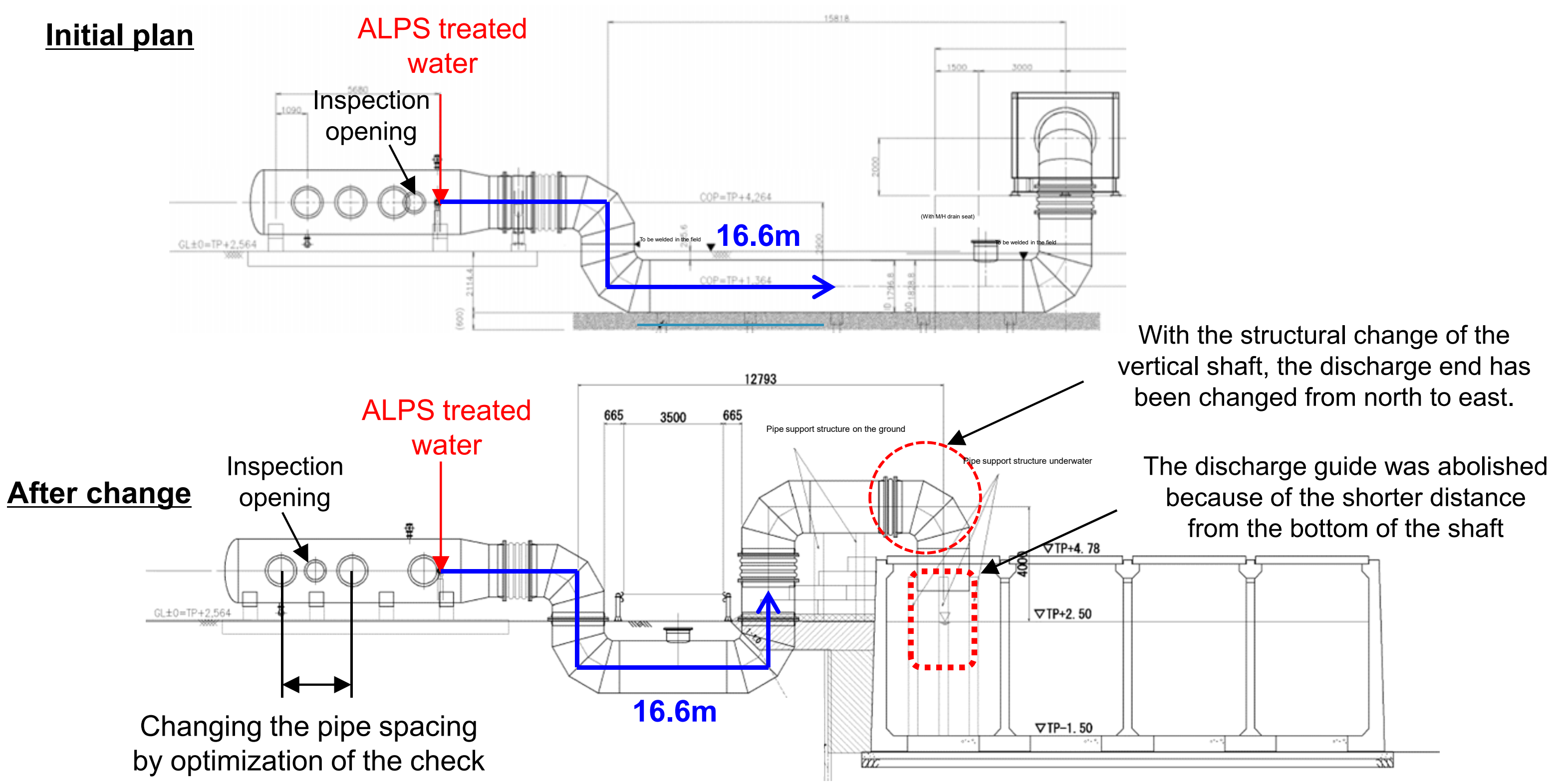




[Reference] Uncertainty in mixing and dilution in seawater pipe (2/2)

TEPCO

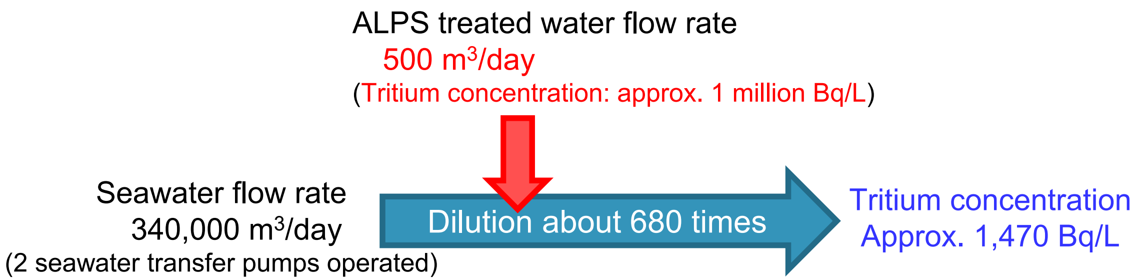
- At present, a reanalysis of the mixing and dilution simulation after the shape change of the seawater pipe is underway.



Pipe size (Header pipe: 2200 A, downstream pipe: 1800 A) unchanged

- <u>In the actual operation, by limiting the tritium concentration of the ALPS treated water to a maximum of 1 million Bq/L</u>, the ALPS treated water can be diluted to 1,500 Bq/L by operating 2 seawater transfer pumps even if the ALPS treated water flow rate is a maximum of 500 m³/day. The most conservative conditions are the ALPS treated water flow rate of 500 m³/day and the seawater flow rate of 340,000 m³/day.

<u>Tritium concentration: in the case of 1,000,000 Bq/L</u>



*: Simple calculation of tritium concentration after dilution with seawater.
(Uncertainty due to flow rate measurement error and analysis is not included.)

The Japanese version shall prevail.

[4]-2 Handling of uncertainty and variability in discharging ALPS treated water into the sea (1/3)

TEPCO

- There are uncertainties and variability in the processes above when considering the entire process of discharging ALPS treated water into the sea. For operational purposes, the details of each process are as follows.

No.	Process	Item	Operational considerations
1	Measurement/ confirmation Process	Variability in the concentration of representative samples collected during circulation and agitation operation	The variability in tritium concentration (relative standard deviation of 3.8%) in the circulation/agitation demonstration test is within the range of analytical uncertainty (± 10%). Therefore, variability in the concentration of representative samples collected in the circulation and agitation operation is not considered.
2	Analytical process	Uncertainty in the analysis results	Since the analytical uncertainty for tritium is ± 10% (provisional), conservatively, + 10% is considered when calculating the dilution.
3	Discharge process	Instrument accuracy of the ALPS treated water flowmeter	Each flow meter has an instrument error of ± 2.1% FS, so each is considered conservatively when calculating dilution. Example) ALPS treated water flow meter: Set the measured flow rate to + 2.1% FS to increase the flow rate. Seawater flowmeter: Set the measured flow rate to -2.1% FS to decrease the flow rate.
		Instrument accuracy of the seawater flowmeter	
4		Uncertainty in mixing and dilution conditions in seawater pipe	For operational purposes, limiting the tritium concentration in ALPS treated water to a maximum of 1 million Bq/L makes the current flow rate setting the most conservative. The maximum concentration at the outlet of the analytical model is 1.64 times the theoretical mass concentration. Even if this is taken into account, “tritium concentration after seawater dilution (operational value)” will be set so that the tritium concentration does not exceed 1,500 Bq/L.

[4]-2 Handling of uncertainty and variability in discharging ALPS treated water into the sea (2/3)

TEPCO

- When considering the entire process of discharging ALPS treated water into the sea, the uncertainty and variability will be set to the side where the value of the tritium concentration higher.
- The upper limit of tritium concentration (operational value) after dilution with seawater is set at 800 Bq/L. This results in a conservative setting for the theoretical tritium concentration after dilution with seawater of about "680 - 700 Bq/L". Therefore the condition of the limiting value of "1,500 Bq/L" can be satisfied even considering the uncertainty of the mixing/dilution conditions.

Analytical process → **Discharge process**

Limit value: lower than 1,500 Bq/L

Dilution calculation this time

Tritium analysis results before discharge	
MAX:	1.1 million Bq/L
Ave:	685,000 Bq/L
min:	165,000 Bq/L

Dilution ratio
Approx. 1,370 times
Approx. 850 times
Approx. 645 times

Evaluation values after dilution with seawater
Upper limit of the operational value Approx. 800 Bq/L
Approx. 260 Bq/L

Approx. 1,300 Bq/L

1.64 times *2

Consider uncertainty in mixing and dilution conditions in seawater pipe

Uncertainty of analysis + 10%

instrument error *1

Set conservatively due to analysis uncertainty and instrumental error

Normal dilution calculation

Tritium analysis results before discharge	
MAX:	1 million Bq/L
Ave:	620,000 Bq/L
min:	150,000 Bq/L

Dilution ratio
Approx. 1470 times
Approx. 884 times
Approx. 680 times

The upper limit of dilution ratio (2 seawater transfer pumps operated)

Theoretical values after dilution with seawater
Approx. 680 - 700 Bq/L
Approx. 220Bq/L

*1: ALPS treated water flow meter, and seawater flow meter are conservatively considered when calculating dilution.

*2: The provisional value as of now. In the future, a review will be made in accordance with the criteria for mostly falling below 1,500 Bq/L.

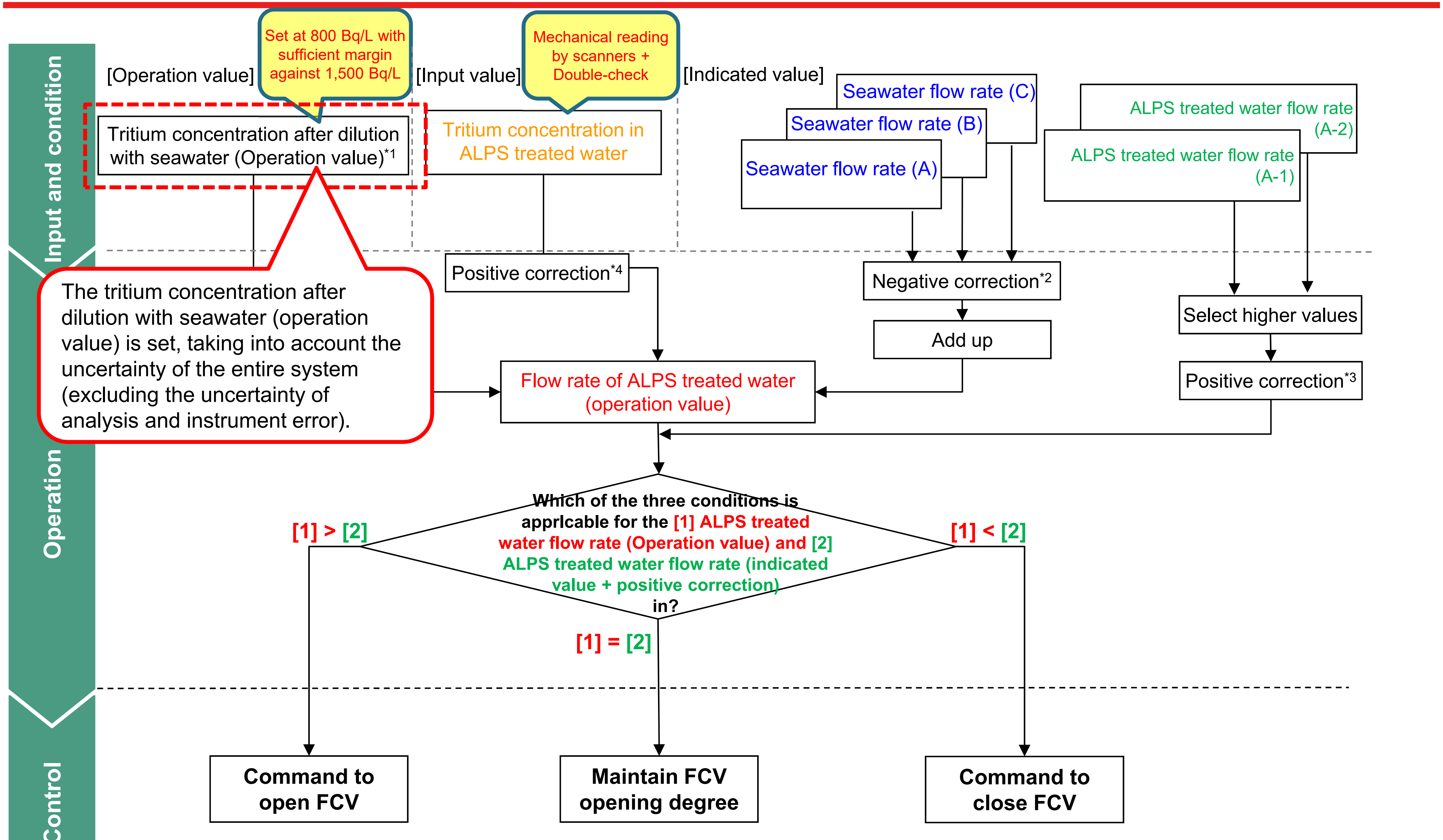
- The above setting is sufficiently below the regulatory concentration limit of 60,000 Bq/L for tritium. The drainage water concentration at a level of fewer than 1,500 Bq/L set based on the government policy can be sufficiently satisfied.
- As explained at the 11th Review Meeting, this setting can be used without problems.

Item	Yearly average	Basis
[Example] Evaluation postulating that ALPS treated water with a tritium concentration of 620,000 Bq/L * has been discharged for 1 year.		
ALPS treated water flow rate	120 m^3/day	If ALPS treated water with a tritium concentration of 620,000 Bq/L continues to be discharged at a level below 22 trillion Bq/year at a facility availability of 80%
Tritium concentration to be discharged (2 seawater transfer pumps operated)	220Bq/L	ALPS treated water with a tritium concentration of 620,000 Bq/L is discharged at 120 m^3/day and diluted with 2 seawater transfer pumps

*: Mean tritium concentration of ALPS treated water, etc., stored in ALPS treated water storage tanks

TEPCO

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater
[Reference] Control of the ALPS treated water flow rate

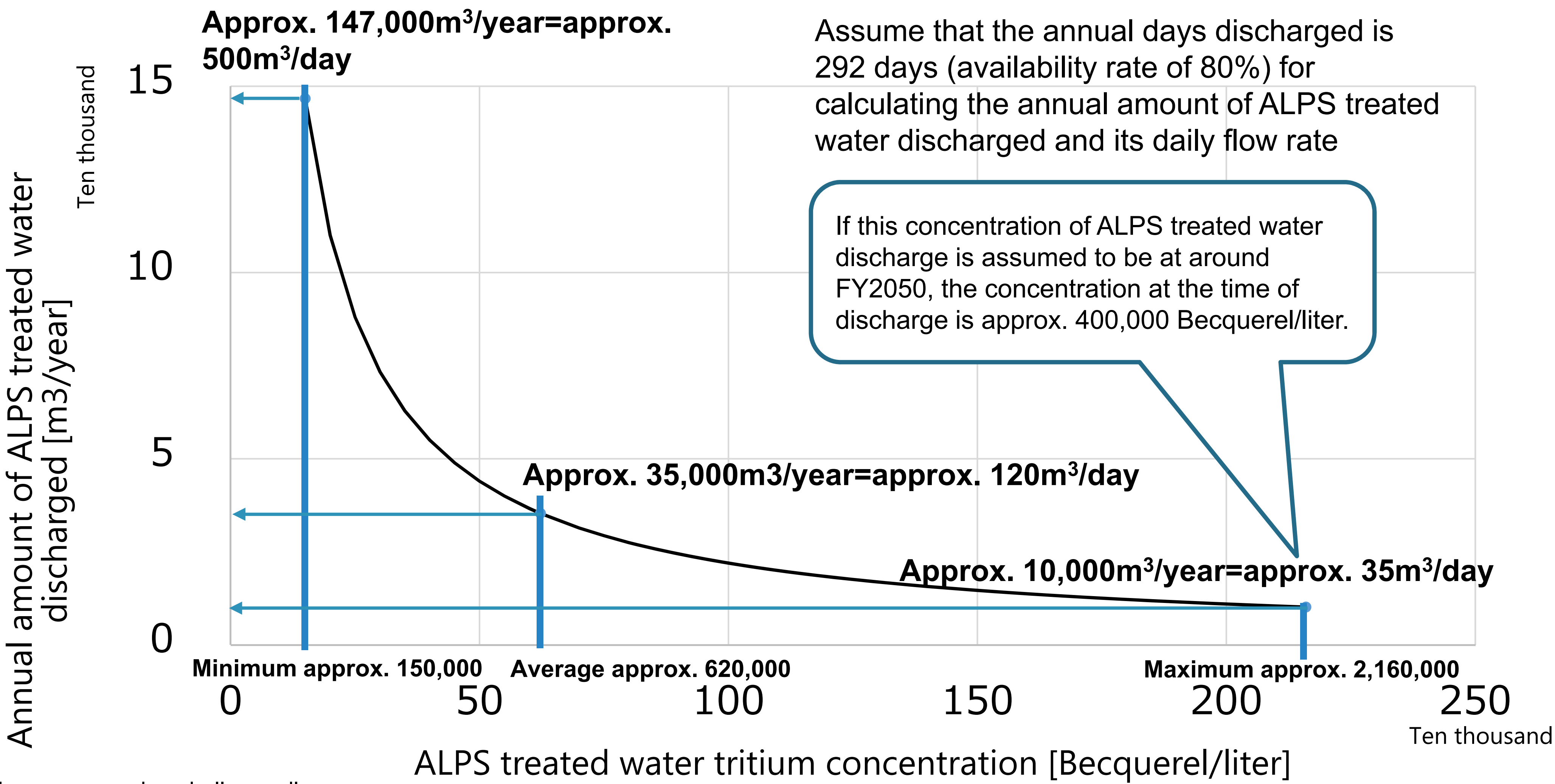


*1: The concentration is registered into the monitoring and control device before the facilities are put into service. Unless there is a change in the planned conditions, it must not be changed in principle.
*2: Assuming a non-conservative case due to error of instruments (when the actual flow rate is lower than the indicated value), the value is corrected according to the instrument error (2.1% FS).
*3: Assuming a non-conservative case due to error of instruments (when the actual flow rate is higher than the indicated value), the value is corrected according to the instrument error (2.1% FS).
*4: Assuming a non-conservative case due to an uncertainty of analyses (when the actual concentration is higher than the analysis value), the value is corrected according to the uncertainty ([Tentative] 10%).

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater

[Reference] Relation between the amount of annual discharge of ALPS treated water, and the tritium concentration of ALPS treated water

- If the standard for annual discharge of tritium is set below 22 trillion Becquerel, the amount of water that can be discharged fluctuates in accordance with the tritium concentration in the ALPS treated water (less concentration equates to more discharge being possible)

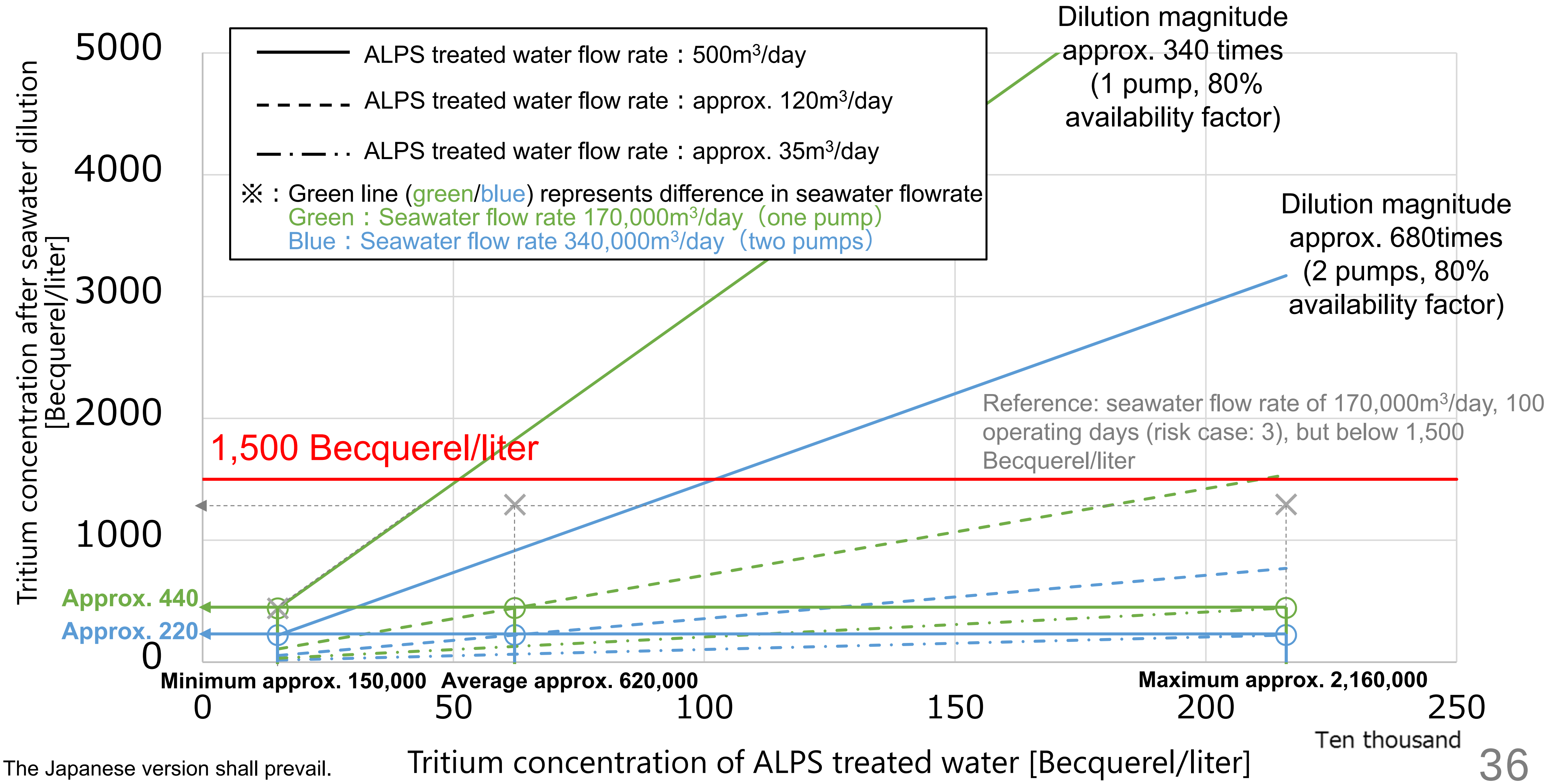


The Japanese version shall prevail.

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater [Reference] Relation between tritium concentration and ALPS treated water flow rate

TEPCO

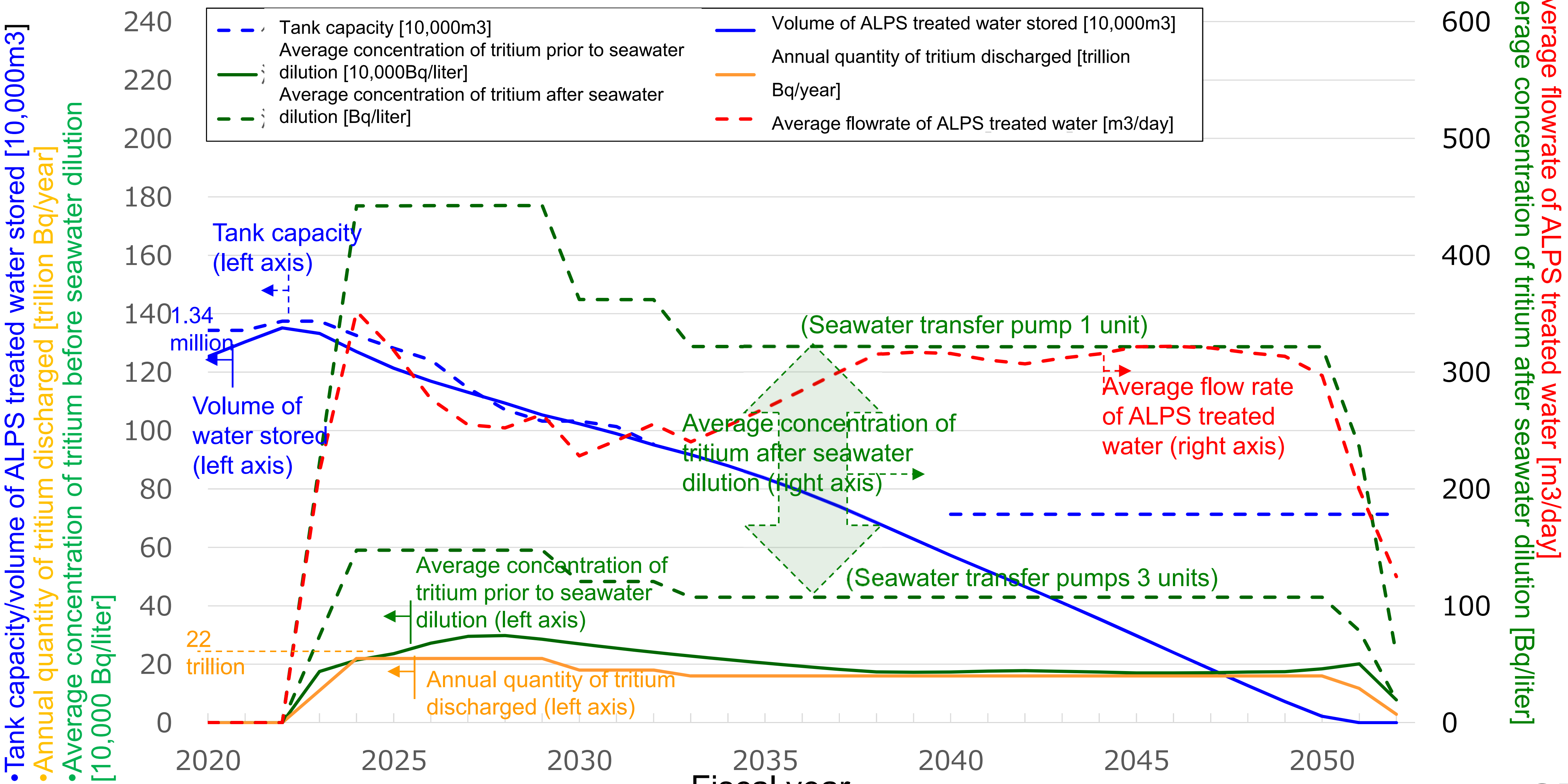
- By combining ALPS treated water tritium concentration, ALPS treated water flow rate and seawater flow rate, keep tritium concentration after seawater dilution below 1,500 Becquerel/ liter, and realize a facility that can reliably continue discharge of ALPS treated water.



The Japanese version shall prevail.

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater
[Supplement] Discharge simulation (the total amount of tritium in the buildings is maximum)

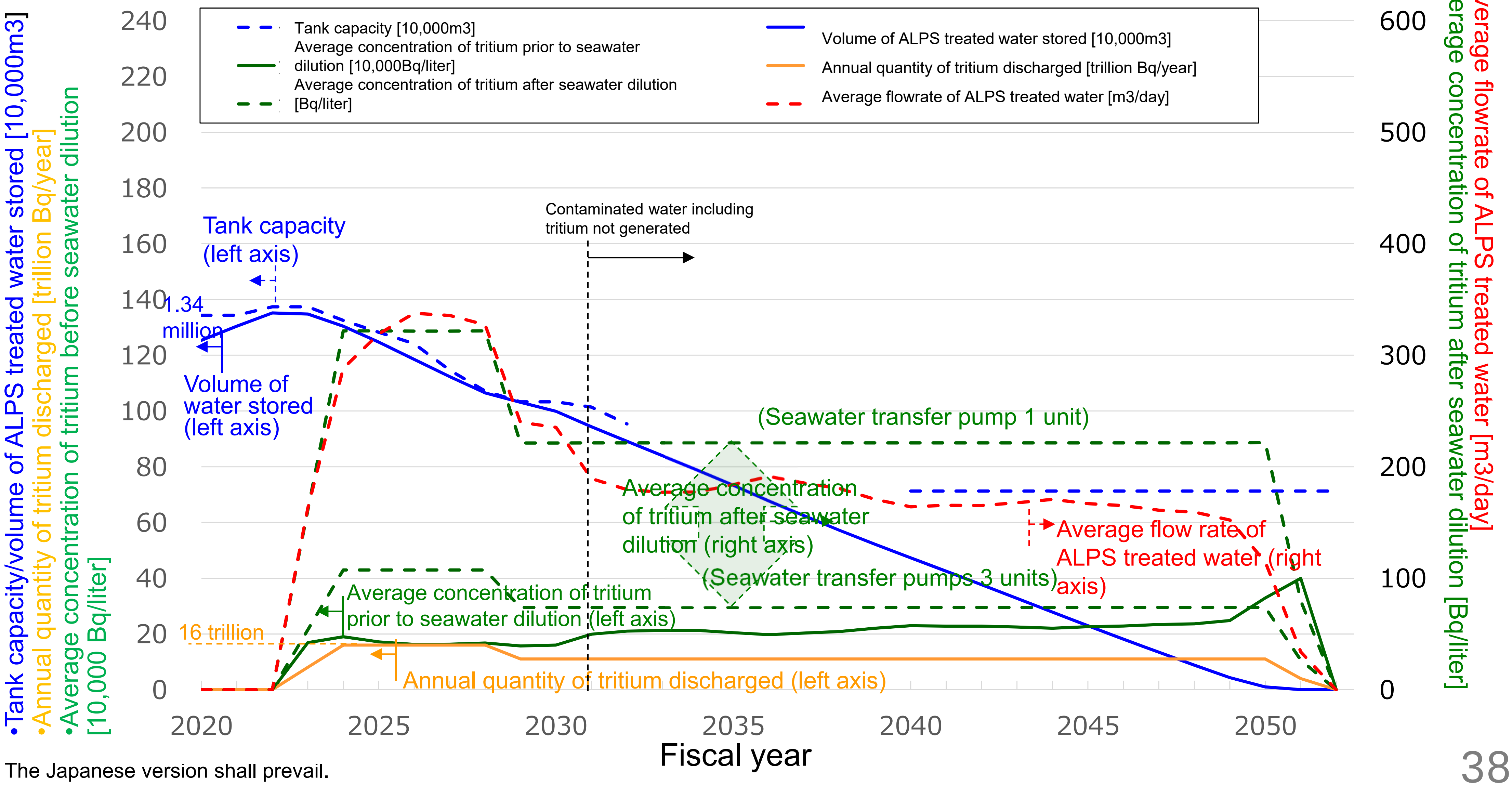
- FY2023: 11 trillion Bq/year (carefully start with discharging small amounts = set to be half the volume of that in and after FY2024)
- FY2024-FY2029: 22 trillion Bq/year
- FY2030-FY2032: 18 trillion Bq/year
- In and after FY2033: 16 trillion Bq/year



The Japanese version shall prevail.

2-1 (1) [1] Control and monitoring of mixing/dilution ratio of ALPS treated water with seawater [Supplement] Discharge simulation (the total amount of tritium in the buildings is the minimum)

- FY2023: 8 trillion Bq/year (carefully start with discharging small amounts = set to be half the volume of that in and after FY2024)
- FY2024-FY2028: 16 trillion Bq/year
- In and after FY2029: 11 trillion Bq/year



The Japanese version shall prevail.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [5]

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

(1) Facilities for discharging into the sea

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

- The reason why the mini-flow line installed at the ALPS treated water transfer pump outlet is connected to the measurement/confirmation tank should be explained .
- Equipment for which the most severe single failure is assumed should be indicated, including the valve body itself and the detectors and electrical signal systems necessary to cope with abnormal events.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-1. Extraction of specific abnormal events

TEPCO

- In discharging ALPS treated water into the sea, the discharge of ALPS treated water into the sea without meeting the conditions specified in the plan is defined as "unintentional discharge of ALPS treated water into the sea," which is the top event in the examination. Events that unsatisfied each of the conditions specified in the plan are defined as the specific contents of the top event.

No.	Scheduled contents		Remarks
1	Water to be discharged	ALPS treated water	The sum of the ratios to regulatory concentrations limits of radioactive materials other than tritium is less than 1.
2	Discharge method	The drainage concentration for tritium, which is difficult to remove, should be less than 1,500 Bq/L.	The flow rate of ALPS treated water is determined based on the tritium concentration of ALPS treated water checked in advance and the seawater flow rate.
		When discharging, the ALPS treated water must be diluted to a large extent (100 times or more) with seawater.	Based on the maximum flow rate of ALPS treated water of 500 m^3/day and the seawater transfer pump of 170,000 m^3/day per unit, even if a single seawater transfer pump is in operation, it is possible to dilute 340 times.
3	Discharge routes	Transfer at the Transfer facility and discharge into the sea through the Dilution facility.	

Top event

Unintentional discharge of ALPS treated water into the sea

Abnormal event

[Definition (1)]
Discharge radioactive materials with an incomplete measurement and check (insufficient measurement/confirmation)

[Definition (2)]
Discharge with tritium concentration equal to or greater than 1,500 Bq/L or less than 100 times dilution.
(insufficient dilution with seawater)

[Definition (3)]
Leakage from facilities
(failing to dilute with seawater)

: Revised description

The Japanese version shall prevail.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-2. Extraction of initiating eventss and causes leading to abnormal events (1/2)

- Using Master Logic Diagram (MLD)*, an abbreviated fault tree, analysis was carried out on whether an abnormal event would occur or not at the ALPS treated water dilution/discharge facilities.
- In developing the MLD, a systematic analysis was carried out under the MLD concept with our members engaged in machinery, electricity, and instrumentation related to the facility design, and supervised by the members involved in safety and risk assessment.
- As a result of the analysis, we have confirmed a need for redundancy for the ALPS treated water flow meter.

*MLD is a top-down analysis method to identify initiating events from top events, revealing the initiating events and causes that would result in abnormal events.

	Contents
Level 1	The top event, "Unintentional discharge of ALPS treated water into the sea," is set.
Level 2	Three abnormal events defined as top events are set (see (1) - (3) below).
Level 3	As for the abnormal events defined in Level 2, specific events that may lead to abnormal events are identified with reference to facility specifications, P&ID, IBD, equipment layout drawings, and operating procedures, focusing on the functions expected in each process.
Level 4	Equipment single failure, misoperation, or single misoperation by the operator anticipated with this facility in service, leading up to Level 3, and disturbances expected to occur with similar frequency to those mentioned above are extracted.
Level 5	Relative to the Level 4 initiating events, the validity of the facility design and operation measures are checked.

Level 1 Top events → **Level 2** Definition of an abnormal event → **Level 3** Specific events → **Level 4** Initiating events → **Level 5** Countermeasures (Design and operation aspects) → **Level 6** Impacts in the case of assuming a single failure of the impact mitigation function

[1] Discharge radioactive materials with an incomplete measurement and check
[2] Discharge with insufficient dilution with seawater
[3] Leakage from facilities

Validation of facility design and operation
(Proper implementation of measures prevents the occurrence of Level 6).

: Revised description

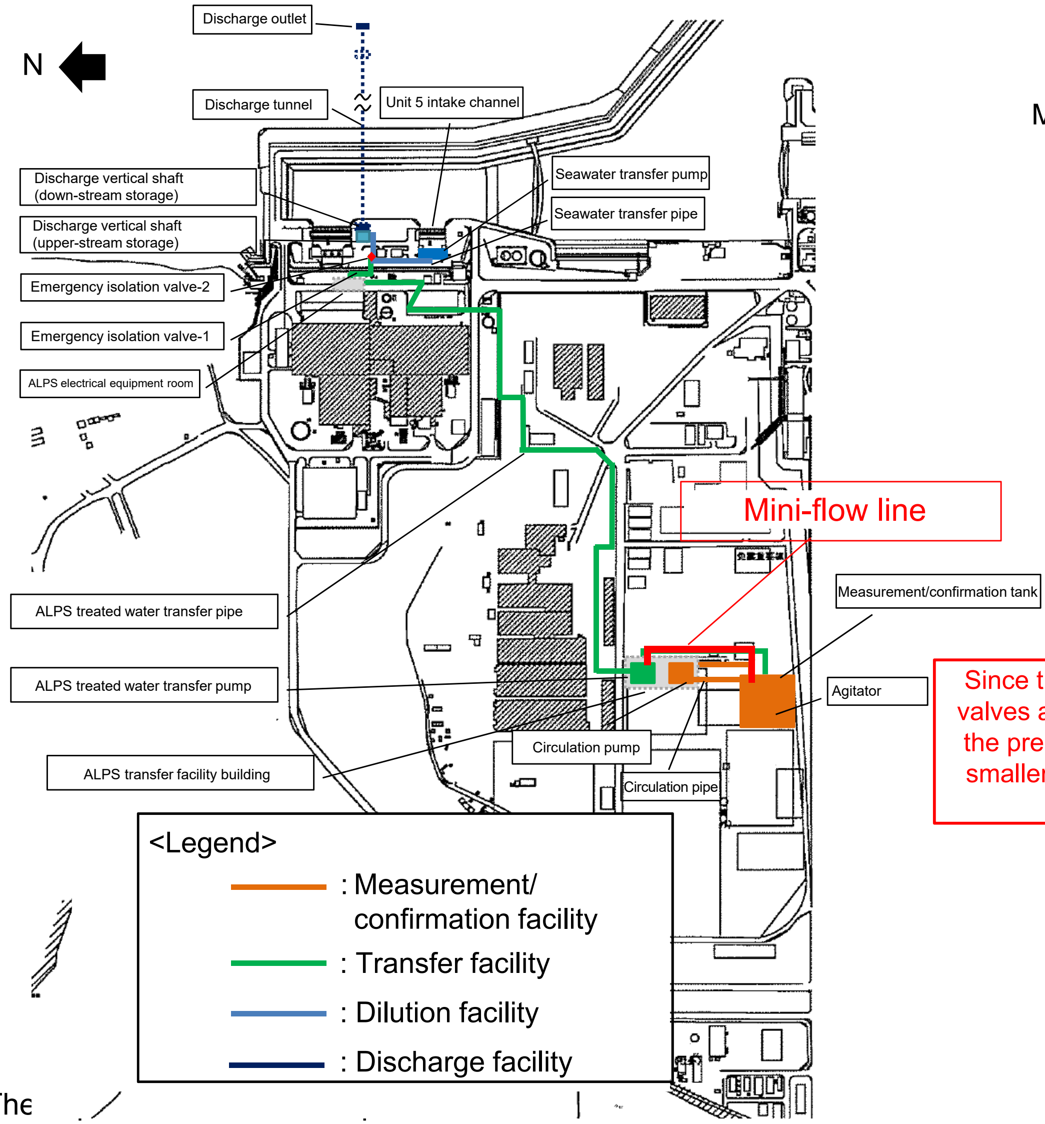
Evaluation method using master logic diagram (MLD)

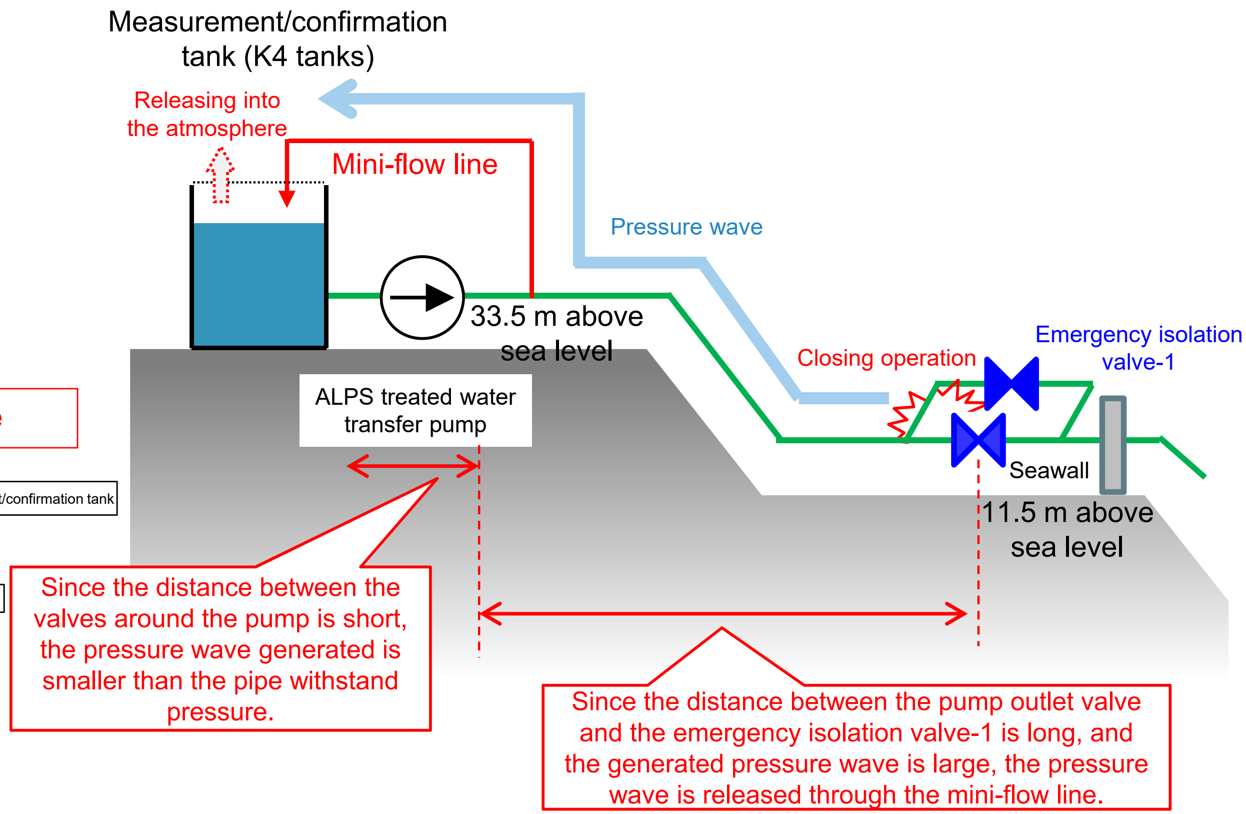
The Japanese version shall prevail.

[5]-3. Design concept of the ALPS treated water dilution/discharge facilities (1/3)

TEPCO

- The mini-flow line is installed to prevent damage to the pump by returning a portion of the pump discharge amount to the upper-stream so that the minimum discharge amount can be secured even if the pump is closed at the discharge side.
- When closing operation is caused by malfunction of an MO valve or the like, damage to facilities such as pipes will be prevented by releasing generated pressure waves to the opening atmosphere (measurement/ confirmation tank) through the mini-flow line.



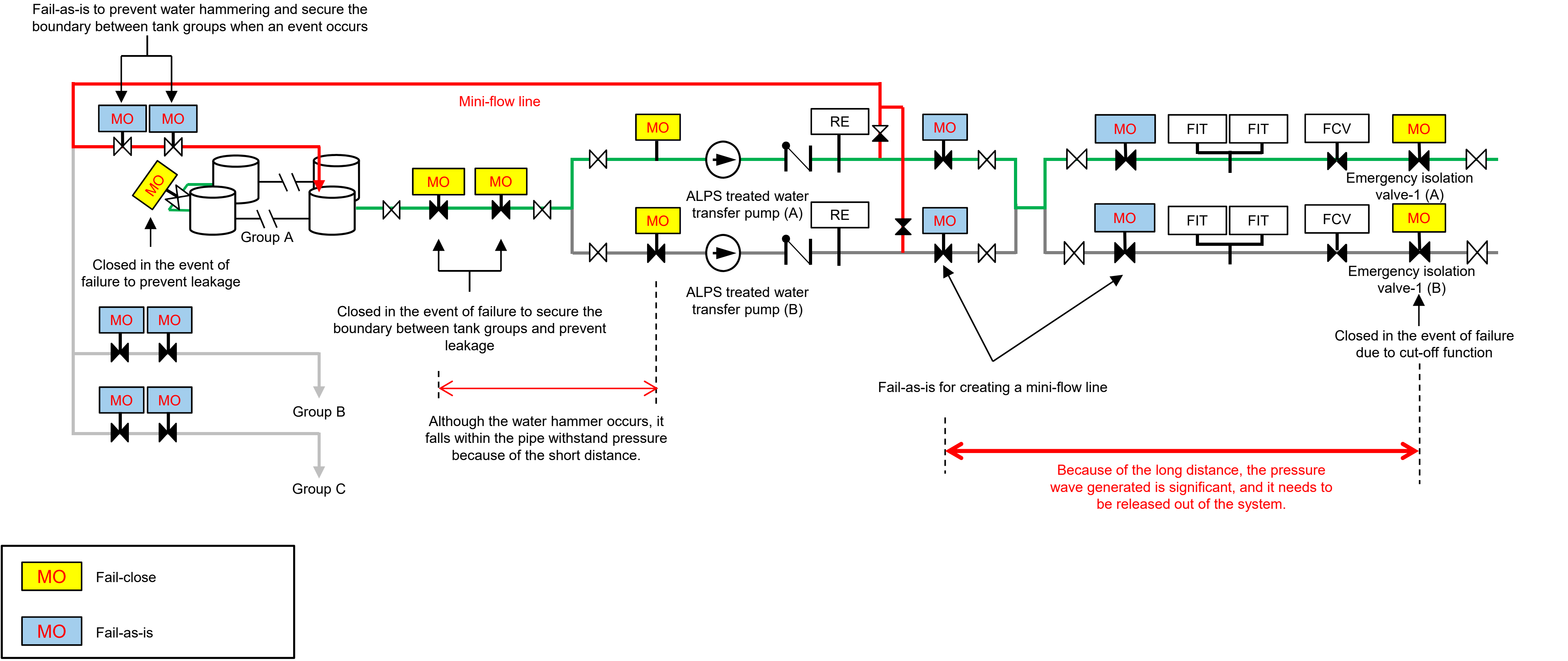


The

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-3. Design concept of the ALPS treated water dilution/discharge facilities (2/3)

TEPCO

- On the other hand, if the emergency isolation valve-1 (MO valve) with a fail-close function and the valve of the same type are closed simultaneously due to a loss of off-site power supply or other events, the pressure wave generated in a part of the transfer pathway will exceed the pipe withstand pressure. Based on this, the operating conditions will be changed to have the mini-flow line path, as shown in the figure below.



The Japanese version shall prevail.

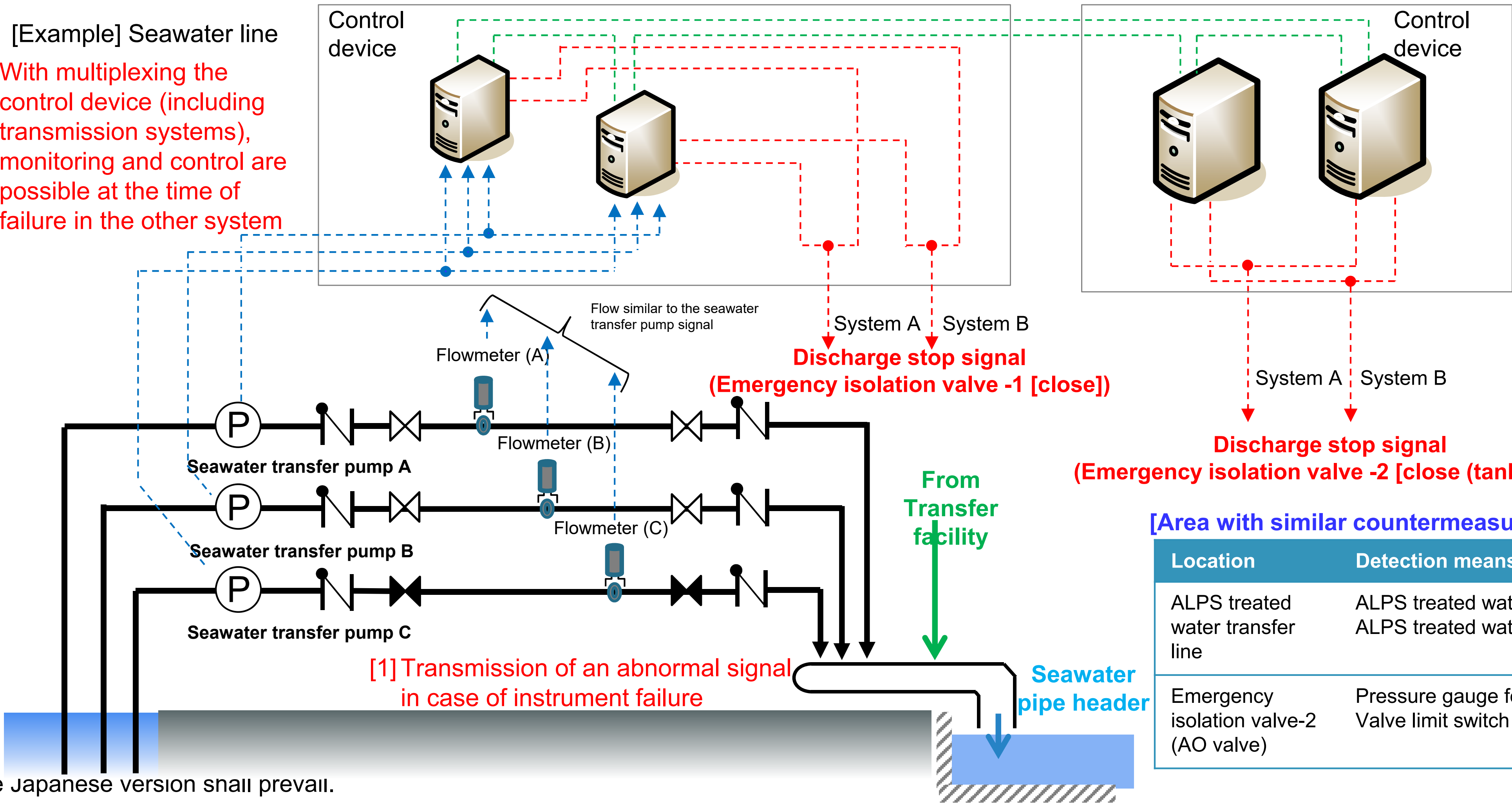
2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-3. Design concept of the ALPS treated water dilution/discharge facilities (3/3)

TEPCO

- Instruments required to cope with abnormal events (ALPS treated water flow meter, seawater flow meter, etc.) are designed to issue an alarm to stop the discharge when the instruments fail.
- The transmission system, including the control device, is multiplexed. With this design, in the event of a single failure, monitoring and control can be performed by the control device and transmission system in another system. (No loss of functions such as emergency isolation)
- In addition, in the event of a pump abnormality, the abnormality signal is transmitted to the control device, and the control can be performed according to the abnormal condition.

[Example] Seawater line

[2] With multiplexing the control device (including transmission systems), monitoring and control are possible at the time of failure in the other system



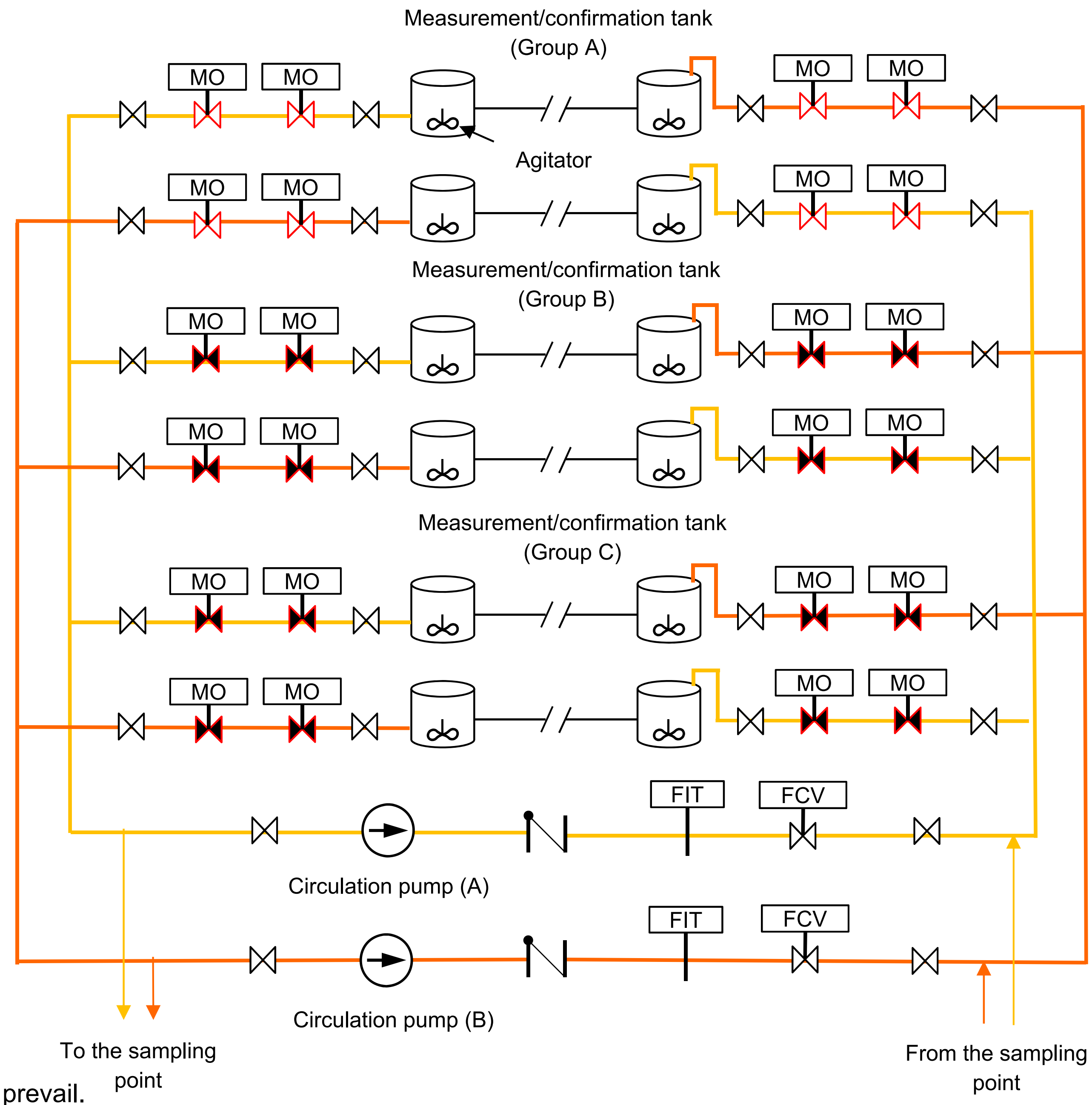
[1] Transmission of an abnormal signal in case of instrument failure

[Area with similar countermeasures]

Location	Detection means
ALPS treated water transfer line	ALPS treated water transfer pump ALPS treated water flowmeter x 2
Emergency isolation valve-2 (AO valve)	Pressure gauge for compressed air Valve limit switch

The Japanese version shall prevail.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[Reference] Design of measurement/confirmation facilities

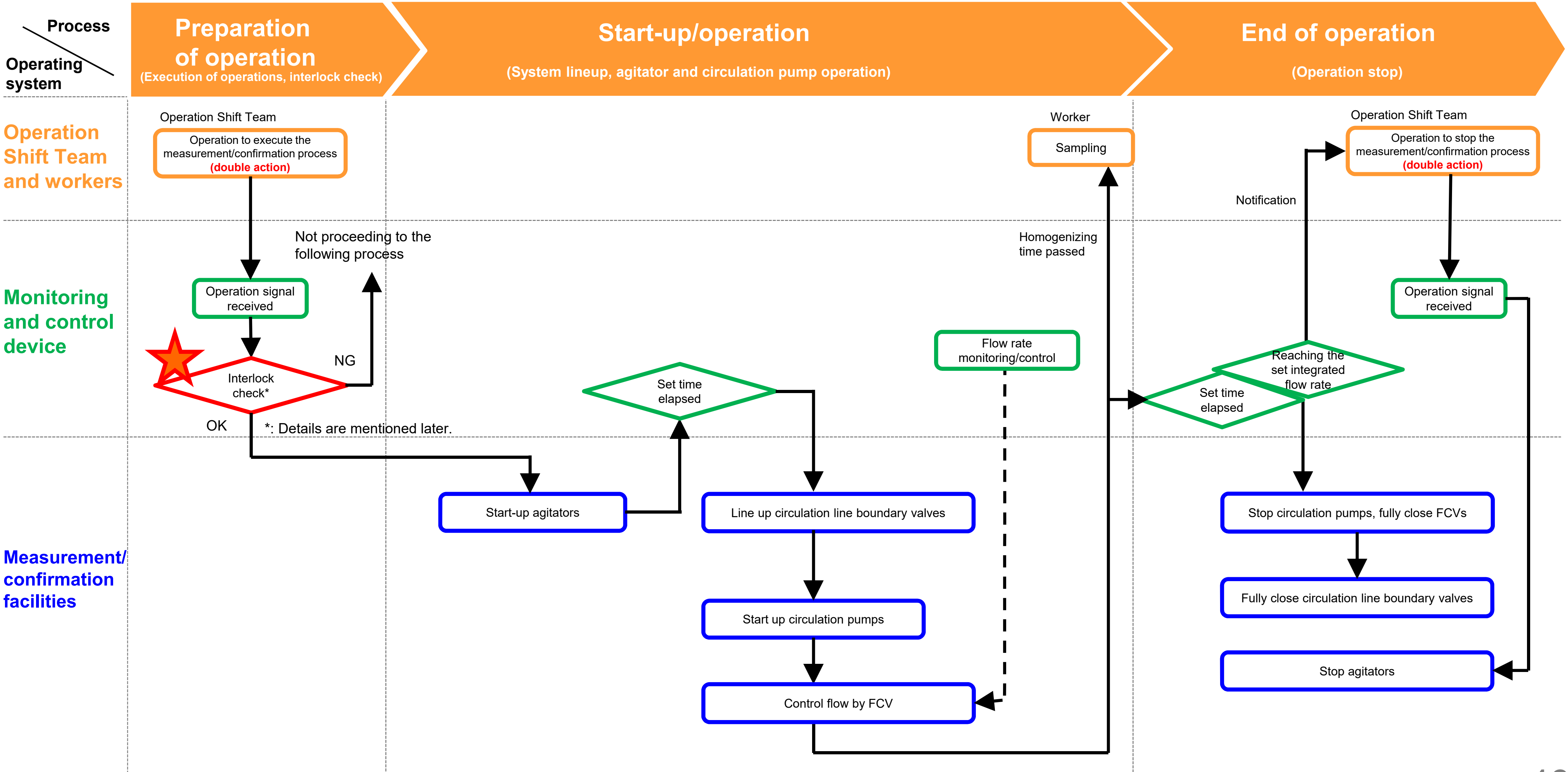


<Abbreviations>
MO: Motor-operated
FCV: Flow rate control valve
FIT: Flow indicator

*: The motor-operated facilities should be capable of receiving power even when switching between Systems A and B.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[Reference] Operating procedures for measurement/confirmation facilities

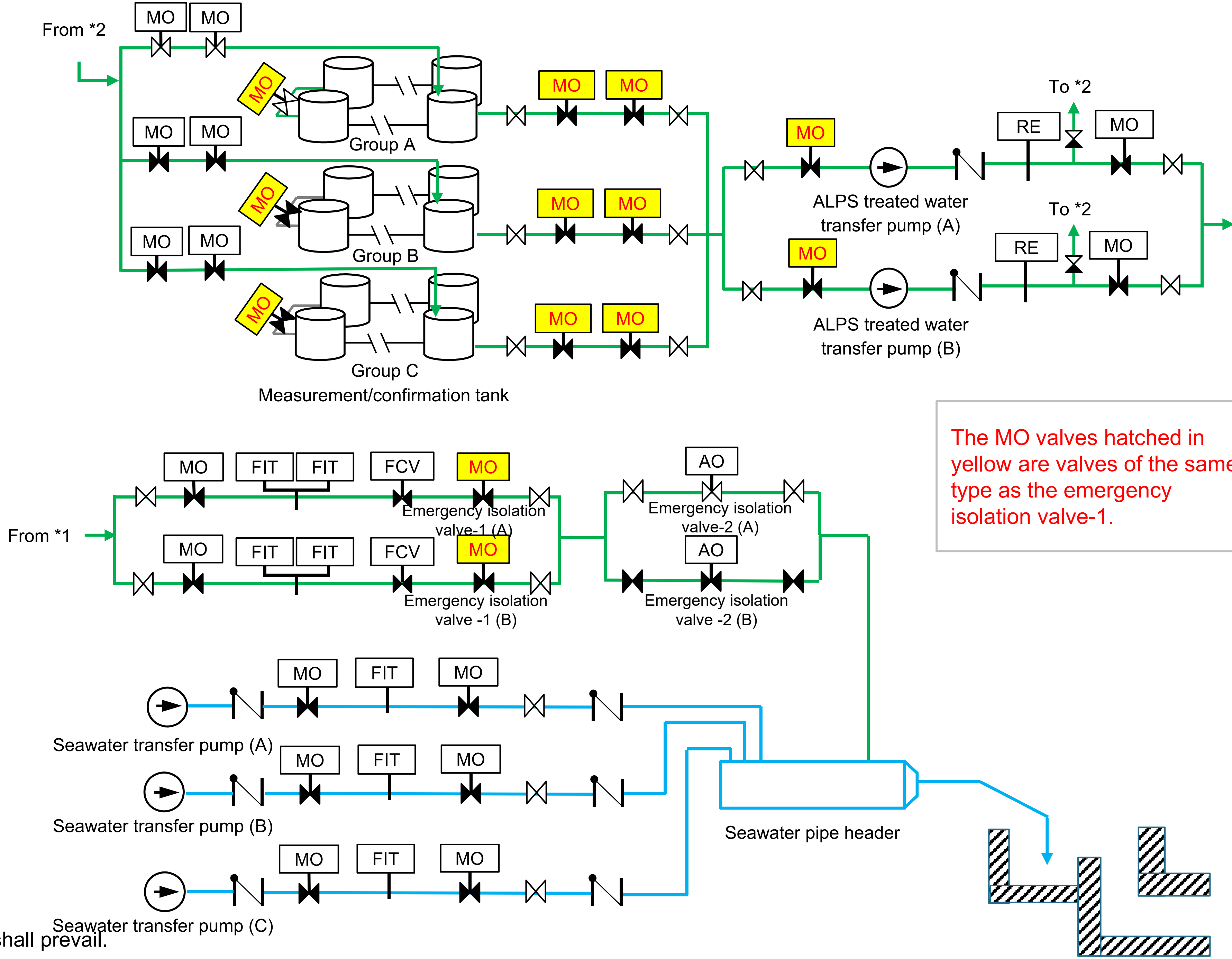
- The operating procedures for the measurement/confirmation facilities are as follows.
  - The measurement/confirmation process is designed to start operation automatically after selecting the target tank group and executing the operation procedure.
  - To prevent mixing and accidental discharge of water between tank groups, a monitoring and control device is provided with an interlock to check that only selected tank groups are in the measurement/confirmation process and that the boundary valves are fully closed.



The Japanese version shall prevail.

[Reference] Design of Transfer facility/Dilution facility

TEPCO



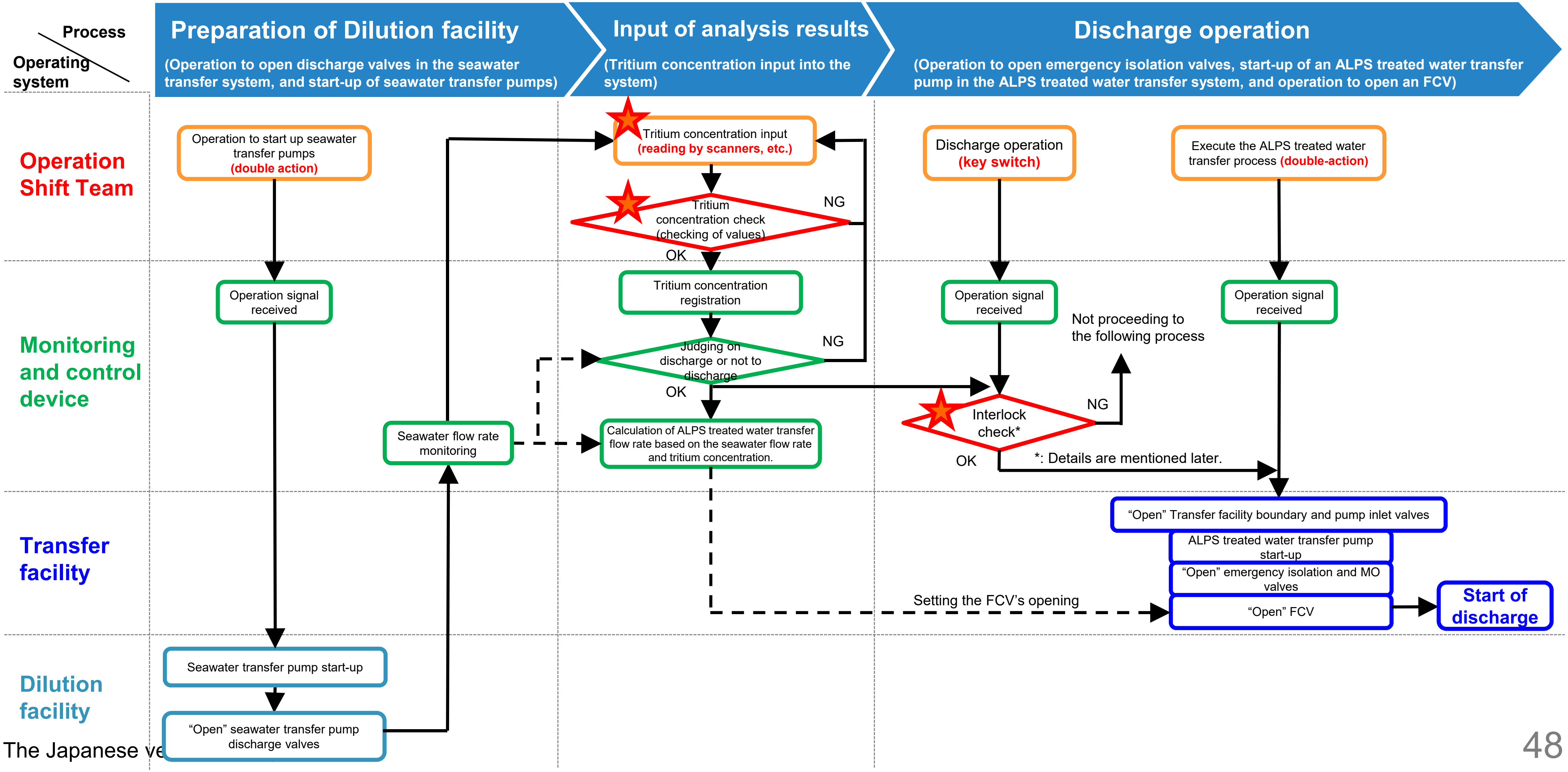
The MO valves hatched in yellow are valves of the same type as the emergency isolation valve-1.

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

The Japanese version shall prevail.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[Reference] Operating procedures for Transfer facility/Dilution facility

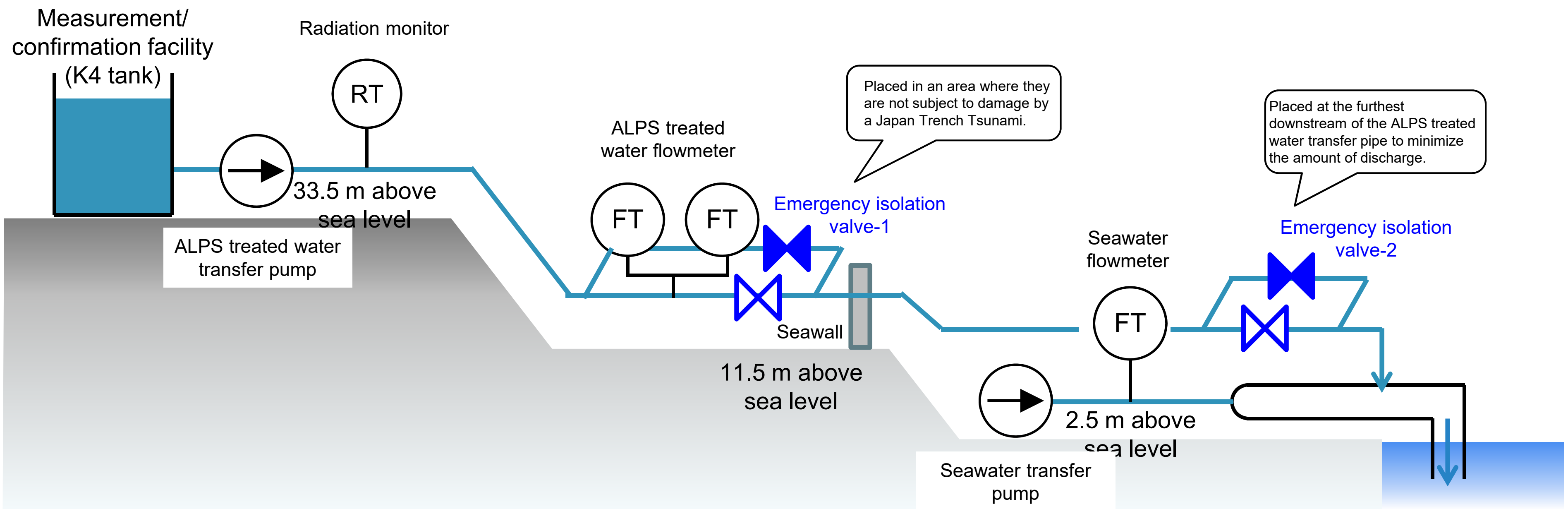
- The operating procedures for discharging ALPS treated water are as follows.
  - To prevent human error, the tritium concentrations should be mechanically imported to the monitoring and control device, such as by scanners (several people will check if the entered values are correct).
  - To prevent accidental discharge, the monitoring and control device is provided with an interlock to check that selected tank groups have completed the measurement/confirmation process and that the boundary valves of other tank groups are fully closed.



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

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

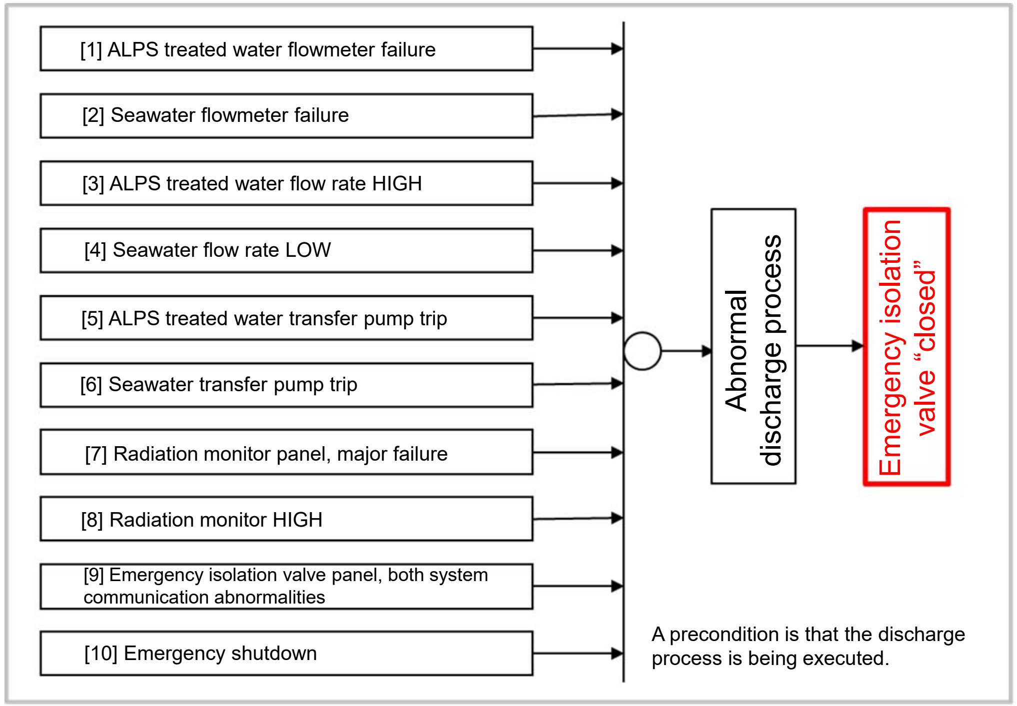
Design	Emergency isolation valve-1	Emergency isolation valve-2
Location of installation	Location not subject to damage by tsunami	Placed at the furthest downstream of ALPS treated water transfer pipe to minimize the amount of discharge during valve operation.
Operating system	Motor-operated (it takes 10 seconds from opening to closing)	AO (it takes 2 seconds from opening to closing)
Concept of design	Two systems are installed and, in the event of failure and maintenance, the system can be switched by opening and closing the front and rear valves to keep the facility availability.	(Same as on the left)



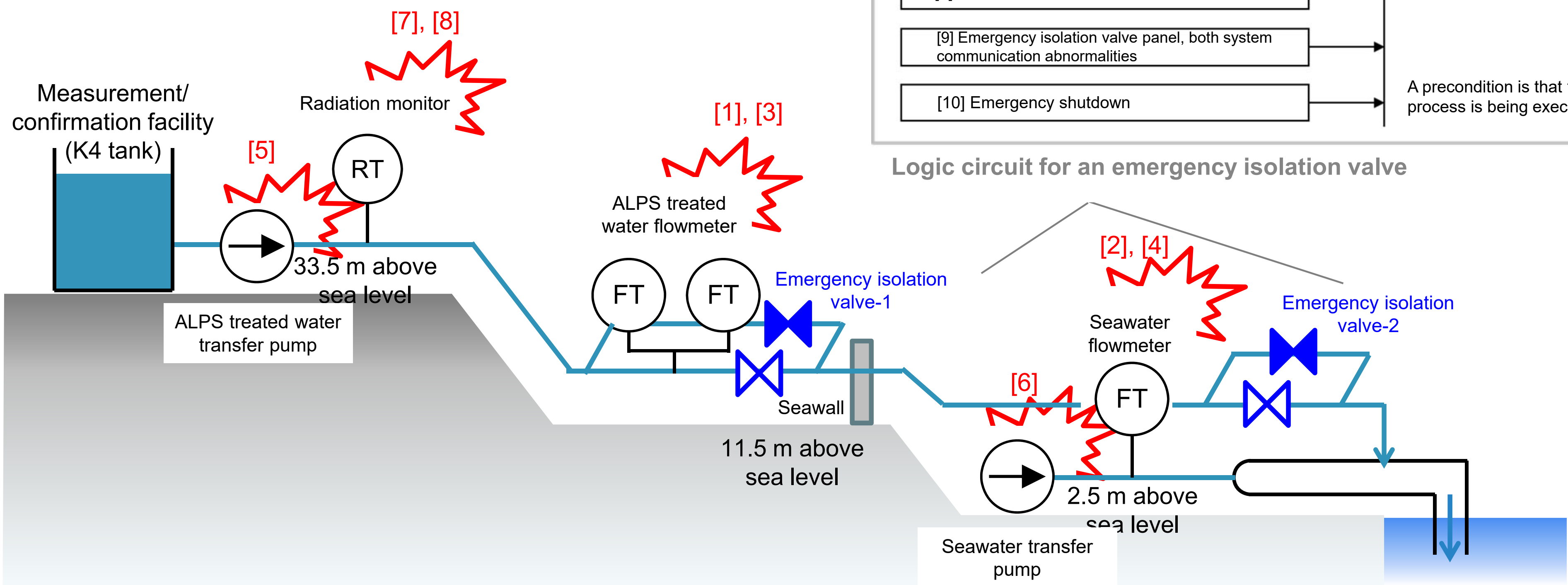
The Japanese version shall prevail.

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

- The operating conditions under which the emergency isolation valve is "closed " are as shown in the figure below, which is 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 an emergency isolation valve

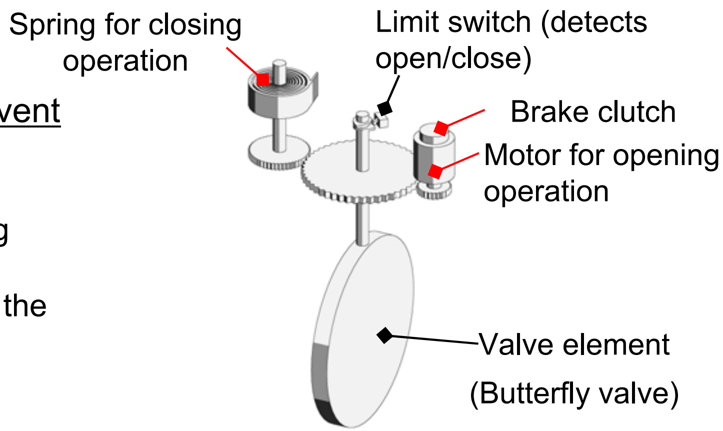


2-1 (1) [6] Validity assessment of the facility design in the event of failure
[Reference] Operating conditions of the emergency isolation valve

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

Emergency isolation valve-1 (MO valve)

- ➢ Spring return type motor-operated emergency isolation valve, which closes fully in the event of loss of power
  - The motor will start up to wind the spring to fully open the valve.
  - 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.

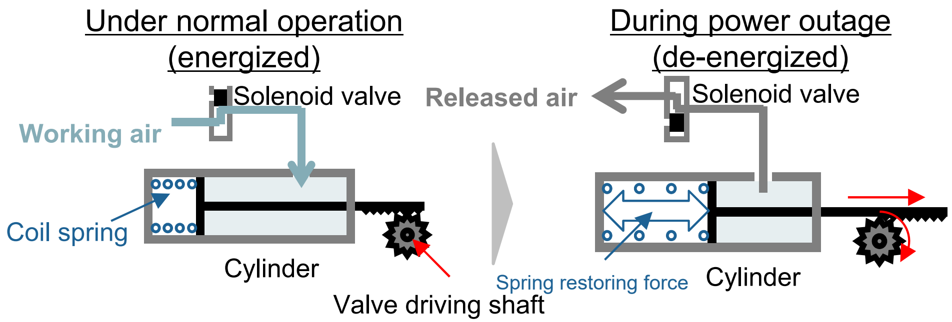


Outline of the structure of emergency isolation valve-1

Emergency isolation valve-2 (AO valve)

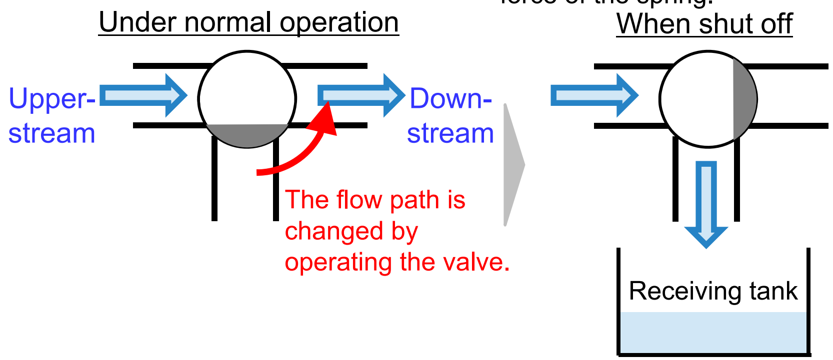
- ➢ Air-operated emergency isolation valve, which closes fully in the event of loss of power
  - The piston in the cylinder is pressurized, and the linear motion generated by the movement of the piston is converted into rotary motion (to drive the valve).
  - This valve has a coil spring in it, and when 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 is designed to shut off the discharge as quickly as possible, countermeasures against water hammers must be taken. Therefore, a three-way valve is adopted.

  → The receiving tank is designed to have a capacity of 1.1 m^3 or more, 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 piping from the emergency isolation valve-1 to the emergency isolation valve-2.



The cylinder is filled with air to maintain the valve "Open."

Once the solenoid valve is de-energized, the air in the cylinder will be released, and the valve driving shaft will be moved by the restoring force of the spring.



The Japanese version shall prevail.

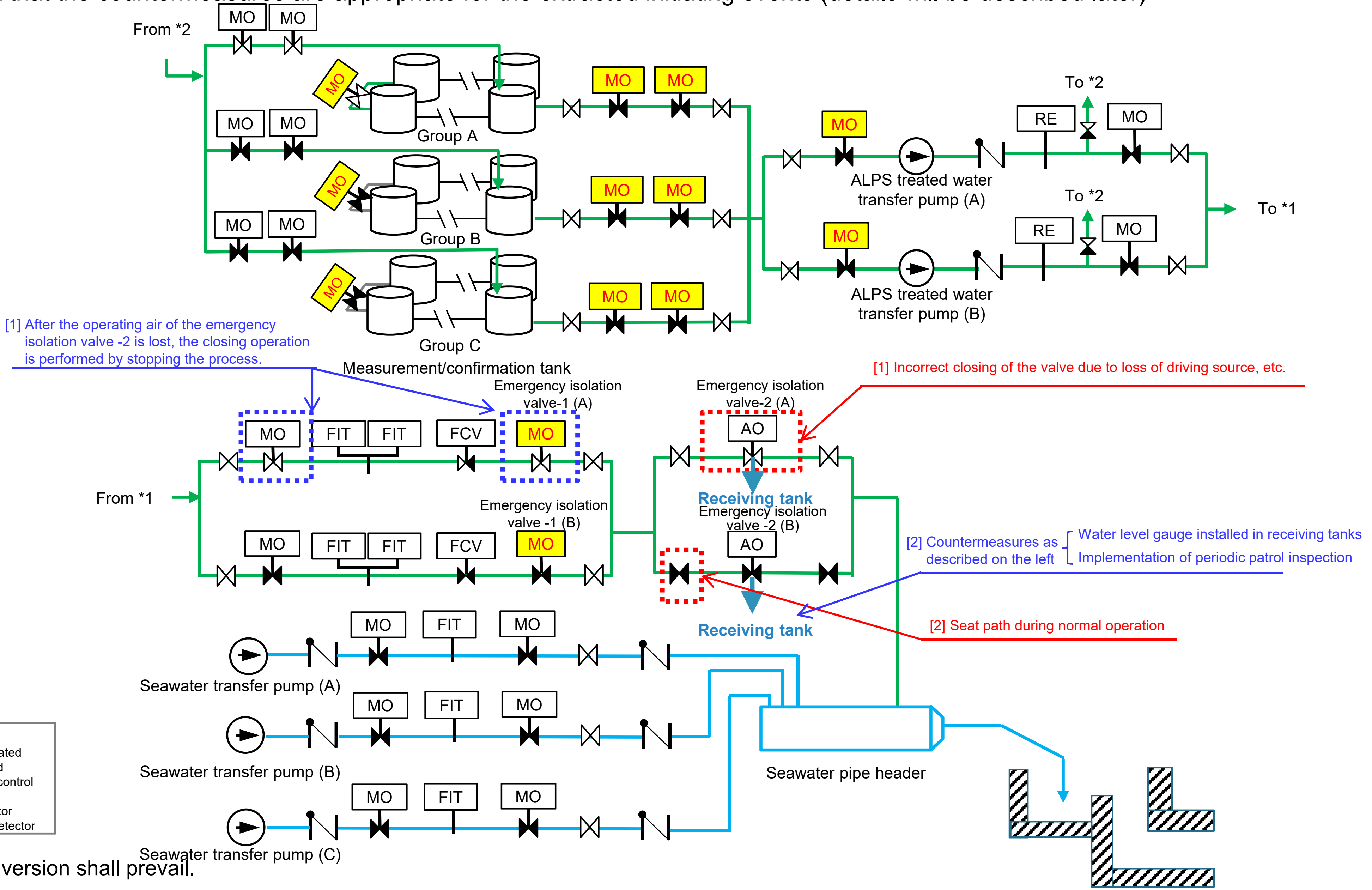
2-1 (1) [6] Validity assessment of the facility design in the event of failure

[Reference] Events leading to abnormal events due to the structure of the emergency isolation valve -2

TEPCO

- Considering that the emergency isolation valve-2 is a three-way valve, the newly extracted initiating events is an overflow of the receiving tank.

-> Check that the countermeasures are appropriate for the extracted initiating events (details will be described later).



<Abbreviations>
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
[5]-4. Results of analysis using MLD

- Based on the above design, the evaluation results added and modified with the MLD are as follows.

-> As in the previous report, it has been confirmed that the abnormal event (1) "Discharge of radioactive materials with an incomplete check" would not occur.

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Initiating events: Timing of occurrence	Initiating events: Abnormality category	Initiating events: Contents	Countermeasures (AND condition)	Impact
Unintentional discharge of ALPS treated water into the sea	[1] Discharge radioactive materials with an incomplete check	Inadequate sampling	Measurement /confirmation process	HE	When selecting a tank group for water sampling, wrong ones are selected (double action input failure)	• Set up interlock check • Check the status of valve opening/closing during water sampling	(Prevention)
				Facility (static)	Water from tank groups other than the target tank group is mixed into the water sampling point.	• Make tank inlet valves and outlet valves dual-redundant, respectively. • Check the status of valve opening/closing during water sampling • Perform time-based maintenance for the circulation line switching valves at appropriate times	(Prevention)
				HE	Wrong sample for analysis	• Workers and analysts to check by matching the analysis instructions with sample bottles	(Prevention)
		Inadequate analysis	Measurement /confirmation process	HE	Incorrect analysis procedure	• Check by matching the internal analysis results with the third-party analysis results	(Prevention)
				HE	Analytical results of different samples are notified to the Discharge and Environmental Radiation Monitoring Group Manager	• Notify data in the core system without transcription • Analysts to check trends of results	(Prevention)

The Japanese version shall prevail.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-4. Results of analysis using MLD

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Initiating events: Timing of occurrence	Initiating events: Abnormality category	Initiating events: Contents	Countermeasures (AND condition)	Impact
Unintentional discharge of ALPS treated water into the sea	[1] Discharge radioactive materials with an incomplete check	Inadequate analysis [continued]	Measurement /confirmation process	HE	Abnormal values in the analysis results are overlooked	• Analyst to detect abnormal values from recent trends • Chemical Analysis & Evaluation Group Manager to detect abnormal values from past analysis results, etc.	(Prevention)
				HE	The analysis results of different samples are notified to the Shift Manager	• Notify data in the core system without transcription • Analysts to check trends of results	(Prevention)
		Inadequately homogenized sample	Measurement /confirmation process	Facility (active)	Insufficient agitation and circulation due to shutdown (failure) of agitator and circulation pump	• Circulation operation shutdown due to agitator shutdown • Regularly check the operation status with the monitoring and control device	(Prevention)
				Facility (active)	Lack of circulation due to declining circulating pump flow rate	• An interlock to shut down the circulation pump is activated with the circulation pump's low flow rate signal • Regularly check the flow rate with the monitoring and control device	(Prevention)
		Incorrect discharge tank	Discharge process	HE	When selecting a tank group for water sampling, wrong ones are selected (double action input failure)	• Set up interlock check • Compare the analysis results with the target tank before the discharge operation	(Prevention)

: addition of description

Countermeasures --> **Blue**: Design, **Green**: Operation

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-4. Results of analysis using MLD

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
			Initiating events				
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Timing of occurrence	Abnormality category	Contents	Countermeasures (AND condition)	Impact
Unintentional discharge of ALPS treated water into the sea	[2] Discharge with insufficient dilution with seawater Discharge	Defect in dilution	Measurement /confirmation process	HE	When the tritium concentration is registered to the monitoring and control system, a value lower than the actual value is input incorrectly (-> The opening of the FCV becomes larger).	• Mechanically input tritium concentrations to the monitoring and control system using a scanner, etc. • Several people check the values mechanically imported to the monitoring and control system	(Prevention)
			Discharge process	Facility (static)	Loss of off-site power supply	• In the event of loss of power, the emergency isolation valve-1 (MO) will be automatically closed • In the event of loss of power, the emergency isolation valve-2 (AO) will be automatically closed • It can be closed by installing a hand-operated valve in the tank inlet/outlet	(1) Discharge assuming a single failure of the emergency isolation valve
			Discharge Process	Facility (active)	When two seawater transfer pumps are in operation, one unit fails	• In the event of seawater transfer pump failure, the emergency isolation valve-1 (MO) will be automatically closed • In the event of seawater transfer pump failure, the emergency isolation valve-2 (AO) will be automatically closed • When the seawater flow rate drops below a certain level at a seawater flowmeter, the emergency isolation valve-1 (MO) will be automatically closed • When the seawater flow rate drops below a certain level at a seawater flowmeter, the emergency isolation valve-2 (AO) will be automatically closed • It can be closed by a hand-operated valve in the tank inlet/outlet • Make arithmetic units dual-redundant	(1) Discharge assuming a single failure of the emergency isolation valve
			Discharge process	Facility (active)	When three seawater transfer pumps are in operation, one unit fails	(Same as the above)	(1) Discharge assuming a single failure of the emergency isolation valve

[dotted box] : addition of description

The Japanese version shall prevail.

Countermeasures --> **Blue**: Design, **Green**: Operation

TEPCO

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-4. Results of analysis using MLD

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Initiating events			Countermeasures (AND condition)	Impact
			Timing of occurrence	Abnormality category	Contents		
Unintentional discharge of ALPS treated water into the sea	[2] Discharge with insufficient dilution with seawater Discharge	Defect in dilution [continued]	Discharge process	Facility (static)	An abnormality occurs in the indication value of the seawater flowmeter, but an interlock fails to activate	• Perform time-based maintenance for the seawater flowmeter at appropriate times • Set off an alarm if an instrument fails • Monitor the deviation of flow rate indication values of two or three seawater transfer pumps, and when the deviation exceeding the instrument error is observed, set off an alarm	(Prevention)
			Discharge Process	Facility (static)	An abnormality occurs in the indication value of the ALPS treated water flow meter (-> Leading to an inadequate opening of the FCV), but an interlock fails to activate	• Perform time-based maintenance for the ALPS treated water flow meters at appropriate times • **[Addition] Make ALPS treated water flow meters dual-redundant** • Set off an alarm if an instrument fails • Set the upper limit flow rate according to the set dilution ratio, and generate an alarm when the upper limit is reached	(Prevention)
			Discharge Process	Facility (static)	FCV failure (mechanical failure such as valving element failure)	• An interlock is to be established to activate the emergency isolation valve if the indication value of the ALPS treated water flow rate does not approach the calculated value of the monitoring and control system. • **[Addition] Make ALPS treated water flow meters dual-redundant** • It can be closed by installing an emergency isolation valve -1 (MO). • It can be closed by installing an emergency isolation valve -2 (AO). • It can be closed by a hand-operated valve in the tank inlet/outlet • Make arithmetic units dual-redundant	(Prevention)

The Japanese version shall prevail.

Countermeasures --> **Blue**: Design, **Green**: Operation

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-4. Results of analysis using MLD

TEPCO

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Initiating events: Timing of occurrence	Initiating events: Abnormality category	Initiating events: Contents	Countermeasures (AND condition)	Impact
Unintentional discharge of ALPS treated water into the sea	[2] Discharge with insufficient dilution with seawater	Defect in dilution [continued]	Discharge Process	Facility (static)	Leakage occurs at the downstream flange of the seawater flowmeter	• Use of seawater transfer pumps with sufficient capacity to meet the required functions • Implementation of periodic patrol inspection	(Prevention)
	[3] Leakage from facilities	Leakage	Constantly (including during inspection)	Facility (static)	[Reference] Complete destruction of three tank groups*	• In the event of an earthquake (seismic intensity 5 lower or higher), the system will be shut down	Assess the impact resulting from the loss of functions
			Constantly (including during inspection)	Facility (static)	[Reference] Transfer pipe rupture*		

*: Assuming the occurrence of an earthquake exceeding the seismic category (C class) of this facility.

The Japanese version shall prevail.

Countermeasures --> **Blue**: Design, **Green**: Operation

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-4. Results of analysis using MLD

TEPCO

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
			Initiating events				
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Timing of occurrence	Abnormality category	Contents	Countermeasures (AND condition)	Impact
Unintentional discharge of ALPS treated water into the sea	[3] Leakage from facilities	Leakage	Constantly (including during inspection)	Facility (static)	Leakage from the circulation pipe flange	• Implementation of periodic patrol inspection • The connection between the PE tubes should be a fusion structure. • Installation of foundation weirs around tanks with flanges • Installation of weirs and leakage detectors around circulation pumps with flanges	(Prevention)
			Constantly (including during inspection)	Facility (static)	Leakage from the transfer pipe flange between the tank outlet and the MO isolation valve	• Implementation of periodic patrol inspection • The connection between the PE tubes should be a fusion structure. • Installation of foundation weirs around tanks with flanges • Installation of weirs and leakage detectors around transfer pumps/MO valves with flanges	(Prevention)
			Constantly (including during inspection)	Facility (static)	Leakage from the transfer pipe flange between the MO isolation valve and the AO isolation valve	• Implementation of periodic patrol inspection • The connection between the PE tubes should be a fusion structure. • Installation of weirs and leakage detectors around MO/AO valves with flanges	(Prevention)
			Constantly (including during inspection)	Facility (static)	Leakage from the transfer pipe flange between the seawater pipe header and the AO isolation valve	• Implementation of periodic patrol inspection • The connection between the PE tubes should be a fusion structure. • Installation of weirs and leakage detectors around AO valves with flanges	(Prevention)

The Japanese version shall prevail.

Countermeasures --> **Blue**: Design, **Green**: Operation

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[5]-4. Results of analysis using MLD

Level 1	Level 2	Level 3	Level 4			Level 5	Level 6
			Initiating events				
Top events	Definition of an abnormal event (OR condition)	Specific events (OR condition)	Timing of occurrence	Abnormality category	Contents	Countermeasures (AND condition)	Impact
Unintentional discharge of ALPS treated water into the sea	[3] Leakage from facilities	Leakage	Discharge Process	Facility (static)	For the emergency isolation valve -2 (AO valve), overflow of the receiving tank due to loss of the drive source (compressed air), etc.	• Implementation of periodic patrol inspection • The limit switch of the air-operated valve can detect the switching of the discharge point (with an interlock to stop discharge) • The operation of the AO valve can be detected from the pressure gauge of compressed air (with an interlock to stop discharge). • Installation of a water level gauge (electrode type) in receiving tanks (detection only)	(Prevention)
			Discharge process	Facilities (active)	During discharge, the receiving tank overflowed by the front valve seat path of the emergency isolation valve -2 (AO valve) at the side of stopping the release.	• Implementation of periodic patrol inspection • Installation of a water level gauge (electrode type) in receiving tanks (detection only)	(Prevention)

: addition of description

The Japanese version shall prevail.

Countermeasures --> **Blue**: Design, **Green**: Operation

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [6]

(2-1 Review based on the Nuclear Reactor Regulation Act)

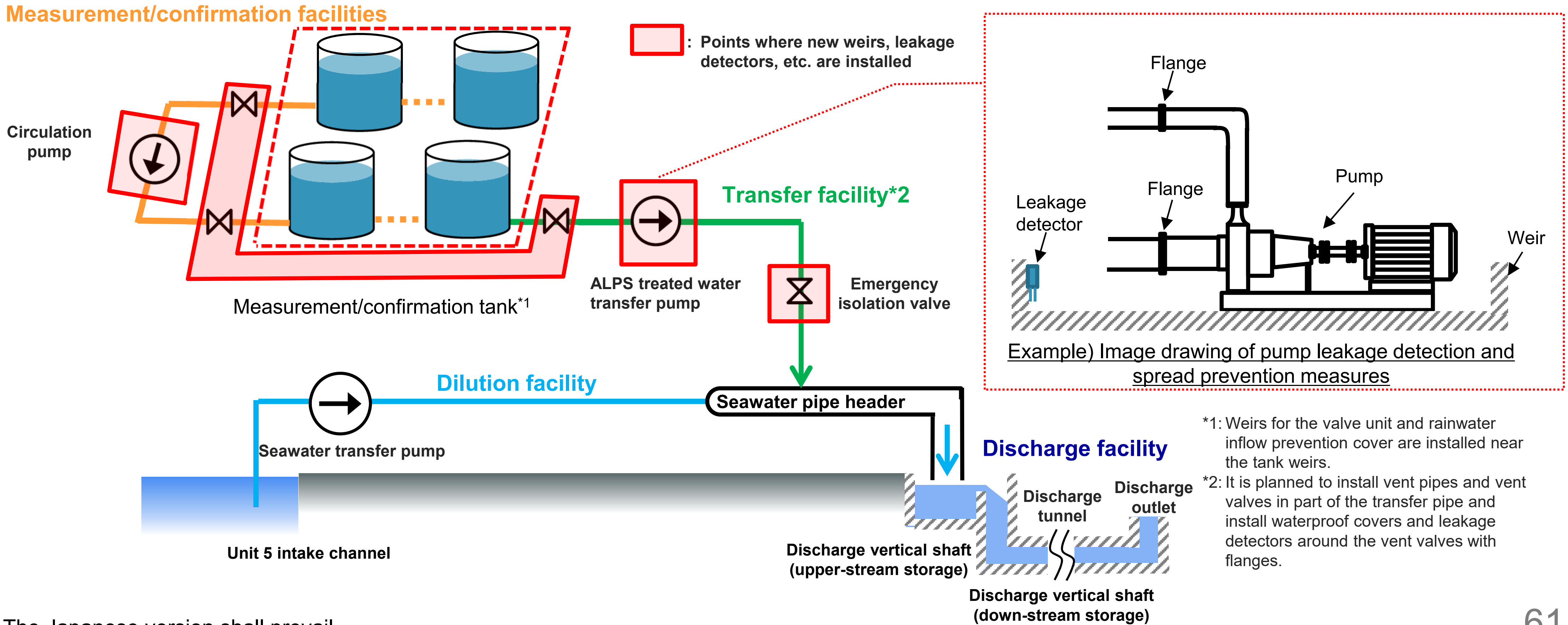
(1) Facilities for discharging into the sea

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

- If a failure of static facilities, etc., unintended discharge of ALPS treated water can be prevented by installing weirs and leakage detectors, periodic patrol inspections, etc. The validity of the measures should be demonstrated quantitatively by appropriately setting the amount of leakage.

[6]-1. Measures to prevent leakage from spreading

- As measures to prevent the spreading of leakage in the ALPS treated water dilution/discharge facilities, weirs will be installed around the circulation pump, ALPS treated water transfer pump, an emergency isolation valve, and inside the weir a leakage detector will be placed.
- A leakage detection alarm will be displayed such as in the central monitoring room of the seismic isolation building. Operators will check the status of operation monitoring parameters such as flow rate, so that they take appropriate measures such as operating and shutting down the pump. (Implementation Plan II-50-Attachment 2-1).
  - Specifically, when an alarm of leakage detection is issued, operators promptly stop the discharge of ALPS treated water into the sea to prevent the expansion of leakage.



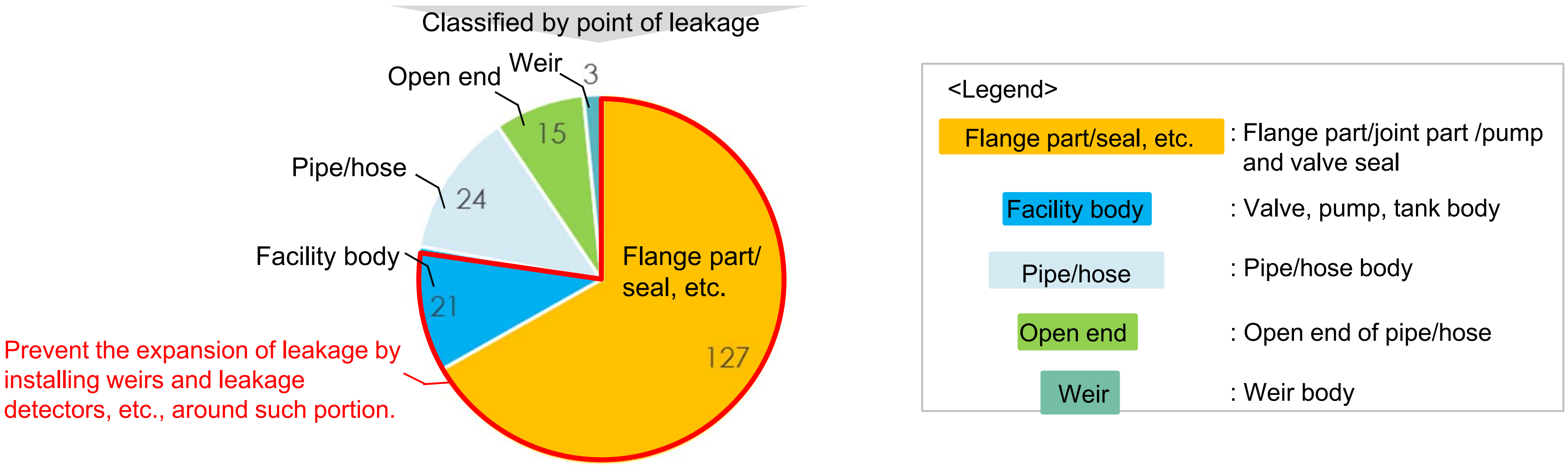
*1: Weirs for the valve unit and rainwater inflow prevention cover are installed near the tank weirs.
*2: It is planned to install vent pipes and vent valves in part of the transfer pipe and install waterproof covers and leakage detectors around the vent valves with flanges.

[6]-2. leakage incidents at the Fukushima Daiichi NPS after the 3.11 Earthquake

TEPCO

- Leakage incidents, which have occurred at the Fukushima Daiichi NPS since the 3.11 Earthquake, are the incidents most likely to occur from the facilities themselves, such as flanges and seals (see the figure below).
- Based on this, in the ALPS treated water dilution/discharge facilities, to prevent the leakage from the main body of the facility such as flanges/seals, weirs and leakage detectors will be installed around such portion.

leakage incidents at specified nuclear facilities since the 3.11 Earthquake: 190 cases



➢ TEPCO's manuals, guides, etc., have been incorporated in leakage incidents from pipes/hoses and open ends other than the main flanges/seals. ALPS treated water dilution/discharge facilities have also included them to take measures.

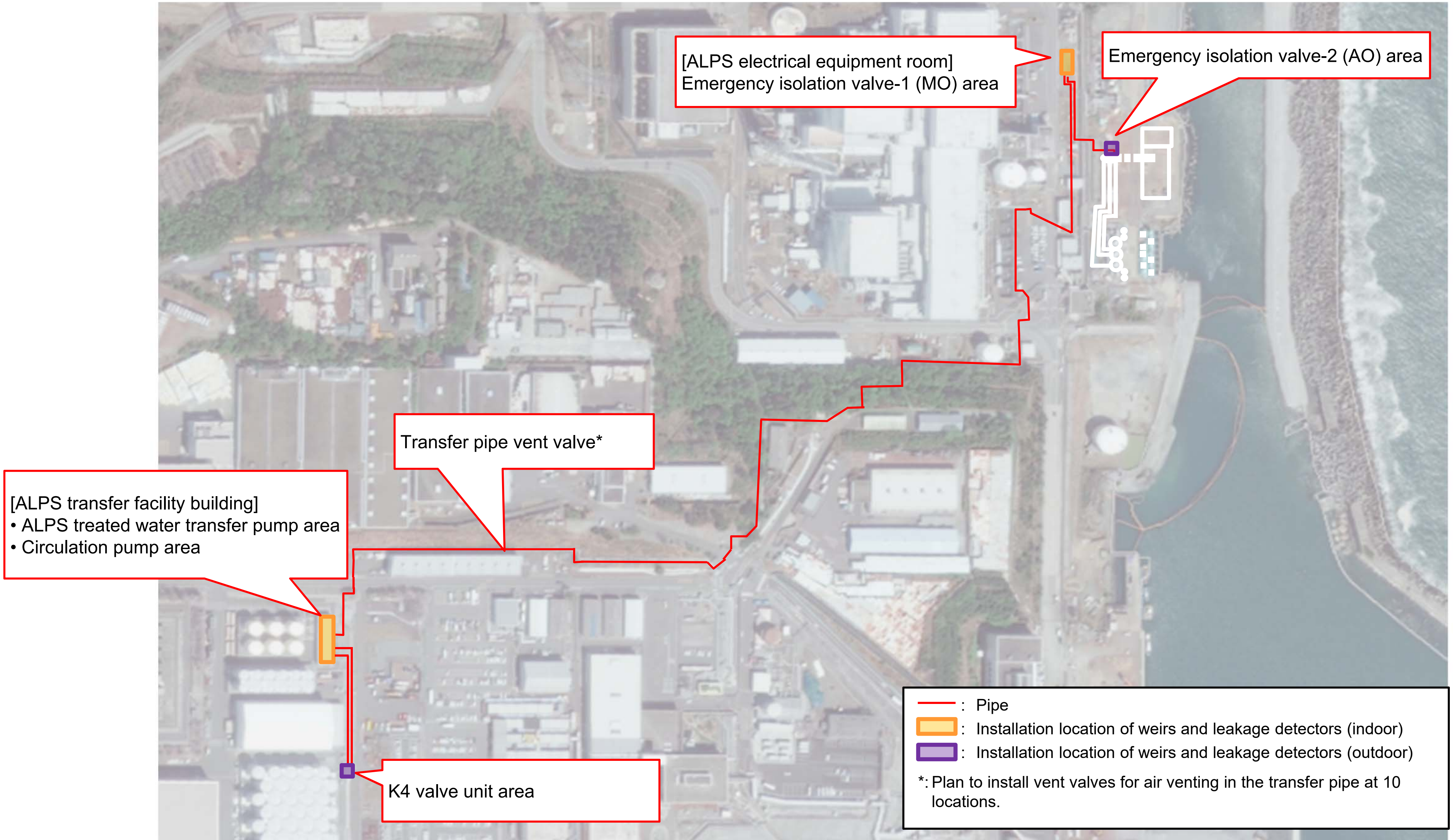
<Example of leakage incidents from pipe/hose and open end>

Leakage incidents at specified nuclear facilities since the 3.11 Earthquake		Measures at ALPS treated water dilution/discharge facilities (established in TEPCO's internal manuals, etc.)
Leakage point	Overview of the leakage	
Pipe/hose	During the transfer work to the rainwater recovery tank, a passerby or a worker in the vicinity accidentally damaged the pressure hose, causing leakage.	Fences, etc., should be installed at places where there is a risk of damage by passers-by or workers nearby.
Open end	The valve status of the existing RO-3 was changed from "closed" to "open" by mistake, resulting in leakage from the pipe.	The valve should be controlled by locking.

2-1 (1) [6] Validity assessment for the facility design in the event of failure
[6]-3. Installation locations of weirs and leakage detectors

TEPCO

- In the ALPS treated water dilution/discharge facilities, the location where weirs or leakage detectors are installed to prevent leakage from spreading is shown in the figure below. (Weirs and leakage detectors are installed in each area.)



The Japanese ve

[6]-4. Estimated amount of leakage

- Based on the results of the mockup test for the leakage incidents below and the maximum leakage amount in the past leakage incidents (flanges, seals, etc.), the estimated leakage amount was evaluated.

[Mockup test results]

- Following the "dropping of strontium treated water from the G6 tank area transfer pipe" occurred on April 20, 2016, a mockup test was conducted to measure drops from the flange to define the measurement from a leakage.
  - Test condition
    - Shape: JIS 10 K RF flange, SGP short pipe (with KV packing)
    - Reproduction of leakage using a toothpick (approx. 2 mm diameter)
    - Pipe diameter: 100 A
    - Test pressure (MPa): 1.0MPa
    - Test temperature: 10.2 °C
    - Test time: 30 minutes (1,800 seconds)
  - Test results
    - Number of drops: 1092 drops
    - Measurement volume: 185 cc

→ 0.1694 cc/drop

Status of the mockup test

[Maximum amount of leakage in past leakage incidents (flanges/seals, etc.)]

- 5 - 7 drops per second

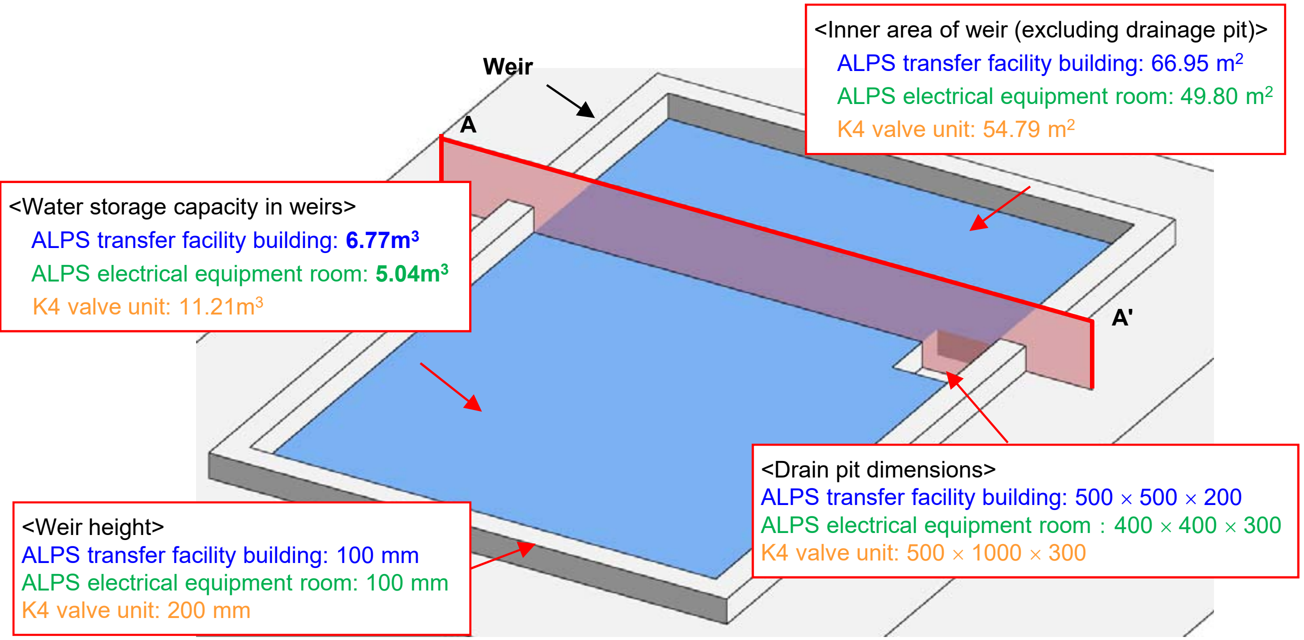
In the past leakage incidents, the maximum flow rate (visual measurement) for leakage from the main body of the facility was 1 drop per second. With this, leakage from the main body of the facility will also be covered in this evaluation.

[Estimated amount of leakage]

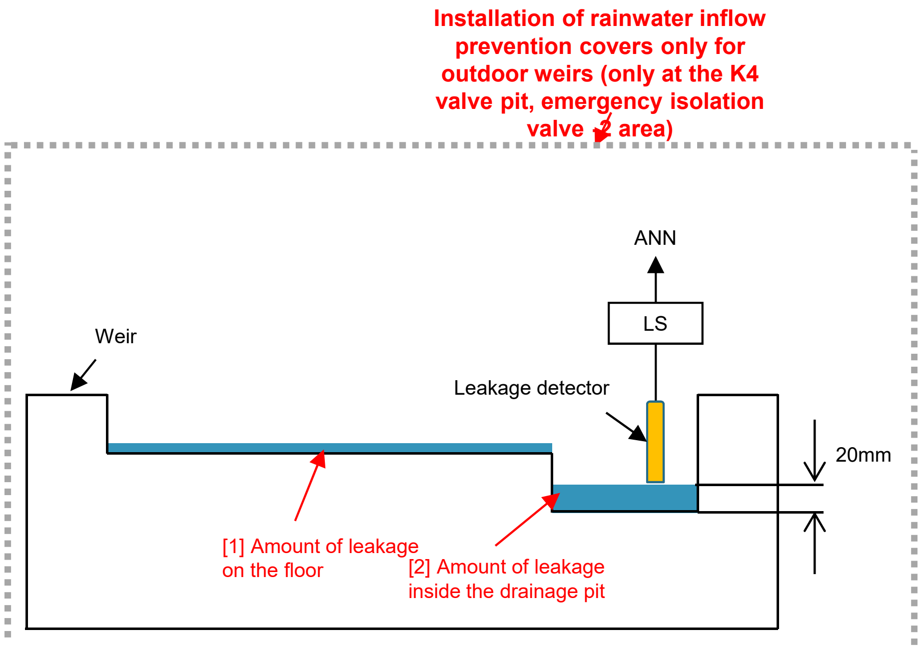
- From the result above, it is assumed that the maximum amount of leakage from the flange/seal portion is 1.19 cc/sec (about 4 L/h).

2-1 (1) [6] Validity assessment for the facility design in the event of failure
[6]-5. Weir capacity and installation locations of leakage detectors

- The inner area of the weir and the arrangement of the leakage detectors in the ALPS transfer facility building, the ALPS electrical equipment room, and the K4 valve unit are as follows. For the inner area of the weir in the emergency isolation valve-2 area and the placement of the leakage detector, details are under consideration.



Schematic diagram of weir and drainage pit



Section layout (A-A')

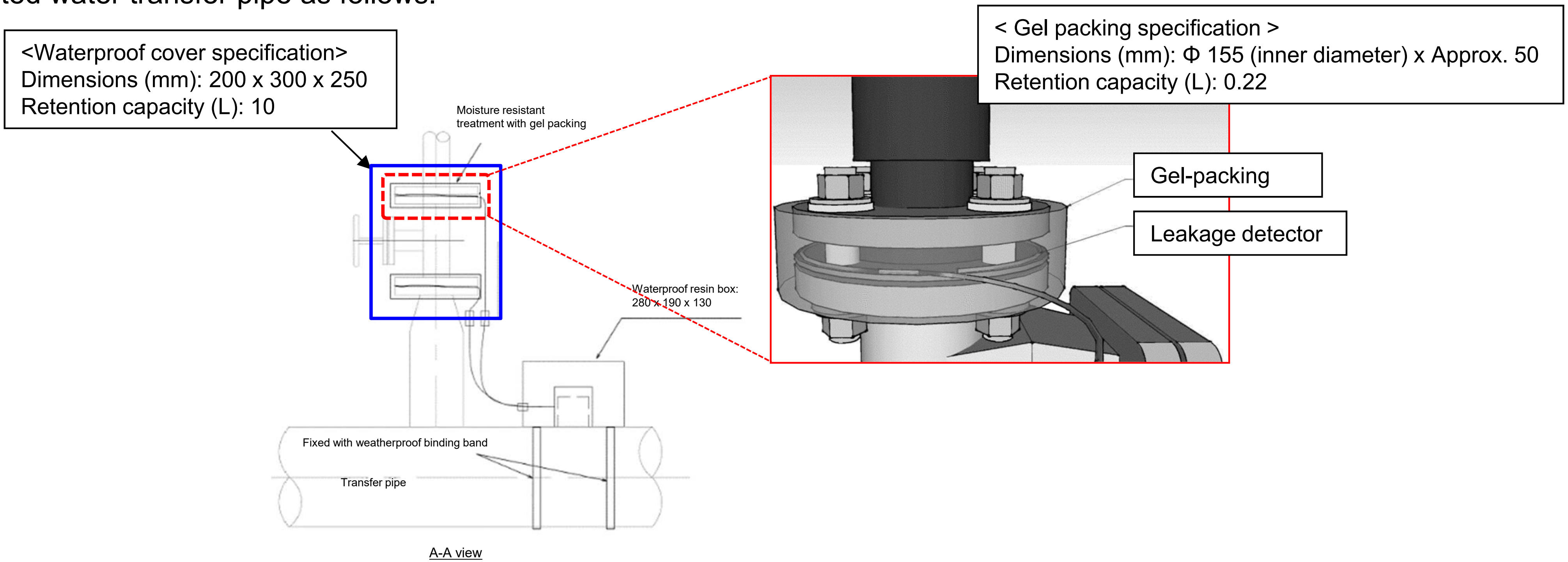
- Regarding weirs, the amount of leakage at the time of leakage detector sensing the leakage and the capacity to be held in the weirs are as follows. The capacity of the weirs are sufficient enough for the operators responce after detection of an leakage, therefore, leakages from the weirs are preventable.

	Amount of leakage at detection by leakage detector ((1) + (2))	Weir retention capacity	The time between leakage detection and the filling of the weir.
ALPS transfer facility building	0.14m^3	6.77m^3	About 1548 hours
ALPS electrical equipment room	0.10m^3	5.04m^3	About 1,152 hours
K4 valve unit	0.12m^3	11.21m^3	About 2,588 hours

The Japanese version shall prevail.

[6]-6. Waterproof cover around vent valves and leakage detectors

- A waterproof cover and a leakage detector are installed on every flange of the vent valve for the air vent of the ALPS treated water transfer pipe as follows.



- The leakage detector is inserted between flange surfaces where the leakage is expected, and the circumference is covered with gel packing.
- The gel packing is a molded product matched to the flange shape and has a seamless structure and sealability (the penetration of the detector hole is caulked).
- Even in the case of leakage from the gel packing, leaked water is received by the surrounding waterproof cover to prevent leakage to the outside (in the gap between the cover and the pipe, sealability is ensured by rubber packing and caulking).
- Assuming that the leaked water is flooded into the waterproof cover when water exceeding the retention capacity of the gel packing leaks, it takes about 2 to 3 hours for the waterproof cover to fill up after the leakage detector detects the leakage.
  - As described above, the amount of water held in the waterproof cover is sufficient enough from detecting leakage to the operators responding to it. Therefore, it is possible to prevent overflow from the waterproof cover.

[Supplement] Leakage detector

TEPCO

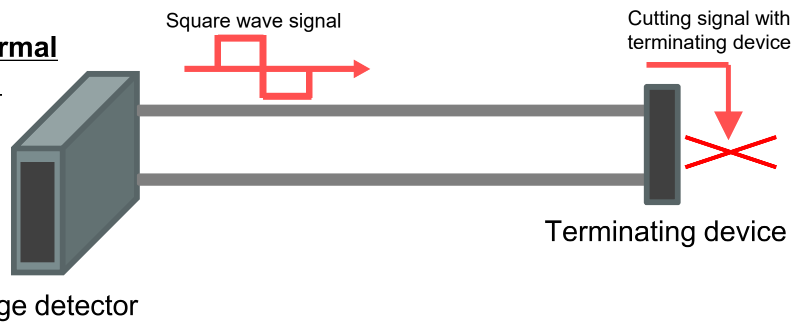
[Operating principle]

- All leakage detectors should be equipped with a disconnection detection function. With the operation principle described below, it is possible to detect a loss of function of the detector due to disconnection and detecting leakage.
  - The detector body transmits a signal for leakage and disconnection detection.
  - Based on the condition of the returned signal, the leakage or disconnection will be judged.

<Leakage detection>

- A detector issues a square wave signal for leakage detection.
  - Usually, the signal is cut by a terminating device.
  - When a liquid comes into contact with the leakage detection band, the signal changed by the resistance of the liquid returns to the detector, and the leakage is judged by comparing it with the transmitted signal.

Under normal operation



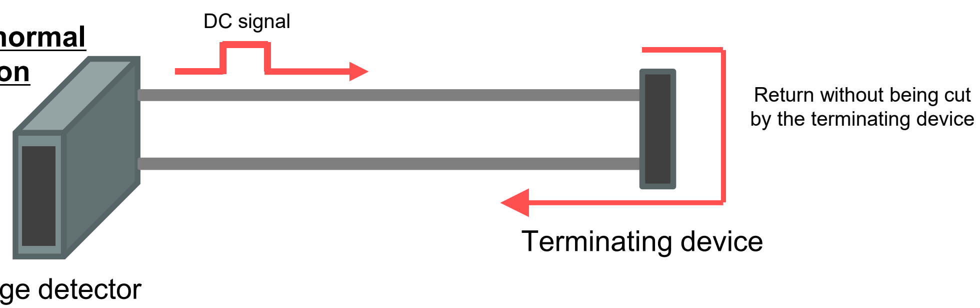
When leakage is detected

The leakage detector compares the transmitted signal with the returned signal to determine leakage.

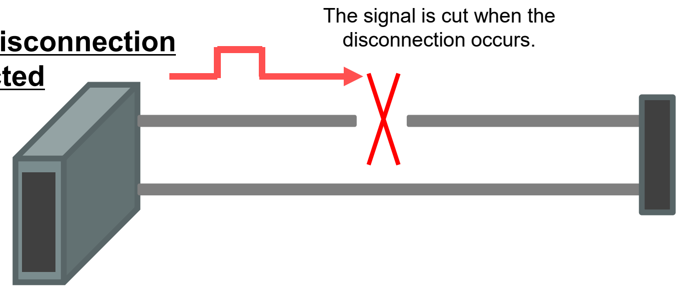
<Disconnection detection>

- A detector issues a direct current signal for disconnection detection.
  - The transmitted signal is returned to the detector and judged normal if it is intact.
  - When disconnection occurs, the signal is cut at the point where it occurs, and it is judged as disconnection when the signal does not return to the leakage detector.

Under normal operation



When disconnection is detected



If the signal does not return to the leakage detector, it is judged as disconnection.

The Japanese version shall prevail.

[6]-7. Validity of measures to prevent leakage from spreading

TEPCO

- As a result of verifying past events, it was confirmed that most leakage incidents occurred from flanges/seals, etc., and the facility body itself.
- With this, in terms of design, weirs and leakage detectors will be installed around the flanges/seals and the main body of the facilities to prevent leakage from spreading (same as other existing facilities). Regarding leakage from pipes/hoses and open ends, the countermeasures applied to other areas will be taken for this facility.
- Regarding operation, when an alarm of leakage detection is issued, operators promptly stop the discharge of ALPS treated water into the sea to prevent the expansion of leakage.

- Based on the mockup test and past leakage incidents, relative to the estimated maximum amount of leakage (approximately 4 L/h), the capacity of the weir to be installed has sufficient enough for the operators response when the leakage detector sensing leakage. With this, it is considered appropriate as a countermeasure to prevent the expansion of leakage.

[Reference] Past leakage incidents rolled out to other areas

- Of the past leakage incidents, the main leakage incidents from pipe/hoses whose countermeasures have been applied to other areas are as follows.

Leakage point	Classification of causes	Major direct cause	Measures for the event*	Measures at ALPS treated water dilution/discharge facilities
Pipe/hose	HE	Assumed that a person working in the vicinity damaged the transfer hose of the rainwater recovery tank by mistake.	• When working in the vicinity of the pressure hoses, take sufficient protective actions such as installing protective plates.	Implement protective measures for hoses, pipes, and the like, as specified in TEPCO's internal guidelines.
	Defective construction	A nail stuck when moving the rainwater treatment transfer hose.	• Comprehensive inspection of the pressure hose of the rainwater transfer facility was conducted. • This case is reflected in the operation and management guidelines of the pressure hose and is notified to related groups. • Replaced pressure hoses with PE pipes.	In the ALPS treated water dilution/discharge facilities, no work of moving the hose is scheduled.
		An incandescent projector fell on the transfer pipe (PE pipe) in the unit 2 building and was damaged by irradiated heat.	• Use of an incandescent projector should be prohibited near a PE pipe laying area.	Do not use any incandescent projector in the ALPS treated water dilution/discharge facilities.

*: Parts underlined have been reflected in TEPCO's internal manuals and guidelines.

2-1 (1) [6] Validity assessment for the facility design in the event of failure [Reference] leakage incidents rolled out to other areas of concern

- Of the past leakage incidents, the main leakage incidents from open ends/weirs whose countermeasures have been applied to other areas are as follows.

Leakage point	Classification of causes	Major direct cause	Measures for the event*	Measures at ALPS treated water dilution/discharge facilities
Open end	HE	The valve connected to the tank pipe of ALPS treated water, etc., was operated from “closed” to “open” by mistake.	• A procedure manual should be prepared based on a drawing indicating a pipe route and a pipe connection point. • Incorporate in the transfer procedure a step to consult the procedure manual and confirm the lineup of the site. <u>• Implement the lock control and identification indications for valves.</u>	Implement lock control and identification indications for valves specified in TEPCO’s internal guidelines.
	Defective construction	No closing action was taken during equipment inspection, etc.	<u>• When removing equipment for inspection, etc., safety measures should be taken, considering the seat path of the isolated valve.</u> <u>• Install closed flanges.</u>	When removing equipment for inspection, etc., take safety measures considering the seat path of the valve, and install a closed flange at the open end.
		The tip of the rainwater collection tank hose was submerged in water, it caused a siphon phenomenon and leakage.	<u>• Lashing is performed by separating the tip of the discharge end of the pressure hose from the water surface. During the transfer, the supervisor should check the transfer as necessary.</u> • At the start and end of the transfer, check the lashing condition of the pressure hose and the backflow of water due to the siphon phenomenon.	No pipes or hoses are set in the ALPS treated water dilution/discharge facilities with a risk of submergence in the weir or tank.
Weir	Natural phenomenon	The response procedure in case of heavy rain and strong wind was unclear, and the water overflowed from the weir.	<u>• The system and procedures for transfer were established.</u> • A roof was installed to prevent rainwater from flowing into the weir.	A rainwater inflow prevention cover is installed in a weir to be installed outdoors in response to a transfer procedure of water in the weir established in TEPCO’s internal guidelines.

*: Parts underlines have been applied to other areas in TEPCO’s internal manuals and guidelines or in the OE information.

2-1 (1) [6] Validity assessment for the facility design in the event of failure
[Reference] Past leakage incidents judged as not requiring its application to other areas

TEPCO

- The past leakage incidents below confirmed not to apply for the ALPS treated water dilution/discharge facilities, on the ground that no consideration is needed due to the difference of environment, facilities used, design from the facilities leakage occurred.

Leakage point	Classification of causes	Major direct cause	Measures for the event	Whether it occurs or not in ALPS treated water dilution/discharge facilities
Pipe/hose	Design defect	Corrosion progressed due to chemical solutions such as hydrochloric acid being passed through the hose of the additional ALPS.	A sign saying "Drainage of chemical solutions prohibited" should be attached. Replace hoses with steel pipes.	Chemicals, resins, or concentrated hydrochloric acid are not used. Therefore, no consideration is required.
		Due to the effect of earthquakes, etc., stress was concentrated in the pipe fusion of the existing RO made of vinyl chloride.	Change to a pipe configuration that is less prone to stress concentration.	No consideration is required since pipes made of vinyl chloride are not used.
		The corrosion progressed because slurry was accumulated in the drainpipe of the existing ALPS.	Periodically clean inside the pipe.	No consideration is required because slurry does not accumulate.
	Defective construction	It is estimated that the gap formation causes gap corrosion during the metal hose welding of sub-drain and other purification facilities.	Replace metal hoses with synthetic rubber hoses.	No consideration is required since no metal hoses are used.
	Insufficient management	The person did not notice that the part was hardened due to the liquid flowing into the air hose of the desalination device (RO3). (The inspection plan was inappropriate.)	The inspection plan should be managed from corrective maintenance to time-based maintenance.	No consideration is required since no air hoses are used.
Open end	Design defect	The system interlock was insufficient. (The pump was designed to continue operating with the valve "closed.")	Change an operation logic to automatically stop the facility when abnormalities of the pump discharge pressure are detected.	No consideration is required because interlocks are provided to stop facilities when abnormalities in the faculties are detected.
Weir	Defective construction	This was due to insufficient water cut-off treatment of the pipe penetration and the mounting bolt.	Water cut-off treatment should be performed by spraying polyurea.	The structure of the inner weir is different from the one at the time of the event described on the left occurred, and no penetrations or mounting bolts are used. With this, no consideration is required.

The Japanese version shall prevail.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [7]

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

(1) Facilities for discharging into the sea

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

- Regarding the setting of the evaluation conditions, the initial conditions should be set so that the evaluation results become the most conservative regardless of the state during operation or maintenance. In addition, the operation method of the essential equipment should be described.
- For validating the extracted abnormal events, the concept of setting evaluation conditions (including initial conditions) that would make the results more stringent in terms of release volume should be explained.
- Concerning the handling of static components under the assumption of a single failure, the handling of static equipment should be organized as in the case of active components; after sorting out the period of use and the presence or absence of a long-term impact mitigation function, with reference to the interpretation of the new regulatory standards for commercial reactors.
- When evaluating the discharge amount in the case of taking measures against abnormal events, appropriate criteria and evaluation conditions should be established, and their concepts should be presented.

2-1 (1) [6] Validity assessment of the facility design in the event of failure
[7]-1. Setting initial conditions on abnormal events

TEPCO

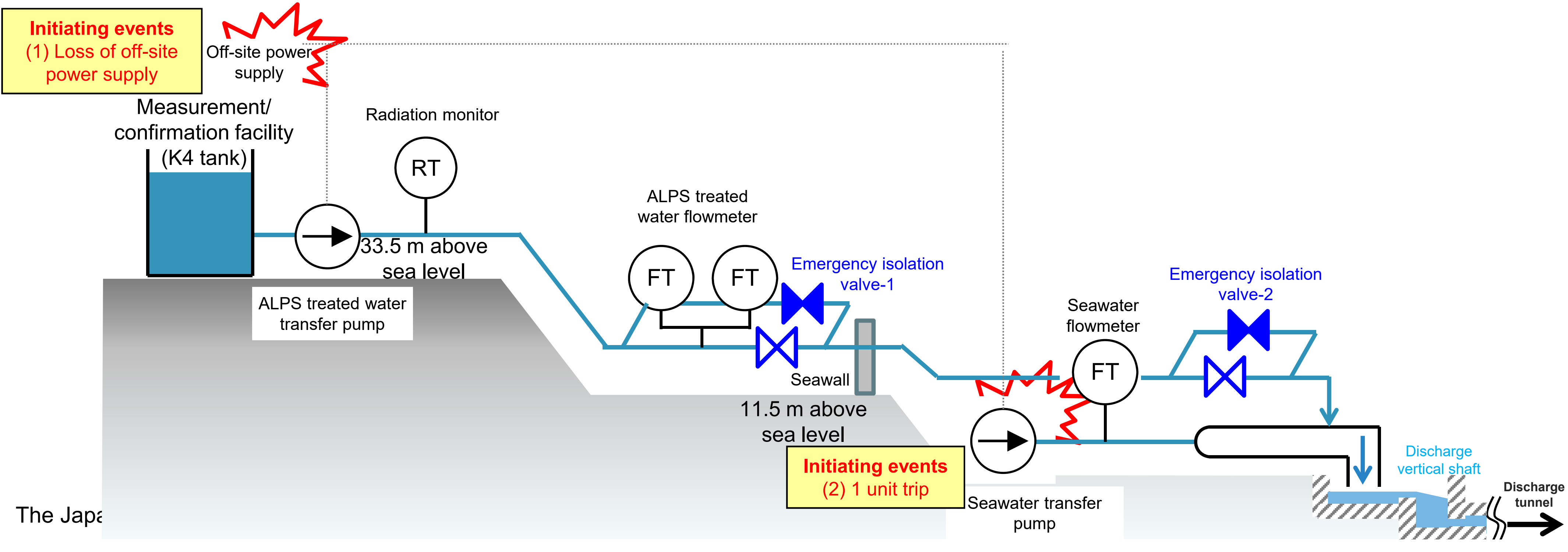
- Based on the results of MLD, (1) "Loss of off-site power supply" and (2) "Trip of one of two or three seawater transfer pumps during operation" were extracted as the initiating events in the event of the abnormal event [2] "Discharge with insufficient dilution with seawater."
- With the above, initial conditions and equipment conditions that become most severe in terms of the amount of ALPS treated water discharged are set as follows.

Initial condition

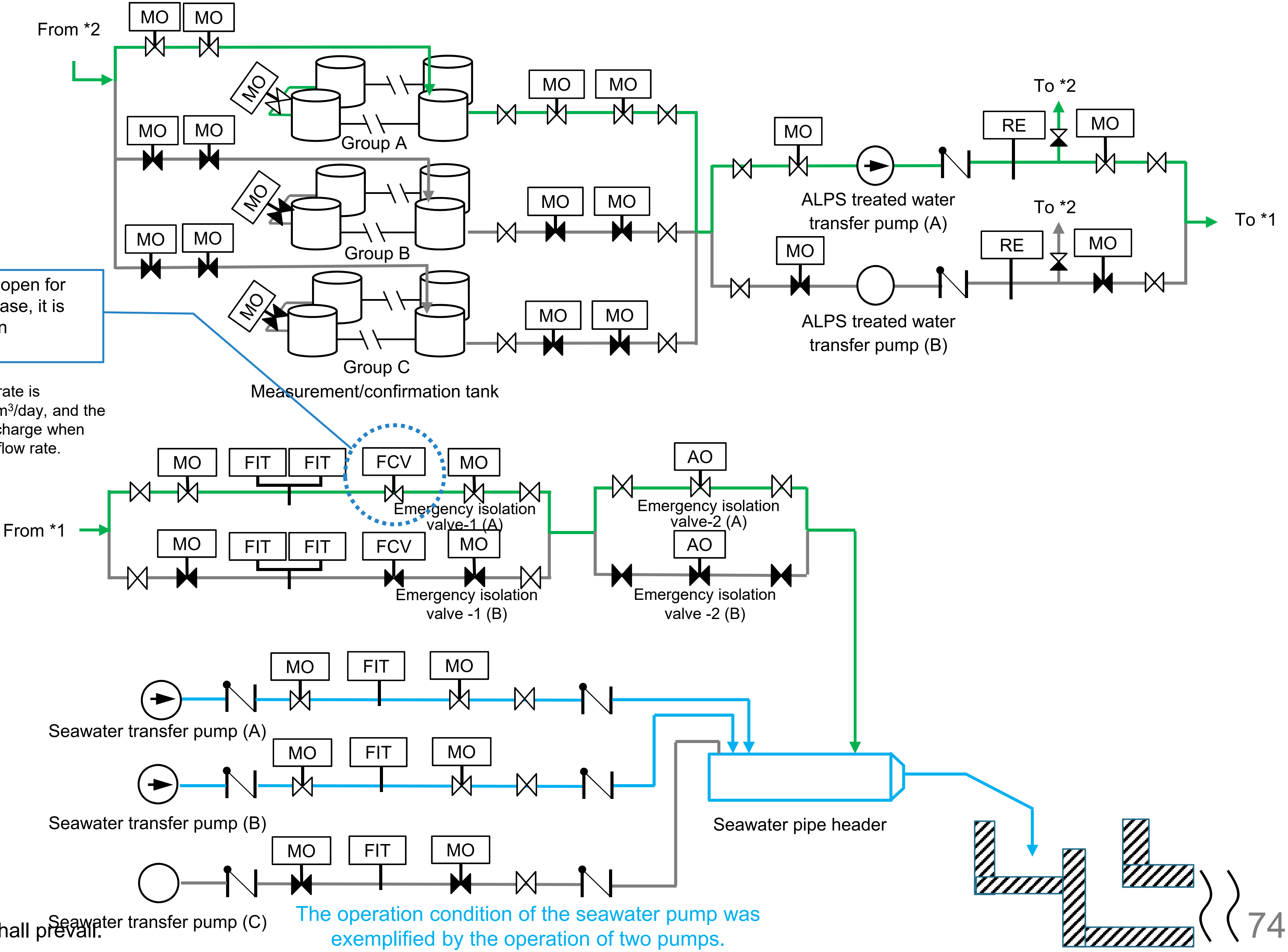
- Abnormal event [2] "Discharge with insufficient dilution with seawater" will occur during discharging ALPS treated water into the sea. Therefore, normal operating conditions should be assumed.

Equipment condition

- The ALPS treated water flow rate is planned to be controlled at 500 m^3/day by FCV since it is in normal operation. In this case, the equipment specification of the ALPS treated water transfer pump as a single item is conservatively set at 720 m^3/day, and two seawater transfer pumps are operated (340,000 m^3/day).



2-1 (1) [6] Validity assessment of the facility design in the event of failure
[Supplement] Detailed equipment conditions



In normal operation, it is "open for adjustment"*, but in this case, it is postulated to be fully open conservatively.

* The ALPS treated water flow rate is controlled not to exceed 500 m^3/day, and the interlock is set to stop the discharge when the flow rate exceeds the set flow rate.

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

The operation condition of the seawater pump was exemplified by the operation of two pumps.

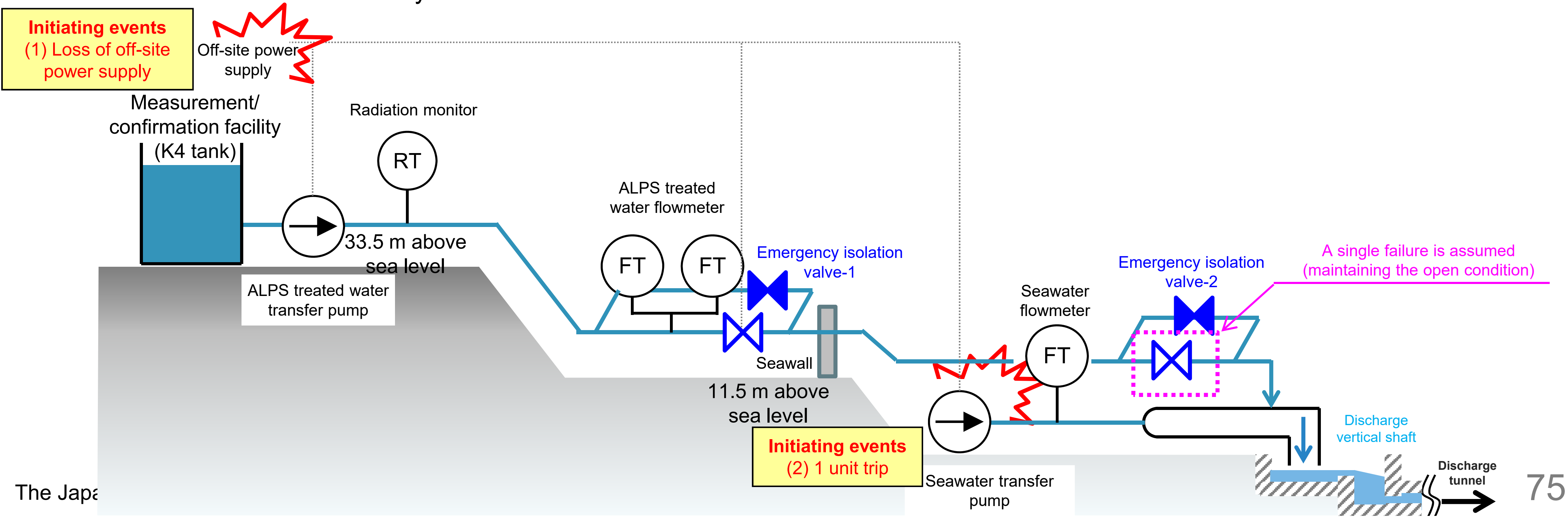
2-1 (1) [6] Validity assessment of the facility design in the event of failure
[7]-2. Assumptions of single failure, etc. in abnormal events

TEPCO

- Under the new regulatory standards, for static equipment such as pipes and filters, it is supposed to assume a failure of static equipment to be used for a long time (longer than 24 hours) after an event. However, if an abnormality occurs, this facility stops the discharge into the sea immediately, and therefore, there is no equipment applicable. Based on this, only active components were considered a target of a single failure, and a single failure was assumed as follows.
  - For both the initiating events (1) “loss of off-site power supply ” and (2)“Trip of one of two or three seawater transfer pumps during operation,” to stop the discharge into the sea by using an emergency isolation valve is a countermeasure against “unintended discharge of ALPS treated water.”
  - In other words, an emergency isolation valve having this function is a necessary facility for coping with an abnormal event. For this reason, a postulate of a single failure or the like in which the evaluation result becomes the severest for the emergency isolation valve is set (the arithmetic unit necessary for the operation (logic circuit) is duplexed, and it is excluded).

Assumption of a single failure

- In the ALPS treated water dilution/discharge facilities, a single failure of the emergency isolation valve-2 is assumed, which is installed the most downstream of the ALPS treated water transfer pipe and has the shortest opening to the closing time of 2 seconds in the AO system.



[7]-3. Evaluation in the event of an abnormal event (loss of off-site power supply)

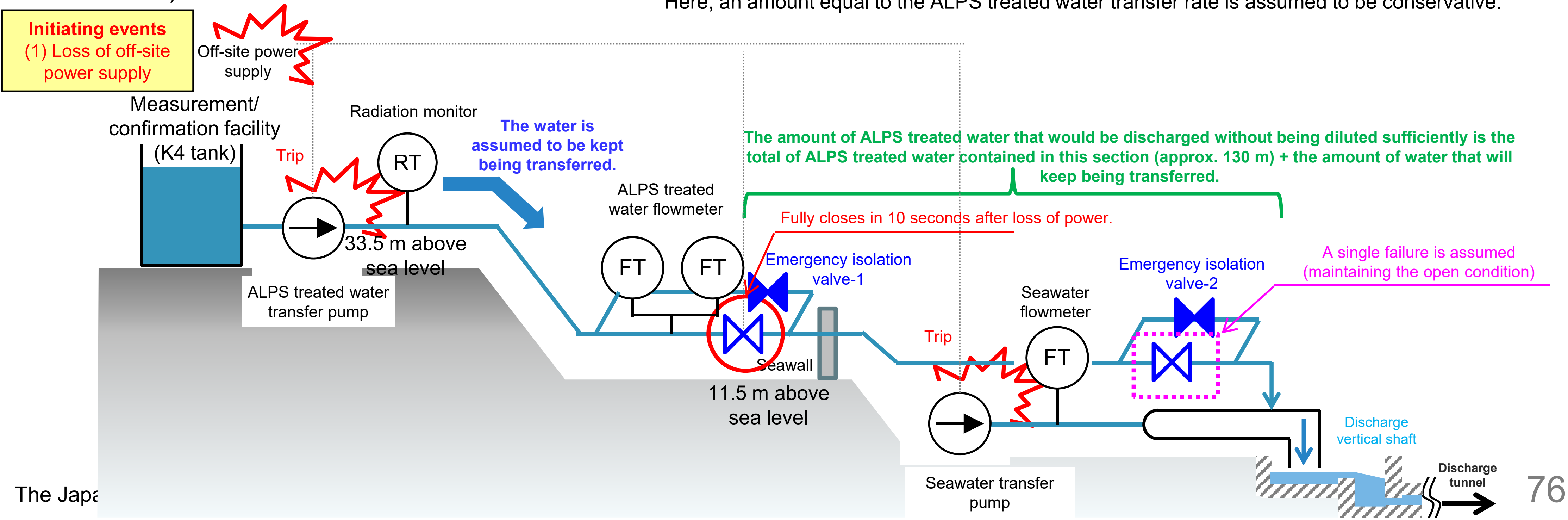
TEPCO

- An event assumed is if (1) “loss of off-site power supply” occurs during the discharge of ALPS treated water into the sea due to a failure in the power transmission system, etc., the seawater transfer pump and the ALPS treated water transfer pump will stop, respectively. Still, the discharge of ALPS treated water will continue due to the water head pressure of the tank, the difference between high and low levels, etc. ALPS treated water is assumed to be discharged into the sea with insufficient dilution.
- Should this event occur, the power supply to the emergency isolation valves will be lost too, which activates the fail close function of the emergency isolation valve-1 to close the valve fully. That means the discharge into the sea will be stopped in a minimum of 10 seconds after the loss of the off-site power supply.

Assessment result

- The amount of ALPS treated water that would be discharged without being diluted sufficiently is approximately 1.1 m^3: the total amount of water contained in the section of about 130 m from the emergency isolation valve-1 to the seawater pipe header (approx. 1.02 m^3) and the amount of ALPS treated water that will keep being transferred due to the hydraulic head of the tanks and the difference in height during the 10 seconds before the emergency isolation valve-1 is closed* (approx. 0.08 m^3).

*Here, an amount equal to the ALPS treated water transfer rate is assumed to be conservative.

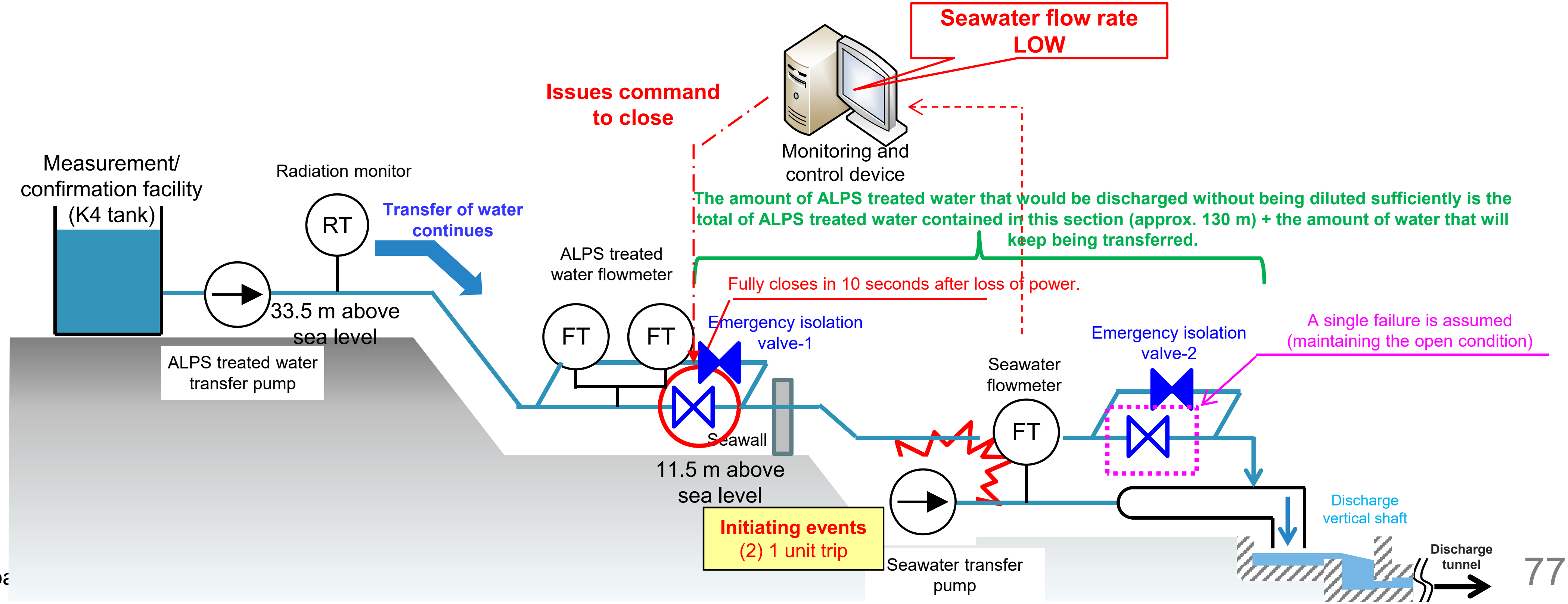


- An event assumed here is as follows: while the discharge of ALPS treated water into the sea is ongoing, (2) tripping of one of the two or three operating seawater transfer pumps occurs, leading to a drop in the seawater flow rate to be used for the dilution of ALPS treated water.
- Emergency isolation valves are designed to be tripped with the "Seawater flow rate LOW" signal input. Therefore, should this event occur, the emergency isolation valve-1 will be fully closed to stop the discharge into the sea in at least 15 seconds*, the time it takes for the monitoring and control device to detect the failure of one seawater transfer pump, issue a command to trip the emergency isolation valve, and fully close the valve.

*: Current design value

Assessment result

➢ The amount of ALPS treated water that would be released without being diluted sufficiently is approximately 1.2 m^3: the total amount of water contained in the section of about 130 m from the emergency isolation valve-1 to the seawater pipe header (approx. 1.02 m^3) and the amount of ALPS treated water that will keep being transferred from the ALPS treated water transfer pump during the 15 seconds before the emergency isolation valve-1 is closed* (approx. 0.12 m^3).



Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [8]

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

(1) Facilities for discharging into the sea

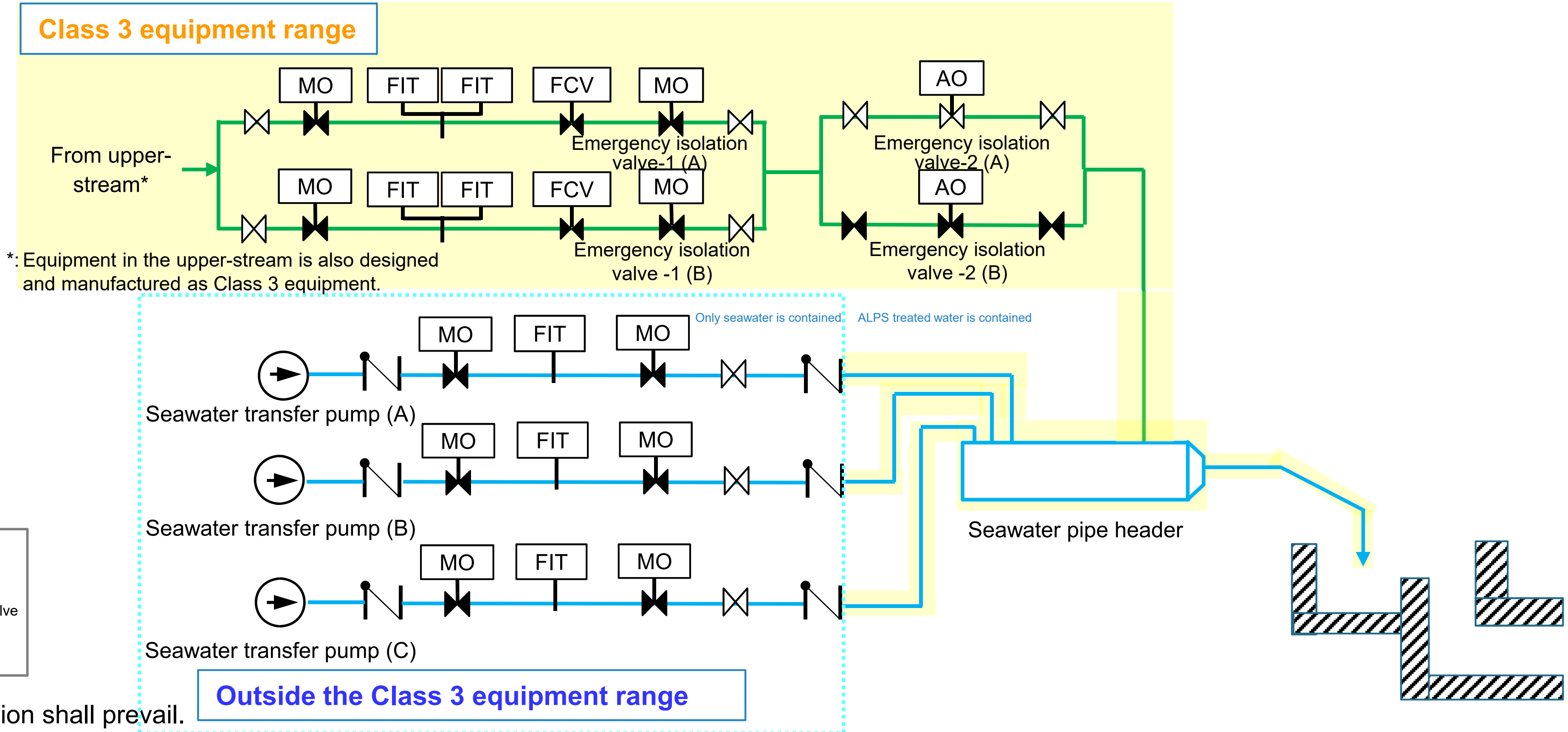
[5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, prevention of misoperation, reliability, etc.

- The reason why some seawater transfer pipes are not classified as Class 3 pipes in light of the Rules on Design and Construction for Nuclear Power Plants," etc., should be explained.

TEPCO

[8]-1. Classification of ALPS treated water dilution/discharge facilities

- ALPS treated water dilution/discharge facilities are classified as follows: pipes containing ALPS treated water in which the sum of the ratios to regulatory concentration limits of radioactive materials other than tritium (including diluted water) is less than 1 are classified as Class 3 equipment since they are equipment handling radioactive liquid waste. In contrast, seawater pipes that contain only seawater for dilution are not classified as Class 3 pipes.
- Furthermore, according to the Technical Standards, check valves must be installed when the fluid that does not contain radioactive materials is made to flow to facilities handling radioactive liquid waste. This system prevents the spread of contamination due to backflow, ensuring that the pipe from the seawater transfer pump outlet to the seawater pipe header contains only seawater for dilution free from radioactive materials.
- The reliability of those pieces of equipment is planned to be secured as shown in the following slides.



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

TEPCO

[8]-2. Securing reliability of seawater transfer pumps and seawater pipes leading up to the seawater pipe header

- Seawater transfer pumps and seawater pipes leading up to the seawater pipe header will be designed and manufactured as follows to secure reliability.
  - Seawater transfer pumps: A Japanese pump manufacturer with a good track record in thermal power generation will design and manufacture the pumps, and material, visual, and pressure tests will be performed.
  - Seawater pipes: Duplex stainless steel pipes (SUS329J4L*), which can ensure highly reliable measurement of flows (roughness on the pipe surface) and high corrosion resistance, are used at orifice sections for the measurement of seawater flows. As Class 3 equipment, the structural strength must be assessed to ensure that there is no problem (to be implemented).
    In addition, seawater pipes leading up to the seawater pipe header will also be tested in the same way as Class 3 pipes (already planned and reflected. See the table below).

*: A material listed in JIS but not in JSME.

Inspections to be performed for steel pipes (Steel pipes are tested by the following inspections regardless of the class)

Check items	Check points	Details to be checked	Criteria
Structural strength, seismic resistance	Material check	Check the record of key materials that are listed in the Implementation Plan.	The Implementation Plan must be complied with.
	Dimension check	Check the diameter and thickness records listed in the Implementation Plan.	The Implementation Plan must be complied with.
	Visual check	Check the appearance of each part.	No significant defects must be found.
	Installation check	Check the installation condition of pipes.	Pipes must be laid and installed as specified in the Implementation Plan.
	Pressure resistance and leakage check	Keep applying pressure that is 1.25 times the maximum working pressure for a certain period, then check that the pipe is resisting the pressure, causing no leakage from the pressure part.	Pipes must be capable of resisting a pressure that is 1.25 times the maximum working pressure without suffering any trouble. The pipes also must be free from leakage from the pressure part.
Functions, performance	Water flow check	Check that water can be made to flow.	The flow of water must be secured.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- **Validity and rationale should be explained for the applicability of the ocean diffusion model to the sea areas near the Fukushima Daiichi Nuclear Power Station.**
- **Regarding the ocean diffusion model, there is a concern that the discharged ALPS treated water may stir up seawater, intensifying vertical mixing. The possibility and impacts of this should be indicated.**
- **Contrary to the vertical cross-sectional view of tritium concentration, the rationale of the setting should be explained that the tritium concentration used in the exposure assessment was twice as high in the uppermost layer as in the lowermost layer.**
- **Regarding the calculation results of the tritium diffusion, the behavior of tritium in consideration of the meteorological and oceanographic data in 2019 should be explained, such as whether it is accumulated when the discharge of ALPS treated water is continued for years or whether it saturates at a certain point in time.**
- **Regarding the impacts of accumulated radioactive materials, the rationale of all the selected transfer models, not only seawater but also hulls, fishing nets, beach sand, etc., should be explained.**
- **A review should be carried out in selecting exposure pathways based on the diffusion and transfer model established by the flowchart shown in GSG-10. Moreover, the details of the approach to selection, including its completeness, should be given, such as by showing the concept of the excluded exposure pathways.**
- **Concerning the dose conversion coefficients for tritium, the rationale for the abundance ratio between tritiated water (HTO) and organically bonded tritium (OBT) should be explained, and reference documents for such ratio should be provided.**
- **64 nuclides (tritium, carbon 14, and 62 nuclides to be removed with ALPS) have been set as the source term. The approach to selection, such as narrowing down the nuclides to be evaluated, should be specified after assessing what kind of nuclides can theoretically exist in ALPS treated water in setting the source term.**
- **The facilities for the discharge into the sea will affect the distribution of radioactive materials in seawater in the port. The impact should be included in the Radiological Environmental Impact Assessment.**
- **In addition to explaining uncertainties in the Radiological Environmental Impact Assessment, uncertainty sources that have dominant effects in the assessment and sources for ensuring conservative results should be clarified and explained.**
- **In assessing potential exposures, time while an accident is kept unnoticed or a delay in responses should be taken into account, and consideration should also be given to performing internal exposures assessment in light of the duration of such event.**
- **Fishing nets are included in the anticipated external exposure pathways in the exposure assessment during normal operation. On the other hand, the potential exposure assessment does not assume external exposure from fishing nets. Thus, the reason for that and the rationale for setting the data used in the assessment should be explained.**
- **Regarding exposure dose assessment of a representative person, the validity should be demonstrated by using the most realistic exposure assessment parameters possible and taking into account the current situation and prospects in the vicinity of the Fukushima Daiichi NPS.**
- **For the coefficients adopted in the Radiological Environmental Impact Assessment, in which part of the ICRP documents (Pub. 72, 124, 144, etc.) is quoted, and the reason for the quotation should be clarified.**

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

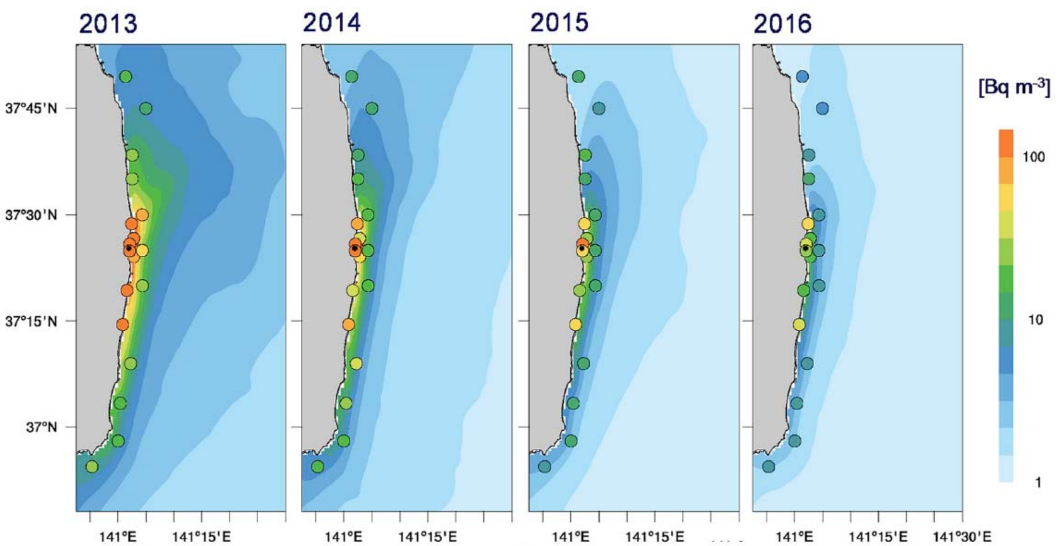
(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- **Validity and rationale should be explained for the applicability of the ocean diffusion model to the sea areas near the Fukushima Daiichi Nuclear Power Station.**

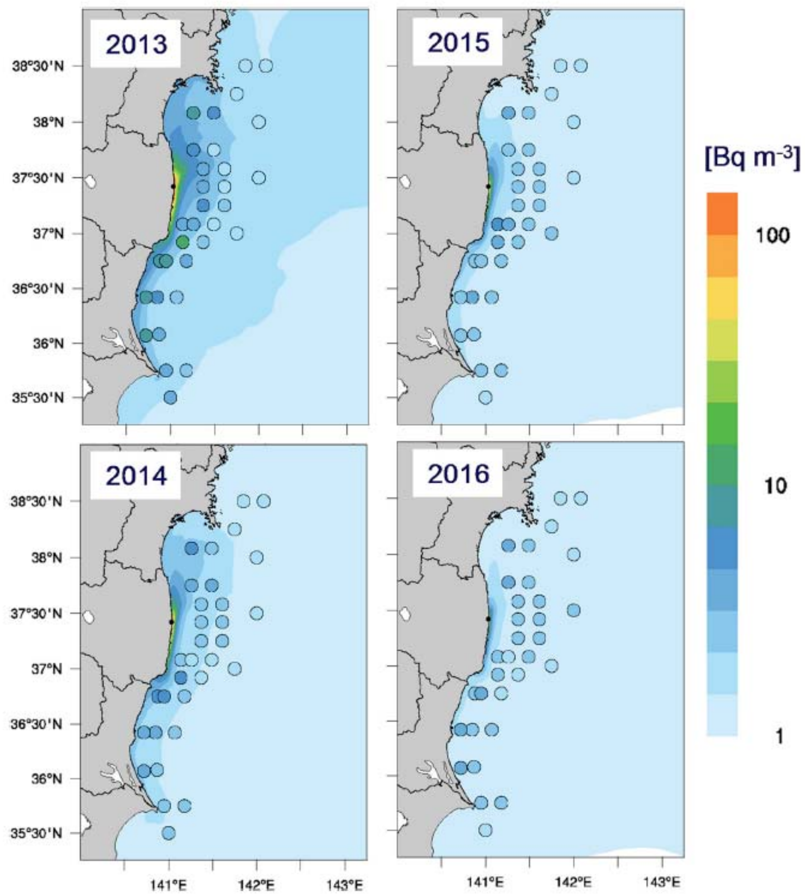
Diffusion and migration modeling after discharge (validity of the model)

- The model used for the calculation of diffusion in the sea area is the model used for the reproduction calculation of the diffusion of cesium leaked at the time of the accident of Fukushima Daiichi NPS.
- The cesium concentration was calculated and reproduced using actual meteorological and oceanographic data at that time. The result was compared with the actual monitoring data to verify the high reproduction performance of the model*.



○ indicates the monitoring points and concentrations.

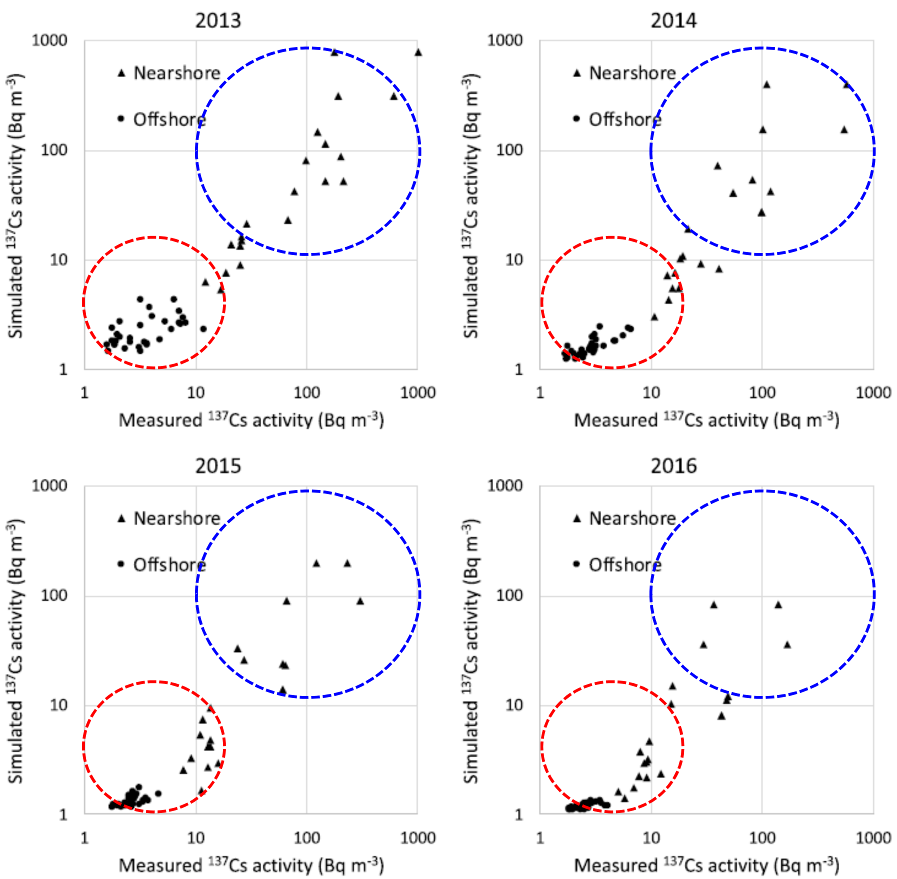
Comparison of the calculated annual mean concentrations of Cs-137 in the sea area around Fukushima Daiichi NPS with monitoring results



Comparison of calculated annual mean concentrations of Cs-137 in wider sea area with monitoring results

* D.Tsumune, T.Tsubono, K.Misumi, Y.Tateda,Y.Toyoda, Y.Onda, and M.Aoyama, "Impacts of direct release and river discharge on oceanic 137Cs derived from the Fukushima Dai-ichi Nuclear Power Plant accident", 2020.

Diffusion and migration modeling after discharge (validity of the model)



Results of comparison between simulated and measured Cs-137 concentrations on the nearshore and offshore sea surfaces.

- The figures on the left show the measured Cs-137 concentration (horizontal axis) and the simulated results (vertical axis) by year of the corrected seawater at the coast and offshore areas of Fukushima.
- The measured values are almost similar to the simulated ones in the upper right region, where the concentration is high (blue dashed line).
- On the other hand, in the lower-left region where the concentration is low (red dashed line), the measured values tend to be higher than the simulated results.
- Measured values are higher in the low concentration region probably because the simulation results do not adequately reflect some sources, such as the supply of cesium from rivers and inflow of cesium due to recirculation by currents in the North Pacific Ocean.

- Cesium ions and tritium dissolved in water are considered to migrate and diffuse in the same way in the sea.
- The upper right high-concentration area is the area that is significantly affected by cesium released from the Fukushima Daiichi NPS. The simulated results agree with the measured results in this area. Therefore, it is adequate to conclude that this model can be used to simulate tritium.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- Regarding the ocean diffusion model, there is a concern that the discharged ALPS treated water may stir up seawater, intensifying vertical mixing. The possibility and impacts of this should be indicated.
- Contrary to the vertical cross-sectional view of tritium concentration, the rationale of the setting should be explained that the tritium concentration used in the exposure assessment was twice as high in the uppermost layer as in the lowermost layer.

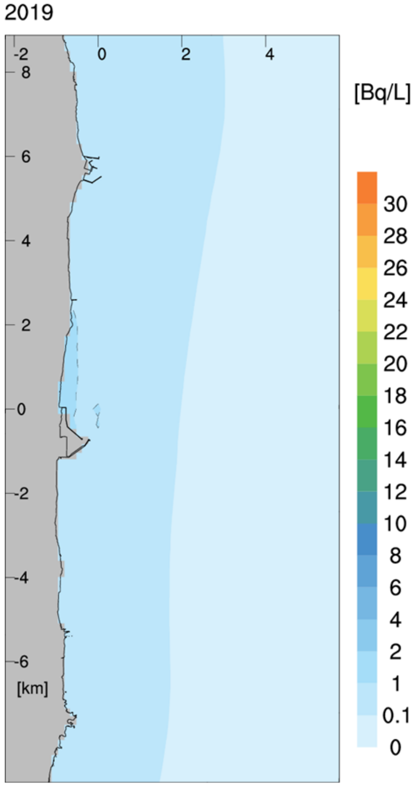
Concentration distribution around the discharge outlet

- The tritium simulation model used for the Radiological Impact Assessment Report is a model to simulate migration and diffusion in vast areas and did not simulate the physical flow around the discharge outlet.
- Therefore, the cross-sectional view shows that the concentration near the seabed around the discharge outlet is higher than in the surrounding areas. Still, the concentration just above the discharge outlet is not so high.
- On the other hand, water will be discharged upward in the actual discharge, and while flowing up, it will entrain surrounding seawater, facilitating the mixing and dilution.
- However, since the ALPS treated water to be discharged has already been diluted more than 100 times with seawater, the salinity and specific gravity of the water are almost the same as those of the surrounding seawater. Therefore, although there is a slight difference in the concentration distribution around the discharge outlet, the diffusion in areas away from the outlet will probably be close to the simulated results.
- This can also be verified by comparing the diffusion simulation results with different discharge points, shown in Report Reference F. The annual mean concentration in the 10 km × 10 km area when ALPS treated water is discharged from the unit 5-6 discharge outlet on the sea surface is 6.6 E-02 Bq/L, which is higher only by 20% of 5.6 E-02 Bq/L, the concentration when ALPS treated water is discharged from an outlet on the seabed 1 km off the coast.
- On the other hand, even when the upward flow is not considered, the mean concentration in the 10 km × 10 km area calculated in the simulation is higher in the upper layer than the concentration around the discharge outlet. That is because the water depth in the surrounding sea gradually becomes deeper, and the concentration on the bottom offshore is much lower than in the upper layer.

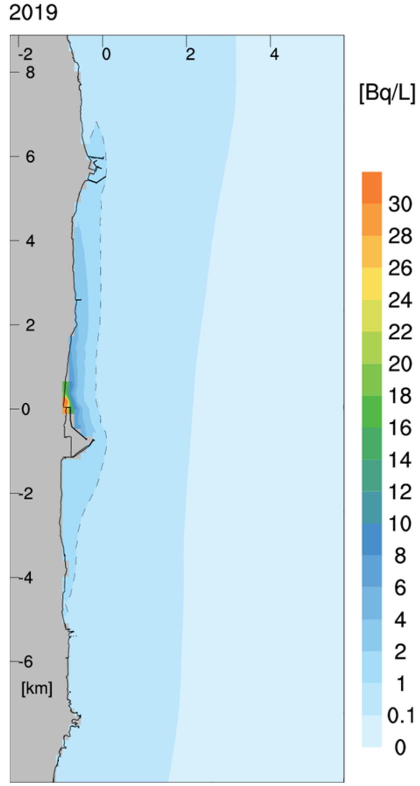
Difference in the diffusion area by discharge location

TEPCO

- The “Reference F: Difference in the diffusion area by discharge location” of the Radiological Impact Assessment Report compares the simulated tritium diffusion when the discharge point is 1km off the coast with the result when a discharge point is a unit 5-6 discharge outlet.
- Although the concentration distribution around the discharge outlet is different, as shown in the figure below, there is no notable difference in the diffusion in the surrounding sea area.

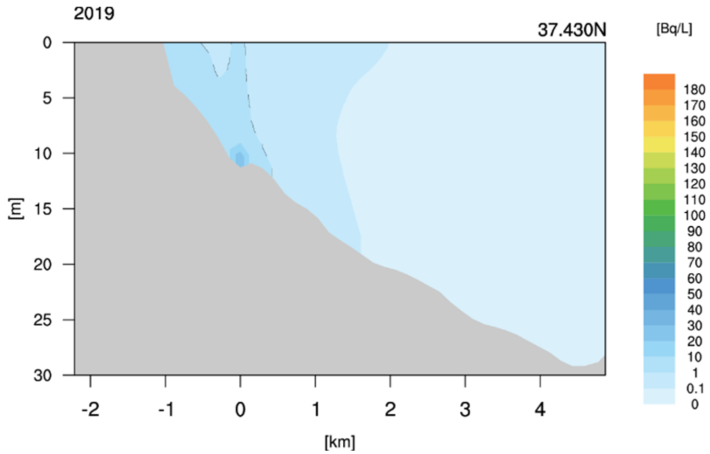


(Discharge from an outlet 1 km off the coast)

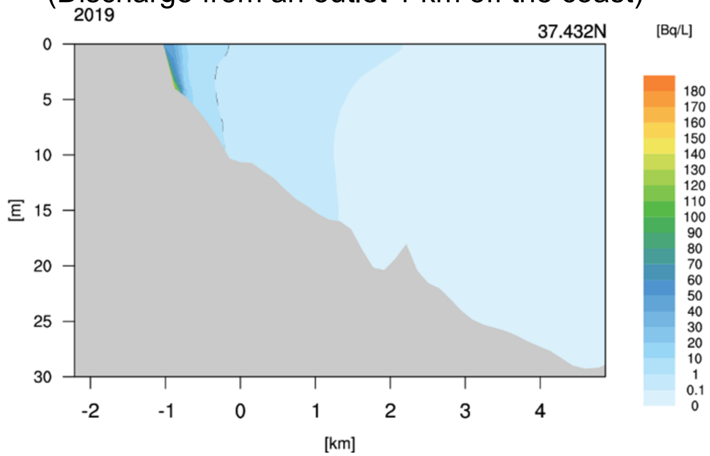


(Discharge from unit 5-6 discharge outlet)

Comparison of the distribution of annual mean tritium concentration in the sea between different discharge locations (sea surface)



(Discharge from an outlet 1 km off the coast)



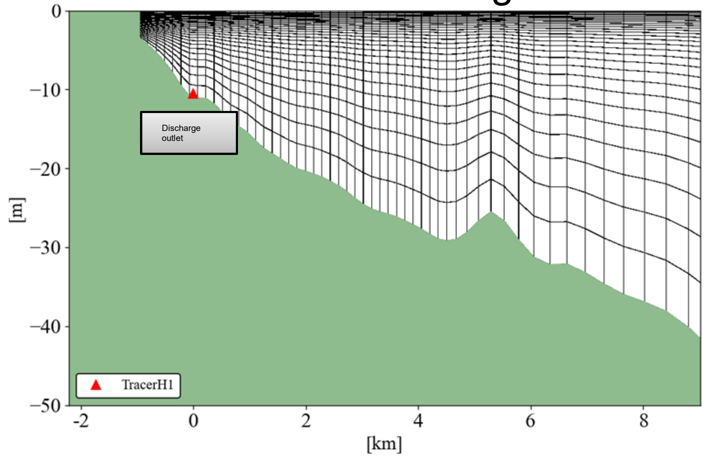
(Discharge from unit 5-6 discharge outlet)

Comparison of the distribution of annual mean tritium concentration in the sea between different discharge locations (cross-sectional view)

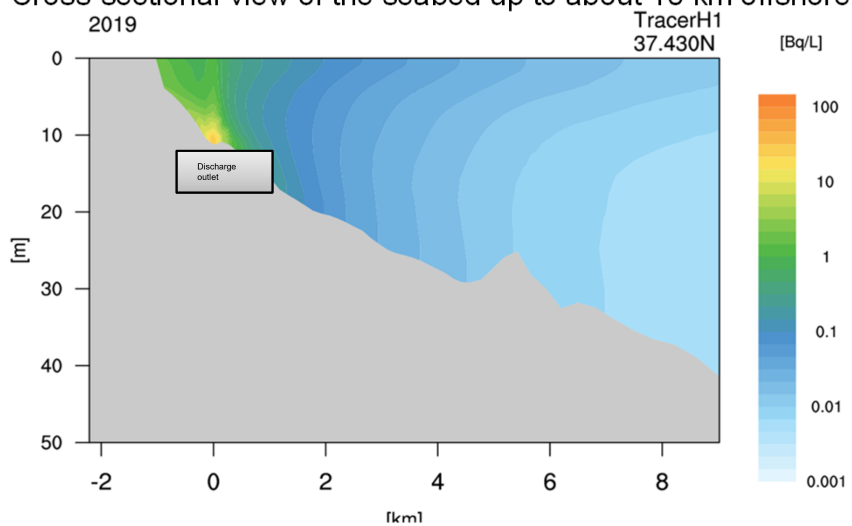
Concentration distribution around the discharge outlet and mean concentration in the 10 km × 10 km area

TEPCO

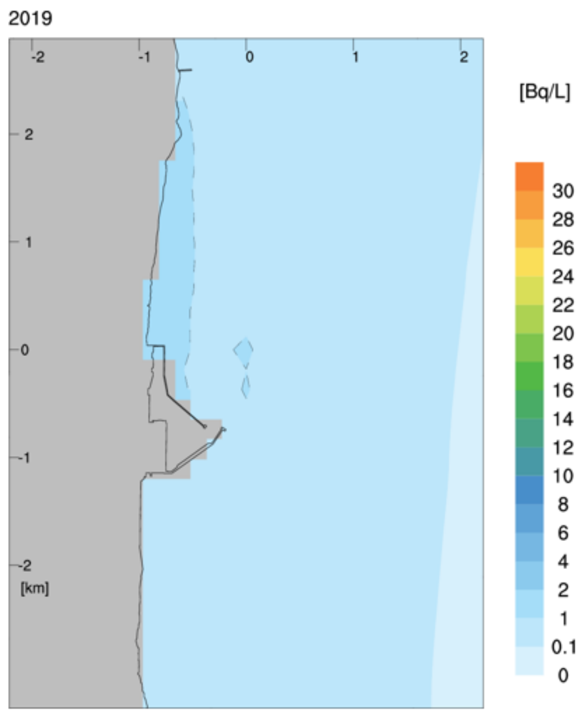
- As shown in the cross-sectional view of the sea bed, the water depth in the sea area around the Fukushima Daiichi NPS becomes gradually deeper toward the open sea. The concentration on the sea bottom becomes lower than on the sea surface.
- Therefore, although the concentration on the sea bottom is locally high near the outlet, the mean concentration in the 10 km × 10 km is higher on the sea surface than on the sea bottom.



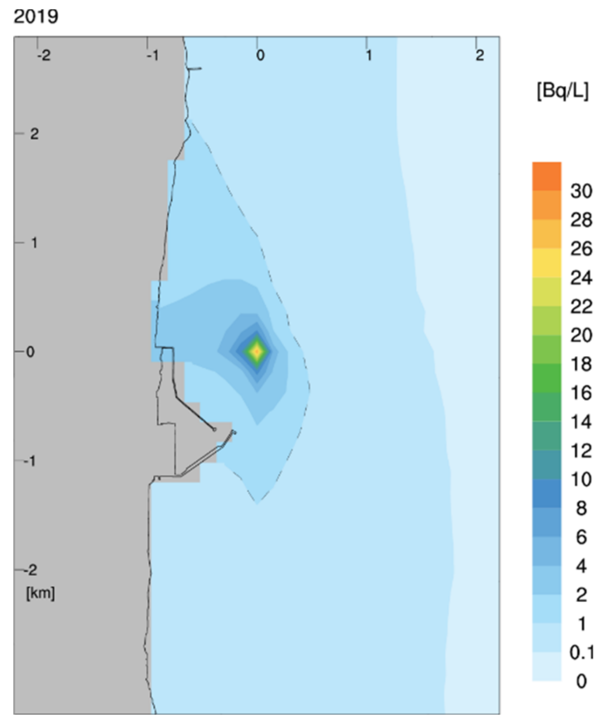
Cross-sectional view of the seabed up to about 10 km offshore



Cross-sectional view of distribution of annual mean tritium concentration up to 10 km offshore



Distribution of annual mean tritium concentration on the sea surface up to 3 km offshore



Distribution of annual mean tritium concentration on the sea bottom up to 3 km offshore

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

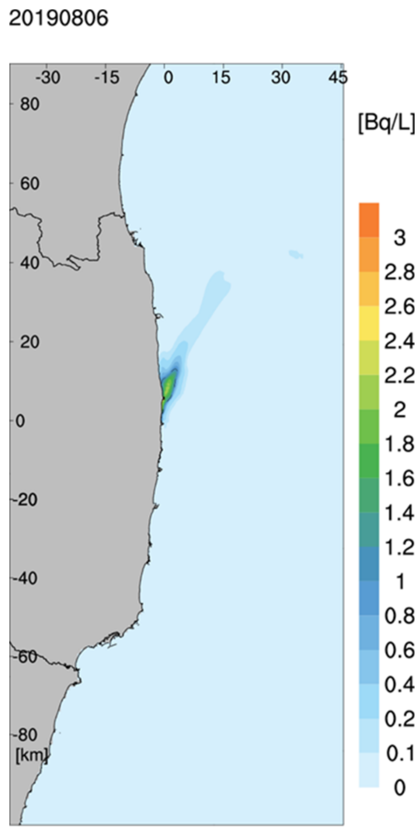
Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

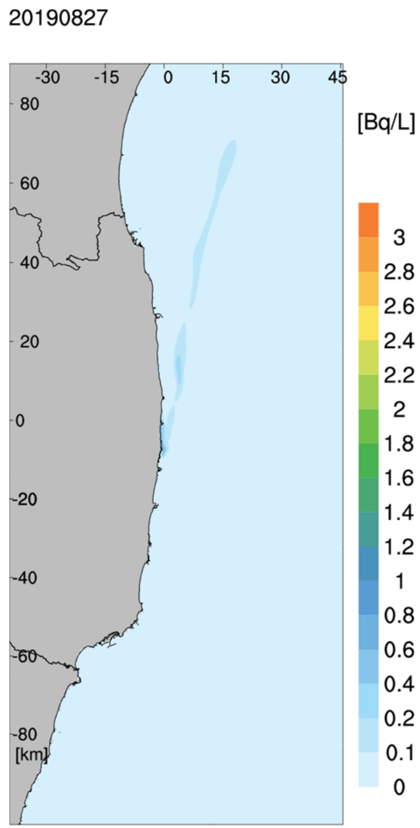
(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- Regarding the calculation results of the tritium diffusion, the behavior of tritium in consideration of the meteorological and oceanographic data in 2019 should be explained, such as whether it is accumulated when the discharge of ALPS treated water is continued for years or whether it saturates at a certain point in time.
- Regarding the impacts of accumulated radioactive materials, the rationale of all the selected transfer models, not only seawater but also hulls, fishing nets, beach sand, etc., should be explained.

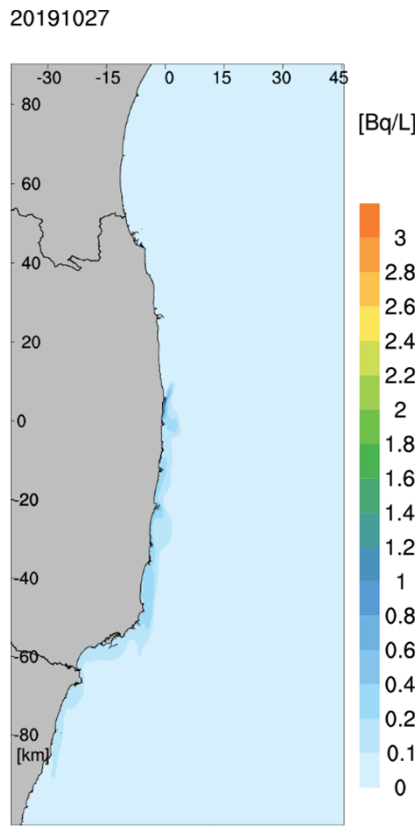
- The following are example maps showing daily concentration distribution when 22 trillion Bq of tritium is released evenly throughout a year. Even when the discharge is continued, the direction and distribution of diffusion change frequently due to tidal currents, and accumulation and increase in concentration are not observed.
- Even a 30-year continuous discharge will not cause any harm due to tritium accumulation.



(When the range of 0.1 Bq/L extends to the easternmost point)



(When the range of 0.1 Bq/L extends to the northernmost point)



(When the range of 0.1 Bq/L extends to the southernmost point)

Distribution of daily mean concentration of tritium on the sea surface

Consideration of the impacts of accumulated radioactive materials

- Radioactive materials other than tritium adhere to and accumulate in sea bottom sediment and other materials.
- In the Radiological Impact Assessment, the adhesion to hulls, fishing nets, and beach sediment, as well as on sea bottom sediment, were taken into account.
- In general, radioactive materials absorbed in sediments (media) become denser than seawater. Still, it is assumed that the media concentration and seawater concentration will eventually reach an equilibrium state, and no further accumulation will proceed.
- Because the ALPS treated water is purified until the sum of the ratios to regulatory concentrations limits of nuclides other than tritium becomes less than 1 and is diluted with seawater 100 times or more before discharge, the concentration in the seawater is expected to be below. It will probably take time for radionuclides to accumulate. However, the assessment was performed to obtain conservative results while assuming that the concentrations were in equilibrium.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- A review should be carried out in selecting exposure pathways based on the diffusion and transfer model established by the flowchart shown in GSG-10. Moreover, the details of the approach to selection, including its completeness, should be given, such as by showing the concept of the excluded exposure pathways.

Rationale behind the selection of transfer pathways according to GSG-10

TEPCO

The table below shows the transfer pathways that GSG-10 indicates as pathways that should be considered in the Radiological Impact Assessment Report and the rationale behind selecting exposure pathways.

Transfer pathways described in GSG-10	Rationale behind the selection of transfer pathways	Rationale behind the selection of exposure pathways
Direct radiation	ALPS treated water has been purified before discharge until the sum of the ratios to regulatory concentrations limits of radionuclides other than tritium becomes less than 1. Therefore, the impact of direct radiation is not selected.	Since this is not selected as a transfer pathway, and therefore is not selected as an exposure pathway.
Atmospheric diffusion	The atmosphere diffusion is not selected since ALPS treated water is contained in tanks and diluted before being discharged into the sea in liquid form.	Since this is not selected as a transfer pathway, and therefore is not selected as an exposure pathway.
Deposition from the atmosphere onto the ground surface and subsequent resuspension	Since atmospheric diffusion is not selected, the deposition onto the ground surface and subsequent resuspension are not selected either.	Since this is not selected as a transfer pathway, and therefore is not selected as an exposure pathway.
Diffusion in water	Since ALPS treated water is discharged into the sea in liquid form, the transfer and diffusion in the seawater are selected.	External exposure to radioactive materials in the seawater while being on vessels or swimming in the sea is selected. In addition, accidental ingestion of water while swimming in the sea may happen; therefore, the revised version will add internal exposure from accidental ingestion while swimming.
Resuspension from seawater to the atmosphere	Since ALPS treated water is diluted before being discharged into the sea and migrates and diffuses in the sea, the impact of resuspension in the atmosphere is not selected.	Since this is not selected as a transfer pathway, and therefore is not selected as an exposure pathway.

2-2 (3) Radiological impact assessment on the surrounding environment due to discharge into the sea

Rationale behind the selection of transfer pathways according to GSG-10

Transfer pathways described in GSG-10	Rationale behind the selection of transfer pathways	Rationale behind the selection of exposure pathways
Accumulation on and resuspension from sea bottom sediment (seabed soil)	The transfer to and accumulation in sea bottom sediment are selected as transfer pathways. Since a decrease in concentration in seawater due to transfer is not taken into account, resuspension in the seawater is not selected.	External exposure from sea bottom sediment is not selected because direct human access to aquatic sediments rarely occurs. *External exposure of marine plants and animals is selected.
Accumulation in beach sediment and resuspension	Radionuclides in the seawater may transfer and accumulate in beach sediment. Therefore, this pathway is selected. Assuming that the impact of resuspension from beach sediment is negligible, this pathway is not selected.	External exposure from beach sediment is selected. Assuming that the impact of resuspension from beach sediment is negligible, internal exposure due to inhalation is not selected.
Transfer to and accumulation in plants and animals	Since ALPS treated water is discharged into the sea in liquid form, the transfer from seawater to marine plants and animals is selected.	Internal exposure from ingestion of marine plants and animals is selected.

Validation of exposure pathways (estimation by the method specified in Tecdoc1759)

- Transfer and exposure pathways that were not selected in the Radiological Impact Assessment were simulated in accordance with the assessment method specified in IAEA Tecdoc1759*.
- The assessment method Tecdoc1759 and simulation conditions are as follows.
  - ✓ The method Tecdoc1759 assumes the assessment of impacts of ocean dumping of radioactive materials.
  - ✓ Radioactive materials in the seawater are divided into three forms to calculate: dissolved materials, materials adsorbed in suspended particles, and materials adsorbed in sea bottom sediment.
  - ✓ Radioactive materials are assumed to reach an equilibrium state instantaneously in the assessment area.

- Concentrations of radionuclides in a dissolved state, those adsorbed in suspended particles, and those absorbed in aquatic sediments were calculated based on the mean concentration in all layers within the 10 km x 10 km area used for the Radiological Impact Assessment.
- The following transfer pathways were simulated. Some of the pathways adopted in the Radiological Impact Assessment were also simulated for comparison.
  - [1] External exposure from sandy beaches (pathway adopted in the Radiological Impact Assessment)
  - [2] Internal exposure from accidental ingestion of coastal sediment
  - [3] Internal exposure from ingestion of water while swimming
  - [4] Internal exposure from accidental inhalation of diffused coastal sediment
  - [5] Internal exposure from inhalation of seawater spray
  - [6] Internal exposure from ingestion of seafood (pathway adopted in the Radiological Impact Assessment)
  - [7] Exposure of the skin from sea bottom sediment settled on the skin
- To consider all nuclides, source terms based on measured values were used.

* IAEA-Tecdoc1759 "Determining the Suitability of Materials for Disposal at Sea under the London Convention 1972 and London Protocol 1996: A Radiological Assessment Procedure"(IAEA,2015)

Validation of exposure pathways (estimation by the method specified in Tecdoc1759)

TEPCO

- The table below shows the results simulated by the method Tecdoc1759 using water in K4 tanks as the source term. The impacts of all pathways that were not selected in the Report are more than two orders of magnitude lower than the total exposure in the Report, and there are no pathways that should be added.
- Furthermore, when both methods assessed the impact of a pathway, the results obtained by the method Tecdoc1759 are lower than the results of the Radiological Impact Assessment.

Assessed case		Report (K4 tank water)	Tecdoc1759	Remarks
External exposure (mSv/year)	Exposure from sea surface	6.5E-09		Exempted from the assessment in Tecdoc1759
	Exposure from hulls	5.2E-09		Exempted from the assessment in Tecdoc1759
	Exposure during underwater work	2.8E-10		Exempted from the assessment in Tecdoc1759
	Exposure from fishing nets	1.6E-06		Exempted from the assessment in Tecdoc1759
	Exposure from sandy beaches	5.0E-07	2.5E-08	In the assessment of the Report, conservative dose conversion coefficients were used for external exposures, and therefore the results are considered to be conservative.
Internal exposure (mSv/year) (Value for adult)	Ingestion of coastal sediment		5.0E-11	
	Ingestion of water while swimming	2.1E-08	2.1E-08	The exposure is mostly to tritium, and both results are almost the same.
	Inhalation of diffused coastal sediment		3.2E-13	
	Inhalation of seawater spray		4.9E-09	
	Ingestion of seafood	6.1E-05	1.6E-05	In the assessment of the Report, the concentration in seafood was assessed using conservative concentrations in seawater rather than taking into account adhesion to suspended particles and sea bottom sediment. Therefore, the assessment result is considered to be conservative.
Exposure of the skin (mSv/year)	When bottom sediment settles on the skin		1.5E-09	A skin tissue loading factor of 0.01 was used in the assessment.
Total (mSv/year)		6.3E-05	1.6E-05	

Validation of exposure pathways (estimation by the method specified in Tecdoc1759)

TEPCO

- The table below shows the results simulated by the method Tecdoc1759 using water in J1-C tanks as the source term. The impacts of all pathways that were not selected in the Report are more than two orders of magnitude lower than the total exposure in the Report, and there are no pathways that should be added.
- Furthermore, when both methods assessed the impact of a pathway, the results obtained by the method Tecdoc1759 are lower than the results of the Radiological Impact Assessment.

Assessed case		Report (J1-C tank water)	Tecdoc1759	Remarks
External exposure (mSv/year)	Exposure from sea surface	1.7E-08		Exempted from the assessment in Tecdoc1759
	Exposure from hulls	1.3E-08		Exempted from the assessment in Tecdoc1759
	Exposure during underwater work	7.6E-10		Exempted from the assessment in Tecdoc1759
	Exposure from fishing nets	4.3E-06		Exempted from the assessment in Tecdoc1759
	Exposure from sandy beaches	1.3E-06	1.3E-08	In the assessment of the Report, conservative dose conversion coefficients were used for external exposures, and therefore the results are considered to be conservative.
Internal exposure (mSv/year) (Value for adult)	Ingestion of coastal sediment		4.2E-11	
	Ingestion of water while swimming	2.0E-08	2.0E-08	The exposure is mostly to tritium, and both results are almost the same.
	Inhalation of diffused coastal sediment		2.7E-12	
	Inhalation of seawater spray		4.8E-09	
	Ingestion of seafood	1.1E-04	2.9E-06	In the assessment of the Report, the concentration in seafood was assessed using conservative concentrations in seawater rather than taking into account adhesion to suspended particles and sea bottom sediment. Therefore, the assessment result is considered to be conservative.
Exposure of the skin (mSv/year)	When bottom sediment settles on the skin		2.2E-09	A skin tissue loading factor of 0.01 was used in the assessment.
Total (mSv/year)		1.1E-04	2.9E-06	

The Japanese version shall prevail.

2-2 (3) Radiological impact assessment on the surrounding environment due to discharge into the sea

Validation of exposure pathways (estimation by the method specified in Tecdoc1759)

- The table below shows the results simulated by the method of Tecdoc1759 using water in J1-G tanks as the source term. The impacts of all pathways that were not selected in the Report are more than two orders of magnitude lower than the total exposure in the Report, and there are no pathways that should be added.
- Furthermore, when both methods assessed the impact of a pathway, the results obtained by the method Tecdoc1759 are lower than the results of the Radiological Impact Assessment.

Assessed case		Report (J1-G tank water)	Tecdoc1759	Remarks
External exposure (mSv/year)	Exposure from sea surface	4.7E-08		Exempted from the assessment in Tecdoc
	Exposure from hulls	3.4E-08		Exempted from the assessment in Tecdoc
	Exposure during underwater work	2.0E-09		Exempted from the assessment in Tecdoc
	Exposure from fishing nets	1.2E-05		Exempted from the assessment in Tecdoc
	Exposure from sandy beaches	3.6E-06	3.1E-08	In the assessment of the Report, conservative dose conversion coefficients were used for external exposures, and therefore the results are considered to be conservative.
Internal exposure (mSv/year) (Value for adult)	Ingestion of coastal sediment		9.8E-11	
	Ingestion of water while swimming	2.0E-08	2.0E-08	The exposure is mostly to tritium, and both results are almost the same.
	Inhalation of diffused coastal sediment		6.8E-12	
	Inhalation of seawater spray		5.0E-09	
	Ingestion of seafood	3.0E-04	4.6E-06	In the assessment of the Report, the concentration in seafood was assessed using conservative concentrations in seawater rather than taking into account adhesion to suspended particles and sea bottom sediment. Therefore, the assessment result is considered to be conservative.
Exposure of the skin (mSv/year)	When bottom sediment settles on the skin		5.2E-09	A skin tissue loading factor of 0.01 was used in the assessment.
Total (mSv/year)		3.1E-04	4.7E-06	

The Japanese version shall prevail.

Reference: Method specified in Tecdoc1759

TEPCO

- Tecdoc1759 is a document published by the IAEA and specifies radiological assessment procedures for determining the suitability of materials for sea dumping under the London Convention 1972 and London Protocol 1996.
- This shows how to calculate exposures of humans, plants, and animals from radioactive materials disposed of in the sea, along with calculation examples.
- To evaluate exposure pathways that were not selected in the Radiological Impact Assessment Report for the discharge of ALPS treated water, pathways presented in this document were simulated by the method specified there.
- In principle, parameters recommended in Tecdoc1759 were used, but the respiration rate adopted is based on the dose assessment guideline of Japan, and the skin equivalent dose conversion coefficients used are those specified in IAEA SRS 44[*1] (beta and gamma-ray emitting nuclides) since they are not provided in Tecdoc1759. The dose conversion coefficients adopted for external exposures are those specified in FGR 15[*3], the latest version. However, Tecdoc1759 recommends using coefficients specified in FGR 12[*2] published by the United States Environmental Protection Agency.

*1: IAEA SAFETY REPORTS SERIES No. 44 “DERIVATION OF ACTIVITY CONCENTRATION VALUES FOR EXCLUSION, EXEMPTION AND CLEARANCE"
*2: FEDERAL GUIDANCE REPORT NO.12 “EXTERNAL EXPOSURE TO RADIONUCLIDES IN AIR, WATER AND SOIL” (U.S. Environmental Protection Agency ,1993)
*3: FEDERAL GUIDANCE REPORT NO.15 “EXTERNAL EXPOSURE TO RADIONUCLIDES IN AIR, WATER AND SOIL” (U.S. Environmental Protection Agency ,2019)

Concept of concentrations in the seawater (1)

- In Tecdoc1759, a single-box model (10 km × 10 km × water depth of 20 m) is used, assuming dumping in a turbulent coastal area (several kilometers off the coast).
- Postulating that the radioactive materials released in the box are instantly mixed with the total amount of seawater in the box. The dissolved and adsorbed (suspended particles and sediments) radioactivity in the seawater is instantaneously balanced.
- When the equilibrium concentration of radionuclide j in the box is calculated to be $C_{BOX}(j)$ based on the annual release of the radionuclide j and the amount of seawater transferred out of the box, the radioactivity of radionuclide j in the dissolved phase in the seawater $C_{DW}(j)$ (Bq/m^3) is given by the following equation:

$$C_{DW}(j) = \frac{C_{BOX}(j)}{1+Kd(j)\left(S+\frac{L_B \rho_B}{D}\right)}$$

- ✓ where $K_d(j)$ is the sediment partition coefficient of radionuclide j (in m^3/kg);
- ✓ S is the suspended sediment concentration (in kg/m^3), 3E-03 kg/m^3 is used;
- ✓ L_B is the thickness of the sediment boundary layer (in m), 1E-02 m is used;
- ✓ ρ_B is the density of the sediment boundary layer (in kg/m^3), 1500 kg/m^3 is used; and
- ✓ D is the depth of the water depth of the model (in m), A water depth of 12 m, the depth of the discharge point, is used.

Concept of concentrations in the seawater (2)

- In the assessment by the method of Tecdoc1759, the annual mean concentration (mean concentration in all layers within the 10 km × 10 km area) of each nuclide in the Radiological Impact Assessment Report was used for $C_{BOX}(j)$.

- The mass density $C_P(j)$ (Bq/kg) of the suspended particles was obtained by the following equation:

  $C_P(j)=K_d(j)C_{DW}(j)$

- The total concentration in seawater $C_W(j)$ of dissolved and suspended particles was obtained by the following equation:

  $C_W(j)=(1+K_d(j)S)\ C_{DW}(j)$

Simulated exposure pathways

- As the main exposure pathways to the general public, a total of 7 pathways were simulated: 5 pathways indicated in Tecdoc1759 as the main pathways through which surrounding residents may be exposed to radionuclides ((1), (2), (4), (5), (6)), and 2 pathways indicated as those that should be considered depending on conditions unique to the site ((3), (7)).
  (1) External exposure from sandy beaches (pathway adopted in the Radiological Impact Assessment)
  (2) Internal exposure from accidental ingestion of coastal sediment
  (3) Ingestion of water while swimming
  (4) Internal exposure from accidental inhalation of diffused coastal sediment
  (5) Internal exposure from inhalation of seawater spray
  (6) Internal exposure from ingestion of seafood (pathway adopted in the Radiological Impact Assessment)
  (7) Exposure due to skin contamination

[1] The annual effective dose to the public from external exposure to radionuclides deposited on the seashore

$E_{ext,\,public}$ (in Sv) can be calculated by the following equation:

$$E_{ext,public} = t_{public} \Sigma_j Cs(j) DC_{gr}(j)$$

- where
- t_{public} is the time spent by members of the public on the shore in a year (500 hours),
- $DC_{gr}(j)$ is the dose conversion factor for ground contamination of radionuclide j (in $(Sv/h)/(Bq/m^2)$); Dose conversion factors for ground surface contamination specified in the latest FGR 15* prepared by the United States Environmental Protection Agency were used.
- $C_s(j)$ is the surface contamination of radionuclide j in the shore sediments (in Bq/m^2).

$$C_s(j) = \frac{C_P(j)\rho_S d_S}{10}$$

- where
- ρ_s is the density of coastal sediment ($1.5\ E + 03\ kg/m^3$);
- d_s is the effective thickness of coastal sediment (0.1 m).
- The activity concentration radionuclide j in suspended particles $C_p(j)$ (in Bq/kg, dry weight) can be calculated by the following equation:

$$C_P(j) = K_d(j) C_{DW}(j)$$

* FEDERAL GUIDANCE REPORT NO.15 "EXTERNAL EXPOSURE TO RADIONUCLIDES IN AIR, WATER AND SOIL" (U.S. Environmental Protection Agency ,2019)

[2] Dose from accidental ingestion of coastal sediment

The annual dose from accidental ingestion of coastal sediment $E_{ing,\ shore,\ public}$ (Sv) can be calculated by the following equation:

$$E_{ing,shore,public} = t_{public} H_{shore} \sum_j \frac{C_{s(j)}}{\rho_S L_B} DC_{ing}(j)$$

- where
- t_{public} is the time spent (500 hours);
- H_{shore} is the hourly ingestion amount of beach sediment (in kg/h),
  The value for adult of 5.0 E-06 kg/h is used.
- The concentration of radionuclides in the ingested material is derived from the value obtained by dividing the contamination density on the surface of coastal sediment Cs(j) by the thickness of the sediment layer L_B (1.0E-02 m) and the density of the sediment (1.5E + 03 kg/m^3).
- DC_{ing}(j) is the effective dose coefficient (in Sv/Bq) for ingestion of radionuclide j.

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[3] Exposure from ingestion of water

As with internal exposure from ingestion of fish and shellfish, the exposure is obtained by calculating the amount of intake of each nuclide (Bq/year) and multiplying the value by the effective dose coefficient for ingestion.

$$E_{drink,public} = t_{public} H_{swim} \sum_j C_W(j) DC_{ing}(j)$$

- where
- t_{public} is the time spent while swimming (96 hours/year);
- H_{swim} is the intake rate of seawater during swimming (conservatively set at 0.2 L/h);
- $C_w(j)$ is the concentration of nuclide j in seawater (Bq/L);
- $DC_{ing}(j)$ is the effective dose coefficient for ingestion of nuclide j

[4] The dose from inhalation of diffused coastal sediment $E_{inh,\ shore,\ public}$ was calculated by the following equation:

$$E_{inh,shore,public} = t_{public} R_{inh,public} DL_{shore} \sum_j C_P(j) DC_{inh}(j)$$

- where
- $R_{inh,\ public}$ is the inhalation rate of a member of the public in m^3/h. The value specified in the dose assessment guideline (0.92 m^3/h for adults) is used;
- DL_{shore} is the load factor (in kg/m^3) for dust from coastal sediment. The recommended value of 2.5E-09 kg/m^3 is used;
- $DC_{inh}(j)$ is the dose coefficient (in Sv/Bq) for inhalation of radionuclide j.
- The concentration of radionuclides in sediment $C_p(j)$ (Bq/kg) can be calculated by the following equation:

$$C_p(j) = K_d(j) C_{DW}(j)$$

- t_{public} is the time spent at the beach (500 hours/year).

[5] The dose from inhalation of seawater spray in the air on the beach $E_{inh,\ spray,public}$ (in Sv/year) was calculated by the following equation:

$$E_{inh,spray,public} = t_{public} R_{inh,public} \frac{C_{spray}}{\rho_w} \sum_j C_W(j) DC_{inh}(j)$$

- where
- C_{spray} is the concentration of seawater spray in the air (in kg/m^3), The recommended value of 1.0E-02 kg/m^3 was used;
- ρ_w is the density of seawater (1E+03 kg/m^3);
- $C_w(j)$ is the concentration of radionuclide j in the seawater (in Bq/m^3);
- t_{public} is the time spent at the beach (500 hours/year).
- The inhalation rate $R_{inh,\ public}$ (in m^3/h), and the dose coefficient for inhalation $DC_{inh}(j)$ (in Sv/Bq) are the same as those used to calculate the dose from inhalation of diffused coastal sediment.

[6] Internal exposure from ingestion of seafood was calculated the same way as used in the Report, except for the seawater concentration.

$$E_{ing,food,public} = \sum_k H_B(k)\ (j) \sum_j C_{EB}(j,k) DC_{ing}(j)$$

- where
- $H_B(k)$ is the annual ingestion (in kg) of seafood k. The same value as the one used for the Radiological Impact Assessment was used;
- $DC_{ing}(j)$ is the effective dose coefficient (in Sv/Bq) for ingestion of radionuclide j;
- $C_{EB}(j,k)$ is the concentration of nuclide j (in Bq/kg) in the edible part of seafood k obtained by the following equation:

$$C_{EB}(j,k) = CF(j,k) C_{DW}(j)$$

- where
- CF(j, k) is the enrichment factor for nuclide j in seafood k;
- $C_{DW}(j)$ is the concentration of nuclide j dissolved in seawater.

[7] Exposure from sea bottom sediment that is adhered to fishing nets during fishing operation and settled on the skin was simulated and calculated by the following equation:

$$E_{skin} = t_{public} \Sigma_j S_d DC_{skin}(j)$$

- where
- t_{public} is the exposure time.
- S_d is the surface contamination density (Bq/cm^2);
- $DC_{skin}(j)$ [($Sv/year$)/(Bq/cm^2)] is the dose conversion coefficient for the skin specified in IAEA SRS44* (beta and gamma-ray emitting nuclides);
- The surface contamination density S_d was calculated by the following equation:

$$S_d = K_d(j) C_{DW}(j) \rho d$$

- where
- $K_d(j)$ is the distribution coefficient of the nuclide j between seawater and sea bottom sediment ((Bq/kg)/(Bq/L));
- $C_{DW}(j)$ is the concentration of nuclide j in seawater (Bq/L);
- ρ is the density of sea bottom sediment (1.5 E-03 kg/cm^3);
- d is the thickness of the sea bottom sediment settled on the skin (0.01 cm).

* IAEA SAFETY REPORTS SERIES No. 44 "DERIVATION OF ACTIVITY CONCENTRATION VALUES FOR EXCLUSION, EXEMPTION AND CLEARANCE"

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- Concerning the dose conversion coefficients for tritium, the rationale for the abundance ratio between tritiated water (HTO) and organically bonded tritium (OBT) should be explained, and reference documents for such ratio should be provided.

How to handle OBT (Organic Bonded Tritium) in relation to dose conversion coefficients for tritium

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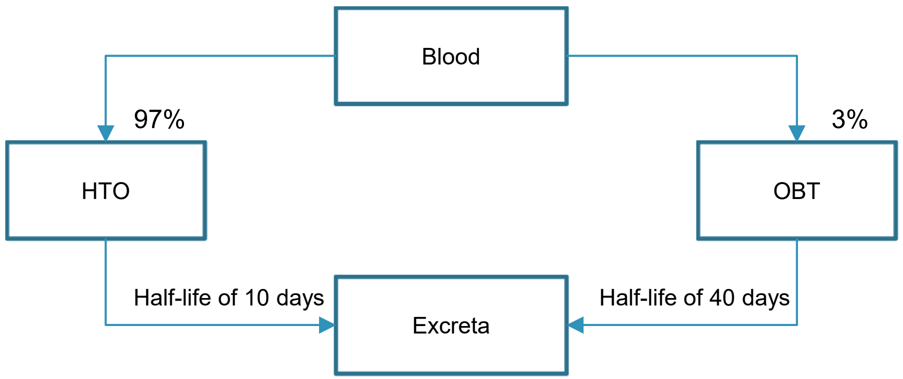
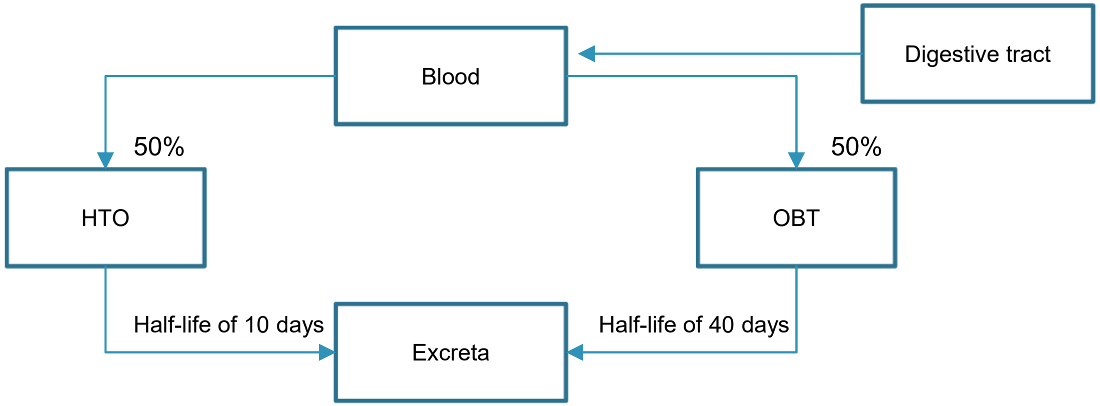
- According to the model of ICRP Publication 56*1, about 3% of tritiated water (HTO) taken into the body changes into OBT and remains in the body longer than tritiated water. The half-life of tritiated water in the body is about 10 days, while that of OBT is about 40 days.
- On the other hand, when tritium is taken into the body as OBT, 50% of which is assumed to be immediately converted to tritiated water in the blood. With the half-life mentioned above, each form of tritium is eventually excreted from the blood as tritiated water.
- Based on such a pharmacokinetic model in the body, ICRP Publication 72*2 sets the effective dose coefficients for tritium as follows.
  - Tritiated water 1.8E-11 Sv/Bq
  - OBT 4.2E-11 Sv/Bq



ICRP model for ingestion of tritiated water
(Source: Annex C of UNSCEAR2016*3)



ICRP model for ingestion of OBT
(Source: Annex C of UNSCEAR2016)

*1: ICRP Publication56 “Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part1”
*2: ICRP Publication72 “Age-dependent Doses to the Members of the Public from Intake of Radionuclides - Part 5 Compilation of Ingestion and Inhalation Coefficients"
*3: 2016 Report of United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

How to handle OBT (Organic Bonded Tritium) in relation to dose conversion coefficients for tritium

- In the Radiological Environmental Impact Assessment Report, all tritium was assessed as tritiated water (HTO) since the ALPS treated water to be discharged contains few organic substances containing OBT.
- Although there is little data on organically bound tritium in the environment, it does not seem to exceed the concentration of HTO.
- TEPCO has continued to measure the tritium in flounder fish off the coast of Fukushima since the fish is large and advantageous for analyses. However, OBT has never been detected so far.
- Even if several percent of the tritium to be ingested is assumed to be OBT in the assessment, that does not affect the results of the Radiological Impact Assessment since the proportion of tritium in the exposure assessment results is small.

Example: Change in exposures when OBT makes up 10% of the tritium to be ingested

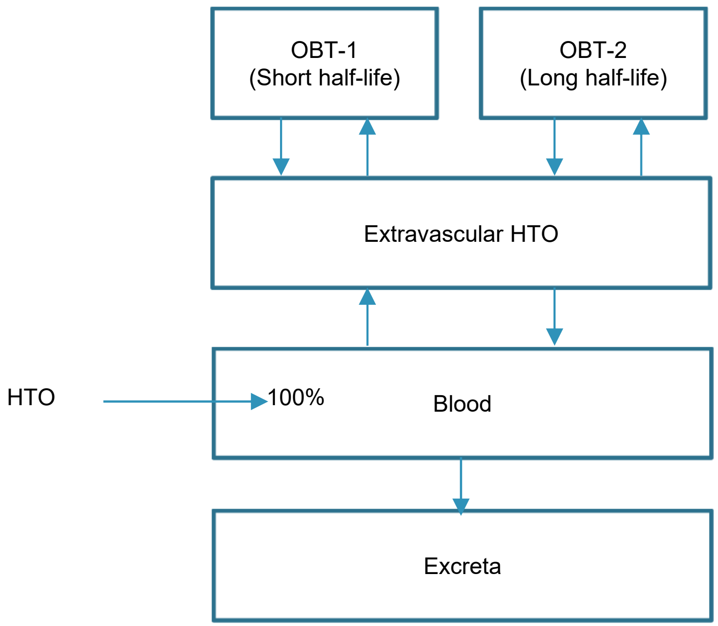
$$0.9 \times 1.8E\text{-}11[Sv/Bq] + 0.1 \times 4.2E\text{-}11[Sv/Bq] = 2.0E\text{-}11[Sv/Bq]$$

The exposure to tritium may increase by about 10% compared with the exposure when all the tritium is assumed to be tritiated water. However, the proportion of tritium in the total exposure is small, and the effect on the exposure assessment results is negligible.

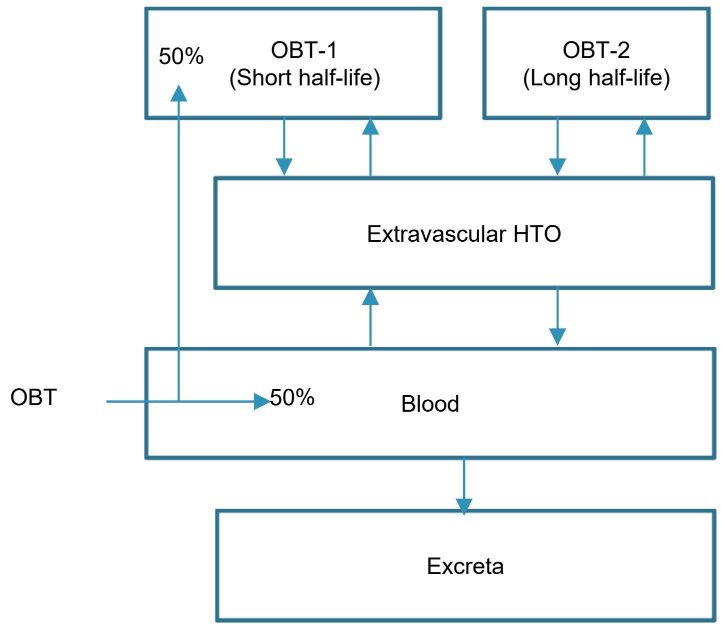
Reference: New pharmacokinetic model presented by ICRP

- The ICRP Publication 134* provides a new pharmacokinetic model that incorporates OBT with a biological half-life of about 40 days and OBT with a biological half-life of about 1 year, which remains in the body for a more extended period.
- The effective dose coefficients based on this model are higher than those presented in Publication 72, as shown below. Even so, calculating exposures using those coefficients does not significantly affect the exposure assessment results.
  - Tritiated water 1.9E-11 Sv/Bq
  - OBT 5.1E-11 Sv/Bq
- The model predicts that about 6% of total tritium in the body will be OBT if tritiated water is ingested continuously.

New model for ingestion of tritiated water



New model for ingestion of OBT



* ICRP Publication134 “Occupational Intakes of Radionuclides: Part 2”

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

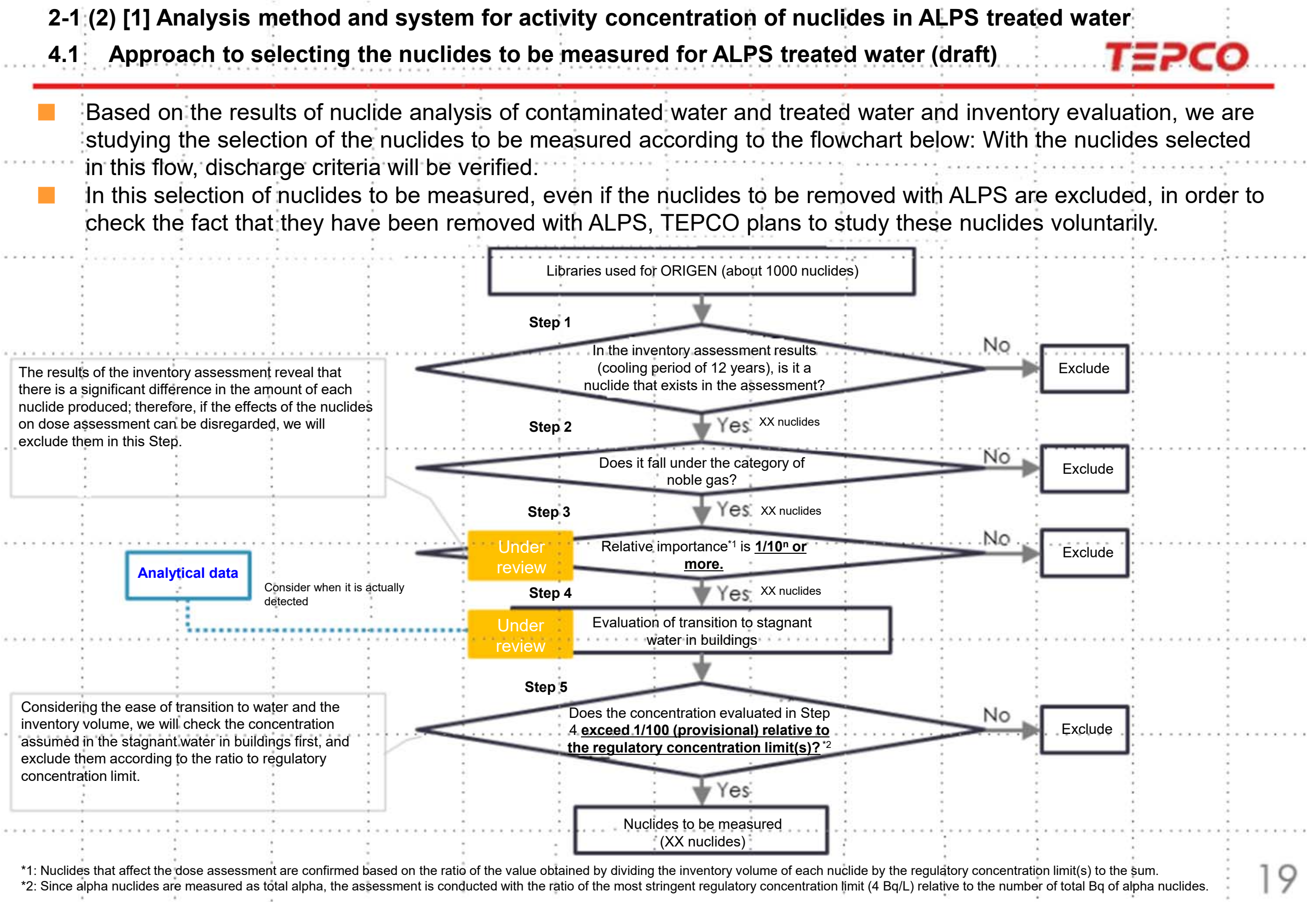
(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- 64 nuclides (tritium, carbon 14, and 62 nuclides to be removed with ALPS) have been set as the source term. The approach to selection, such as narrowing down the nuclides to be evaluated, should be specified after assessing what kind of nuclides can theoretically exist in ALPS treated water in setting the source term.

2-2 (3) Radiological impact assessment on the surrounding environment due to discharge into the sea
Selection of the source term

- As shown in Document 1-1 for the 9th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water, selecting radionuclides to be measured is considered, and the discharge limits will also be verified.
- The source terms used for the Radiological Impact Assessment Report will be reviewed as well based on the result of the above consideration, including the necessity of revisions.



Approach to selecting the nuclides to be measured for ALPS treated water (draft) (excerpts from Document 1-1 for the 9th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water)

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- The facilities for the discharge into the sea will affect the distribution of radioactive materials in seawater in the port. The impact should be included in the Radiological Environmental Impact Assessment.

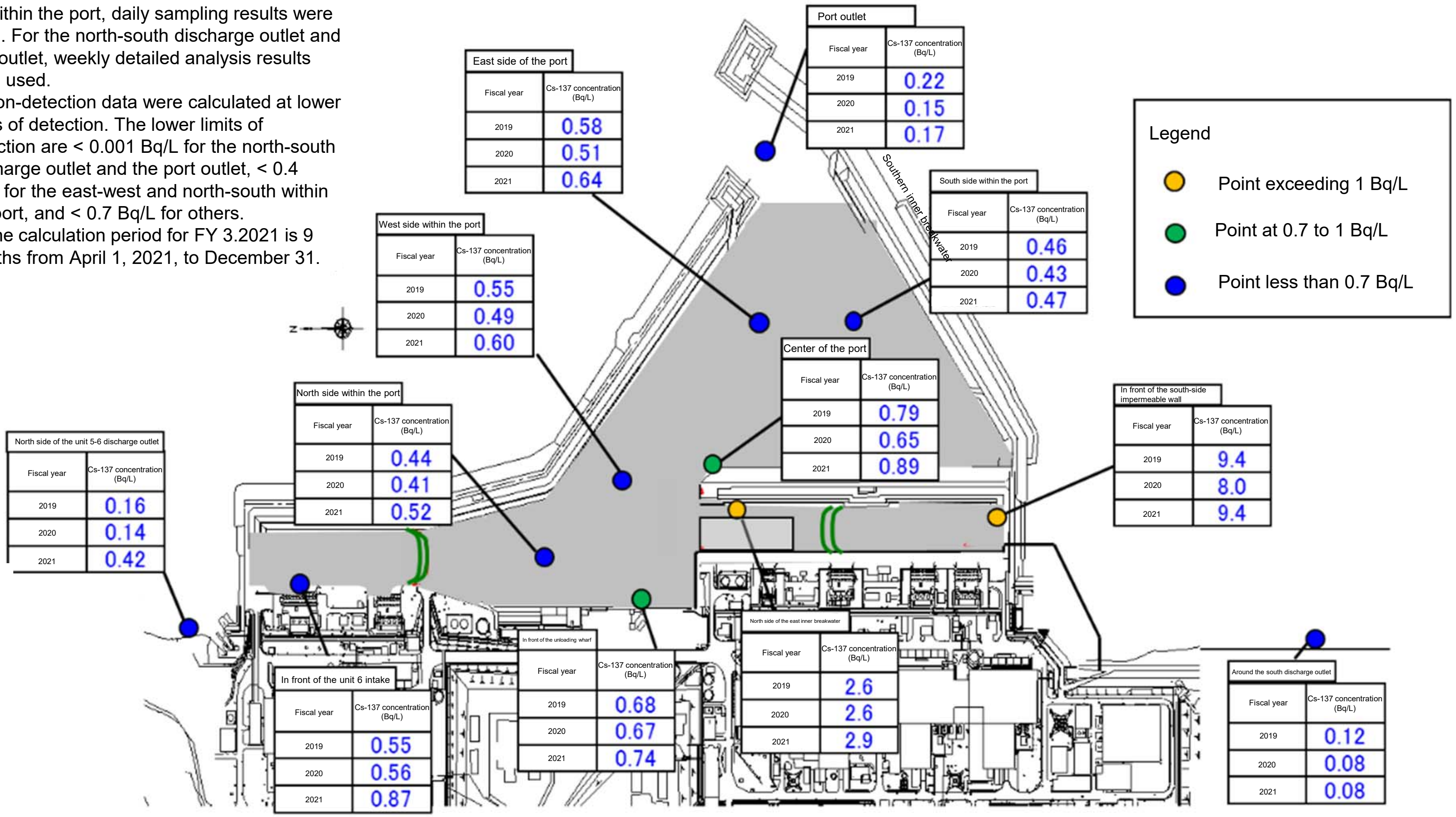
2-1 [1] (3) Methods of seawater intake and discharging ALPS treated water after dilution

Impacts of radioactive materials in seawater in the port (Cs-137 concentration in the port)

TEPCO

- The seawater for diluting the ALPS treated water is planned to be taken from the unit 5 intake. However, regarding the seawater concentration within the port, the concentration of radioactive materials is slightly higher than that of the seawater in the surrounding sea area. Considering this point, as well as the impact of the seabed soil within the port, in the plan the seawater will be drawn from the north side of the unit 5-6 discharge outlet.
- The current state of Cs-137 concentration in the port is shown below: The concentration near the water intake of units 1 to 4 is high, and it becomes lower as measurement points are away from the water intake of units 1 to 4 toward the port outlet or units 5 and 6.

Note:
1. Within the port, daily sampling results were used. For the north-south discharge outlet and port outlet, weekly detailed analysis results were used.
2. Non-detection data were calculated at lower limits of detection. The lower limits of detection are < 0.001 Bq/L for the north-south discharge outlet and the port outlet, < 0.4 Bq/L for the east-west and north-south within the port, and < 0.7 Bq/L for others.
3. The calculation period for FY 3.2021 is 9 months from April 1, 2021, to December 31.



Port outlet

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.22
2020	0.15
2021	0.17

East side of the port

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.58
2020	0.51
2021	0.64

South side within the port

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.46
2020	0.43
2021	0.47

West side within the port

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.55
2020	0.49
2021	0.60

Center of the port

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.79
2020	0.65
2021	0.89

In front of the south-side impermeable wall

Fiscal year	Cs-137 concentration (Bq/L)
2019	9.4
2020	8.0
2021	9.4

North side within the port

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.44
2020	0.41
2021	0.52

North side of the unit 5-6 discharge outlet

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.16
2020	0.14
2021	0.42

In front of the unit 6 intake

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.55
2020	0.56
2021	0.87

In front of the unloading wharf

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.68
2020	0.67
2021	0.74

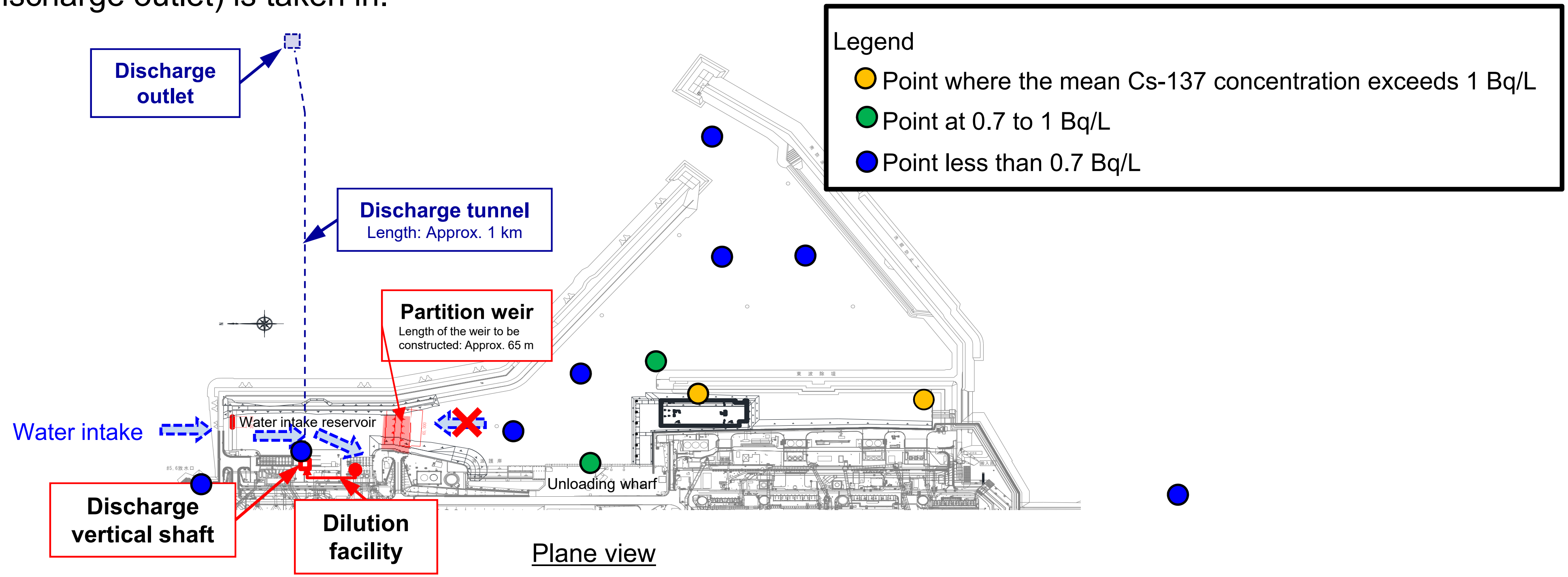
North side of the east inner breakwater

Fiscal year	Cs-137 concentration (Bq/L)
2019	2.6
2020	2.6
2021	2.9

Around the south discharge outlet

Fiscal year	Cs-137 concentration (Bq/L)
2019	0.12
2020	0.08
2021	0.08

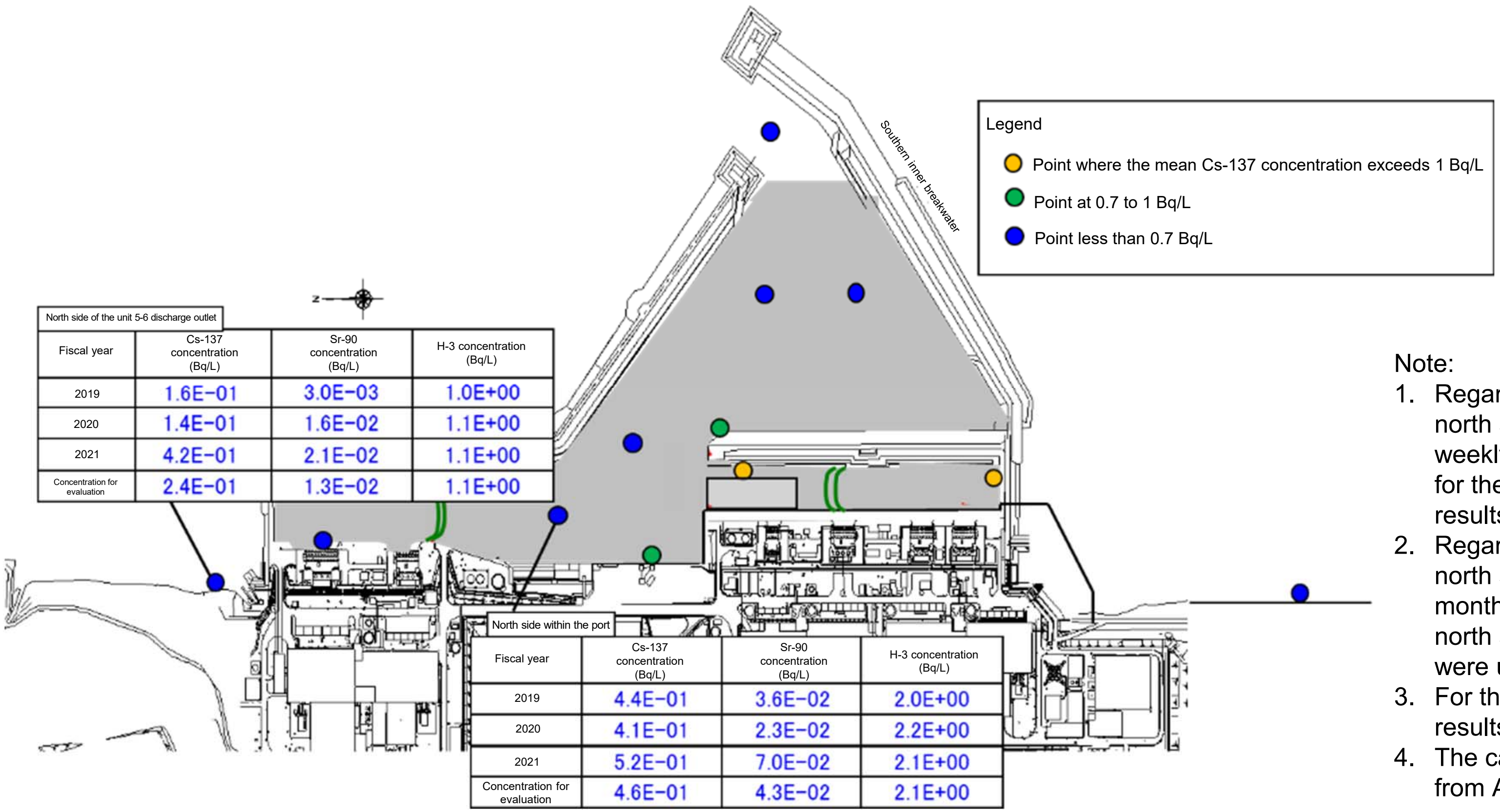
- Regarding the design of intake facilities, a unit 5-6 intake open-channel will be separated with a partition weir (riprap sloping weir + sheet) from the units 1-4 side port side, and a part of the north breakwater permeation prevention work will be remodeled so that the seawater for dilution is taken in from outside the port.
- This design prevents the intake of highly radioactive seawater from the side of units 1-4 intakes, reducing impacts outside the port.
- As a result, the concentration of radioactive materials in seawater in the unit 5-6 intake open-channel, which will become a reservoir, may decrease. In contrast, the concentration around the unloading wharf, where diffusion to the unit 5-6 intake channel will be restricted, may slightly increase.
- To compare impacts to the outside of the port, external effects were assessed in cases where seawater inside the port (area on the side of units 1 to 4) is taken in and where seawater outside the port (north side of the unit 5-6 discharge outlet) is taken in.



Plane view

Impacts of radioactive materials in seawater of the port (concentrations of radioactive materials in seawater to be taken in for dilution)

- Concentrations of seawater to be taken in are set as per the below table, based on the monitoring results (for about 3 years from FY 2019). The water taken from the outside of the port was on the north of the unit 5-6 discharge outlet, and the water taken within the port was north side within the port.
- The target nuclides were Cs-137, Sr-90, and H-3 (In the Cs-137 and Sr-90, it was assumed that the progeny nuclides Ba-137 and Y-90 are contained with the same concentration).
- The minimum detection limits differ between the port and outside the port (it is higher within the port). Based on this, there is a high possibility that the Cs-137 and H-3 on the north side within the port are overestimated, but this does not change the fact that the concentrations on the north side of the unit 5-6 discharge outlet are lower.



North side of the unit 5-6 discharge outlet

Fiscal year	Cs-137 concentration (Bq/L)	Sr-90 concentration (Bq/L)	H-3 concentration (Bq/L)
2019	1.6E-01	3.0E-03	1.0E+00
2020	1.4E-01	1.6E-02	1.1E+00
2021	4.2E-01	2.1E-02	1.1E+00
Concentration for evaluation	2.4E-01	1.3E-02	1.1E+00

North side within the port

Fiscal year	Cs-137 concentration (Bq/L)	Sr-90 concentration (Bq/L)	H-3 concentration (Bq/L)
2019	4.4E-01	3.6E-02	2.0E+00
2020	4.1E-01	2.3E-02	2.2E+00
2021	5.2E-01	7.0E-02	2.1E+00
Concentration for evaluation	4.6E-01	4.3E-02	2.1E+00

Note:
1. Regarding the concentration of Cs-137 for the north side of the unit 5-6 discharge outlet, weekly detailed analysis results were used, and for the north side within the port daily analysis results were used.
2. Regarding the concentration of Sr-90, for the north side of the unit 5-6 discharge outlet monthly analysis results were used, and for the north side within the port weekly analysis results were used.
3. For the H-3 concentrations, the weekly analysis results are used for both cases.
4. The calculation period for FY2021 is 9 months, from April 1, 2021, to December 31, 2021.

- The inventory of each nuclide contained in the seawater for dilution (when 3 seawater pumps for dilution are in operation) was determined by the following equation. It was assessed in addition to the source term for exposure assessment (annual amount of radioactivity released with ALPS treated water).

Annual amount transferred [Bq/year] = Seawater concentration for evaluation [Bq/L] × 340,000 [m^3/day] × 1000 [L/m^3] × 365 [day/year] × 0.8 (availability rate)

- Two types of source terms were used for the exposure assessment: “measured values of the K4 tank group” and “hypothetical ALPS treated water” used for radiological impact assessment. The amount of added radioactivity transferred is shown in the table below.

Table: Annual amount of radioactivity transferred by nuclide of seawater for dilution

Nuclide	Measured values of the K4 tank group		Water intake on the north side within the port	
	Concentration for evaluation (Bq/L)	Volume to be transferred (Bq/year)	Concentration for evaluation (Bq/L)	Volume to be transferred (Bq/year)
Cs-137	2.4E-01	3.6E+10	4.6E-01	6.9E+10
Sr-90	1.3E-02	1.9E+09	4.3E-02	6.4E+09
H-3	1.1E+00	1.6E+11	2.1E+00	3.1E+11

- The results of the exposure assessment are shown in the table below. Water intake outside the port has fewer impacts on the external exposures.
- However, the results in both assessments are more minor compared with the dose limit of 1 mSv/year and the target dose of 0.05 mSv/year. Even if seawater inside the port is taken in for dilution, the impact of radiation exposure is more minor.

Results of human exposures assessment

Assessed case		Measured values of the K4 tank group			Hypothetical ALPS treated water			Remarks
		Radiological Impact Assessment Report	Water intake on the north side of the unit 5-6 discharge outlet	Water intake on the north side within the port	Radiological Impact Assessment Report	Water intake on the north side of the unit 5-6 discharge outlet	Water intake on the north side within the port	
External exposure (mSv/year)	Exposure from sea surface	6.5E-09	7.4E-08	1.4E-07	1.8E-07	2.5E-07	3.1E-07	
	Exposure from hulls	5.2E-09	5.9E-08	1.1E-07	1.4E-07	1.9E-07	2.4E-07	
	Exposure during underwater work	2.8E-10	3.3E-09	6.0E-09	7.9E-09	1.1E-08	1.4E-08	
	Exposure from sandy beaches	5.0E-07	6.0E-06	1.1E-05	1.4E-05	1.9E-05	2.4E-05	
	Exposure from fishing nets	1.6E-06	1.7E-05	3.1E-05	4.5E-05	6.0E-05	7.4E-05	
Internal exposure (mSv/year)		6.1E-05	7.3E-05	8.4E-05	2.0E-03	2.0E-03	2.1E-03	Value for adult
Total (mSv/year)		6.3E-05	9.6E-05	1.3E-04	2.1E-03	2.1E-03	2.2E-03	

Results of internal exposures assessment by age

Assessed case		Measured values of the K4 tank group			Hypothetical ALPS treated water			Remarks
		Radiological Impact Assessment Report	Water intake on the north side of the unit 5-6 discharge outlet	Water intake on the north side of the unit 5-6 discharge outlet	Radiological Impact Assessment Report	Water intake on the north side of the unit 5-6 discharge outlet	Water intake on the north side of the unit 5-6 discharge outlet	
Internal exposure (mSv/year)	Adult	6.1E-05	7.3E-05	8.4E-05	2.0E-03	2.0E-03	2.1E-03	
	Children under school age	9.4E-05	9.9E-05	1.1E-04	3.1E-03	3.1E-03	3.1E-03	
	Infants	1.1E-04	1.1E-04	1.2E-04	3.9E-03	3.9E-03	3.9E-03	

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- In addition to explaining uncertainties in the Radiological Environmental Impact Assessment, uncertainty sources that have dominant effects in the assessment and sources for ensuring conservative results should be clarified and explained.

Uncertainties in the Radiological Impact Assessment

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■ The table below shows the magnitude of uncertainties determined in reference to the results of simulations according to the flow of the Radiological Impact Assessment and how to handle them in the Radiological Impact Assessment.

Summary of uncertainties (1/2)

Item	Details of uncertainty	How to handle in the Radiological Impact Assessment	Magnitude of uncertainty*
Selection of the source terms	Composition of nuclides in the source term is uncertain. Annual releases are undetermined.	All of the 64 nuclides are subject to assessment. Even nuclides that have not been detected until now are also assumed to be contained at the lower detection limits to make the assessment conservative. Furthermore, ALPS treated water in which the sum of the ratios to regulatory concentration limits of 63 nuclides other than tritium is 1, the upper limit, was assumed as hypothetical ALPS treated water that has the most significant impact on exposures to ensure conservative assessment. The assessment results using the hypothetical ALPS treated water are more than 30 times larger than the results of the assessment that used K4 tank water as the source term where non-detected nuclides were taken into account and to be on the conservative side.	+30
Modeling of diffusion and transfer in the environment	Uncertainty of the simulation itself	A document that simulated the diffusion of cesium using the same model to reproduce the monitoring results shows no difference in the shape of diffusion and that the simulated concentrations are almost the same as measured concentrations in high-concentration areas. Although there is uncertainty, it seems to be less than double.	±2
	Uncertainty of the weather conditions used in the simulation	In the report, higher concentrations were adopted from data over 2 years. Subsequently, a total of 7 years' worth of data was assessed to confirm that the variability in the mean concentration in the 10 km × 10 km area is only about 20%.	±1.2
	Uncertainty in the selection of transfer pathways	The pathways were selected based on precedent assessments in Japan. As the pathway due to enrichment in seafood, which is assumed to have the most significant impact on exposures in the ocean, only fish and shellfish caught in the 10 km × 10km area around the power plant are used for the assessment. Therefore, the uncertainty in selecting transfer pathways does not seem to have significant effects on the assessment results. In addition, the simulations using the IAEA Tecdoc1759 have verified that no pathway has significant effects on the assessment results.	-
	Uncertainties of coefficients for the transfer to hulls, fishing nets, and sandy beaches that affects external exposures	These pathways have not been regarded as a significant problem at the leading nuclear facilities in Japan and overseas, and external exposures have a more minor impact than internal exposures. Therefore, the uncertainties do not seem to affect the assessment results significantly. In addition, the exposure from sandy beaches was determined using the IAEA Tecdos1579, and the result has verified that the method adopted in the Radiological Impact Assessment is more conservative.	-
Selection of exposure pathways	There are uncertainties because the selected exposure pathways do not cover all the pathways.	The pathways were selected based on precedent assessments in Japan. Since external exposures have a more minor impact than internal exposures, uncertainties in selecting transfer pathways do not seem to have significant effects on the assessment results. In addition, the simulations using the IAEA Tecdoc1759 have verified that no pathway has significant effects on the assessment results.	-
Selection of a representative person	At present, the area around the power plant under reconstruction has few residents, and it is difficult to understand the detailed living habits of the residents. Therefore, the lifestyle data contains uncertainties.	Up-to-date data was used for the intake of seafood, an exposure pathway that significantly impacts the result of internal exposures. The data used is nationwide data and may differ from those in the vicinity of the power plant. However, compared with data in Tohoku Region, the difference is only about 10%, and all fish and shellfish that are assumed to be ingested in the Report are products caught in the 10 km x 10 km area around the power plant, including processed products. Therefore, the assessment seemed to produce overestimated results.	-

*The magnitude of uncertainties is expressed in magnifications, and the mark + shows overestimation, while the mark - underestimation.

Uncertainties in the Radiological Impact Assessment

TEPCO

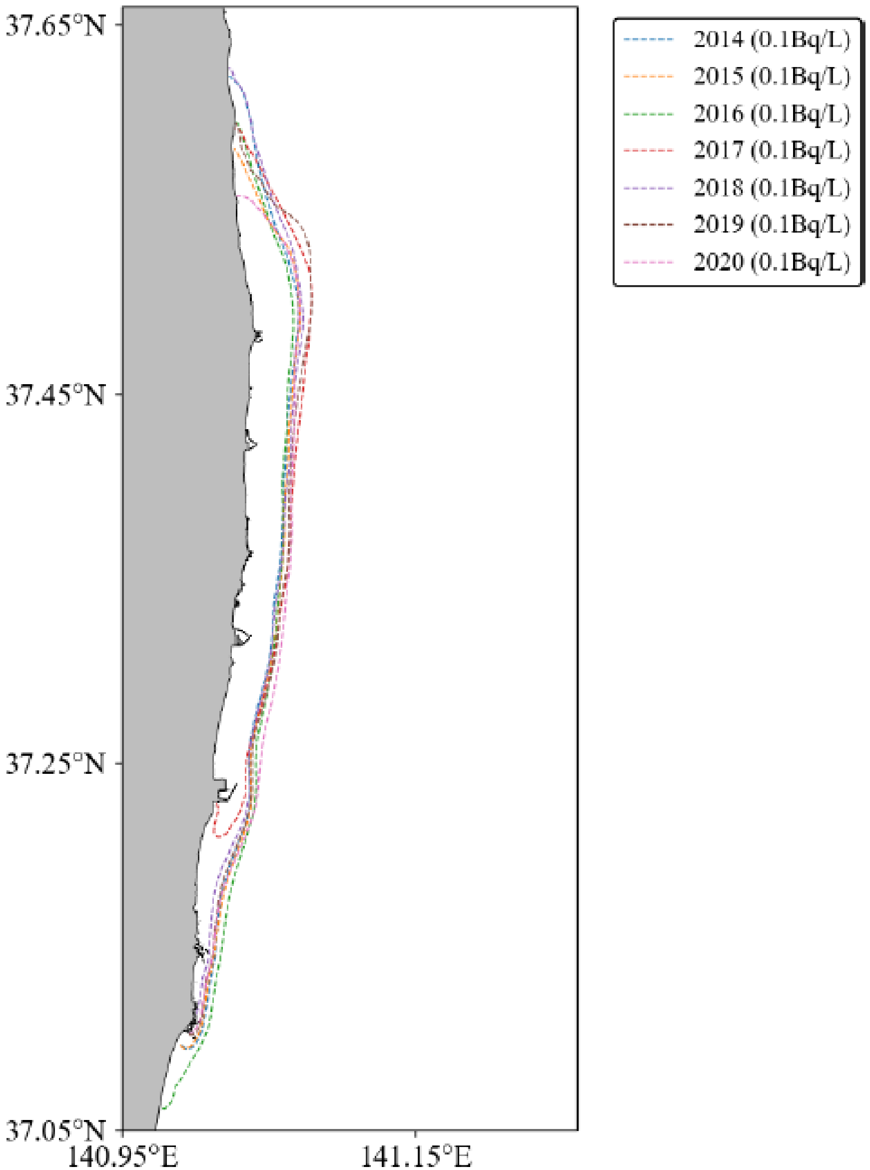
- Among uncertainties of exposure pathways, the uncertainty of the source term and that of enrichment factor in fish and shellfish are considered to have dominant impacts. In this assessment, those uncertainties are probably covered by the conservative setting for the source term and seafood catch.

Summary of uncertainties (2/2)

Item	Details of uncertainty	How to handle in the Radiological Impact Assessment	Magnitude of uncertainty*
Dose assessment	The dose conversion coefficients used for assessing external exposures are taken from the Japan Handbook for Determining Environmental Impacts of Decommissioning Work. However, coefficients for all 64 nuclides are not set, and only gamma rays are assessed. The assessment contains uncertainties due to those reasons.	For nuclides for which dose conversion coefficients are not specified in the Handbook, the coefficient of Co-60 was used for βγ nuclides and that of Am-243 for α nuclides, which are the most significant value, to be on the conservative side. Therefore, some uncertainties may lead to somewhat overestimated results. In addition, impacts were assessed using the dose conversion coefficients for external exposures specified in FGR-15 published by the United States Environmental Protection Agency instead of those used in the Radiological Impact Assessment Report. The results in the Report are about 3 to 40 times larger. Even so, the effect on exposure is smaller than that of internal exposures, and that does not affect the total value of exposures.	-
	TRS-422 says enrichment factors in seafood contain an uncertainty of about one order of magnitude.	The source term set is a hypothetical source term in which the sum of the radios to regulatory concentration limits of only nuclides, which have significant impacts on internal exposures, is 1. In addition, all of the seafood to be ingested is assumed to be caught in the 10 km × 10 km area around the power plant, including processed products. Therefore, the results of the assessment are considered to be sufficiently conservative.	±10
Overall assessment	Assuming that the setting of the source term contains the most significant uncertainties, the Report uses a hypothetical ALPS treated water that was set as highly conservative conditions as the source term given the uncertainties. The enrichment factors in fish and shellfish, which have significant impacts on the assessment of internal exposures, are considered to contain an uncertainty of up to one order of magnitude. However, the uncertainties are probably covered by the conservative setting of the source term and the seafood, and the assessment results seem to be on the conservative side.		

*The magnitude of uncertainties is expressed in magnifications, and the mark + shows overestimation, while the mark - underestimation.

Uncertainties in the assessment (annual fluctuation in meteorological and oceanographic data)



The area where the mean tritium concentration calculated based on the meteorological and oceanographic data in years from 2014 to 2020 is 0.1 Bq/L.

- The figure shows the simulation results using the meteorological and oceanographic data for the 7 years from 2014 to 2020.
- The table below shows the annual mean concentrations in each year of the 7 years within the 10 km × 10 km area around the power plant.
- The year-to-year difference in the diffusion area and the mean concentration results are negligible. It is probably possible to use the simulation results of 2019 to assess a long-term period.

Mean tritium concentrations in the 10 km × 10 km are around the power plant calculated based on the meteorological and oceanographic data in the years from 2014 to 2020

Year	All layers	Surface layer	Bottom layer
2014	4.8E-02	1.0E-01	5.0E-02
2015	4.9E-02	9.6E-02	5.3E-02
2016	4.9E-02	9.6E-02	5.3E-02
2017	5.8E-02	1.2E-01	6.3E-02
2018	5.0E-02	1.1E-01	5.4E-02
2019	5.6E-02	1.2E-01	6.0E-02
2020	5.4E-02	1.1E-01	6.0E-02
Mean	5.2E-02	1.1E-01	5.6E-02
Standard deviation	3.8E-03	9.3E-03	4.4E-03

Uncertainties in the assessment (verification using the external dose conversion coefficients provided by the United States Environmental Protection Agency)

TEPCO

- For typical exposure situations, the United States Environmental Protection Agency (hereinafter EPA) provides external dose conversion coefficients for each nuclide in FGR-15*.
- In the Radiological Impact Assessment Report, the external dose conversion coefficients for γ-rays specified in the domestically prepared Handbook for Determining Environmental Impacts of Decommissioning Work (hereinafter the Decommissioning Work Handbook) were used in the assessment. However, since beta-rays are not considered, and conversion coefficients of different nuclides are adopted for many of the nuclides, verification was performed using conversion coefficients presented by EPA.
- The following exposure pathways were checked since conversion factors presented in FGR-15 are applicable.
  - ✓ External exposure from sea surface........The dose conversion factor for immersion was multiplied by 0.5
  - ✓ External exposure from hulls..................The dose conversion factor for ground surface contamination was used
  - ✓ External exposure during swimming........The dose conversion factor for immersion was used
  - ✓ External exposure from sandy beaches...The dose conversion factor for ground surface contamination was used
- Since the purpose of this study was to verify the conversion factors, a source term based on measured values was used. Regarding other conditions, such as concentration in seawater and transfer factors, the same conditions as those presented in the Radiological Impact Assessment Report were used.
- FGR-15 provides external dose conversion coefficients based on ICRP Publication 103 (2007 Recommendation). It cannot be directly applied to the regulation based on the current ICRP Publication 60 (2000 Recommendation), but they were used for verification this time.

* FEDERAL GUIDANCE REPORT NO.15 "EXTERNAL EXPOSURE TO RADIONUCLIDES IN AIR, WATER AND SOIL" (U.S. Environmental Protection Agency ,2019)

Uncertainties in the assessment (verification using the external dose conversion coefficients provided by the United States Environmental Protection Agency)

- The table below shows the comparison of exposure assessment results.
- In all cases, assessment results using conversion factors in the Decommissioning Work Handbook are about 3 to 70 times more conservative.

Comparison of external exposures with those obtained through the assessment using factors prepared by EPA.

Assessment conditions	Source term	(1) Source term based on measured values								
		i. K4 tank group			ii. J1-C tank group			iii. J1-G tank group		
	Assessed case	Decommissioning Work Handbook	FGR15	HB/FGR ratio	Decommissioning Work Handbook	FGR15	HB/FGR ratio	Decommissioning Work Handbook	FGR15	HB/FGR ratio
	Unit	mSv/year	mSv/year	Times	mSv/year	mSv/year	Times	mSv/year	mSv/year	Times
Exposure pathways	Seawater surface	6.5E-09	9.4E-10	6.9	1.7E-08	3.5E-10	49	4.7E-08	8.6E-10	55
	Hull	5.2E-09	1.8E-09	2.9	1.3E-08	9.8E-10	13	3.4E-08	2.2E-09	15
	Swimming	2.8E-10	2.9E-11	9.7	7.6E-10	1.1E-11	69	2.0E-09	2.7E-11	74
	Sandy beach	5.0E-07	9.0E-08	5.6	1.3E-06	3.7E-08	35	3.6E-06	8.9E-08	40

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- In assessing potential exposures, time while an accident is kept unnoticed or a delay in responses should be taken into account, and consideration should also be given to performing internal exposures assessment in light of the duration of such event.
- Fishing nets are included in the anticipated external exposure pathways in the exposure assessment during normal operation. On the other hand, the potential exposure assessment does not assume external exposure from fishing nets. Thus, the reason for that and the rationale for setting the data used in the assessment should be explained.

- The procedures for the assessment of potential exposures described in IAEA GSG-10 are as follows:

Assessment of potential exposures

Identification and selection of potential exposure scenarios	Identify and select events that may lead to potential exposures
↓ Selection of the source terms	Define the type and amount of radioactive materials released as a result of the selected events
↓ Modeling of diffusion and movement in the environment	Study how the various radioactive materials discharged into the sea diffuse, transfer, and accumulate
↓ Identification of exposure pathways	Study the pathways by which people are exposed to the diffused and transferred radioactive materials
↓ Identification of the representative person	Set the representative person for potential exposures
↓ Assessment of the dose	Assess the dose to the representative person for potential exposures
↓ Comparison of estimated doses and risks with criteria*	Compare the estimated doses and risks with criteria.

* IAEA GSG-10 gives 1 to several millisieverts (usually 5 mSv) as a criterion with which the comparison should be made.

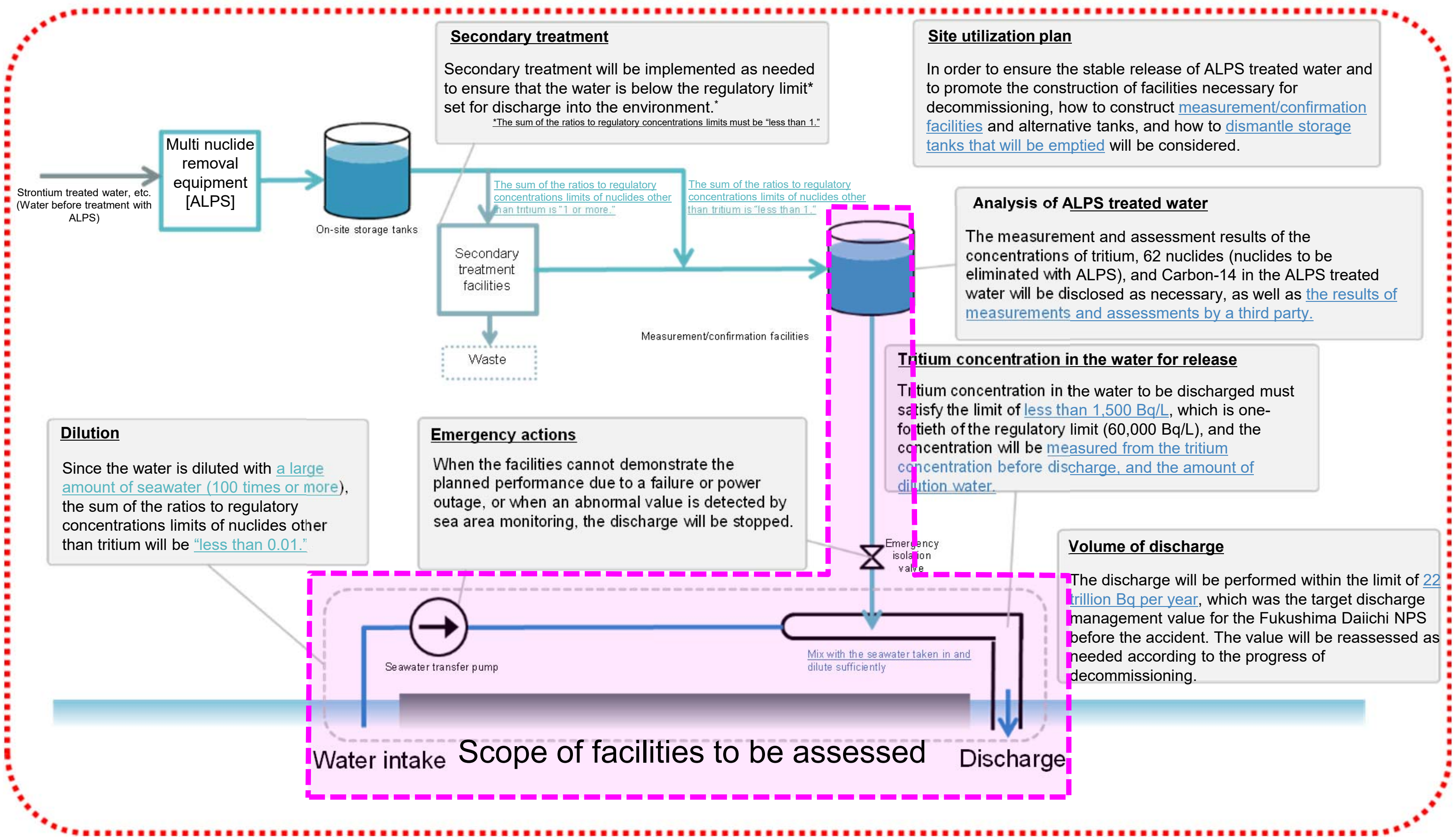
- The scenarios were selected according to the following procedure while considering the outline of safety facilities described in the "Studies on the Handling of ALPS Treated Water, etc.," released by TEPCO on August 25, 2021.
  - [1] The facilities for discharging ALPS treated water into the sea handle two types of water: **undiluted and diluted ALPS treated water.** The diluted ALPS treated water is allowed to be discharged and subject to the normal exposure assessment. Therefore, events that may lead to undiluted ALPS treated water discharge were assumed.
  - [2] There are two pathways through which undiluted ALPS treated water may be discharged: leakage to the outside of the system due to pipe rupture and discharge of ALPS treated water without dilution with seawater through the normal discharge pipe. In the case of leakage, the inventory of the water will be reduced since it will penetrate underground within the site before it is discharged into the sea. Therefore, **the case where ALPS treated water is discharged directly into the sea seems to be the severest scenario.**
  - [3] The specific scenario selected is **a case where seawater supply for dilution stops due to the shutdown of the seawater pump for dilution, and the emergency isolation valve that should be tripped is not activated, letting the ALPS treated water continue to be discharged.**

Assessment of potential exposures (3) Target facilities

TEPCO

- Facilities that are taken into account when considering potential exposure scenarios are those downstream from the measurement/confirmation facilities shown in the figure below.
- Therefore, the target facilities contain two types of radioactive water: diluted and undiluted ALPS treated water.

[Conceptual diagram of facilities for discharging ALPS treated water into the sea]



The Japanese version shall prevail.

Assessment of potential exposures (4) Selection of the source terms

- It is impossible to determine the concentrations of all 63 nuclides in the ALPS treated water discharged in the scenario to assess potential exposures. Therefore, other than tritium, one of the 63 nuclides was assumed to be contained at the regulatory concentration limit (descendant nuclides in equilibrium state are at the regulatory limit for the parent nuclide), and exposures were calculated for all 63 nuclides. Then, the result of the nuclide that was assessed to be the largest was adopted as the estimated value.
- To set the release of the other nuclide (source term), which is not tritium, at a more significant amount to be on a conservative side, the tritium concentration in the ALPS treated water to be discharged set to 100,000 Bq/L, a lower value, and the event was assumed to occur while the ALPS treated water was being released at 1500 Bq/L after diluted with seawater of 340,000 m^3/day.
- Thus, the discharge rate of ALPS treated water was set as follows.

  340,000 m^3/day × 1,500 Bq/L /100,000 Bq/L = 5,100 m^3/day
- Therefore, the source term (daily release) was set as follows.
  - ✓ Tritium: 100,000 Bq/L × 1,000 L/m^3 × 5,100 m^3/day = 5.1E+11Bq/day
  - ✓ Other nuclides:

    Regulatory concentration limit [Bq/L] × 1,000 L/m^3 × 5,100 m^3/day for each nuclide

    Example: When Cs-137 is selected, 90 Bq/L × 1,000 L/m^3 × 5,100 m^3/day = 4.6E+08 Bq/day

- In the exposure assessment during normal operation, radionuclides transferred to hulls, beach sand, and fishing nets are assumed to reach the equilibrium state after being accumulated over a long period. They are considered to have little effect by increasing the concentration in a short period. Therefore, they were not selected as exposure pathways in the Radiological Impact Assessment Report.
- However, to ensure the comprehensiveness of the assessment, all exposure pathways evaluated in the exposure assessment during the normal operation were reviewed as target pathways subject to the evaluation.
- Specifically, exposures to radionuclides transferred to hulls, beach sand, and fishing nets were calculated using concentrations in seawater that increase for only 2 days, the time duration while the discharge is being continued, assuming that radionuclides are instantaneously transferred and reach an equilibrium state.
- Exposures to radionuclides transferred to seafood were also calculated in the same way while assuming that the radionuclides concentrate instantaneously for only 2 days in the fish and shellfish to be ingested and that the concentration increases for only 2 days.

Assessment of potential exposures (6) Concept of potential exposure pathways

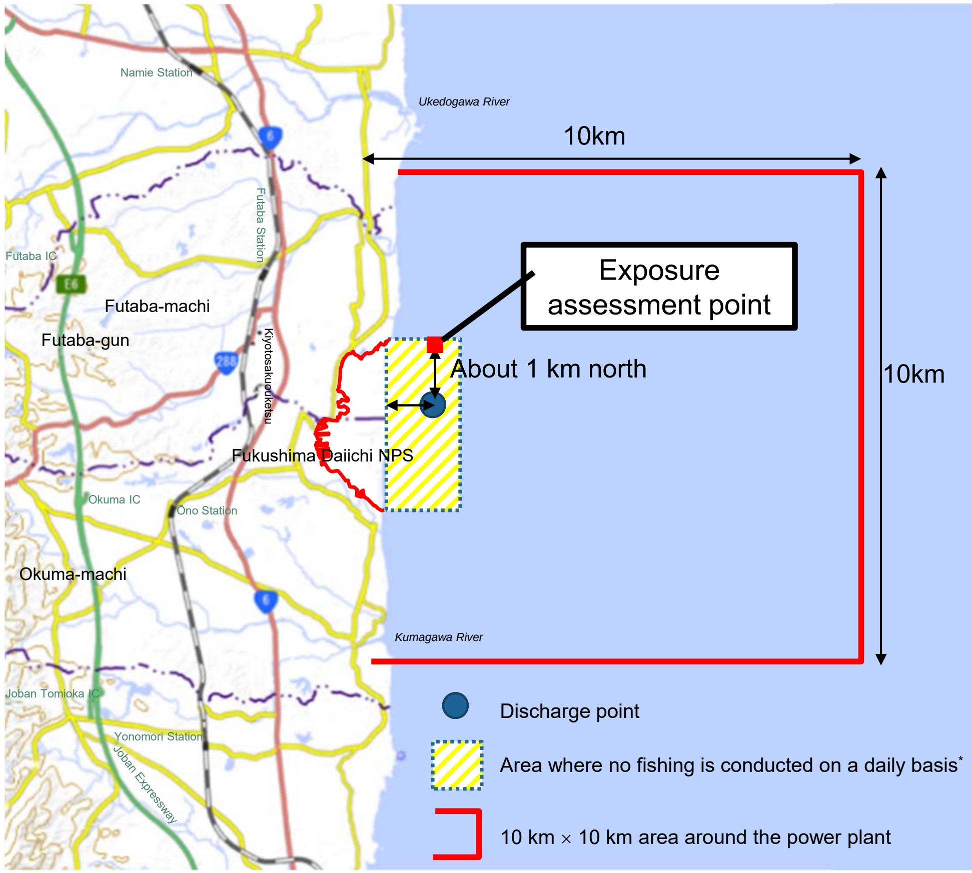
TEPCO

- Exposure pathways for the assessment of potential exposures are summarized as follows again.
- The Radiological Impact Assessment Report will incorporate the changes at the time of revision.

Exposure pathways during normal operation	Concept of potential exposure pathways	Selection of exposure pathways
External exposure from sea surface	Since undiluted ALPS treated water is discharged, the concentration of radioactive materials in seawater temporarily rises, and the impact of external exposure from the sea surface increases. In addition, there is a risk of accidental exposure when an accident occurs. Considering those matters, this pathway was selected.	○
External exposure during underwater operations	Although exposure to water increases with the increase in the concentration of radioactive materials in seawater, the operation hours are relatively short. Therefore, this pathway was excluded. However, to ensure comprehensiveness, it was decided to include this.	X -> ○ (Added)
Internal exposure during underwater operations	As the exposure during underwater operations was added to the target, it was decided to include the internal exposure due to accidental ingestion of seawater during underwater operations as well.	X -> ○ (Added)
External exposure from hulls, beaches and fishing nets	The transfer of radioactive materials to the hull occurs due to an accumulation over a long period. Therefore, considering that the increase in seawater concentration for a short period has little impact, this pathway was excluded in the Report. However, the exposure was calculated to ensure comprehensiveness while assuming that the concentration reaches an equilibrium state with the concentration in seawater, which rises for only 2 days.	X -> ○ (Added)
Internal exposure from ingestion of seafood	The transfer of radioactive materials to seafood occurs due to an accumulation over a long period. Therefore, considering that the increase in the concentration in seawater for a short period has little impact and that it is possible to take measures such as restriction of shipment in case it occurs, this pathway was excluded in the Report. However, to ensure comprehensiveness, the exposure was calculated while assuming that the concentration reaches an equilibrium state with the concentration in seawater that rises for only 2 days and that the seafood is ingested for only 2 days.	X -> ○ (Added)

- The representative person was assumed as follows for the assessment of potential exposures.

  - ✓ A crew member of a vessel engaged in fishing and other operations in the vicinity of the power plant when an abnormal discharge occurs.
  - ✓ Considering that tidal currents around the power plant flow north-south in most areas, the working point was set at a point closest to the north of the discharge outlet (about 1 km north) outside the area where no fishing is conducted on a daily basis.
  - ✓ The crew member was assumed to engage in diving operation for 8 hours per day, and during that time, they were assumed to ingest 1 L of seawater per day accidentally.
  - ✓ In the Report, the duration of exposure was set at one day because it is possible to have vessels evacuate from the relevant sea area or restrict them from entering the area. However, in cases where vessels cannot evacuate for some reason, the exposure for 2 days was assessed, assuming that the discharge would continue for 2 days.



*Area where common fishery rights are not set

Potential exposure assessment point

Source: This map was created by Tokyo Electric Power Company Holdings, Inc. based on a map published by the Geographical Survey Institute (Electronic Map Web)
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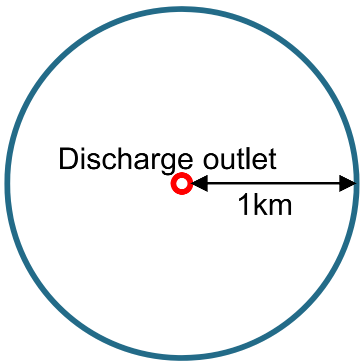
Assessment of potential exposures (8) Exposure calculation (concentration in seawater used for assessment)

- The concentration of radioactive materials in seawater that was used for the assessment was the maximum daily mean concentration on the circumference of 1 km from the discharge outlet, regardless of the directions, which was determined based on the result of diffusion simulation using the meteorological and oceanographic data for 2 years, 2014 and 2019. The concentration was assumed to continue for 2 days.
- When ALPS treated water is continued to be discharged at 1 Bq/day under meteorological conditions recorded in the two years, 2014 and 2019, the maximum daily mean concentration on the circumference of 1 km is 2.4E-10 Bq/L.
- This value was multiplied by the source term (daily release of each nuclide) to obtain the concentration of each nuclide in seawater used in the assessment.



The maximum daily mean concentration on the circumference of 1 km from the discharge outlet was used for the assessment.

Method to determine concentrations in seawater used for the assessment of exposures

- The table below shows the results of the exposure assessment. The results of Te-127, the most significant estimated exposure, were used since it significantly impacts external exposures.
- Tritium was used to assess the internal exposure due to accidental ingestion of seawater since the exposure to tritium, which will be discharged at concentrations higher than the regulatory concentration limit, is higher than the exposure to Te-127.
- A person cannot be exposed to radionuclides on a vessel and a beach simultaneously, but the results were added to be on the conservative side.
- The estimated exposure is 0.26 mSv, which is much smaller than the decision criteria of 5 mSv.

Results of the potential exposure assessment

Assessed case		Average amount of ingestion of seafood	Large amount of ingestion of seafood	Target nuclide
External exposure (mSv)	Exposure from sea surface	1.5E-04		Te-127
	Exposure from hulls	1.0E-04		
	Exposure during underwater work	1.4E-04		
	Exposure from sandy beaches	1.4E-01		
	Exposure from fishing nets	1.2E-01		
Internal exposure (mSv)	Exposure from accidental ingestion of seawater	4.4E-06		H-3
		2.1E-06		Te-127
	Exposure from ingestion of seafood	3.7E-04	1.6E-03	Te-127
Total (mSv)		2.6E-01	2.6E-01	

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- Regarding exposure dose assessment of a representative person, the validity should be demonstrated by using the most realistic exposure assessment parameters possible and taking into account the current situation and prospects in the vicinity of the Fukushima Daiichi NPS.

Assessment of exposure of representative individuals (1) Living habits of the representative person

- Since the area around the Fukushima Daiichi NPS is currently undergoing reconstruction, it is difficult to investigate the living habits of the representative person. Therefore, as parameters for living habits that affect external exposures, those used in the simulation of the “Dose Assessment to the General Public in the Safety Review of Commercial Light Water Reactor Facilities” were used.
- It is also difficult to investigate the amount of seafood ingested which affects internal exposures. Therefore, the amount of ingestion by food groups presented in the National Health and Nutrition Survey in Japan in 2019 (Ministry of Health, Labour and Welfare, 2019) was used.
- In the setting, ingestion of processed seafood was also included in the sum. Considering the uncertainty, the ingestion by a person who ingests a large amount of seafood was set at the mean value + 2 σ, which corresponds to the 95 percentile.
- These settings are regarded as appropriate. However, considering that some areas to the north of the power plant, which is within the 10 km × 10 km area, have been excluded from the evaluation areas, and that there are sandy beaches in the coastal area, it has been decided, given the future situation, to specifically identify the assessment points for the exposure from sandy beaches and to perform additional assessments.

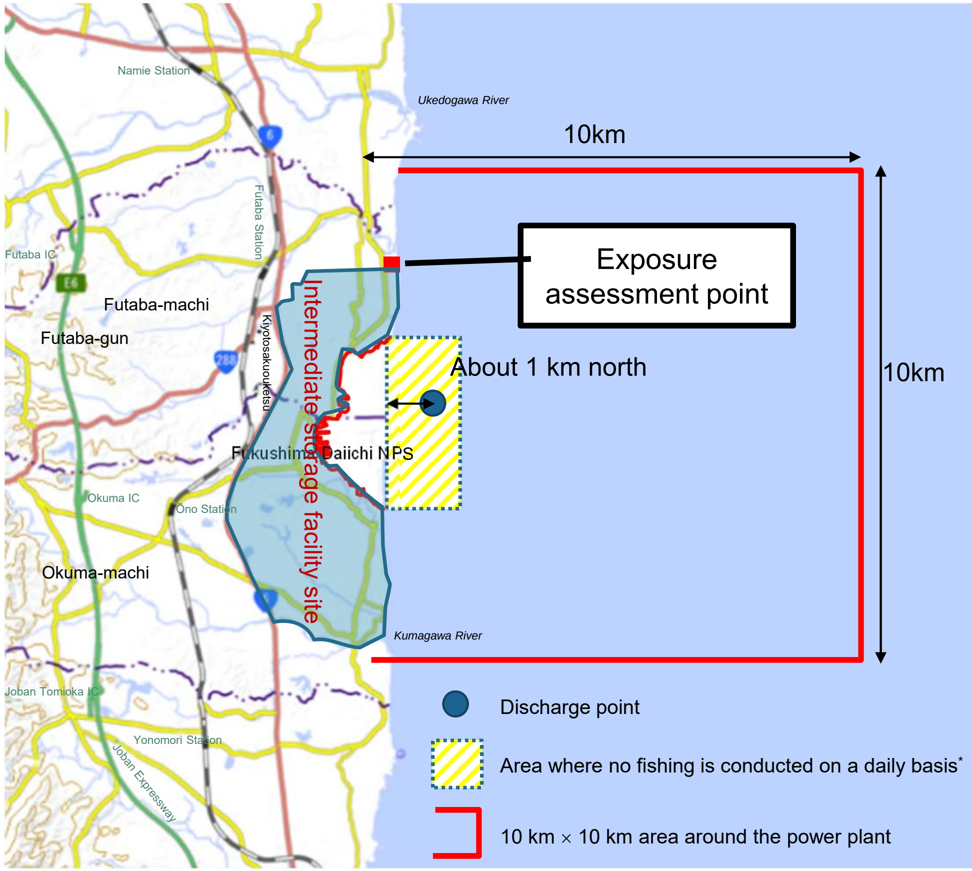
Assessment of exposure to the representative person (2) Assessment point for exposure from beaches

TEPCO

- Areas around the power plant are sites for intermediate storage facilities where decontaminated soil is stored, and the storage will probably continue until 2045.
- Therefore, it is unlikely that people will live within the premises of the intermediate storage facilities while the discharge of ALPS treated water is continued. Thus, the assessment point was set around a beach outside the Difficult-to-Return Zones, the closest to the north of the power plant.
- The table below shows annual mean tritium concentrations in seawater near the assessment point. The value in 2019 is about 16 times larger than the mean concentration in all layers of 10 km × 10 km, 0.056 Bq/L, which was used in the assessment for the Report.

Tritium concentration in seawater near the assessment point

	Annual mean concentration (Bq/L)
2014	0.7
2019	0.9



*Area where common fishery rights are not set

Assessment point for exposure from beaches

Source: This map was created by Tokyo Electric Power Company Holdings, Inc. based on a map published by the Geographical Survey Institute (Electronic Map Web)
https://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1

- When the exposure from beach sand is calculated using the annual mean concentration of 0.9 Bq/L (2019), the exposure from beaches rises, as shown in the table, becoming the largest among the external exposures.
- Internal exposure is still the pathway that has the most significant impact. The increase in the estimated exposure is up to 20%, even in the case of a person who ingests a large amount of seafood.

Results of the human exposure assessment in the Report

Assessed case	Source term	(1) Source term based on measured values						(2) Source term using hypothetical ALPS treated water	
		i. K4 tank group		ii. J1-C tank group		iii. J1-G tank group			
	Ingestion of seafood	Average	Large	Average	Large	Average	Large	Average	Large
External exposure (mSv/year)	Seawater surface	6.5E-09		1.7E-08		4.7E-08		1.8E-07	
	Hull	5.2E-09		1.3E-08		3.4E-08		1.4E-07	
	Swimming	2.8E-10		7.6E-10		2.0E-09		7.9E-09	
	Beach sand	5.0E-07		1.3E-06		3.6E-06		1.4E-05	
	Fishing net	1.6E-06		4.3E-06		1.2E-05		4.5E-05	
Internal exposure (mSv/year)		1.5E-05	6.1E-05	2.8E-05	1.1E-04	7.9E-05	3.0E-04	4.8E-04	2.0E-03
Total		1.7E-05	6.3E-05	3.4E-05	1.1E-04	9.4E-05	3.1E-04	5.4E-04	2.1E-03

Results with the revised concentration in seawater for the assessment of exposure from beach sand

Assessed case	Source term	(1) Source term based on measured values						(2) Source term using hypothetical ALPS treated water	
		i. K4 tank group		ii. J1-C tank group		iii. J1-G tank group			
	Ingestion of seafood	Average	Large	Average	Large	Average	Large	Average	Large
External exposure (mSv/year)	Seawater surface	6.5E-09		1.7E-08		4.7E-08		1.8E-07	
	Hull	5.2E-09		1.3E-08		3.4E-08		1.4E-07	
	Swimming	2.8E-10		7.6E-10		2.0E-09		7.9E-09	
	Beach sand	8.0E-06		2.1E-05		5.8E-05		2.2E-04	
	Fishing net	1.6E-06		4.3E-06		1.2E-05		4.5E-05	
Internal exposure (mSv/year)		1.5E-05	6.1E-05	2.8E-05	1.1E-04	7.9E-05	3.0E-04	4.8E-04	2.0E-03
Total		2.5E-05	7.1E-05	5.4E-05	1.3E-04	1.5E-04	3.7E-04	7.5E-04	2.3E-03

*The hatched values were revised.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- For the coefficients adopted in the Radiological Environmental Impact Assessment, in which part of the ICRP documents (Pub. 72, 124, 144, etc.) is quoted, and the reason for the quotation should be clarified.

- Coefficients presented by ICRP documents were used in the Radiological Impact Assessment Report. The following table shows the sources of the adopted coefficients and the reasons for their adoption.

Adopted coefficients	Source document	Source paragraphs	Reasons for the adoption
Effective dose conversion coefficients for external exposures	Handbook for Determining Environmental Impacts of Decommissioning Work	Table 4-4-12: Effective dose conversion coefficients for external exposures in marine systems	Exposure assessment models were developed based on domestic licensing cases. The effective dose conversion coefficients are values calculated using shielding codes for licensing. In addition, coefficients for a relatively large number of nuclides are provided.
Coefficients for transfer to hulls and fishing nets	Application for the Designation of Reprocessing Business of Rokkasho Plant	Attachment VII 5.1.3.3.2 External exposures to radioactive materials in liquid waste	Those coefficients have been used for approval and permission in Japan.
Coefficients for the transfer to sandy beaches	Dose Assessment to the General Public in the Safety Review of Commercial Light Water Reactor Facilities	3. Calculation of exposure doses to radioactive materials in liquid waste	Those coefficients have been used in reports of domestic regulatory bodies.
Effective dose coefficients for ingestion	ICRP Pub.72"Age-dependent Doses to the Members of the Public from Intake of Radionuclides-Part 5 Compilation of Ingestion and Inhalation Coefficients"	ANNEX A.Dose coefficients for ingestion and inhalation of radionuclides and effective dose rates for exposure to inert gases	This document is internationally recognized and widely used to assess internal exposures both in Japan and overseas.
Enrichment factors for seafood	IAEA Technical Reports Series No.422 "Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment"	3.CONCENTRATION FACTORS FOR BIOLOGICAL MATERIAL	This document is internationally recognized.
	UCRL-50564 Rev.1 " CONCENTRATION FACTORS OF CHEMICAL ELEMENTS IN EDIBLE AQUATIC ORGANISMS"	Table.1 Concentration factors in marine plants	The enrichment factor for Rb is not presented in TRS No. 422. The enrichment factors for seafood provided by UCRL-50564 are adopted in the Guidelines for the Assessment of Target Doses around Commercial Light Water Reactor Facilities.
Distribution coefficients for sea bottom sediment	IAEA Technical Reports Series No.422 "Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment"	2.3.OCEAN MARGIN Kds (TABLE II)	This document is internationally recognized.
Living habits of the representative person	Dose Assessment to the General Public in the Safety Review of Commercial Light Water Reactor Facilities	3. Calculation of exposure doses to radioactive materials in liquid waste	The area around the Fukushima Daiichi NPS is undergoing reconstruction, and it is challenging to investigate the living habits. Therefore, the data adopted as the living habits of a critical group in a report of a domestic regulatory body was used.
Ingestion of seafood	National Health and Nutrition Survey	Table 5-1. Intake by food group - Average value, standard deviation, and median value by food group and age—Total, 1-year-old and over	The area around the Fukushima Daiichi NPS is undergoing reconstruction, and it is challenging to investigate living habits. Therefore, public data from a national survey was used to create the ingestion data for adults.

The source of adopted coefficients and reasons (2)

- Coefficients presented by ICRP documents were used in the Radiological Impact Assessment Report. The following table shows the sources of the adopted coefficients and the reasons for their adoption.

Adopted coefficients	Source document	Source paragraphs	Reasons for the adoption
Dose conversion coefficients for plants and animals	ICRP Pub.136"Dose Coefficients for Non-human Biota Environmentally Exposed to Radiation", Biota DC Program	ANNEX B.DOSE COEFFICIENTS FOR NON-HUMAN BIOTA Biota DC Program	ICRP published this document to specify the dose conversion coefficients necessary for assessing the exposures to plants and animals by the method recommended in Pub.108. BiotaDC is a website run by ICRP that can calculate conversion coefficients not specified in Pub.136. This website was used to obtain all of the necessary parameters.
Concentration ratios for plants and animals	ICRP Pub.124" Protection of the Environment under Different Exposure Situations"	4.4.Concentration ratio values for marine Reference Animals and Plants and their applicability	ICRP published this document to specify transfer coefficients (concentration ratios) for plants and animals necessary for assessing exposures to plants and animals by the method recommended in Pub.108. As the latest document, adopting values provided by IAEA TRS-479 “Handbook of Parameter Values for the Prediction of Radionuclide Transfer to Wildlife” is considered.
	IAEA Technical Reports Series No.422 "Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment"	3.CONCENTRATION FACTORS FOR BIOLOGICAL MATERIAL	For nuclides for which concentration ratios are not specified in ICRP Pub.124, concentration factors, which are technically different and a parameter for the transfer of radioactive materials to plants and animals, were adopted from this document.

Responses to issues pointed out* at the Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

*: Document 1-3 for the 12th Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

Issues pointed out [9]

(2-2 Major items to be confirmed regarding activities in line with government policy)

(3) Radiological impact assessment on the surrounding environment due to discharge into the sea

- Other revisions

Other revisions (inclusion of parameters of IAEA TRS-479)

- In the Radiological Impact Assessment Report, exposures of marine plants and animals are assessed as assessments for environmental protection.
- Concerning the transfer of radioactive materials to marine plants and animals, ICRP Pub.114[*1] provides concentration ratios for standard plants and animals (3 species of marine plants are animals: flatfish, crabs, and brown algae). On the other hand, IAEA TRS-479[*2] subdivides plants and animals based on new knowledge and shows the latest concentration ratio parameters.
- At the time of a revision of the Radiological Impact Assessment Report, the concentration ratio parameters will be updated while referring to the values presented by TRS-479.
- However, the concentration ratios for only a limited number of elements are shown there for the subdivided plants and animals, and dose conversion coefficients for plants and animals necessary for calculating exposures are not provided. Therefore, exposures from the individual subdivided plants and animals will not be assessed. Still, only exposures from standard plants and animals for which the concentration ratios have been updated in TRS-479 will be amended according to the updated values.

*1 ICRP Pub.124 “Protection of the Environment under Different Exposure Situations”
*2 IAEA Technical report series No.479 “Handbook of parameter values for the prediction of radionuclide transfer to wildlife”

- The data will be updated according to the following standards for handling concentration ratios.
  - ✓ The concentration ratio parameters provided by TRS-479 for subdivided plants and animals are classified into the categories of standard organisms (fish, crabs, brown seaweed) as shown in the table below, and the maximum values are calculated.
  - ✓ If the maximum value calculated is greater than the concentration ratio used in the Radiological Impact Assessment Report, the Report will be amended accordingly.
  - ✓ If no new concentration ratios are given, or if the value presented is less than the concentration ratio used in the Radiological Impact Assessment Report, the Report will not be amended.

Standard for adopting concentration ratios of TRS-479

Standard plants and animals	Classification of TRS-479	Handling of concentration ratios
Fish	Fish: benthic feeding	The maximum concentration ratio, including the values in the Radiological Impact Assessment Report, will be used as the concentration ratio for the standard flatfish.
	Fish: piscivorous	
	Fish: forage	
Crab	Large crustaceans	The maximum concentration ratio, including the values in the Radiological Impact Assessment Report, will be used as the concentration ratio for the standard crab.
	Small crustaceans	
	Molluscs: bivalves	
	Molluscs: cephalopods	
	Molluscs: gastropods	
Macroalgae	Brown seaweed	The maximum concentration ratio, including the values in the Radiological Impact Assessment Report, will be used as the concentration ratio for the standard brown seaweed.

2-2 (3) Radiological impact assessment on the surrounding environment due to discharge into the sea

Other revisions (inclusion of parameters of IAEA TRS-479)

TEPCO

- The table below compares concentration ratios before and after the amendment. (The hatched values were revised)
- The concentration ratios provided by TRS-479 cover many nuclides and more significant arithmetic mean values were adopted.

	Target nuclide	Concentration ratio ((Bq/kg-f.w)/(Bq/L))					
		Flatfish Value described in the Report	Flatfish Value revised according to TRS-479	Crab Value described in the Report	Crab Value revised according to TRS-479	Brown seaweed Value described in the Report	Brown seaweed Value revised according to TRS-479
1	H-3	1.0E+00	1.0E+00	1.0E+00	1.0E+00	3.7E-01	3.7E-01
2	C-14	1.2E+04	1.2E+04	1.0E+04	1.0E+04	8.0E+03	8.0E+03
3	Mn-54	2.5E+02	2.6E+03	2.5E+03	4.5E+04	1.1E+04	1.1E+04
4	Fe-59	3.0E+04	3.0E+04	5.0E+05	5.0E+05	2.0E+04	2.0E+04
5	Co-58	3.3E+02	1.1E+04	4.7E+03	5.5E+03	6.8E+02	1.7E+03
6	Co-60	3.3E+02	1.1E+04	4.7E+03	5.5E+03	6.8E+02	1.7E+03
7	Ni-63	2.7E+02	2.7E+02	9.1E+02	6.4E+03	2.0E+03	2.0E+03
8	Zn-65	2.2E+04	2.5E+04	3.0E+05	3.0E+05	1.3E+04	1.3E+04
9	Rb-86	3.6E+01	3.6E+01	1.4E+01	1.4E+01	1.2E+01	1.2E+01
10	Sr-89	1.0E+01	4.4E+01	2.4E+00	1.5E+02	4.3E+01	4.3E+01
11	Sr-90	1.0E+01	4.4E+01	2.4E+00	1.5E+02	4.3E+01	4.3E+01
12	Y-90	-	-	-	-	-	-
13	Y-91	2.0E+01	2.0E+01	1.0E+03	1.0E+03	1.0E+03	1.0E+03
14	Nb-95	3.0E+01	3.0E+01	1.0E+02	8.8E+02	8.1E+01	4.9E+02
15	Tc-99	8.0E+01	8.0E+01	1.9E+02	1.8E+04	3.7E+04	5.3E+04
16	Ru-103	1.6E+01	2.9E+01	1.0E+02	1.6E+03	2.9E+02	1.2E+03
17	Ru-106	1.6E+01	2.9E+01	1.0E+02	1.6E+03	2.9E+02	1.2E+03
18	Rh-103m	-	-	-	-	-	-
19	Rh-106	-	-	-	-	-	-
20	Ag-110m	8.1E+03	1.1E+04	2.0E+05	2.0E+05	1.9E+03	3.9E+03
21	Cd-113m	1.3E+04	2.9E+04	1.2E+04	1.3E+05	1.6E+03	1.6E+03
22	Cd-115m	1.3E+04	2.9E+04	1.2E+04	1.3E+05	1.6E+03	1.6E+03
23	Sn-119m	5.0E+05	5.0E+05	5.0E+05	5.0E+05	2.0E+05	2.0E+05
24	Sn-123	5.0E+05	5.0E+05	5.0E+05	5.0E+05	2.0E+05	2.0E+05
25	Sn-126	5.0E+05	5.0E+05	5.0E+05	5.0E+05	2.0E+05	2.0E+05
26	Sb-124	6.0E+02	6.0E+02	3.0E+02	4.7E+02	1.5E+03	1.5E+03
27	Sb-125	6.0E+02	6.0E+02	3.0E+02	4.7E+02	1.5E+03	1.5E+03
28	Te-123m	1.0E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+04	1.0E+04
29	Te-125m	1.0E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+04	1.0E+04
30	Te-127	1.0E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+04	1.0E+04
31	Te-127m	1.0E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+04	1.0E+04
32	Te-129	-	-	-	-	-	-
33	Te-129m	1.0E+03	1.0E+03	1.0E+03	1.0E+03	1.0E+04	1.0E+04
34	I-129	9.0E+00	9.0E+00	3.0E+00	8.8E+03	1.4E+03	4.2E+03
35	Cs-134	3.6E+01	1.2E+02	1.4E+01	6.3E+01	1.2E+01	9.6E+01
36	Cs-135	3.6E+01	1.2E+02	1.4E+01	6.3E+01	1.2E+01	9.6E+01
37	Cs-136	3.6E+01	1.2E+02	1.4E+01	6.3E+01	1.2E+01	9.6E+01
38	Cs-137	3.6E+01	1.2E+02	1.4E+01	6.3E+01	1.2E+01	9.6E+01
39	Ba-137m	-	-	-	-	-	-
40	Ba-140	9.6E+00	9.6E+00	8.0E+02	8.0E+02	1.6E+03	1.6E+03
41	Ce-141	2.1E+02	3.9E+02	1.0E+02	2.2E+03	9.5E+02	2.1E+03
42	Ce-144	2.1E+02	3.9E+02	1.0E+02	2.2E+03	9.5E+02	2.1E+03
43	Pr-144	-	-	-	-	-	-
44	Pr-144m	-	-	-	-	-	-
45	Pm-146	7.3E+02	7.3E+02	2.4E+04	2.4E+04	5.9E+03	5.9E+03
46	Pm-147	7.3E+02	7.3E+02	2.4E+04	2.4E+04	5.9E+03	5.9E+03
47	Pm-148	7.3E+02	7.3E+02	2.4E+04	2.4E+04	5.9E+03	5.9E+03
48	Pm-148m	7.3E+02	7.3E+02	2.4E+04	2.4E+04	5.9E+03	5.9E+03
49	Sm-151	7.3E+02	7.3E+02	2.4E+04	2.4E+04	5.9E+03	5.9E+03
50	Eu-152	7.3E+02	7.3E+02	2.4E+04	2.4E+04	1.1E+03	1.4E+03
51	Eu-154	7.3E+02	7.3E+02	2.4E+04	2.4E+04	1.1E+03	1.4E+03
52	Eu-155	7.3E+02	7.3E+02	2.4E+04	2.4E+04	1.1E+03	1.4E+03
53	Gd-153	7.3E+02	7.3E+02	2.4E+04	2.4E+04	5.9E+03	5.9E+03
54	Tb-160	6.0E+01	6.0E+01	4.0E+03	4.0E+03	2.0E+03	2.0E+03
55	Pu-238	2.1E+01	2.5E+03	3.8E+01	1.7E+03	2.4E+03	4.1E+03
56	Pu-239	2.1E+01	2.5E+03	3.8E+01	1.7E+03	2.4E+03	4.1E+03
57	Pu-240	2.1E+01	2.5E+03	3.8E+01	1.7E+03	2.4E+03	4.1E+03
58	Pu-241	2.1E+01	2.5E+03	3.8E+01	1.7E+03	2.4E+03	4.1E+03
59	Am-241	1.9E+02	3.2E+02	5.0E+02	9.9E+03	7.7E+01	4.3E+02
60	Am-242m	1.9E+02	3.2E+02	5.0E+02	9.9E+03	7.7E+01	4.3E+02
61	Am-243	1.9E+02	3.2E+02	5.0E+02	9.9E+03	7.7E+01	4.3E+02
62	Cm-242	1.9E+02	1.9E+02	5.0E+02	3.2E+04	8.4E+03	1.2E+04
63	Cm-243	1.9E+02	1.9E+02	5.0E+02	3.2E+04	8.4E+03	1.2E+04
64	Cm-244	1.9E+02	1.9E+02	5.0E+02	3.2E+04	8.4E+03	1.2E+04

- Even after revising the concentration ratios according to IAEA TRS-479, that did not make a difference in the total estimated exposures of plants and animals.
- Although internal exposures increase when concentration ratios are revised, all targets selected as standard plants and animals, i.e., flatfish, crabs, and seaweed, are mainly affected by external exposures from sea bottom sediments.

Estimated exposures after revision of concentration ratios

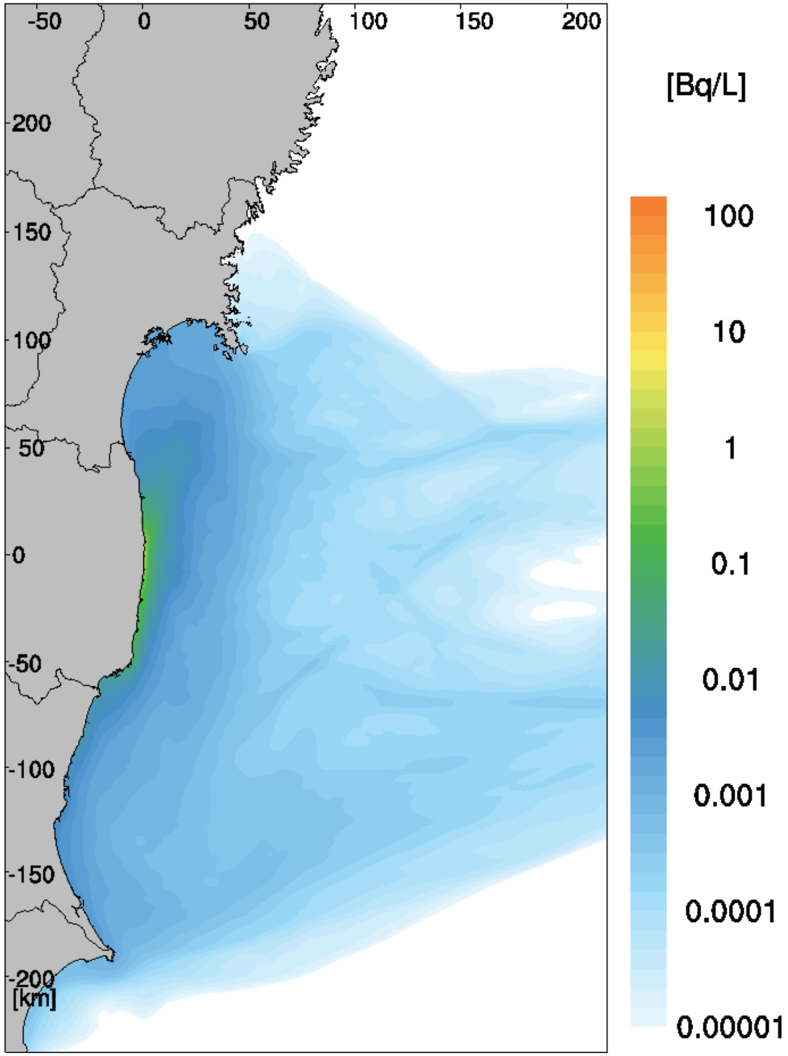
Assessed case		(1) Source term based on measured values									(2) Source term using hypothetical ALPS treated water		
		i. K4 tank group			ii. J1-C tank group			iii. J1-G tank group					
		Internal exposure	External exposure	Total	Internal exposure	External exposure	Total	Internal exposure	External exposure	Total	Internal exposure	External exposure	Total
Exposure (mGy/day)	Flatfish	1.5E-06	1.6E-05	1.7E-05	3.8E-06	1.8E-05	2.2E-05	1.1E-05	4.5E-05	5.6E-05	3.2E-06	7.8E-03	7.8E-03
	Crab	1.8E-06	1.6E-05	1.7E-05	4.1E-06	1.8E-05	2.2E-05	1.1E-05	4.4E-05	5.5E-05	4.6E-05	7.5E-03	7.5E-03
	Brown seaweed	5.7E-07	1.9E-05	1.9E-05	1.4E-06	2.2E-05	2.3E-05	3.9E-06	5.5E-05	5.9E-05	6.7E-06	8.4E-03	8.4E-03
Derived consideration reference level (DCRL) Flatfish: 1-10 mGy/day Crab: 10-100 mGy/day Brown seaweed: 1-10 mGy/day													

Estimated exposures in the Radiological Impact Assessment Report

Assessed case		(1) Source term based on measured values									(2) Source term using hypothetical ALPS treated water		
		i. K4 tank group			ii. J1-C tank group			iii. J1-G tank group					
		Internal exposure	External exposure	Total	Internal exposure	External exposure	Total	Internal exposure	External exposure	Total	Internal exposure	External exposure	Total
Exposure (mGy/day)	Flatfish	1.5E-06	1.6E-05	1.7E-05	3.8E-06	1.8E-05	2.2E-05	1.1E-05	4.5E-05	5.6E-05	2.5E-06	7.8E-03	7.8E-03
	Crab	1.6E-06	1.6E-05	1.7E-05	3.8E-06	1.8E-05	2.2E-05	1.1E-05	4.4E-05	5.5E-05	9.8E-06	7.5E-03	7.5E-03
	Brown seaweed	5.5E-07	1.9E-05	1.9E-05	1.4E-06	2.2E-05	2.3E-05	3.9E-06	5.5E-05	5.9E-05	3.8E-06	8.4E-03	8.4E-03
Derived consideration reference level (DCRL) Flatfish: 1-10 mGy/day Crab: 10-100 mGy/day Brown seaweed: 1-10 mGy/day													

Other revisions (Impacts to the outside by the diffusion simulation model)

2019



- The figure on the left shows annual mean concentrations up to 1E-05 Bq/L in all regions calculated from the 2019 meteorological and oceanographic data.
- The maximum annual mean concentration at the boundary of the calculation range was 1.6 E-04 Bq/L, measured at the eastern boundary of the region.
- The maximum daily mean concentration in the year was 1.0E-2 Bq/L, which was also measured at the eastern boundary of the region.
- The simulated concentrations at the boundaries of the calculation region are sufficiently low compared with tritium concentrations in seawater in ocean areas around Japan (approx. 1.0E-01Bq/L)*.
- In addition, considering the estimated results in the 10 km × 10 km area around the power plant, it is appropriate to assume that there is no need to assess radiological impacts outside the calculation region.

* Commissioned Project Survey Report such as Disaster Prevention Measures, etc. for Nuclear Facilities (Investigation of radioactivity and comprehensive evaluation in marine environment) (March 2021, Marine Ecology Research Institute)

Other revisions (dose constraints)

- No dose constraint value has been established for nuclear power plants in Japan. Therefore, in the Radiological Impact Assessment Report, the results were compared with the target dose for commercial light water reactors in normal operation, 0.05 mSv.
- On February 16, 2022, the Nuclear Regulation Authority issued the "Concept and Assessment Guidelines for Verifications in the Radiological Impact Assessment," which says that "it must be verified that the estimated result of the representative person should be small when compared to the fluctuation range of the annual radiation dose humans in the region are exposed to through their living habits, etc., that is less than 50 μSv/year. The 50 μSv/year value is the target dose for commercial light water reactors in normal operation, which corresponds to the dose constraint set in the IAEA Safety Standards.
- In this Report, the dose target of 0.05 mSv/year will be revised as the dose constraint.
- General radiological impact assessments adopt this dose constraint-equivalent annual release as the upper limit. However, regarding the discharge of ALPS treated water, the Japanese government's basic policy set the discharge control limit of 22 trillion Bq/year, the level for the Fukushima Daiichi NPS before the accident, before the start of the assessment of this Report. Therefore, the Report will not be reviewed even when the revision is made.

- In the exposure assessment to the general public due to the discharge of ALPS treated water, exposures of the representative person are assessed while assuming that the most significant amount of discharge is continued during the discharge period and that the transfer and enrichment of radioactive materials have reached an equilibrium state.
- The result is smaller than the dose limit of 1 mSv/year for the general public and the dose target (dose constraint value) of 0.05 mSv/year as well, but the release of ALPS treated water will continue for 30 to 40 years.
- The dose commitment is set as a tool to assess radiological impacts over a long period.

- The dose commitment E (τ) is given by the following formula:

$$E(\tau) = \int_0^{\tau} E(t)dt$$

- where
  - ✓ E (t) is the annual effective dose to which a representative person is exposed when t years have passed since the start of the discharge of ALPS treated water,
  - ✓ τ is the duration of the release (in years).

Other revisions (Dose commitment): Concept

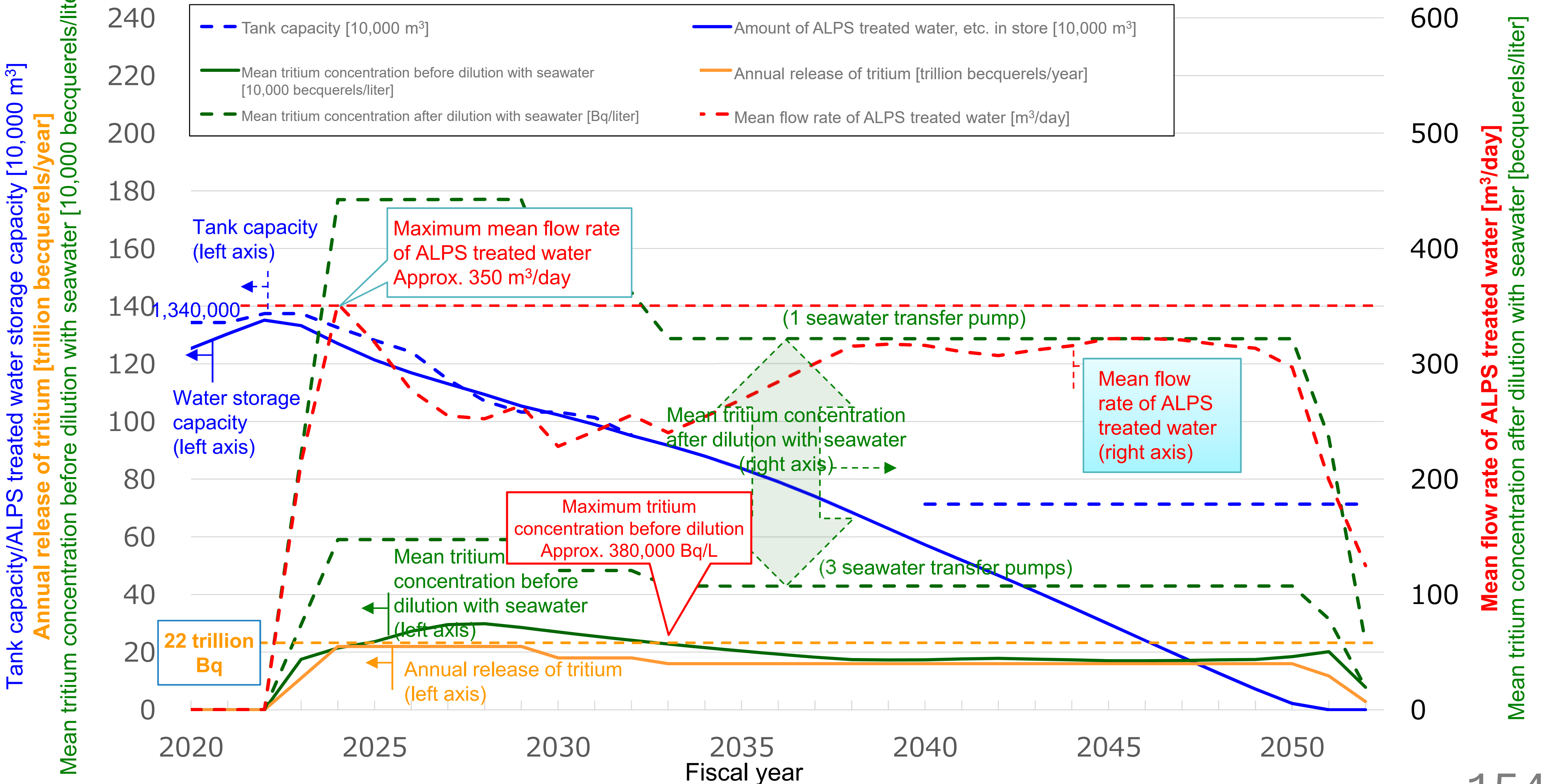
- If an action causes exposure for several years, the exposure due to the action in the previous year will be added as the action continues in the second and third years, and the exposure will increase year by year until equilibrium is reached.
- However, in the exposure assessment for the discharge of ALPS treated water, the “hypothetical ALPS treated water,” which would have the most significant impact, is used as the source term, and the radioactive materials in beach sand, sea bottom sediment, fish and shellfish, etc., are assumed to have reached an equilibrium state. Therefore, the exposure of the representative person does not change during the 30-year discharge period.
- Once the discharge is ended, the radioactive materials in beach sand, fish and shellfish, etc., in the equilibrium state will decrease.
- Therefore, the annual exposure of the representative person does not seem to have a significant effect on the exposures estimated in the Radiological Impact Assessment Report.
- To be on the safe side, the evaluation of the dose deposit will be confirmed, including the necessity.

2-2 (3) Radiological impact assessment on the surrounding environment due to discharge into the sea

Details of other revisions (Dose commitment) [Reference] Prospects for release when the total amount of tritium in buildings is assumed to be maximum

- FY 2023: 11 trillion becquerels/year (Start discharging with a small amount of water with caution = set as half the amount of the fiscal 2024 and subsequent years)
- FY 2024 to FY 2029: 22 trillion becquerels per year
- FY 2030 to FY 2032: 18 trillion becquerels per year
- After FY 2033: 16 trillion becquerels per year

Neither the annual release of tritium nor the mean flow rate of treated water exceeds the initial peak.



The Japanese version shall prevail.