Document 1-1 for the 9th 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

February 15, 2022

Tokyo Electric Power Company Holdings, Inc.

The Japanese version shall prevail.

Table of Contents

Responses to

major issues* concerning the content of the application for the facilities for discharge of ALPS Treated Water into the sea

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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

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

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

- Explain a policy for selecting nuclides that may affect dose assessment, other than tritium (H-3), carbon (C-14), and 62 nuclides to be removed by ALPS.

1. Study overview on the target nuclides to be measured in the ALPS treated water

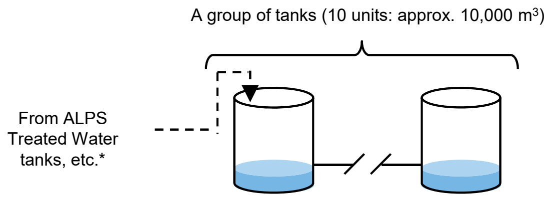
2-1 (2) [1] Analysis methods and systems for the radioactive concentration of nuclides in ALPS treated water
1.1 Study overview

TEPCO

- When discharging ALPS Treated Water into the sea, the water discharged must be satisfied the criteria, whose value of the ratio of concentration to the regulatory limits is less than1, on the stage before the dilution and discharge in the measurement/confirmation process shown in the figure [2] below.
- Regarding the nuclides to be confirmed in this process, in releasing the ALPS Treated Water into the sea, we will select nuclides that need to be checked before the discharge by thorough verification based on knowledge of decommissioning and burial facilities.
- In the selection process, it is expected that radionuclides that are difficult to measure due to low energy radiation, having more minor effects on the human body, will be included in the target to be studied. In conducting this study, we will check whether these nuclides may affect the dose assessment of ALPS treated water.

(1) Receiving process

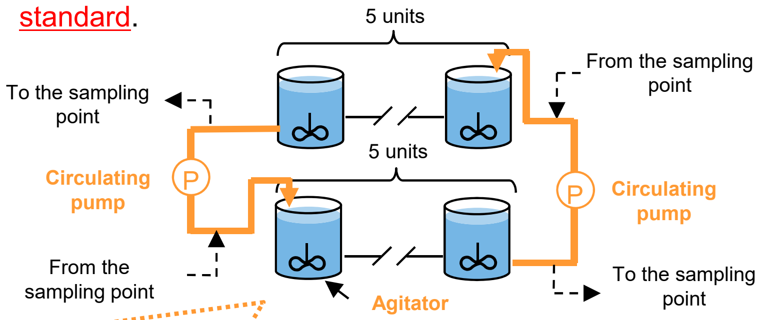
ALPS Treated Water from ALPS Treated Water storage tanks, etc., is transferred into a group of empty tanks.



*: Existing transfer pipe is used for receiving.

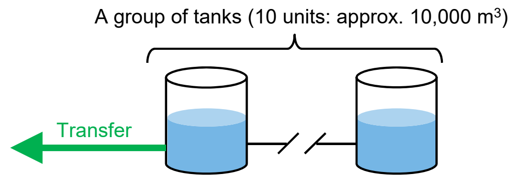
(2) Measurement/confirmation process

After the quality of water in the tank group is homogenized by the agitator and circulation pumps, the water is sampled to check if it meets the discharge standard.



(3) Discharge process

After confirming that the ALPS Treated Water satisfies the discharge criteria, the water is transferred to the Dilution facility by the Transfer facility.



ALPS Treated Water will be analyzed for H-3 and radioactive nuclides other than H-3 **to check that the radioactive nuclides other than H-3 satisfy the criteria** in the Measurement/confirmation facility before being discharged. The water will be discharged by diluting it with seawater in the Dilution facility in order to reduce the H-3 concentration.
(Implementation Plan III-3-2-1-2)

Outline of the ALPS Treated Water dilution/discharge facilities operation

The Japanese version shall prevail.

TEPCO

- In the discharge into the sea, we will thoroughly verify the nuclides that may be significantly contained in the accumulated water in buildings of the Fukushima Daiichi NPS (hereinafter referred to as “1F”) again. To be more specific, the study will be carried out on the following subjects:

Study approach

- Considering the fuel and structural materials of units 1 - 3, we will first perform nuclide analysis and inventory assessment as below. Based on the results of the analysis and evaluation, as well as the effects on the dose assessment, we will select the nuclides to be measured at the time of discharge.

Nuclide analysis

➢ We actually analyze to verify, if the nuclides in the accumulated water of the plant buildings that may contain target nuclides of the studies on the decommissioning or burial facilities. The results of the other nuclide in the past are also verified.

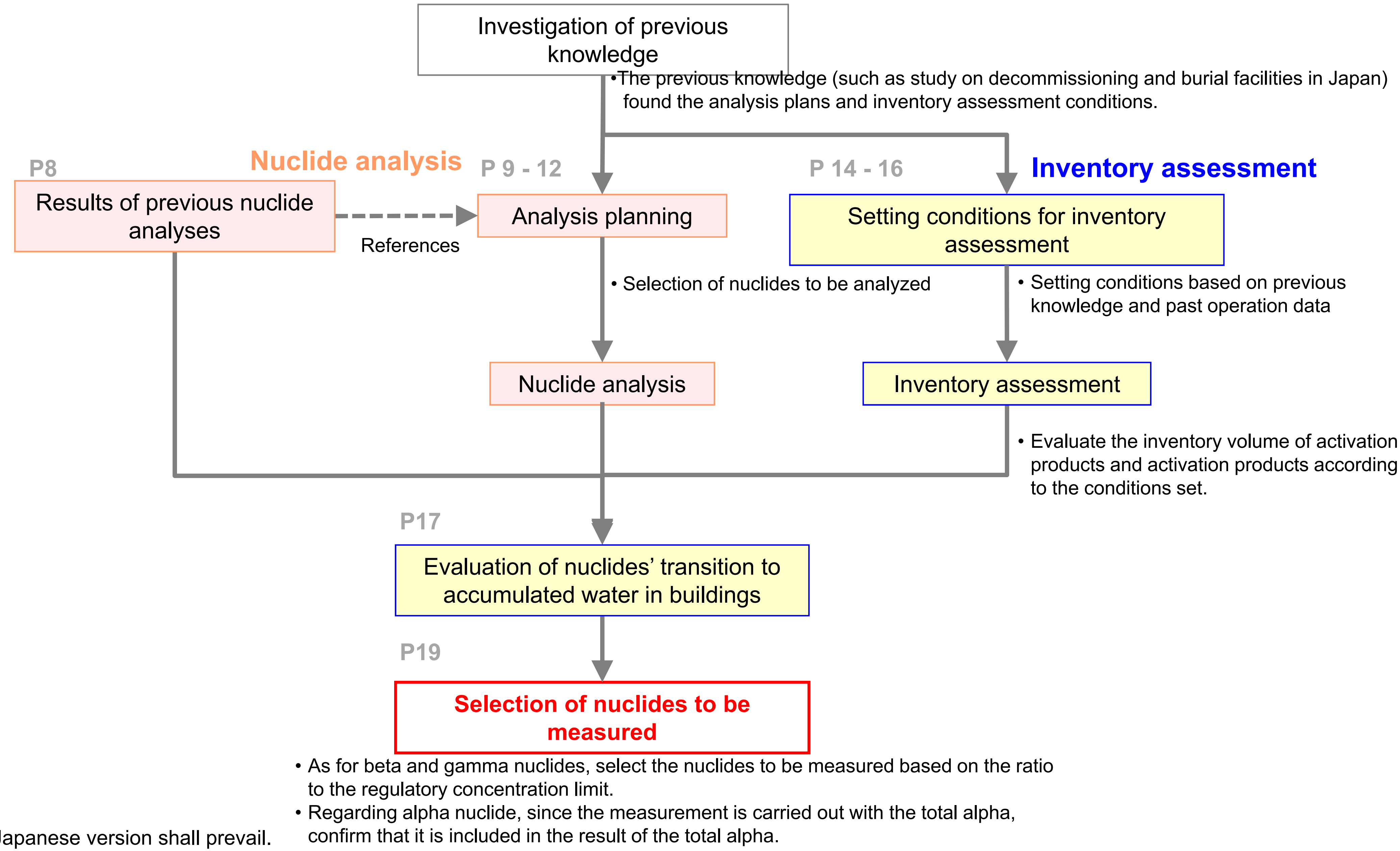
Inventory assessment

➢ Using the same method at the time reviewing and determining the nuclides to be removed from the ALPS Treated Water, inventory assessments of activation products is conducted. And the mass of inventory generated by activation of structures in the reactor vessels is evaluated, referring to studies on the decommissioning processing and burial facilities. In the evaluation process, having been passed the 12 years from the event to the discharge, the decrease of the value of the mass inventory through the attenuation is took into account.

Based on the above evaluation results, adding the tendency of nuclides to move into the water, we will determine the possibility of the existence of nuclides that may be contained in the accumulated water in buildings.

- In this study, we will also conduct the nuclide analysis and inventory assessment for alpha nuclide to check the properties of alpha nuclide that may be contained in the accumulated water in buildings. In the actual operation, we will measure total alpha nuclide as before.

- The diagram below summarizes the study approach:



2. Nuclide analysis of contaminated water and treated water

2.1 Results of previous nuclide analyses

TEPCO

- Regarding the nuclide analysis for ALPS Treated Water, TEPCO has measured recently the 62 target nuclides to be removed from ALPS Treated Water, H-3 and C-14. Other than that, Japan Atomic Energy Agency (JAEA) and TEPCO have also analyzed 20 nuclides (JAEA has published the results at TEPCO*).
- In studying the nuclides to be measured, we will consider the results of these previous analyses and plan additional analysis when necessary.

*Published on htT.P.s://frandli-db.jaea.go.jp/FRAnDLi/ (Partly citing data published by TEPCO).

Fission products: 56 nuclides

Rb-86	Sr-89	Sr-90	Y-90	Y-91	Nb-95	Tc-99
Ru-103	Ru-106	Rh-103m	Rh-106	Ag-110m	Cd-113m	Cd-115m
Sn-119m	Sn-123	Sn-126	Sb-124	Sb-125	Te-123m	Te-125m
Te-127	Te-127m	Te-129	Te-129m	I-129	Cs-134	Cs-135
Cs-136	Cs-137	Ba-137m	Ba-140	Ce-141	Ce-144	Pr-144
Pr-144m	Pm-146	Pm-147	Pm-148	Pm-148m	Sm-151	Eu-152
Eu-154	Eu-155	Gd-153	Tb-160	Pu-238	Pu-239	Pu-240
Pu-241	Am-241	Am-242m	Am-243	Cm-242	Cm-243	Cm-244

Corrosion products: 6 nuclides

Mn-54
Fe-59
Co-58
Co-60
Ni-63
Zn-65

Other nuclides: 2 nuclides

H-3	C-14

Nuclides other than 64 nuclides: 20 nuclides

Cl-36	Ca-41	Ni-59
Se-79	Nb-94	Mo-99
Tc-99m	Te-132	I-131
I-132	La-140	U-233
U-234	U-235	U-236
U-238	Np-237	Pu-242
Cm-245	Cm-246	

List of nuclides analyzed in the past

2.2 Previous knowledge on analysis planning

- The nuclide analysis this time, we will check the presence of nuclides significantly in the accumulated water in the buildings, which note in the studies on the decommissioning and burial facility.
- The previous knowledge verified is as follows:

[1] Joint Electric Power Research Project "Study on Decommissioning of BWR (Part 2)" (FY 1996)

[2] Tokai low-level radioactive waste burial facility, Type II waste disposal business license application, "Selection of major radionuclides" (February 2018, Japan Atomic Power Company)

[3] Research materials obtained when the JAEA studied the nuclides to be analyzed in order to understand the property of radioactive waste at the 1F.

- The upper three orders of magnitude relative to the nuclides with the highest relative importance D/C, among the nuclides included in either nuclear reactor waste or cycle waste, for trench disposal, pit disposal, and surplus depth disposal in "The upper limit of activity concentration for burial disposal of low-level radioactive waste."
- Those selected as important nuclides in the "TRU waste disposal technical review document - secondary TRU waste disposal research and development report."
- Those selected as important nuclides in "Technical Reliability of Geological Disposal of High-Level Radioactive Waste in Japan - Second Summary of Research and Development on Geological Disposal - General Report."
- "Application for burial business license for Rokkasho low-level radioactive waste disposal center (near-surface pit disposal) and JPDR (near-surface trench disposal) by Japan Nuclear Fuel Limited."

- We have confirmed that the nuclides assessed in the previous knowledge include many nuclides confirmed at the time of studying the nuclides to be removed with ALPS. Based on this, the analysis plan was developed from the following viewpoints:

➢ Nuclides that have not been assessed among the nuclides extracted from previous knowledge.
(however, excluding nuclides with short half-lives and the inventory volume to be reduced sufficiently due to attenuation.)

2.3 Candidate nuclides for analysis that have been extracted from previous knowledge (other than alpha nuclides)

TEPCO

- Based on previous knowledge, the table below shows that nuclides to be analyzed other than alpha nuclides were extracted. The nuclides extracted will be measured by external organizations, since there is difficulties to measure them in house.
- Regarding the nuclides extracted in the table below, mainly low energy nuclides are extracted compared with typical nuclides at 1 F, Cs-137 (Ba -137 m): 0.662 MeV (gamma rays) and Sr -90 (Y-90): 2.28 MeV (beta rays),.

No.	Literature (P9)	Candidate nuclide	Disintegration form	Energy [MeV]	Regulatory concentration limit(s) [Bq/cm^3]	Measurement method (proposed)	Remarks
1	(1) - (3)	Cl-36	β-	0.709550	9.0E-01	Measured by low back gas flow counter after pretreatment (separation and precipitation)	Analysis under consideration External analysis results available *1
2	(1) and (3)	Se-79	β-	0.150630	2.0E-01	Measured by liquid scintillation counter after pretreatment (separation, precipitation and resolution)	External analysis results available *1
3	(1) - (3)	Zr-93	β-	0.090800	1.0E+00	Measured by inductively coupled plasma mass spectrometer after pretreatment (separation) (ICP-MS)	
4	(3)	Pd-107	β-	0.034000	2.0E+01		
5	(1) - (3)	Ca-41	EC	0.003310	4.0E+00	Measured by Si (Li) detector after pretreatment (separation, filtration, and evaporation to dryness)	External analysis results available *1
6	(1) and (2)	Fe-55	EC	0.005900	2.0E+00	Measured by low-energy photon counting device after pretreatment (separation) (LEPS)	
7	(1) - (3)	Ni-59	EC	0.006930	1.0E+01		
8	[2]	Nb-93m	IT	0.016615	7.0E+00		
9	(1) and (3)	Mo-93	EC	0.016615	3.0E-01		
10	(3)*2	Sn-121m	β- IT	0.359800 0.026359	2.0E+00		*2: Based on the research materials, it is extracted as it is the most generated isotope of Sn from Zircaloy, such as a cladding tube.
11	(1) and (2)	Ba-133	EC	0.356013	5.0E-01	Germanium semiconductor detector (Ge)	

*1: Cl-36: Less than the detection limit (8.0E-03 to 1.4E-01 Bq/cm^3: 2011 to 2015), Ca-41: less than the detection limit (2.0E + 01 to 1.7E + 02 Bq/L: 2011 to 2013)
Se-79: detected at 2.2E-01 to 8.3E+00 Bq/cm^3 in accumulated water (2011 to 2013), less than the detection limit at ALPS inlet to outlet (5.0E-02 to 3.0E-01 Bq/cm^3: 2013 to 2017

2.4 Candidate nuclides for analysis that have been extracted from the previous knowledge (alpha nuclides)

TEPCO

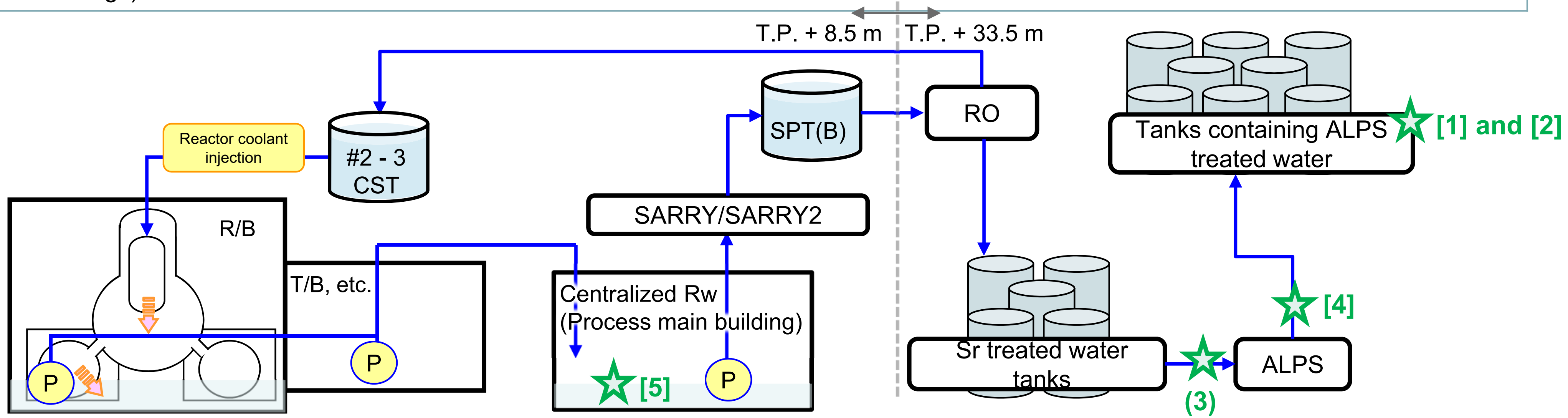
- Similarly, for alpha-nuclides, candidate analysis nuclides were extracted from the previous knowledge. Regarding the nuclides extracted, as an inhouse measurement is unable, the measurement will be implemented by external organizations.
- By analyzing these, we will confirm alpha nuclides that may be contained significantly in the accumulated water in buildings.

No.	Literature (P9)	Candidate nuclide	Disintegration form	Energy [MeV]	Regulatory concentration limit(s) [Bq/cm^3]	Half-life [y]	Measurement method (proposed)	Remarks
1	(3)	U-233	α	4.824200	2.0E-02	1.6E+05	Measured by inductively coupled plasma mass spectrometer after pretreatment (separation) (ICP-MS)	External analysis results available (N.D.)
2	(1) and (3)	U-234	α	4.774600	2.0E-02	2.5E+05		External analysis results available
3	(1) and (3)	U-235	α	4.395400	2.0E-02	7.0E+08		External analysis results available
4	(1) and (3)	U-236	α	4.494000	2.0E-02	2.3E+07		External analysis results available
5	(1) and (3)	U-238	α	4.198000	2.0E-02	4.5E+09		External analysis results available
6	(1) and (3)	Np-237	α	4.788000	9.0E-03	2.1E+06		External analysis results available
7	(1) - (3)	Pu-238	α	5.499030	4.0E-03	8.8E+01	Measured by alpha spectrometer after pretreatment (separation)	Pu-238 to Pu-241 are nuclides to be removed with ALPS. The concentration of Pu-241 is estimated by isotope.
8	(1) - (3)	Pu-239	α	5.156590	4.0E-03	2.4E+04		
9	(1) - (3)	Pu-240	α	5.168170	4.0E-03	6.6E+03		
10	(1) - (3)	Pu-241	β-	0.020780	2.0E-01	1.4E+01	-	
11	(1) and (3)	Pu-242	α	4.902300	4.0E-03	3.8E+05	Measured by alpha spectrometer after pretreatment (separation)	External analysis results available (N.D.)
12	(1) - (3)	Am-241	α	5.485560	5.0E-03	4.3E+02		Am-241 to Am-243 are nuclides to be removed with ALPS. Since the energies of Am-241 and Am-243 are close in value, they are measured as a combined value. The concentration of Am-242m is estimated by isotope.
13	(1) and (3)	Am-242m	IT	0.018856	5.0E-03	1.4E+02	-	
14	(1) and (3)	Am-243	α	5.275300	5.0E-03	7.4E+03	Measured by alpha spectrometer after pretreatment (separation)	
15	(3)	Cm-242	α	6.112720	6.0E-02	4.5E-01		Cm-242 to Cm-234 are nuclides to be removed with ALPS. Regarding Cm-243 and Cm-244 and Cm-245 and Cm-246, their energies are close so that they will be measured as combined values. Cm-245 and Cm-246 have been analyzed externally.
16	(3)	Cm-243	α	5.785200	6.0E-03	2.9E+01		
17	(1) and (3)	Cm-244	α	5.804770	7.0E-03	1.8E+01		
18	(3)	Cm-245	α	5.361100	5.0E-03	8.4E+03		
19	(3)	Cm-246	α	5.386500	5.0E-03	4.7E+03		

2.5 Assay sample

- Candidate nuclides to be analyzed extracted up to the previous page are being checked by analyzing the samples in the table below.

No.	Sampling point	Objective	Reason for selection
[1]	K4 tank group (ALPS treated water)	To check that nuclides are not significantly present in ALPS Treated Water (removed with ALPS).	In the ALPS Treated Water stored within the site, the sum of the ratios to regulatory concentrations limits is the lowest.
[2]	H4-E7 tank (ALPS treated water)		The measured value of C-14 is the highest in the ALPS Treated Water tank.
(3)	Before treatment by additional ALPS (Sr treated water)	To check that the nuclides confirmed to be significantly present before the ALPS treatment have been removed after the ALPS treatment.	To check the properties of the water before ALPS treatment.
[4]	After treatment by additional ALPS (ALPS treated water)		To check the properties of the water after the ALPS treatment at the exact timing as [3].
[5]	Main process building (accumulated water in buildings)	To identify the nuclides significantly present in the accumulated water in buildings.	To check the properties of the accumulated water in the building.



3. Study of fission products and activation products

3.1 Overview of inventory assessment

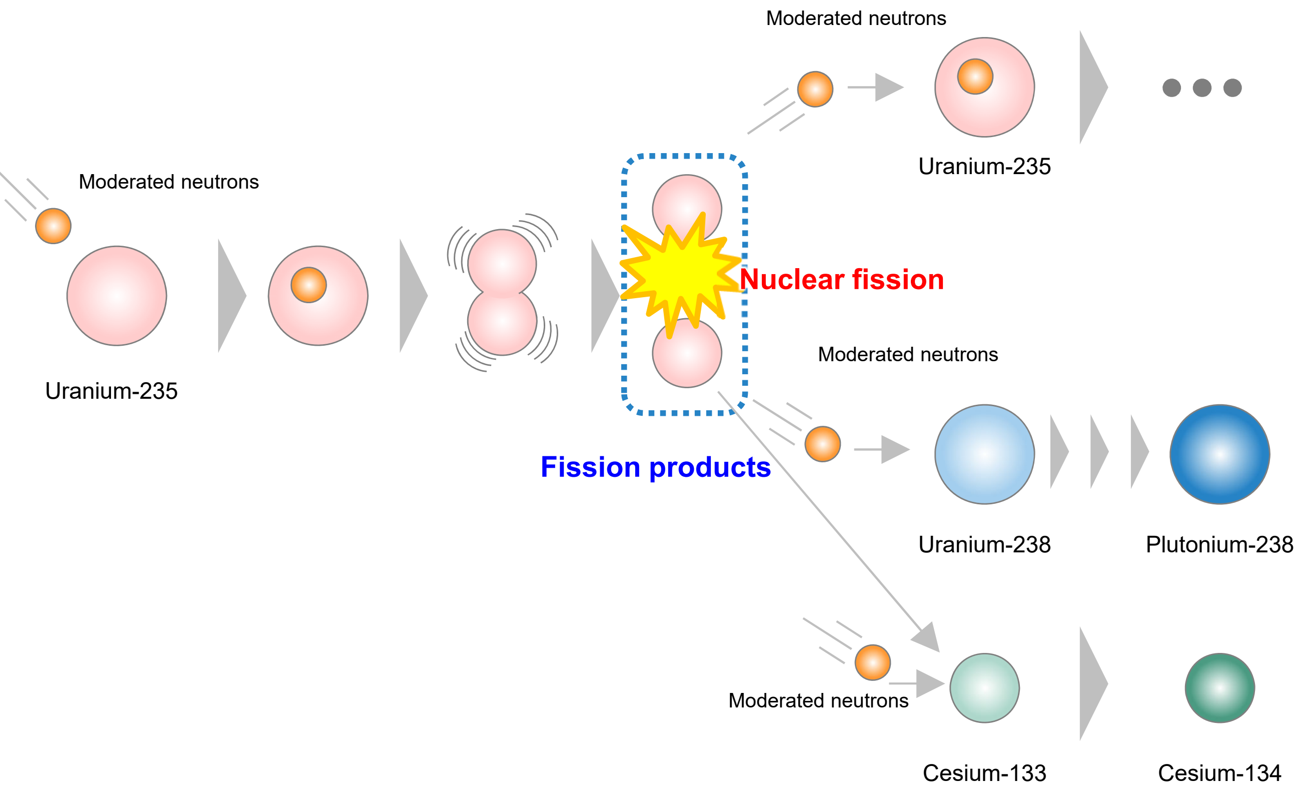
- In the inventory assessment, activation products have been evaluated in the safety evaluation of nuclear power plants (also used for the study of nuclides to be removed with ALPS). Additionally, the research on decommissioning and burial facilities conducted the activation calculation of equipment in nuclear power plants.
- Referring to the above two evaluations, the study follows as per the below table. The code to be used is ORIGEN * as in the previous evaluation.

*: ORNL Isotope Generation and Depletion Code. A code system for calculating generation, disintegration, depletion of radioactive materials.

No.	Evaluation	Description
1	Assessment of fission products	Referring to the safety evaluation of conventional nuclear power plants (the same as at the time of studying the nuclides to be removed with ALPS), the inventory volume as of March 2011 was evaluated based on the condition of the fuel loaded in the reactor pressure vessels of 1F-Units 1 to 3, as well as the condition of the burnup assumed from the loading period of each fuel. From March 2011 onwards, a decrease in the 12-year inventory volume due to attenuation was calculated.
2	Assessment of activation products	With reference to the research of decommissioning and burial facilities, about the following 4 types of equipment and structures existing inside the reactor pressure vessel and the lower part thereof, the inventory volume as of March 2011 was assessed based on the irradiation period from the reactor core. • Reactor internals • Fuel assembly (excluding nuclear fuel materials) • Pressure vessel • Pedestals In addition, about the corrosion products to be generated due to the corrosion and activation of components of equipment comprising the reactor cooling system, the inventory volume as of March 2011 was assessed with the data of feedwater metal at the time of operation. In both assessments, from March 2011 onwards, a reduction in the inventory volume over 12 years due to attenuation was calculated.

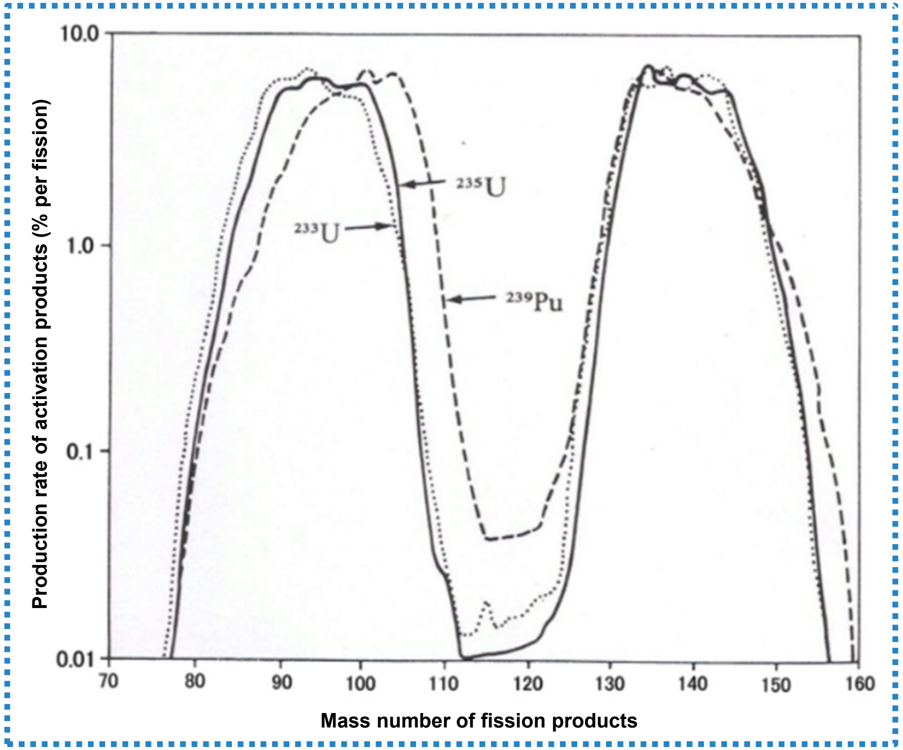
3.2 Overview of inventory assessment (fission product)

- As in the study for the nuclides to be removed from ALPS, products to be generated by nuclear fissions will be evaluated. This evaluation will consider attenuation that 12 years have passed since March 2011.
- In this assessment, we will evaluate the inventory volume to be generated, disintegrated, or depleted primarily due to the following phenomena:
  - When Uranium-235 undergoes fission, it splits into 2 nuclides with the peaks around mainly mass numbers 95 and 140.
  - Nuclides generated by Uranium-238 absorbing neutrons, such as plutonium, and the nuclides generated by activation products absorbing neutrons, such as Cesium-134, are produced.



Reference: Encyclopedia of Energy, "Fission of Uranium and Production and Fission of Plutonium", the Ministry of the Environment, products inside the nuclear reactor

Mass distribution of fission products

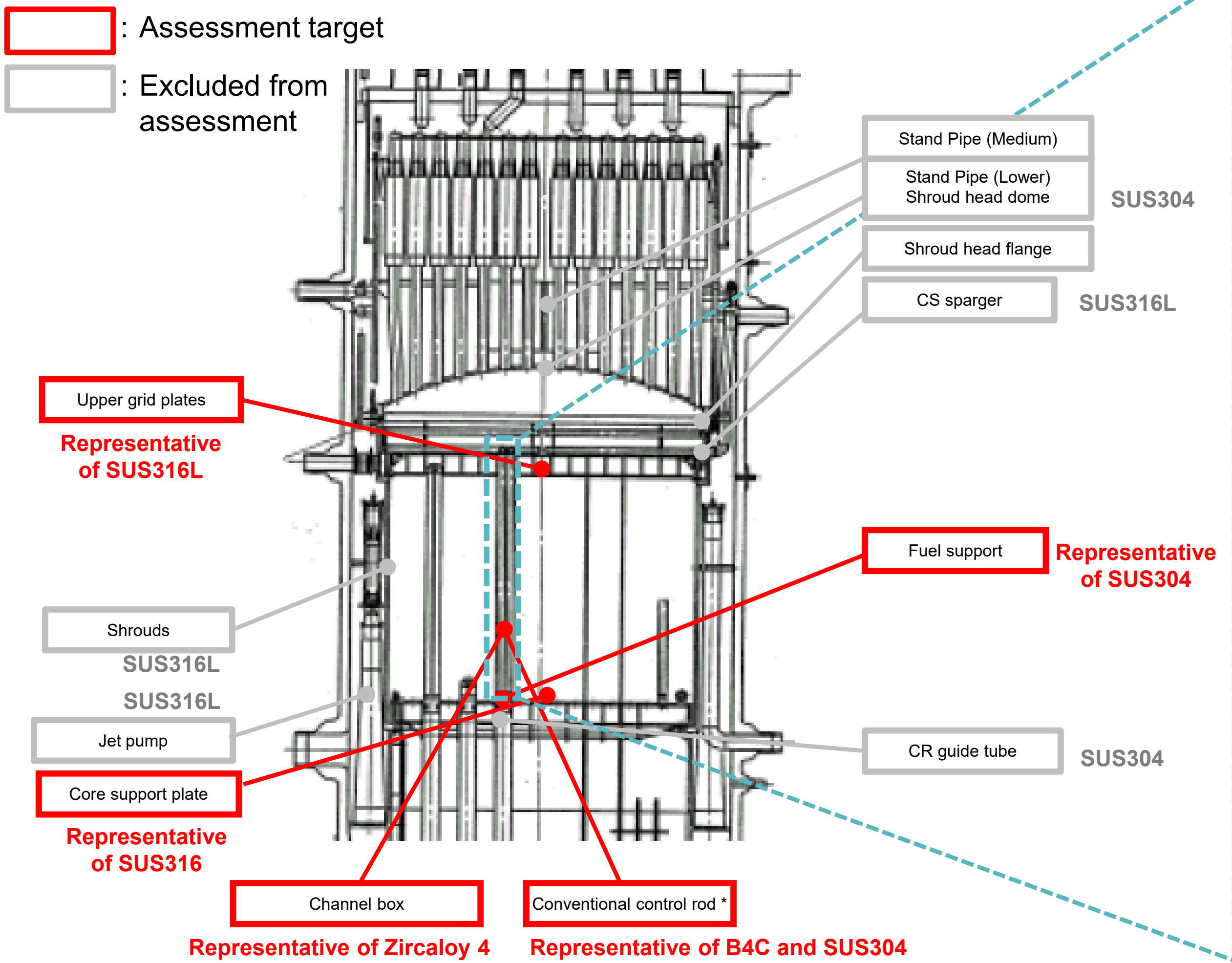


Based on the ATOMICA's "atomic mass number distribution of fission products."
Source: W. Marshall, ed.: Development of Reactor Technology (Vol.1), Shoukabou, p. 72

The Japanese version shall prevail.

3.3 Overview of inventory assessment (activation products)

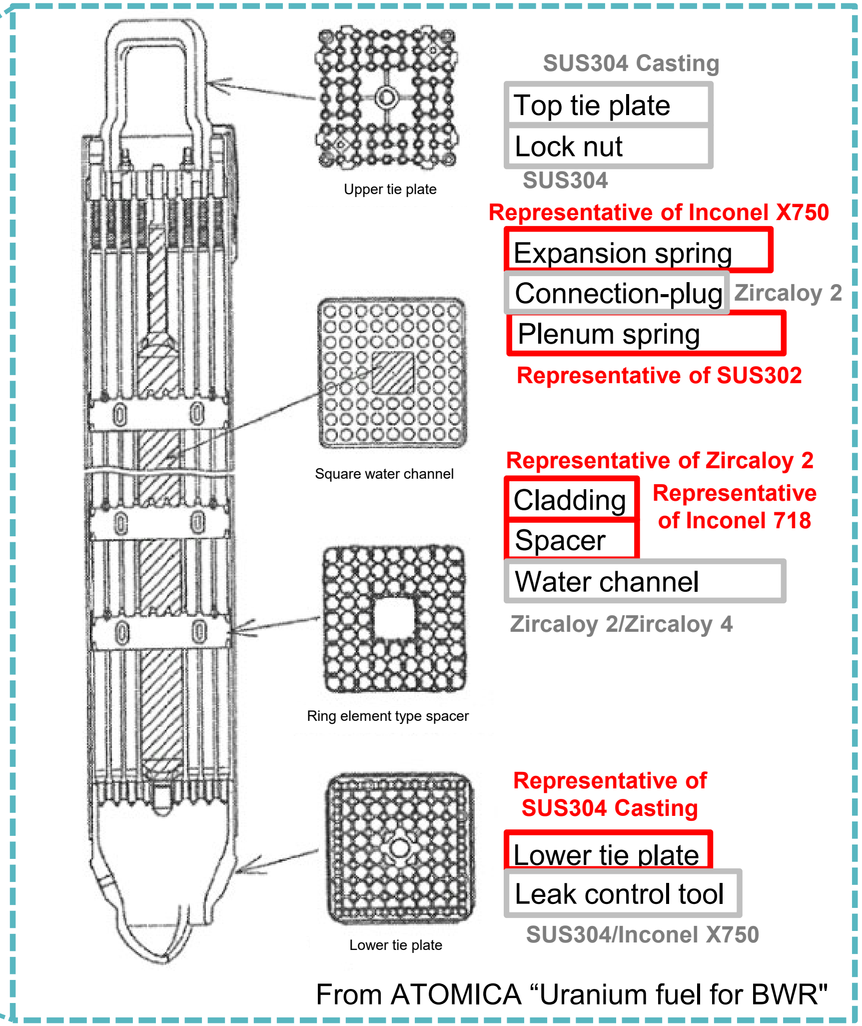
- Activation products evaluate activation caused by neutron absorbed into materials by calculation. In this evaluation, not all equipment will be evaluated, and when materials overlap, those closer to the core (the amount of activation is greater) will be selected and assessed as a conservative approach.



*It was confirmed that there were no Hf-type control rods in the reactor of units 1-3 of the 1F at the time of the Earthquake.

Based on "the structure drawing of BWR reactor internals", Inspection and Evaluation Guideline for BWR reactor internals

Target objects for the inventory assessment of reactor internals



Target objects for the inventory assessment of fuel assembly (excluding nuclear fuel materials)

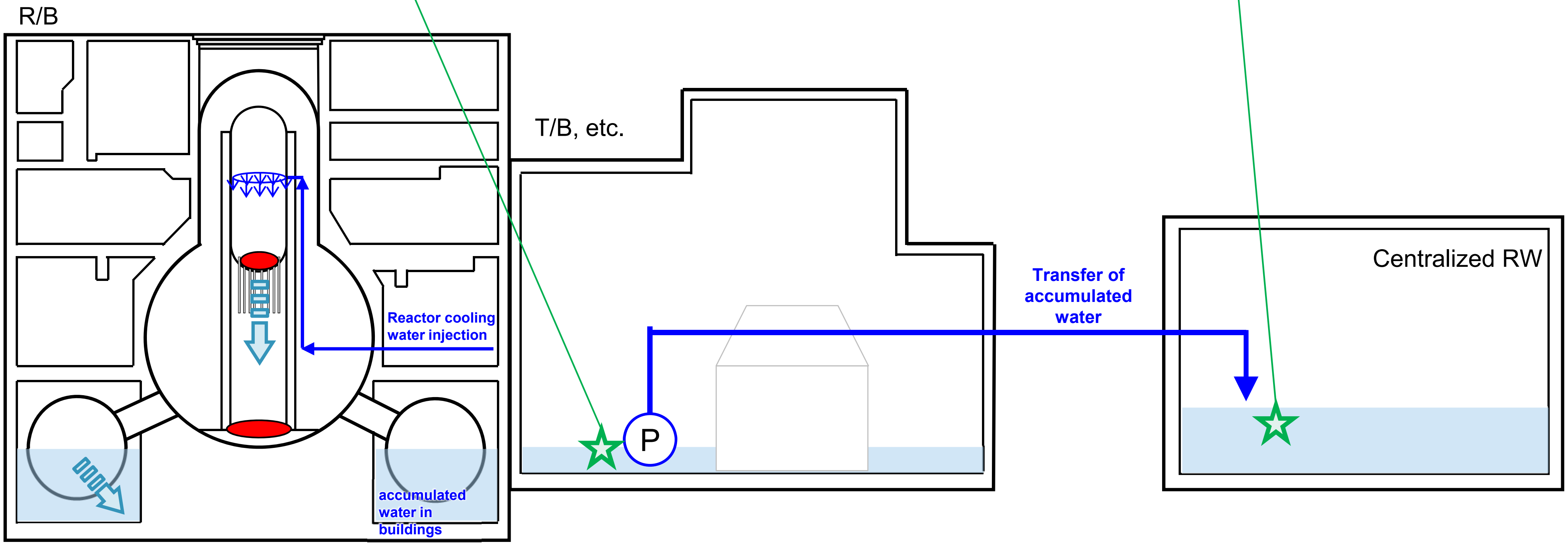
- After evaluating the inventory volume of fission products and activation products, considering that these radioactive materials have been transferred to the accumulated water in buildings, we will assess the transition of the radioactive materials to the accumulated water in buildings, based on the results of the previous analysis of the accumulated water in buildings, research on decommissioning and burial facilities, and other documents.

Results of previous analysis of accumulated water in buildings [Bq/L]

Building	Date	I-131	Cs-137	Sr-90
Unit 1 T/B	2011.3.27	3.0E+07	1.6E+08	2.1E+04
Unit 2 T/B	2011.3.24	2.0E+09	2.8E+08	1.4E+08
Unit 3 T/B	2011.3.27	1.6E+09	1.6E+08	1.5E+07

Results of previous analysis of accumulated water in buildings [Bq/L]

Building	Date	Co-60	Cs-137	Sr-90
PMB	2011.8.30	1.1E+04	9.6E+08	1.1E+08
PMB	2011.11.1	4.9E+03	7.4E+08	2.9E+08



Results of the previous analysis of the accumulated water in buildings as well as the state of accumulated water in buildings immediately after the Earthquake (image drawing)

4. (Proposed) Approach to selecting the nuclides to be measured of ALPS treated water

Main findings at the review meeting (for each major issue)*1

2-2 Confirmation regarding activities in line with government policy)
(3) Radiological impact assessment on the surrounding environment due to discharge into the sea*2

- The source term is the 64 nuclides (that means tritium, carbon 14, and 62 nuclides to be removed by ALPS). In developing the source term, first assess what kind of nuclides may be present in the ALPS Treated Water theoretically and specify the selection concept, such as for narrowing down the nuclides to be evaluated.

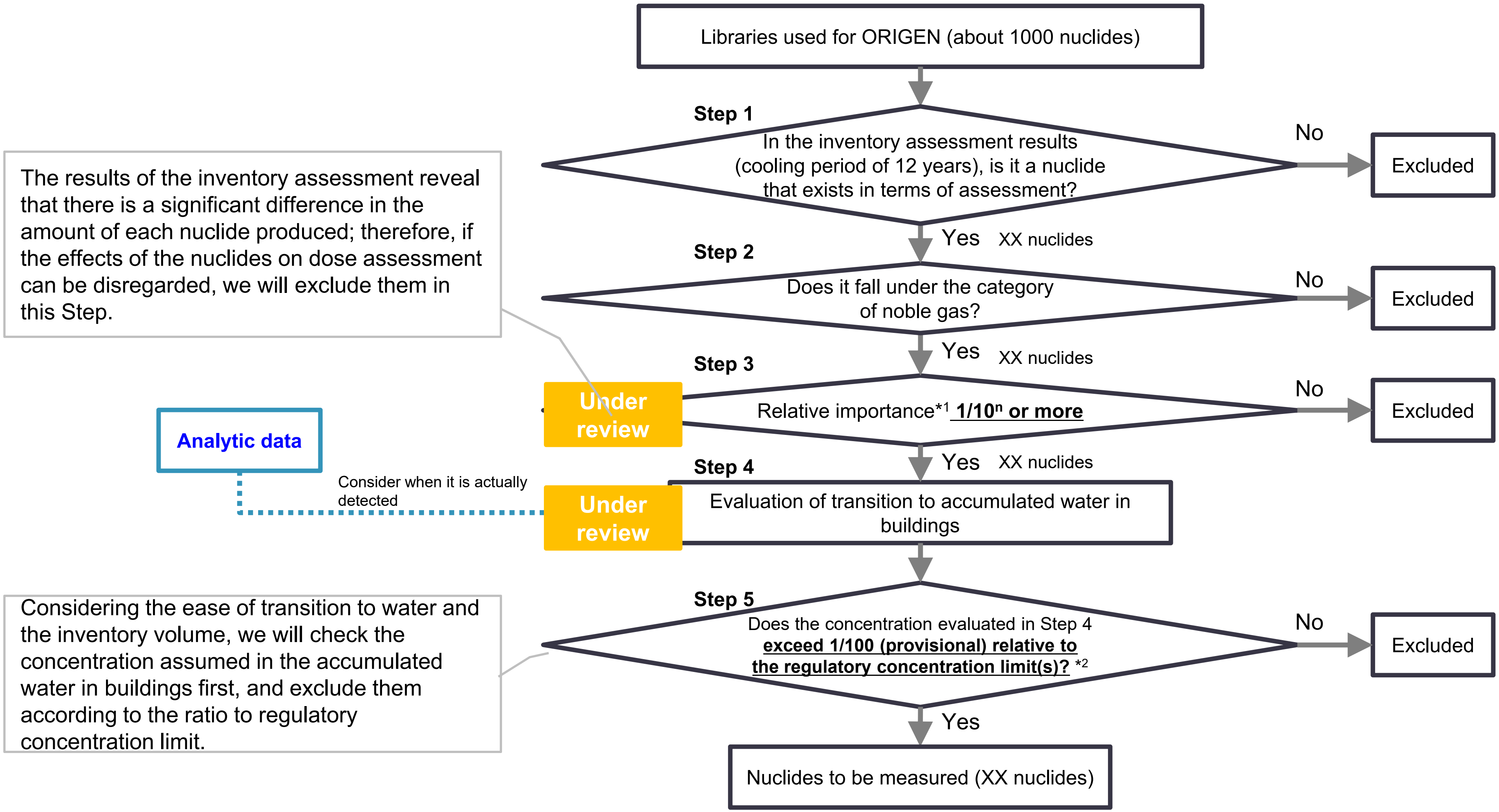
*1: (the 97th) Specified Nuclear Facilities Monitoring and Assessment Review Meeting, Documents 2-2, Attachment 2

*2: Although the content of the point at issue is different, the concept of nuclide selection is answered in this section.

4.1 (Proposed) Approach to selecting the nuclides to be measured of ALPS treated water

TEPCO

- Based on the results of nuclide analysis of contaminated water and treated water and inventory assessment, we are studying the selection of the nuclides to be measured according to the flowchart below: With the nuclides selected in this flow, discharge criteria will be verified.
- In this selection of nuclides to be measured, even if the nuclides to be removed from ALPS are excluded, in order to check the fact that they have been removed from ALPS, TEPCO plans to verify these nuclides voluntarily.



*1: Nuclides that affect the dose assessment are confirmed based on the ratio of the value obtained by dividing the inventory volume of each nuclide by the regulatory concentration limit(s) to the sum.
*2: Since alpha nuclides are measured as total alpha, the assessment is conducted with the ratio of the most stringent regulatory concentration limit (4 Bq/L) relative to the number of total Bq of alpha nuclides.

Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS Treated Water into the sea

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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

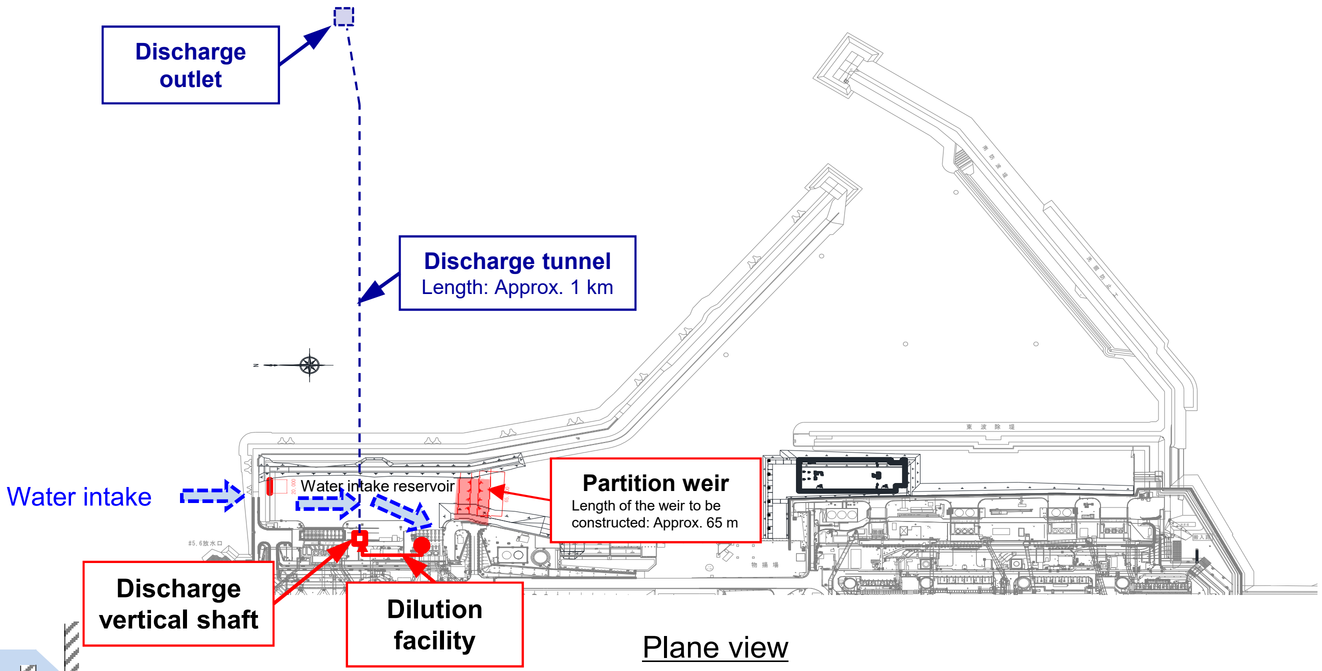
(1) Discharge facility of ALPS Treated Water into the Sea

[3] Methods of seawater intake and discharging ALPS Treated Water after dilution

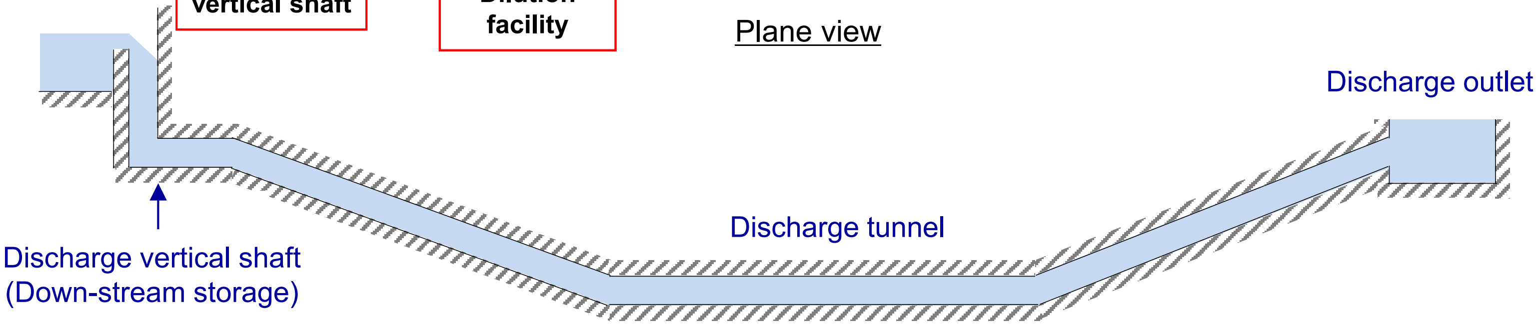
- In setting the mixing and diluting ratio as well as in assessing the effective dose at the site boundary, the effects of radioactive materials that may exist at the site of intaking seawater should be considered. When the impact cannot be disregarded, measures for preventing the transition of radioactive materials within the port to the intake site should be explained.

Intake and Discharge facility

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



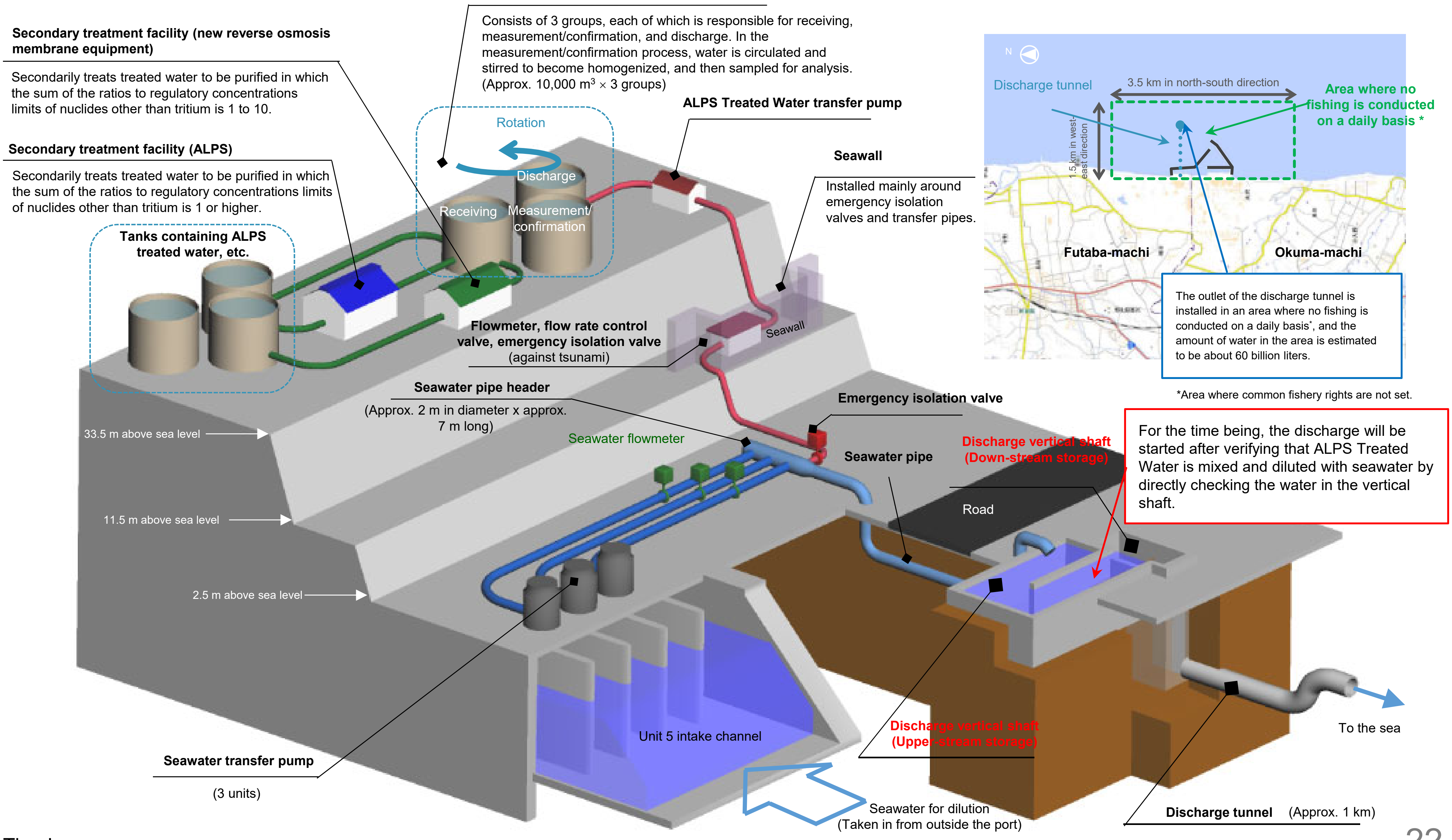
Plane view



Cross-sectional view

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

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)
htT.P.s://maps.gsi.go.jp/#13/37.422730/141.044970/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0m0f1



Methods of seawater intake and discharging ALPS Treated Water after dilution

Effects on exposure to radioactive materials contained in seawater for dilution

Main findings at the review meeting (for each major issue)*1

- Specify the results of confirming the water quality, including the concentration of radioactive materials in the seawater at the intake side.

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

Water intake method

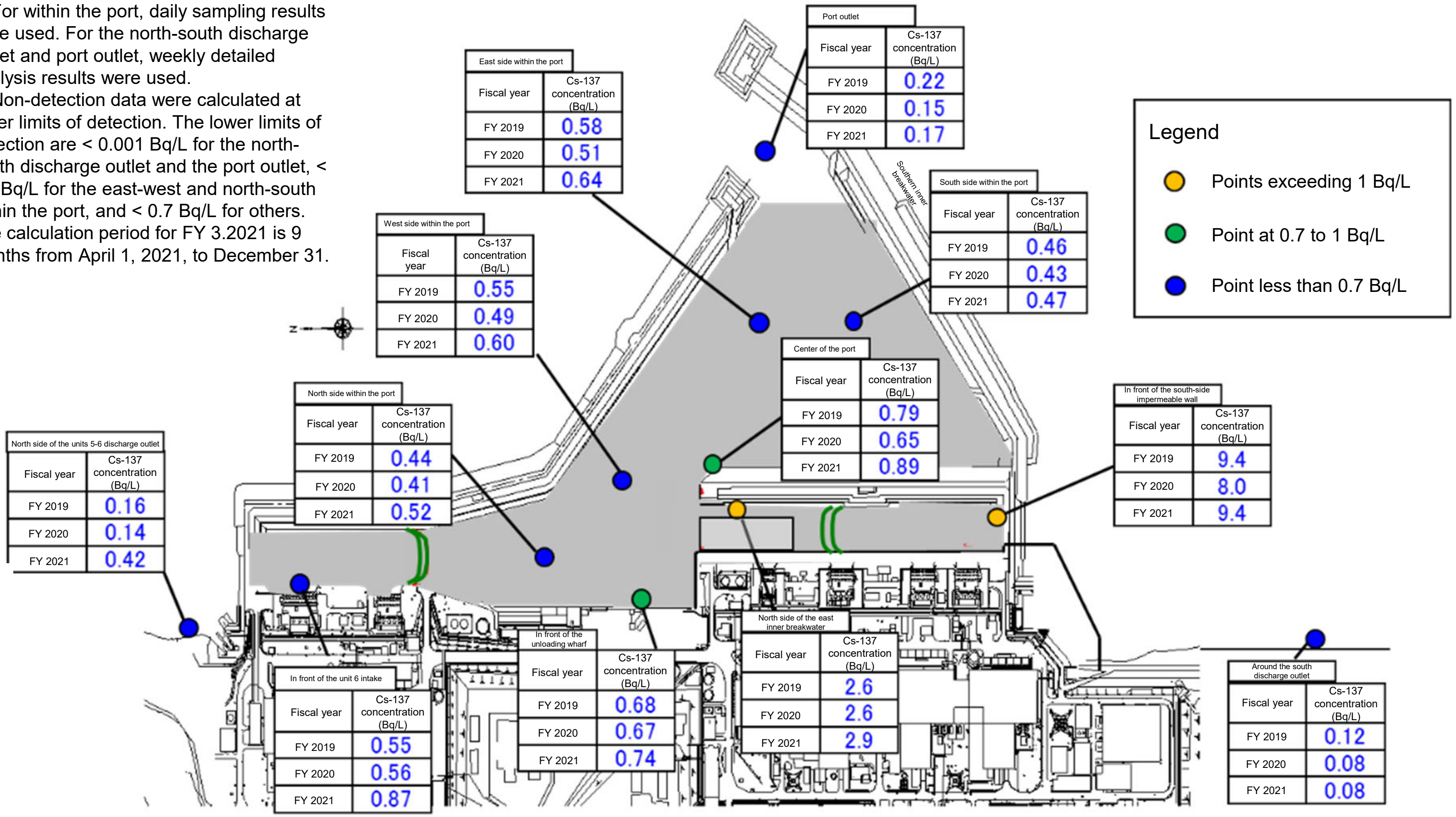
Discharge method

3.1 Concentration of seawater of 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 units 5-6 discharge outlet.
- Based on the method of the Radiological Impact Assessment Report (published November 17, 2021), we compared cases to check how different the impact of the discharge into the ocean would be in a case where the seawater outside the port is taken in from the north side of the units 5-6 discharge outlet and a case where the seawater within the port is taken in.
- The current state of Cs-137 concentration in the port is shown below:

Note:
1. For 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. 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)
FY 2019	0.22
FY 2020	0.15
FY 2021	0.17

East side within the port

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

South side within the port

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

West side within the port

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

Center of the port

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

In front of the south-side impermeable wall

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

North side within the port

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

North side of the units 5-6 discharge outlet

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

In front of the unit 6 intake

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

In front of the unloading wharf

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

North side of the east inner breakwater

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

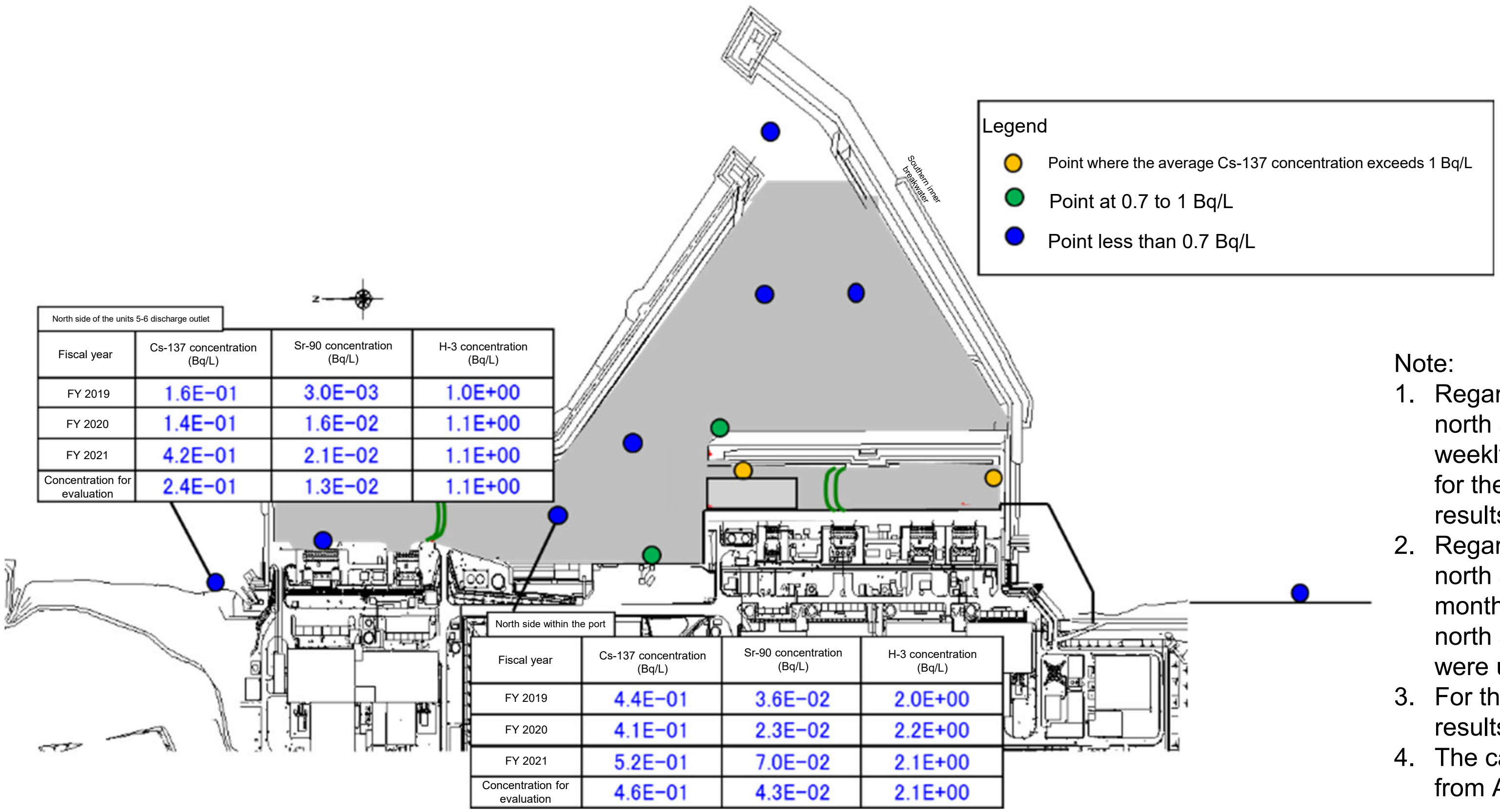
Around the south discharge outlet

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

3.2 Seawater concentration used for evaluation

TEPCO

- 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 units 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 units 5-6 discharge outlet are lower.



North side of the units 5-6 discharge outlet

Fiscal year	Cs-137 concentration (Bq/L)	Sr-90 concentration (Bq/L)	H-3 concentration (Bq/L)
FY 2019	1.6E−01	3.0E−03	1.0E+00
FY 2020	1.4E−01	1.6E−02	1.1E+00
FY 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)
FY 2019	4.4E−01	3.6E−02	2.0E+00
FY 2020	4.1E−01	2.3E−02	2.2E+00
FY 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 units 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 units 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.

3.3 Methods of exposure assessment

TEPCO

- the following formula calculates the inventory of each nuclide contained in the seawater for dilution (annual amount of radioactivity transferred) , and the result was used for adding the 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)

- The source terms for the exposure assessment used are two types : "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

	Intake on the north side of the units 5-6 discharge outlet		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	2.4E+10	4.6E-01	4.6E+10
Sr-90	1.3E-02	1.3E+09	4.3E-02	4.3E+09
H-3	1.1E+00	1.1E+11	2.1E+00	2.1E+11

3.4 Evaluation results

- The results of the exposure assessment are shown in the table below.
- 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, however the impact of radiation exposure is more minor when the water is taken from the north side of the units 5/ 6 discharge outlet outside the port.

Table 1: Results of human exposures assessment

Assessment case		Measured values of the K4 tank group			Hypothetical ALPS treated water			Remarks
		Radiological Impact Assessment Report	Intake on the north side of the units 5-6 discharge outlet	Intake on the north side within the port	Radiological Impact Assessment Report	Intake on the north side of the units 5-6 discharge outlet	Intake on the north side within the port	
External exposure (mSv/year)	Exposure from sea level	6.5E-09	5.1E-08	9.3E-08	1.8E-07	2.3E-07	2.7E-07	
	Exposure from the hull	5.2E-09	4.1E-08	7.4E-08	1.4E-07	1.7E-07	2.0E-07	
	Exposure during undersea work	2.8E-10	2.3E-09	4.1E-09	7.9E-09	9.9E-09	1.2E-08	
	Exposure from sandy beaches	5.0E-07	4.1E-06	7.5E-06	1.4E-05	1.7E-05	2.1E-05	
	Exposure from fishing nets	1.6E-06	1.2E-05	2.1E-05	4.5E-05	5.5E-05	6.4E-05	
Internal exposure (mSv/year)		6.1E-05	6.9E-05	7.6E-05	2.0E-03	2.0E-03	2.0E-03	Adult value
Total (mSv/year)		6.3E-05	8.5E-05	1.1E-04	2.1E-03	2.1E-03	2.1E-03	

Table 2: Results of internal exposures assessment by age

Assessment case		Measured values of the K4 tank group			Hypothetical ALPS treated water			Remarks
		Radiological Impact Assessment Report	Intake on the north side of the units 5-6 discharge outlet	Intake on the north side within the port	Radiological Impact Assessment Report	Intake on the north side of the units 5-6 discharge outlet	Intake on the north side within the port	
Internal exposure (mSv/year)	Adult	6.1E-05	6.9E-05	7.6E-05	2.0E-03	2.0E-03	2.0E-03	
	Children under school age	9.4E-05	9.7E-05	1.0E-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	

Methods of seawater intake and discharging ALPS Treated Water after dilution

Effects on exposure to radioactive materials contained in seawater for dilution

Water intake method

Main findings at the review meeting (for each major issue)*1

- When explaining the Discharge facility including water intake facilities, undersea tunnels, the concept of a partition weir and the transition rate to the seawater intake points should be presented.

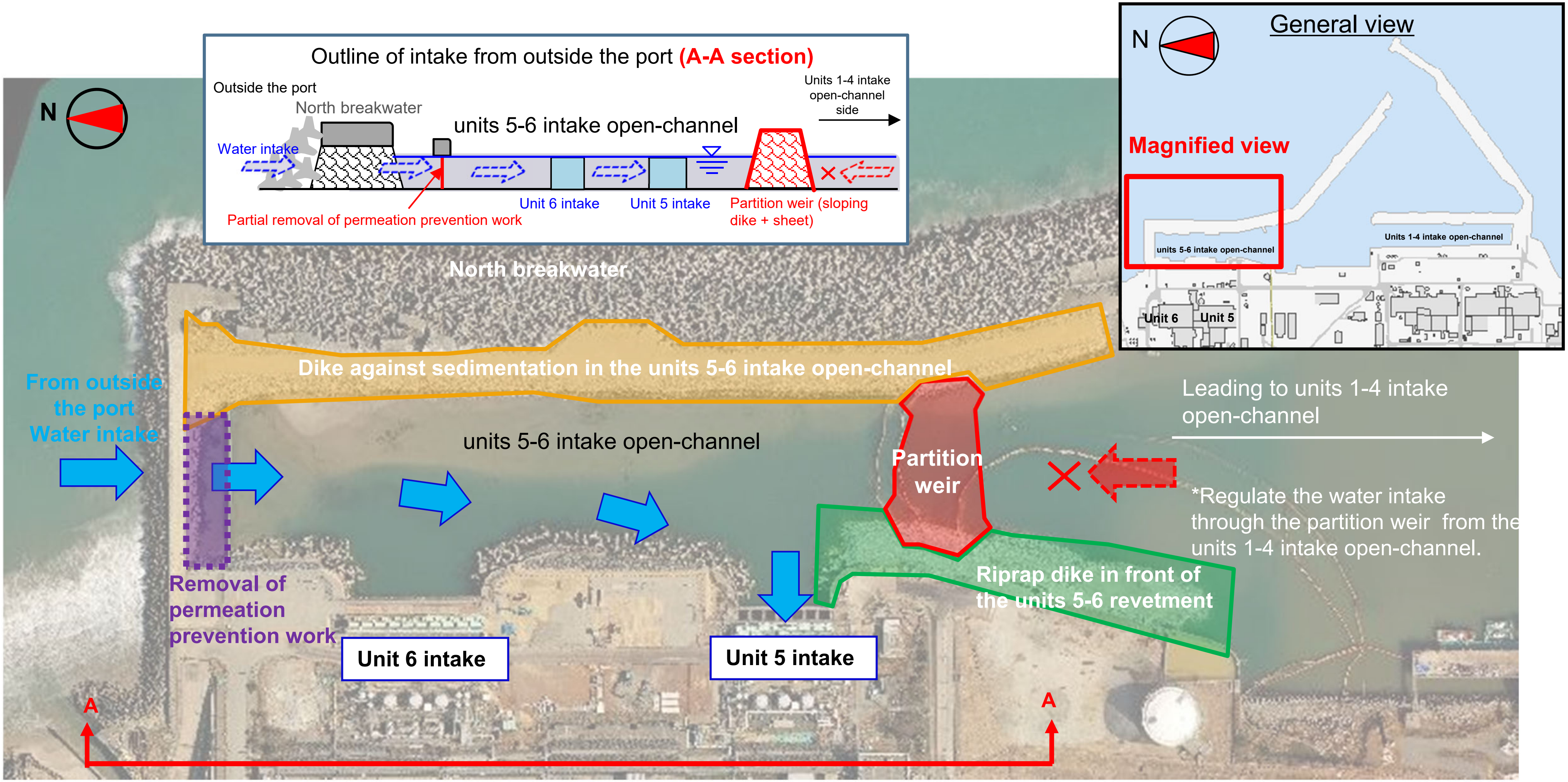
*1: (the 97th) Specified Nuclear Facilities Monitoring and Assessment Review Meeting, Documents 2-2, Attachment 2

Discharge method

4.1 Water intake methods: Overall schematic diagram

TEPCO

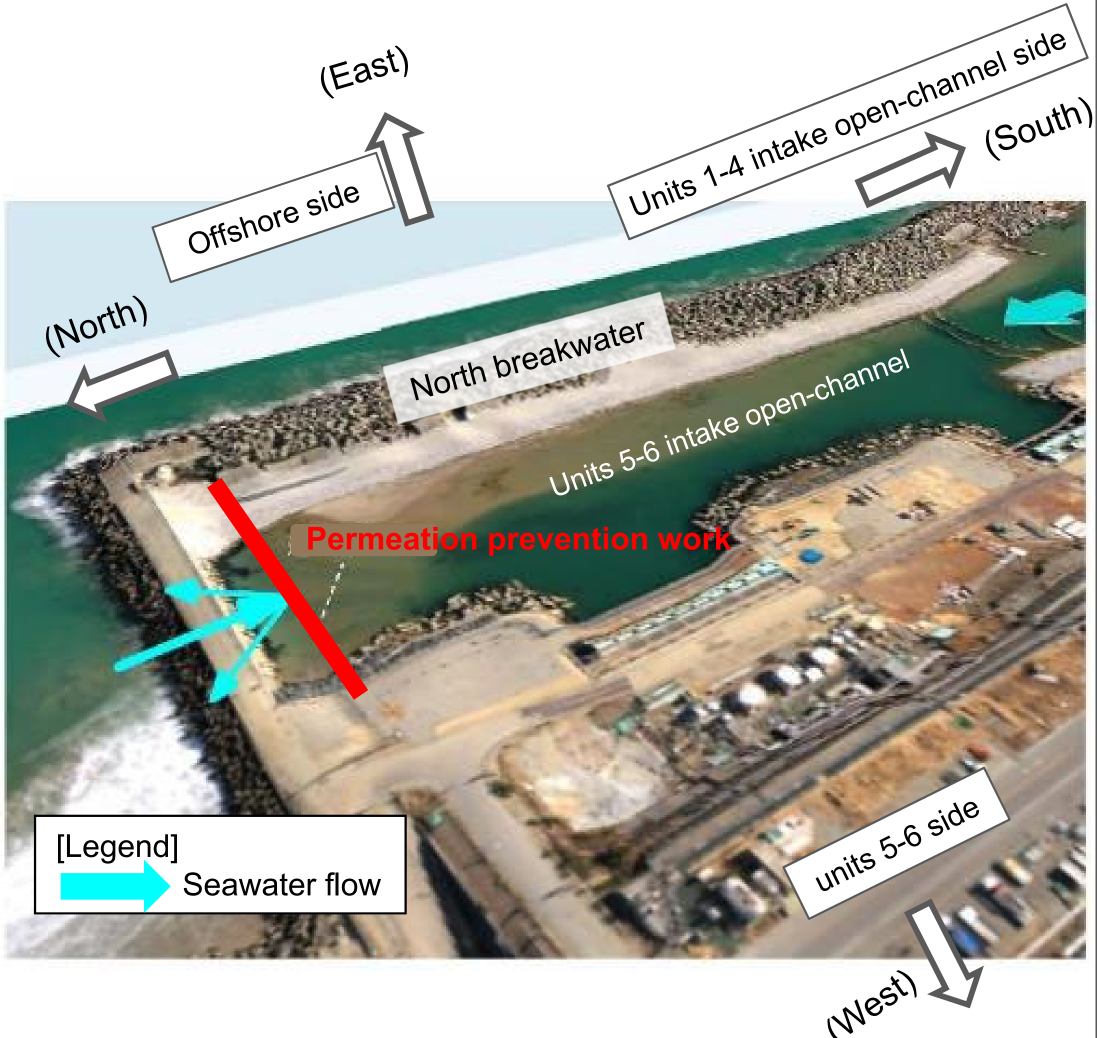
- units 5-6 intake open-channel are shut with a partition weir (riprap sloping weir + sheet) from the units 1-4 side port. A part of the north breakwater permeation prevention work is remodeled so that the seawater for dilution is taken in from outside the port.
- Taking the seawater from outside the port by shutting from the port on the side of units 1-4, it is possible to suppress the drawing in of the seawater of a relatively high concentration of radioactive materials within the port.



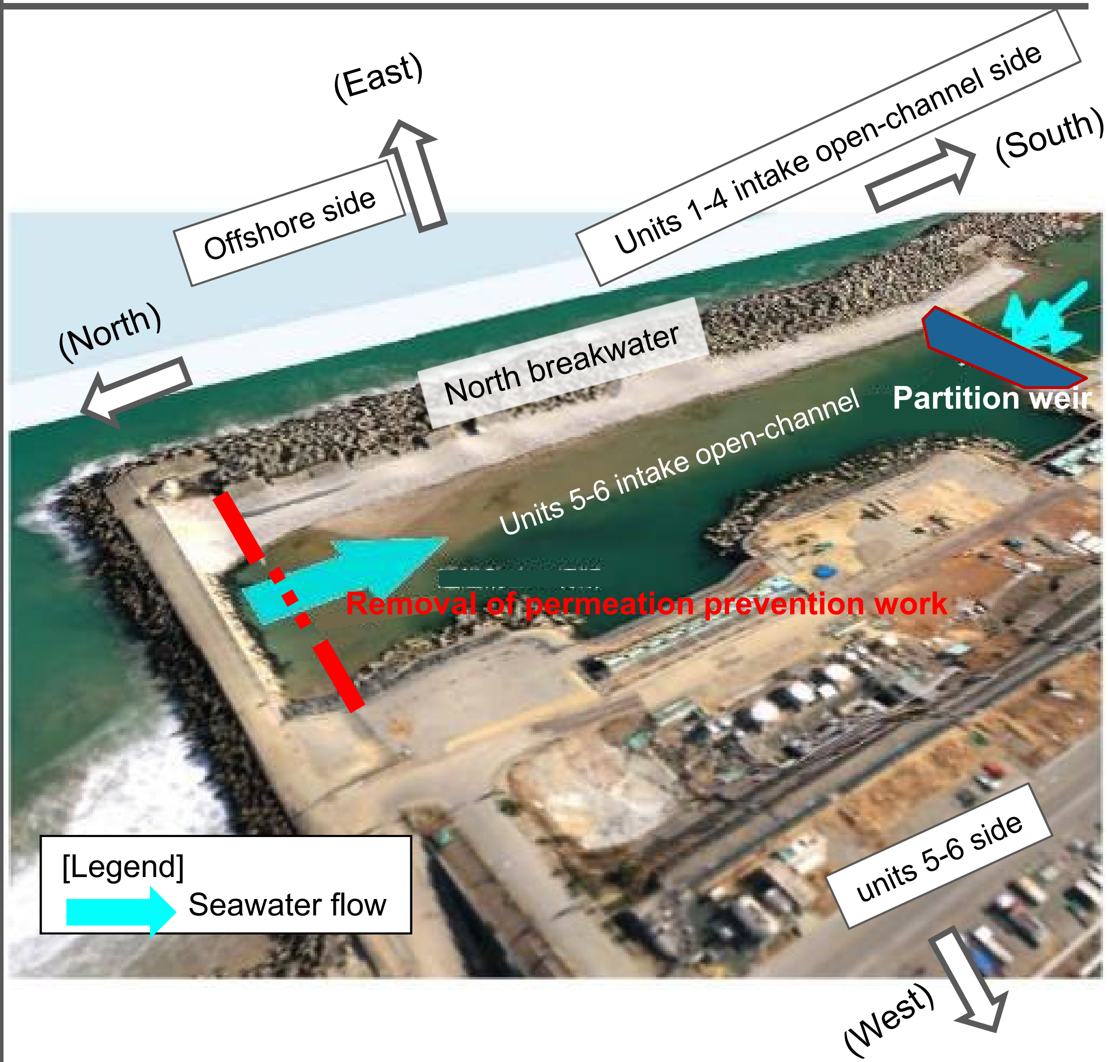
Overview of water intake method

[Supplement] Outline of the seawater intake method

Current status	After completion of construction



- With the permeation prevention work on the north breakwater, there is little inflow of seawater from the north side of the port.



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

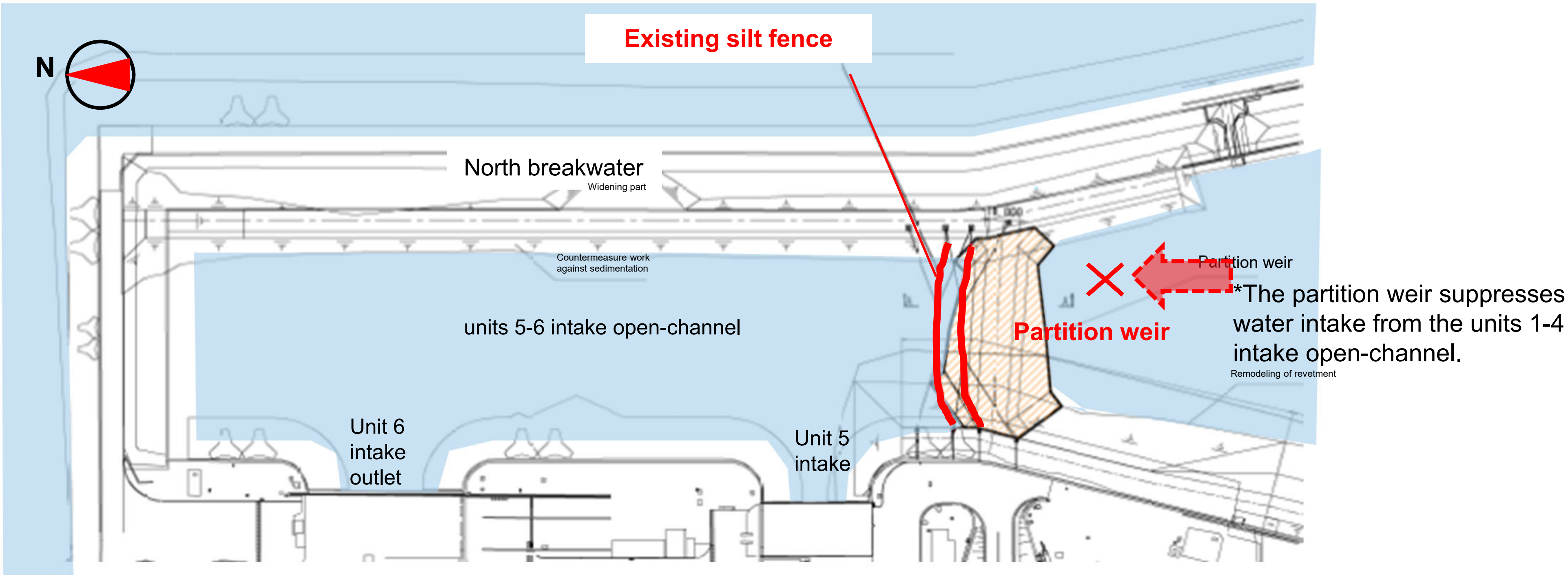
4.2 Water intake method: Positioning of partition weir (1/2)

Current status

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

Positioning

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



Partition weir position map

4.2 Water intake method: Positioning of partition weir (2/2)

TEPCO

Before constructing the partition weir

- units 5-6 intake open-channel and the units 1-4 intake open-channel are separated by two silt fences (two locations).
- Since the silt fences and ropes are damaged (wore) due to the influence of the tides and waves by tidal levels, routine maintenance and replacements are required every two to three years (Performed recently in February 2016, February 2018, and March 2021).
- Due to the impact of tides and waves by tidal levels, the silt fences are unable to regulate the drawing in of the seawater with a high concentration of radioactive materials.

After constructing the partition weir

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

4.3 Water intake method: Radioactive material concentration in seabed soil after construction of partition weir

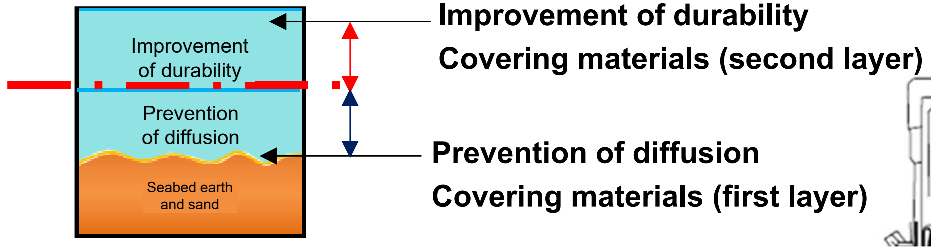
- The sedimentation on the covered soil inside the units 5-6 intake open-channel (A) is the permeated soil of the north breakwater and is the equivalent level to the concentration of radio active materials of the outside the port (T-1). On the other hand, the concentration is high in the south side (B, C) to the silt fences. It is assumed that the seabed soil is impacted from within the port on units 1-4 side (including the earth and sand brought in from the K discharge channel, etc.).
- Replacing the silt fences with the partition weir can regulate the seawater and seabed soil transfer from within the port on units 1-4 side. This will be a measure to prevent the transition of radioactive materials within the port to the water intake site.

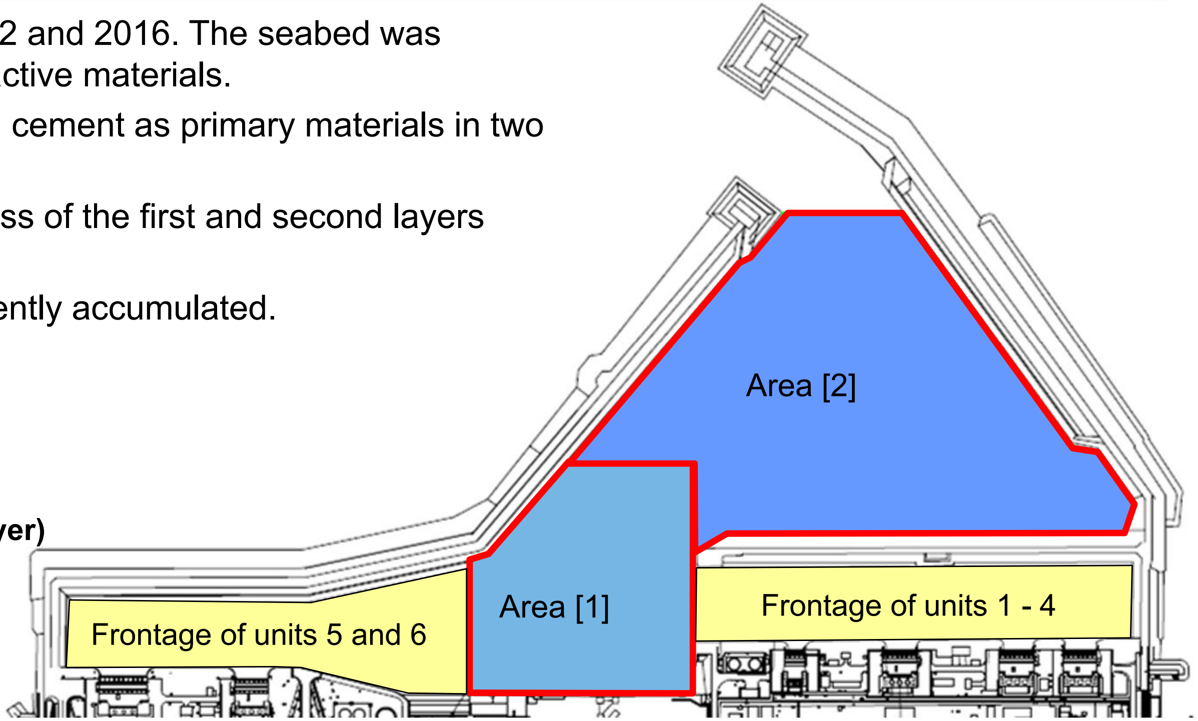
Survey points	Concentration of radioactive materials (Bq/kg, dry earth)		Survey year
T-1 (Outside the port)	Cs-134	6 - 69	2017 - 2021
	Cs-137	110 - 410	
Within the port A (GL±0) North side of silt fences	Cs-134	4 - 26	2018 - 2021
	Cs-137	187 - 281	
Within the port A (GL-500) North side of silt fences	Cs-134	17 - 20	2021
	Cs-137	467 - 554	
Within the port B (GL±0) South side of silt fences	Cs-134	723	2018
	Cs-137	6,475	
Within the port C (GL±0) South side of silt fences	Cs-134	183	2018
	Cs-137	1,893	

[Reference] Status inside the units 5-6 intake open-channel (status of seabed soil covering)

- The work covering the seabed soil completed between 2012 and 2016. The seabed was covered with solidified soil to suppress the spread of radioactive materials.
- The seabed earth and sand were covered by bentonite and cement as primary materials in two layers.
- On the seabed in front of the units 5-6, the average thickness of the first and second layers covered is about 60 cm in total.
- On the covering materials, sand of more than 1.5 m is currently accumulated.

Example of covering





Locations of covered seabed soil within the port

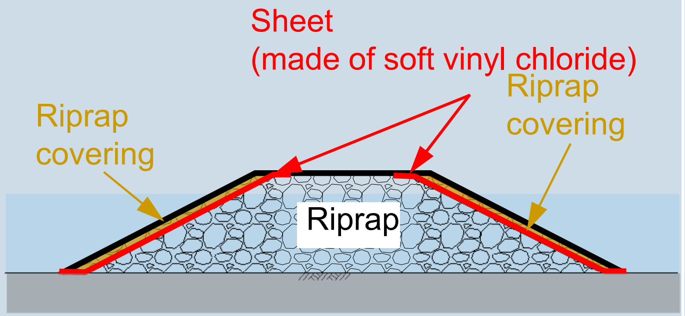
Results of covered seabed soil within the port

		Prevention of diffusion: First layer			Improvement of durability: Second Layer		
Construction area	Construction Area (m^2)	Placing capacity (m^3)	Start date	Date of completion	Placing capacity (m^3)	Start date	Date of completion
In front of units 1 - 4	34,000	6,200	2012.3.14	2012.3.39	9,600	2012.4.5	2012.5.11
In front of units 5 and 6	38,600	7,700	2012.5.16	2012.5.29	9,700	2012.5.31	2012.7.5
Area [1]	50,900	10,700	2014.07.17	2014.10.03	21,200	2015.06.23	2015.12.21
Area [2]	129,700	21,800	2014.12.14	2015.04.23	48,600	2016.03.21	2016.12.26
Total	253,200	46,400			89,100		

4.4 Water intake method: Study on partition weir construction methods

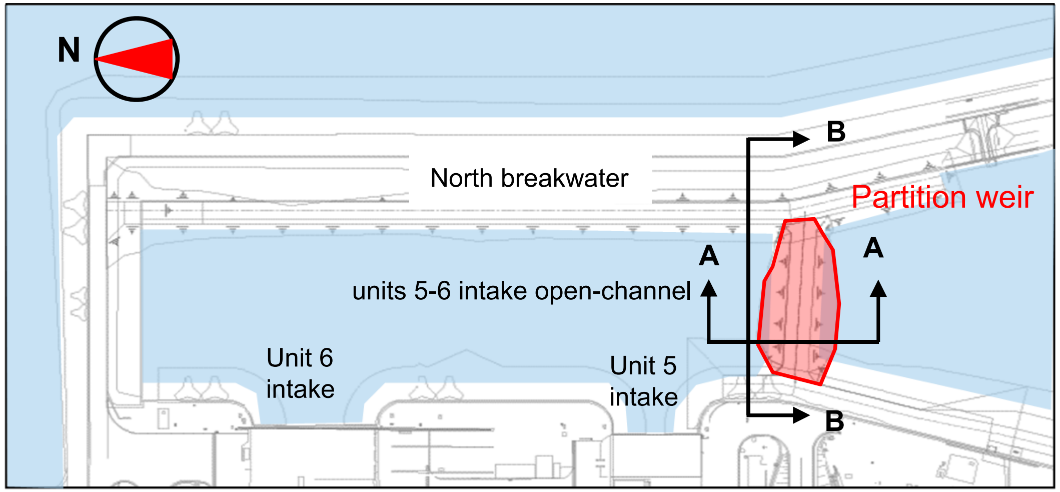
➢ As shown in the table below, as a result of a comparative study of the partition weir construction methods, sheets (soft vinyl chloride mats) will be laid on both sides of the riprap sloping weir.

Comparison of partition weir construction methods

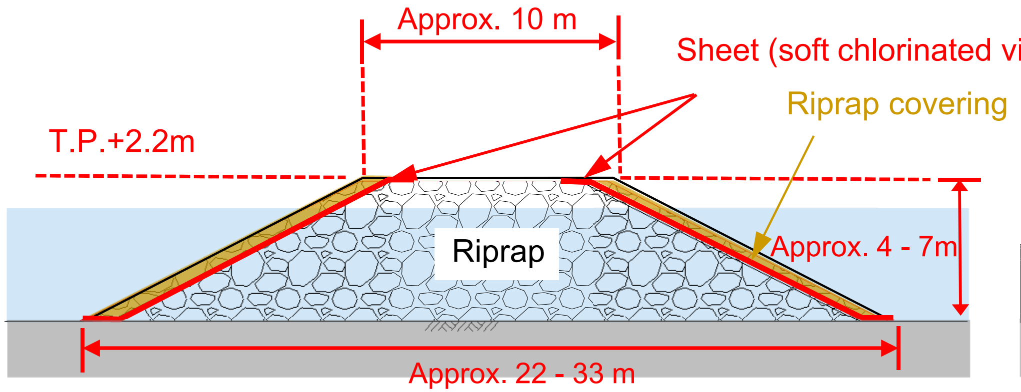
	Riprap sloping dike + sheet	Concrete wall	Earth retaining steel sheet pile
Construction method			
Workability	○ Riprap will be thrown in from the land, and sheets will be installed only. There are many proven results.	× It is challenging to implement the water cut-off treatment underwater.	△ It is challenging because the covering of seabed soil will be broken.
Concern about radioactive materials	○ This was used in many recent construction work.	× It swirls up the seabed soil when excavating the base foundation.	× It swirls up the seabed soil when driving a steel sheet pile.
Evaluation	○	×	×

4.5 Water intake method: Structure of partition weir

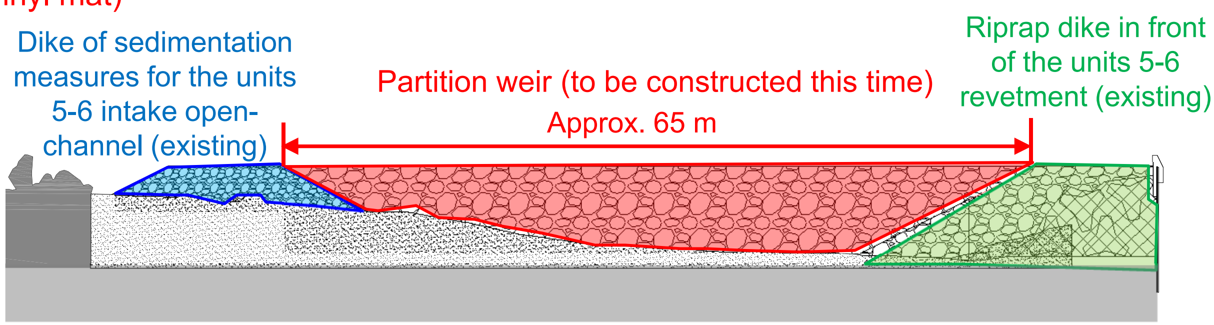
- The structural section of the partition weir is shown below:
- The height point of the top-end of the partition weir is the Tokyo Peil (T.P.) +2.2 m, which is higher than the condition of HHWL (the highest sea level in the past: T.P. + 1.15 m), and the inflow of seawater from the units 1-4 side can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



Plane view of partition weir



A-A cross-sectional view

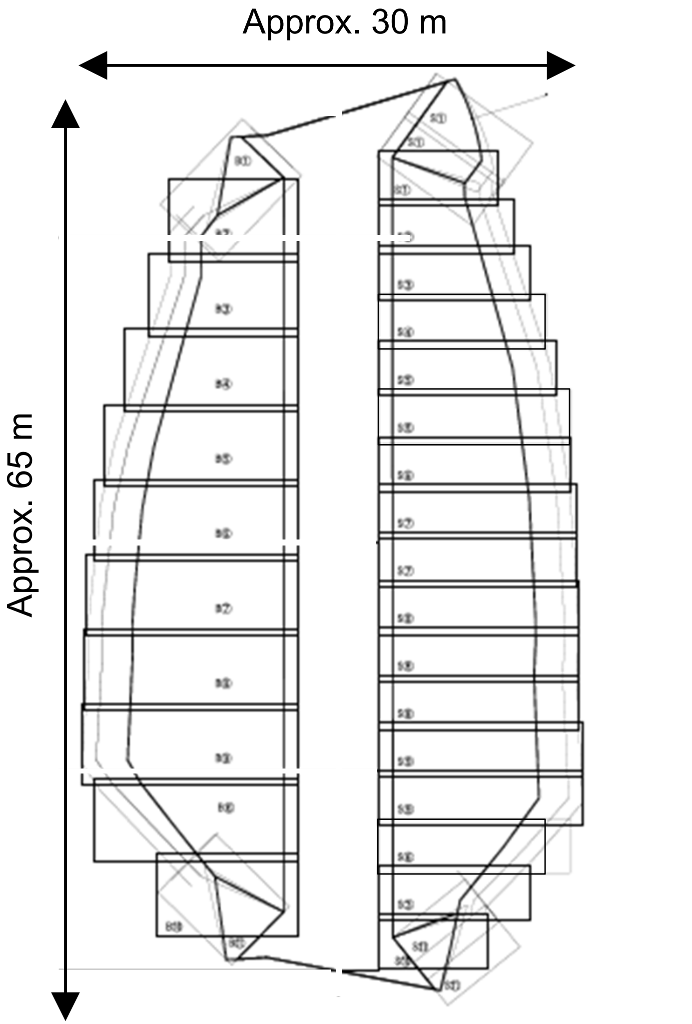


B-B cross-sectional view

The Japanese version shall prevail.

Partition weir (sheet)

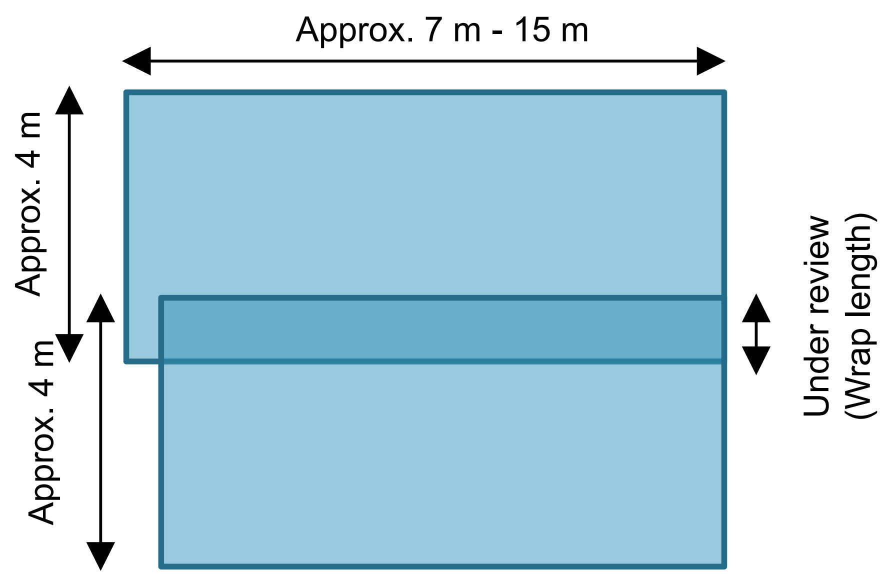
- Sheet specification: Soft vinyl chloride mat with the thickness of 5 mm
- Overlapping (wrapping) or deposition of the sheets are planned, and the details will be discussed in the future.



Sheet distribution drawing (current plan)

Sheet specifications

Item	Specifications
Material	Soft vinyl chloride
Dimensions	Width 4 m x Length 7 m - 15 m
Thickness	5mm
Wrap length	Under review

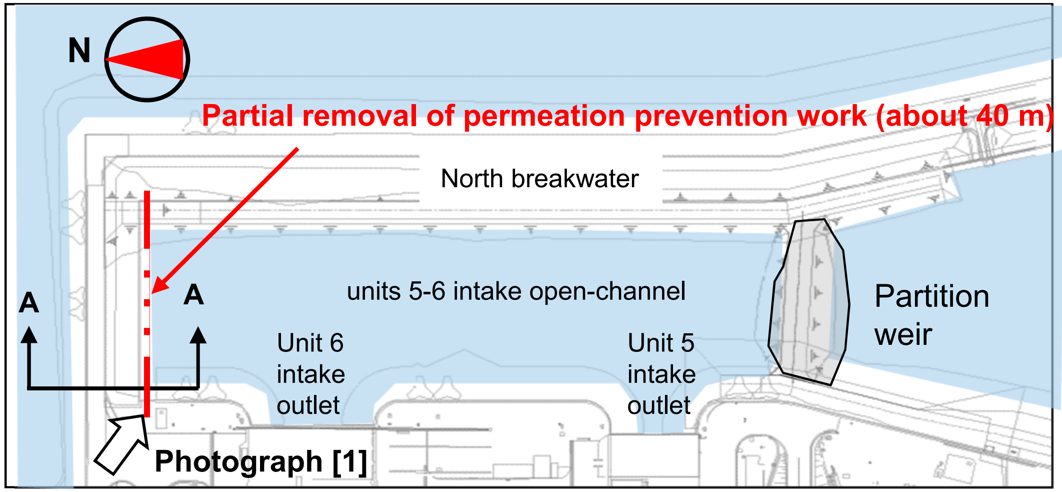


Sheet example

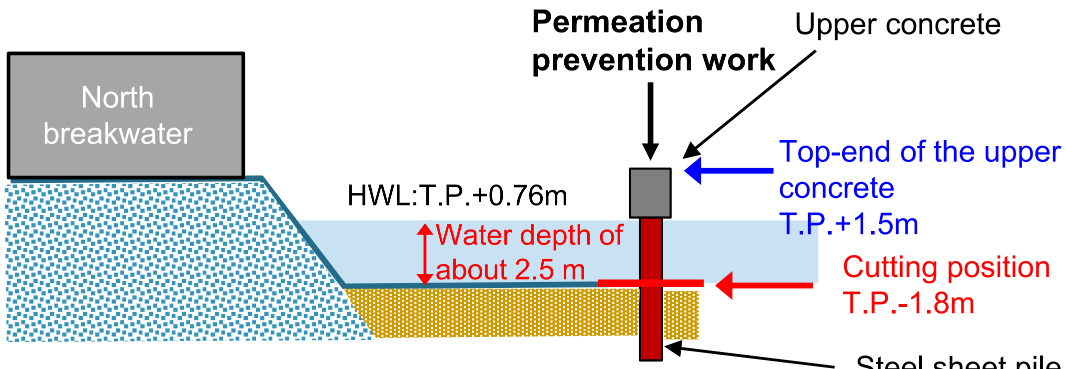
4.7 Water intake method: Removal of permeation prevention work

TEPCO

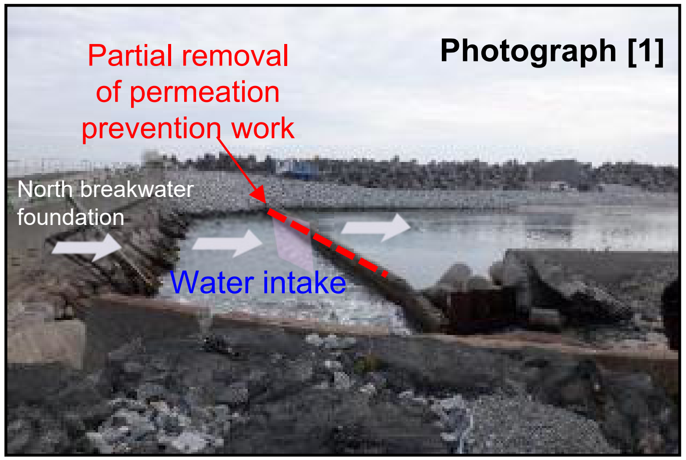
- A part of the permeation prevention work (partition wall) located inside the north breakwater (south side) is cut and removed, and seawater for dilution is taken in from outside the port.
- The removed permeation prevention work (concrete and steel sheet pile) is stored as solid waste within the plant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



Plane view of the partial removal of permeation prevention work



Permeation prevention work, A-A cross-sectional view



Outline of removal of permeation prevention work

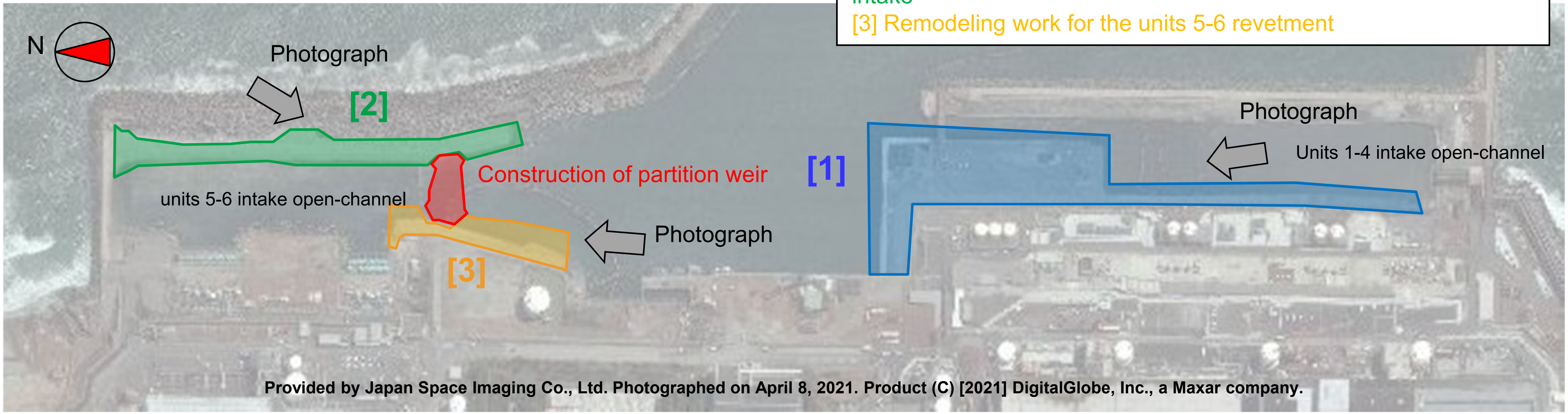
* In the period between after the construction of the partition weir and to the partial removal of the permeation prevention work, there will be almost no supply of seawater from the units 1-4 intake open-channel side. However, seawater will be supplied from the side of the north breakwater. Accordingly,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

The Japanese version shall prevail.

4.8 Water intake method: Radioactive material concentration in seawater during the construction of the partition weir (1/2)

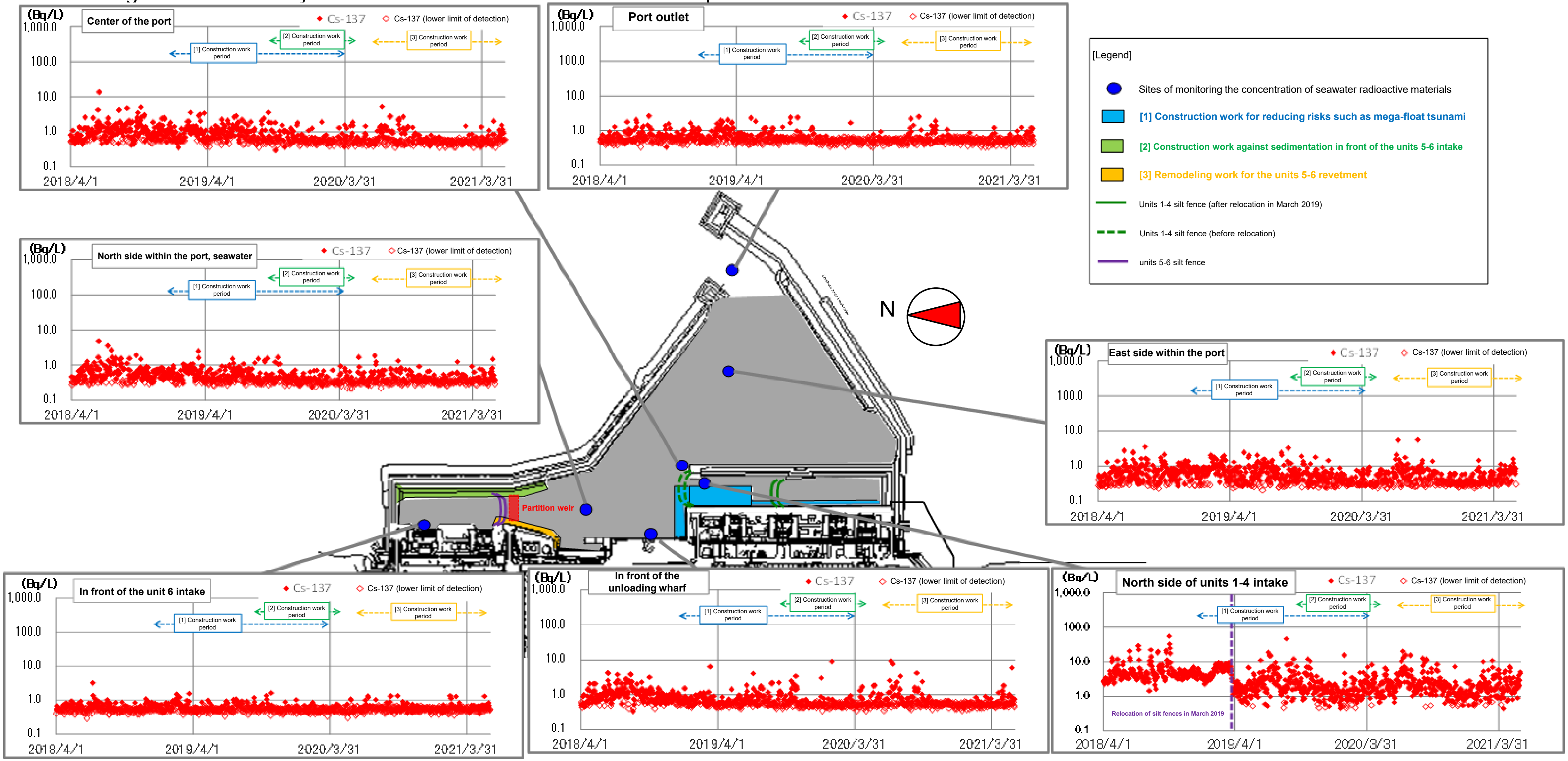
- In the last three years, we have experienced pouring materials such as riprap into the sea by using work ships and backhoes within the port.
- During the construction work, we installed the construction fence to prevent contamination, slowed down the work speed, and carefully carried out the work to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

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



4.8 Water intake method: Radioactive material concentration in seawater during the construction of partition weir (2/2)

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



Concentration of seawater radioactive materials during the construction within the port

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

4.9 Water intake method: Water for diluting ALPS Treated Water after the construction of partition weir

TEPCO

- The intake volume for diluting water will be greater than the water volume taken in for cooling units 5-6 auxiliary equipment in the past*. However, the construction of the partition weir enables suppression of the drawing of the seawater that contains relatively high concentration of radioactive materials from within the port on the units 1-4 side.

- Constructing the partition weir enables suppressing the earth and sand brought in from within the port on the units 1-4 side that have been prevented by the silt fence. With this, it is possible to suppress the risk of increasing the concentration of radioactive materials in seawater for dilution caused by the accumulation of earth and sand at the units 5-6 intake.

- In addition, as the seawater for dilution, it is possible to take in the seawater with a lower concentration of radioactive materials from outside the port.

Based on the above, the construction of a partition weir will be a measure to suppress the transition of the radioactive materials of the seawater within the port to the seawater for diluting ALPS treated water.

* Amount of seawater intake for dilution: Approx. 4.0 - 6.0 m^3/s
units 5-6 auxiliary cooling water after the Earthquake: Approx.1.3 m^3/s
units 5-6 fuel cooling water before the Earthquake: Approx. 112 m^3/s

Methods of seawater intake and discharging ALPS Treated Water after dilution

Effects on exposure to radioactive materials contained in seawater for dilution

Water intake method

Discharge method

Main findings at the review meeting (for each major issue)*1

- In relation to the overall layout and the elevation difference, we should demonstrate that discharge is possible from a discharge outlet 1 kilometer away, even if considering the possible backflow of the seawater inside the vertical shaft.

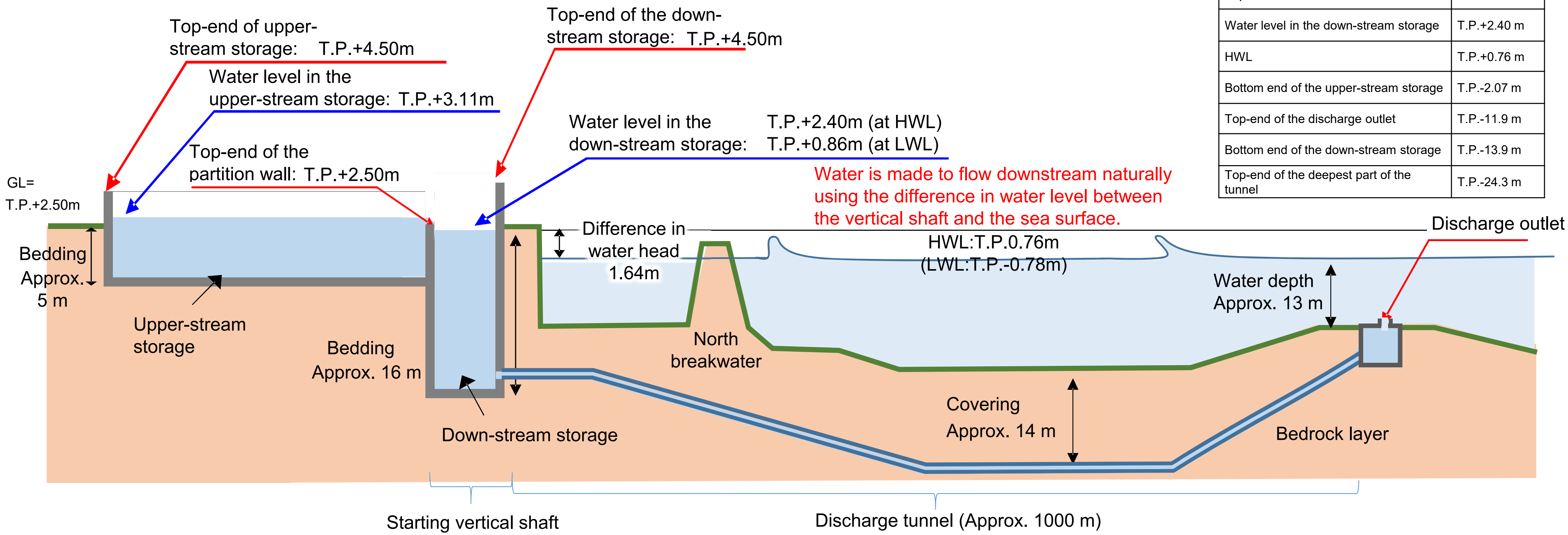
*1: (the 97th) Specified Nuclear Facilities Monitoring and Assessment Review Meeting, Documents 2-2, Attachment 2

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

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

List of water levels and elevations

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



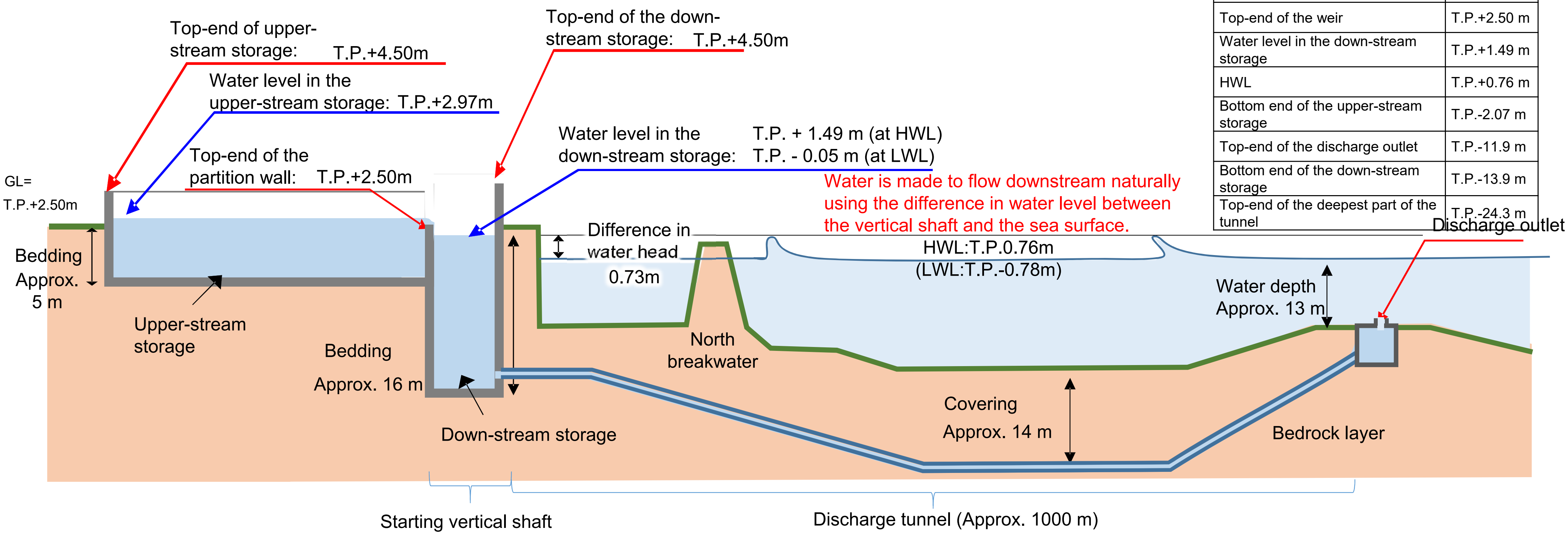
Conceptual diagram of Discharge facility

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

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

List of water levels and elevations

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



Conceptual diagram of Discharge facility

5.3 Hydraulic calculation results

- The hydraulic calculation was carried out under the two operating conditions of two pumps (flow rate: 4 m^3/s) or three pumps (flow rate: 6 m^3/s), considering the tide level and the thickness of the shellfish adhesion as fluctuation factors. Results are shown in the table below. (10 cm of shellfish adhesion inside the discharge tunnel is considered)
- Using 2 pumps, the water level of the discharge vertical shaft (down-stream storage) is about 1.5 m, and there is an allowance of about 3.0 m to the top-end of the vertical shaft.
- using 3 pumps, the water level of the discharge vertical shaft (down-stream storage) is about 2.4 m, and there is an allowance of about 2.1 m to the top-end of the vertical shaft.

Water level in the discharge vertical shaft (upper-stream storage and down-stream storage) (hydraulic calculation results)

Top-end of the discharge vertical shaft (upper-stream storage): T.P. + 4.50 m

Number of operating pumps (discharge flow rate)	Discharge vertical shaft (Upper-stream storage)	Discharge vertical shaft (Down-stream storage)		Velocity of flow in the tunnel
		HWL(T.P.+0.76m)	LWL (T.P.-0.78m)	
Two pumps are operated (4 m^3/s).	T.P.+2.97m	T.P.+1.49m	T.P.-0.05m	0.89m/s
Three pumps are operated (6 m^3/s).	T.P.+3.11m	T.P.+2.40m	T.P.+0.86m	1.34m/s

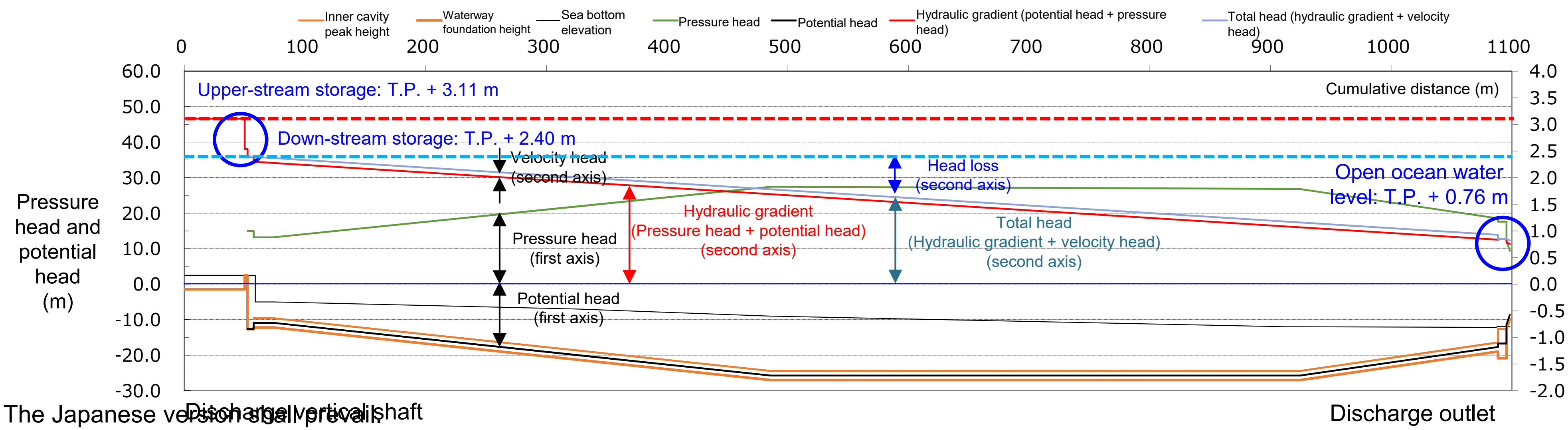
* The water level of the discharge vertical shaft (upper-stream storage) fluctuates with the discharge flow rate from the pump without being affected by tide level.
The water level of the discharge vertical shaft (down-stream storage) fluctuates with the tide level because of gravity flow through the discharge tunnel.
The conditions equivalent to the design wave height, such as typhoons (high waves of 7 m), were also incorporated into the calculation. It was confirmed that the effect of the fluctuation of open sea waves is negligible.

2-1(1) [3] Methods of seawater intake and discharging ALPS Treated Water after dilution
[Reference] Overview of hydraulic calculation of Discharge facility (detailed hydraulic calculation results)

TEPCO

[Calculation conditions] Tide level: T.P. 0.76 m (HWL), flow rate: 6.0 m^3/s, the thickness of shellfish adhesion: 0.10 m

Interval	Distance	Cumulative distance	Above ground Seabed Elevation	Inner cavity foundation height	Inner cavity peak height	Shape of waterway	Waterway Inner diameter	Vertical shaft Inner width	Thickness of shellfish adhesion	Foundation height - Thickness of shellfish adhesion	Top height - Thickness of shellfish adhesion	Waterway Inner diameter - Thickness of shellfish adhesion	Vertical shaft Inner width - Thickness of shellfish adhesion	Hydraulic gradient	Flow condition Pressure: 1 Open: 0	Area	Diameter depth	Flow velocity	Refractive bending rapid expansion/ contraction loss Coefficient	Friction loss coefficient	Outlet/inlet loss coefficient	Refractive bending rapid expansion/ contraction loss	Friction loss	Outlet/inlet loss	Total loss	Energy	Velocity head	Hydraulic gradient	Water surface height	Pressure head
	m	m	T.P. m	T.P. m	T.P. m		m	m	m	T.P. m	T.P. m	m	m	T.P. m		m2	m	m/s				m	m	m	m	T.P. m	m	T.P. m	T.P. m	m
Upper-stream storage	50.00	0.00	2.50	-1.50	5.00	Rectangle	-	4.00	0.10	-1.40	5.00		3.80	3.11	0	17.13	1.34	0.18		0.01			0.00		0.00	3.11	0.00	3.11	3.11	4.51
		50.00	2.50	-1.50	5.00	:	-	4.00	0.10	-1.40	5.00		3.80	3.11	0	17.14	1.34	0.17							0.00	3.11	0.00	3.11	3.11	4.51
Weir part	2.30	50.00	2.50	2.50	5.00	:	-	4.00	0.00	2.50	5.00		4.00	-	-	-	-	-							0.00	3.11	0.00	3.11	3.11	-
		52.30	2.50	2.50	5.00	:	-	4.00	0.00	2.50	5.00		4.00	-	-	-	-	-							0.61	3.11	-	-	3.11	-
Down-stream storage	5.00	52.30	2.50	-12.70	5.00	:	-	4.60	0.10	-12.60	4.90		4.40	2.40	0	65.98	1.92	0.09		0.01			0.00		0.00	2.40	0.00	2.40	2.40	15.00
		57.30	2.50	-12.70	5.00	:	-	4.60	0.10	-12.60	4.90		4.40	2.30	0	65.58	1.92	0.09							0.00	2.40	0.00	2.40	2.40	15.00
Storage wall	1.50	57.30	2.50	-12.21	-9.62	Circular	2.59		0.10	-12.11	-9.72	2.39		2.30	1	4.49	0.60	1.34		0.04			0.00		0.00	2.40	0.09	2.30	-9.72	13.22
		58.80	2.50	-12.21	-9.62	:	2.59		0.10	-12.11	-9.72	2.39		2.30	1	4.49	0.60	1.34							0.00	2.39	0.09	2.30	-9.72	13.21
Tunnel mounting horizontal part	15.00	58.80	-5.00	-12.21	-9.62	:	2.59		0.10	-12.11	-9.72	2.39		2.28	1	4.49	0.60	1.34		0.04			0.02		0.02	2.39	0.09	2.30	-9.72	13.21
		73.80	-5.00	-12.21	-9.62	:	2.59		0.10	-12.11	-9.72	2.39		2.28	1	4.49	0.60	1.34							0.00	2.37	0.09	2.28	-9.72	13.19
Ramp 1	250.02	73.80	-5.00	-12.21	-9.62	:	2.59		0.10	-12.11	-9.72	2.39		1.93	1	4.49	0.60	1.34	0.00	0.04		0.00	0.36		0.36	2.37	0.09	2.28	-9.72	13.19
		323.82	-7.00	-21.21	-18.62	:	2.59		0.10	-21.11	-18.72	2.39		1.93	1	4.49	0.60	1.34							0.00	2.02	0.09	1.93	-18.72	21.84
Ramp 2	162.03	323.82	-7.00	-21.21	-18.62	:	2.59		0.10	-21.11	-18.72	2.39		1.69	1	4.49	0.60	1.34		0.04			0.23		0.23	2.02	0.09	1.93	-18.72	21.84
		485.85	-9.00	-27.04	-24.45	:	2.59		0.10	-26.94	-24.55	2.39		1.69	1	4.49	0.60	1.34							0.00	1.79	0.09	1.69	-24.55	27.44
Horizontal portion 1	426.80	485.85	-9.00	-27.04	-24.45	:	2.59		0.10	-26.94	-24.55	2.39		1.09	1	4.49	0.60	1.34	0.00	0.04		0.00	0.61		0.61	1.79	0.09	1.69	-24.55	27.44
		912.65	-12.00	-27.04	-24.45	:	2.59		0.10	-26.94	-24.55	2.39		1.09	1	4.49	0.60	1.34							0.00	1.18	0.09	1.09	-24.55	26.83
Horizontal portion 2	11.99	912.65	-12.00	-27.04	-24.45	:	2.59		0.10	-26.94	-24.55	2.39		1.07	1	4.49	0.60	1.34		0.04			0.02		0.02	1.18	0.09	1.09	-24.55	26.83
		924.64	-12.00	-27.04	-24.45	:	2.59		0.10	-26.94	-24.55	2.39		1.07	1	4.49	0.60	1.34							0.00	1.16	0.09	1.07	-24.55	26.82
Ramp 3	162.32	924.64	-12.00	-27.04	-24.45	:	2.59		0.10	-26.94	-24.55	2.39		0.84	1	4.49	0.60	1.34	0.00	0.04		0.00	0.23		0.23	1.16	0.09	1.07	-24.55	26.82
		1087.0	-12.20	-19.09	-16.50	:	2.59		0.10	-18.99	-16.60	2.39		0.84	1	4.49	0.60	1.34							0.00	0.93	0.09	0.84	-16.60	18.63
Discharge outlet mounting part	1.72	1087.0	-12.20	-19.09	-16.50	:	2.59		0.10	-18.99	-16.60	2.39		0.84	1	4.49	0.60	1.34		0.04			0.00		0.00	0.93	0.09	0.84	-16.60	18.63
		1088.7	-11.89	-19.00	-16.41	:	2.59		0.10	-18.90	-16.51	2.39		0.85	1	4.49	0.60	1.34	0.86			0.08			0.08	0.93	0.09	0.84	-16.51	18.54
Discharge outlet caisson	7.03	1088.7	-11.89	-20.89	-12.59	Rectangle	8.30	8.00	0.10	-20.79	-12.69	8.10	7.80	0.85	1	63.18	1.99	0.09	0.18	0.01		0.00	0.00		0.00	0.85	0.00	0.85	-12.69	17.59
		1095.7	-11.89	-20.89	-12.59	:	8.30	8.00	0.10	-20.79	-12.69	8.10	7.80	0.78	1	63.18	1.99	0.09							0.00	0.85	0.00	0.85	-12.69	17.59
Discharge outlet	2.70	1095.7	-11.89	-12.59	-	:	-	2.50	0.10	-12.49	-	2.30	2.30	0.76	1	5.29	0.58	1.13	0.41	0.01		0.03	0.00		0.03	0.85	0.07	0.78	0.76	12.13
		1098.4	-11.89	-9.89	-	:	-	2.50	0.10	-9.79	-	2.30	2.30	0.76	1	5.29	0.58	1.13			1.00			0.07	0.07	0.82	0.07	0.76	0.76	9.40
Outlet		1098.4																								0.76	0.00	0.76	0.76	



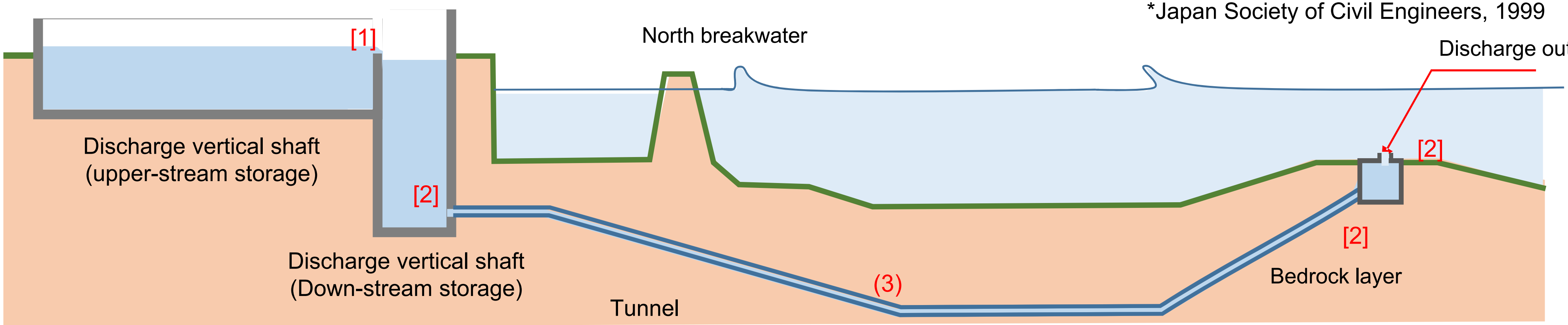
Summary of loss

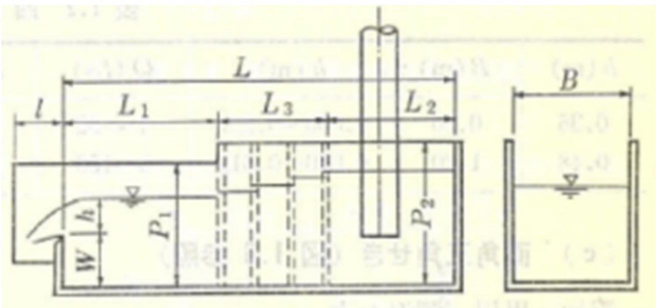
	Loss (m)
Rapid expansion and contraction	0.14
Friction	1.44
Outlet	0.06
Total	1.64

2-1(1) [3] Methods of seawater intake and discharging ALPS Treated Water after dilution
[Reference] Overview of hydraulic calculation of Discharge facility (hydraulic calculation methods)

- The hydraulic calculation was set up using Bernoulli's equation and the continuity equation, and the loss coefficient was set based on The Collection of Hydraulic Formulae*.

*Japan Society of Civil Engineers, 1999





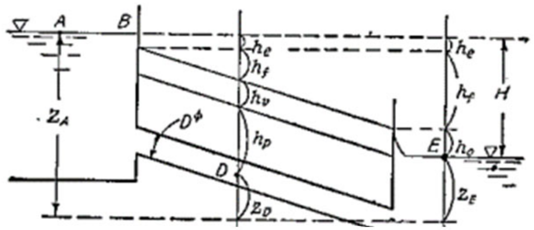
[1] Evaluation of weir (vertical shaft partition wall)

Ishihara and Ishida's formula

$Q=CBh^{3/2}$

$C = 1.785 + (0.00295/h + 0.237\ h/W)(1+\varepsilon)$

Where Q: overflow amount (m^3/s), B: weir width (m), h: overflow depth (m), C: overflow coefficient ($m^{1/2}/s$, W: height from the bottom face of the waterway to the weir edge (m), ε= 0 when the correction factor W ≤ 1 m and ε = 0.55 when W > 1 m (W -1).



Point A: $E=z_A$

Point D: $E=z_D+\frac{p_D}{w}+\frac{v_D^2}{2g}+$ (head loss between A through D)

$$=z_D+\frac{p_D}{w}+\left(1+f_e+f\frac{l}{D}\right)\frac{v^2}{2g}$$

However,

Head of inflow loss $h_e=f_e\frac{v^2}{2g}$ (v: pipe flow rate)

Head of friction loss $h_f=f\frac{l_D}{D}\frac{v^2}{2g}$ (l_D: pipe length up to D)

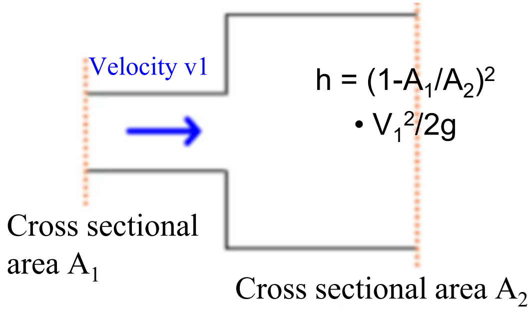
Velocity head $h_v=\frac{v_D^2}{2g}=\frac{v^2}{2g}$

Pressure head $h_p=\frac{p_D}{w}$

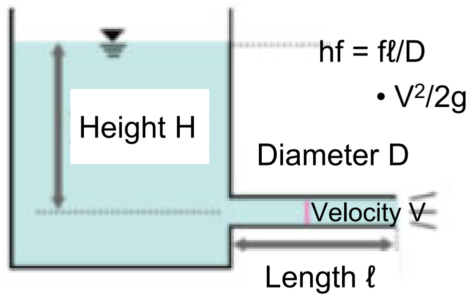
Point E: $E=z_E+$(head loss between A through E)

$$=z_E+h_e+h_f+h_o$$

Hydraulic calculation formula for the fixed section conduit (The Collection of Hydraulic Formulae)



[2] Head loss due to shape change (rapid expansion/contraction) (at tunnel and discharge outlet)



[3] Friction head loss (tunnel section) in a circular pipe

The Japanese version shall prevail.

2-1(1) [3] Methods of seawater intake and discharging ALPS Treated Water after dilution
[Reference] Overview of hydraulic calculation of Discharge facility (surging analysis)

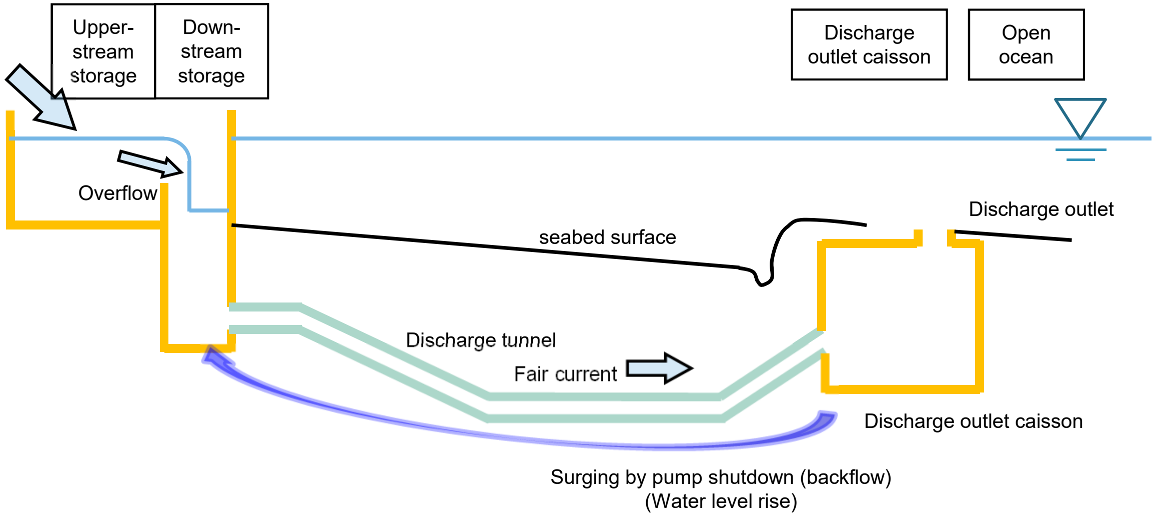
- Out of concern that an abnormal shutdown of a pump, when occurring such as earthquake or tsunami, may cause surging (back-flow) in the water storage and tunnel; therefore, the water level fluctuations in the event of an abnormality were calculated.
- In the surging analysis, the unsteady one-dimensional conduit flow model calculates the water level and flow velocity.

The thickness of shellfish adhesion is not considered, which causes decreasing an energy loss (rising water level in the down-stream storage).

- The calculation was carried out by incorporating the conditions of the wave and storm surge (highest sea level in the past (HHWL)): T.P + 1.15 m) equivalent to the design wave height (50-year-probability significant wave height: 7.0 m) in the analysis. As a result, the maximum water level in the upper-stream storage was T.P. + 2.50 m and T.P. 2.40 m the in the down-stream storage.
- Since the top-end of the upper-stream storage and down-stream storage was T.P + 4.50 m, it was confirmed that there would be no flooding.

Analysis conditions and results

Item	Value
Tidal level	T.P.+0.76m(HWL)
Flow rate	6 m^3/s (3 pumps operated)
Pump down time	30 seconds



Schematic diagram of the Discharge facility

The Japanese version shall prevail.

5.4 Effect of water level fluctuation in a discharge vertical shaft (upper-stream storage)

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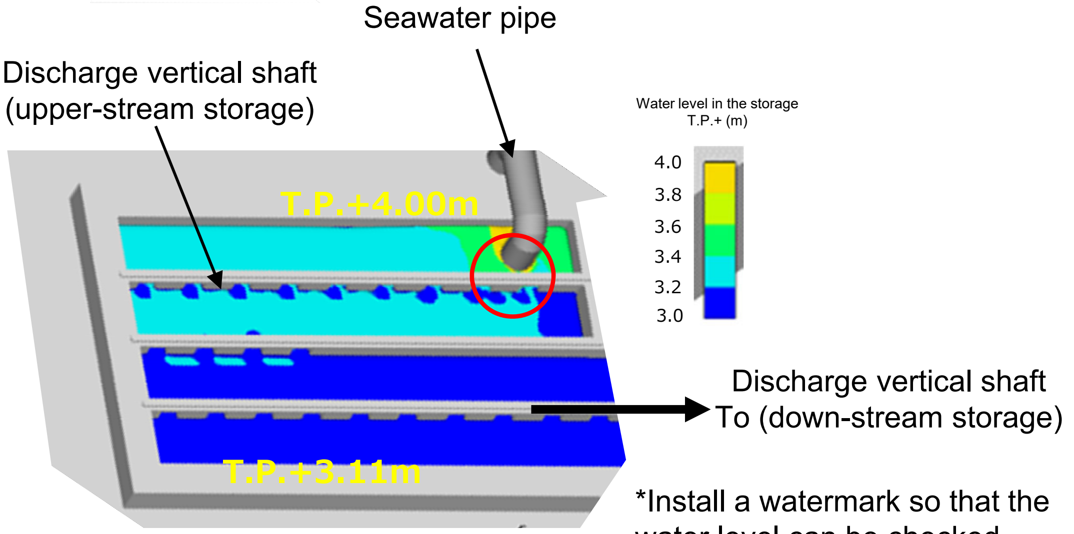
Hydraulic calculation and stream regime analysis

- The water level of the discharge vertical shaft (upper-stream storage) is T.P. + 3.11 m (3 pumps operated = 6 m^3/s).
- The water level locally rises to T.P. + 4.00 m at the inflow point of the seawater pipe.
- The discharge edge of the seawater pipe is open to the atmosphere. Thus, it will not be submerged in the discharge vertical shaft (upper-stream storage). Based on this, back-flow during the pump trip does not occur.

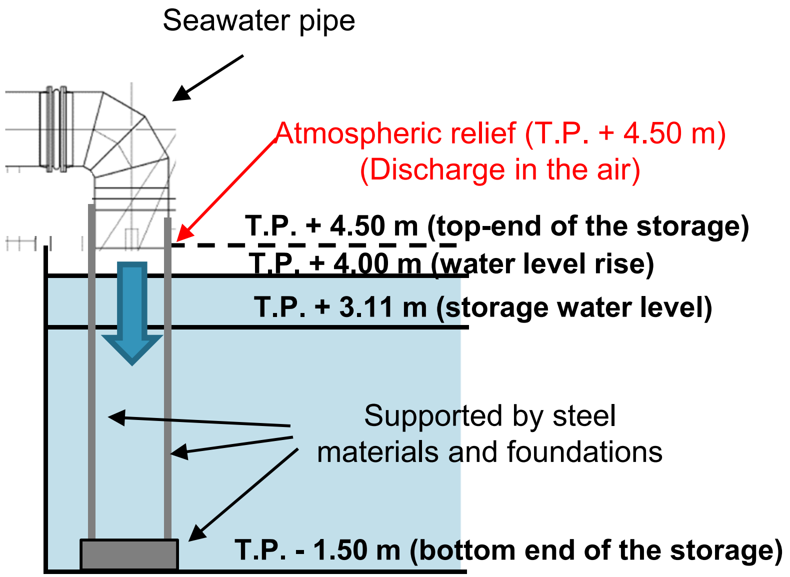
Structural study

- Internal water pressure rises by water level fluctuations. However, regarding the discharge vertical shaft (upper-stream storage), when there is no water inside the tank, the condition will be more severe (taking into account the groundwater outside the storage). The examination results were explained at the 8th review meeting.
- A lid (top plate) is provided to avoid water level fluctuations inside the storage during typhoons and the impact of sloshing during earthquakes. The top plate is bonded to the sidewall and the partition wall, making it advantageous to the structure.
- Seawater pipe is supported by steel materials and foundation.



Water level in the discharge vertical shaft (upper-stream storage)

*Install a watermark so that the water level can be checked.



Inflow to the discharge vertical shaft (upper-stream storage)

Responses to major issues* concerning the content of the application for the facilities for discharge of ALPS Treated Water into the sea

*Document 1-2 for (The 3rd) Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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

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

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

Design of Discharge facility*

Discharge tunnel: Facility overview/design
Discharge outlet caisson: Facility overview/design
Responses to the findings in the 8th Review Meeting

*This report describes the examination results that the design complies with the standards and criteria for general civil engineering structures and has sufficient safety, durability, earthquake resistance, etc.

Discharge tunnel: Facility overview/design

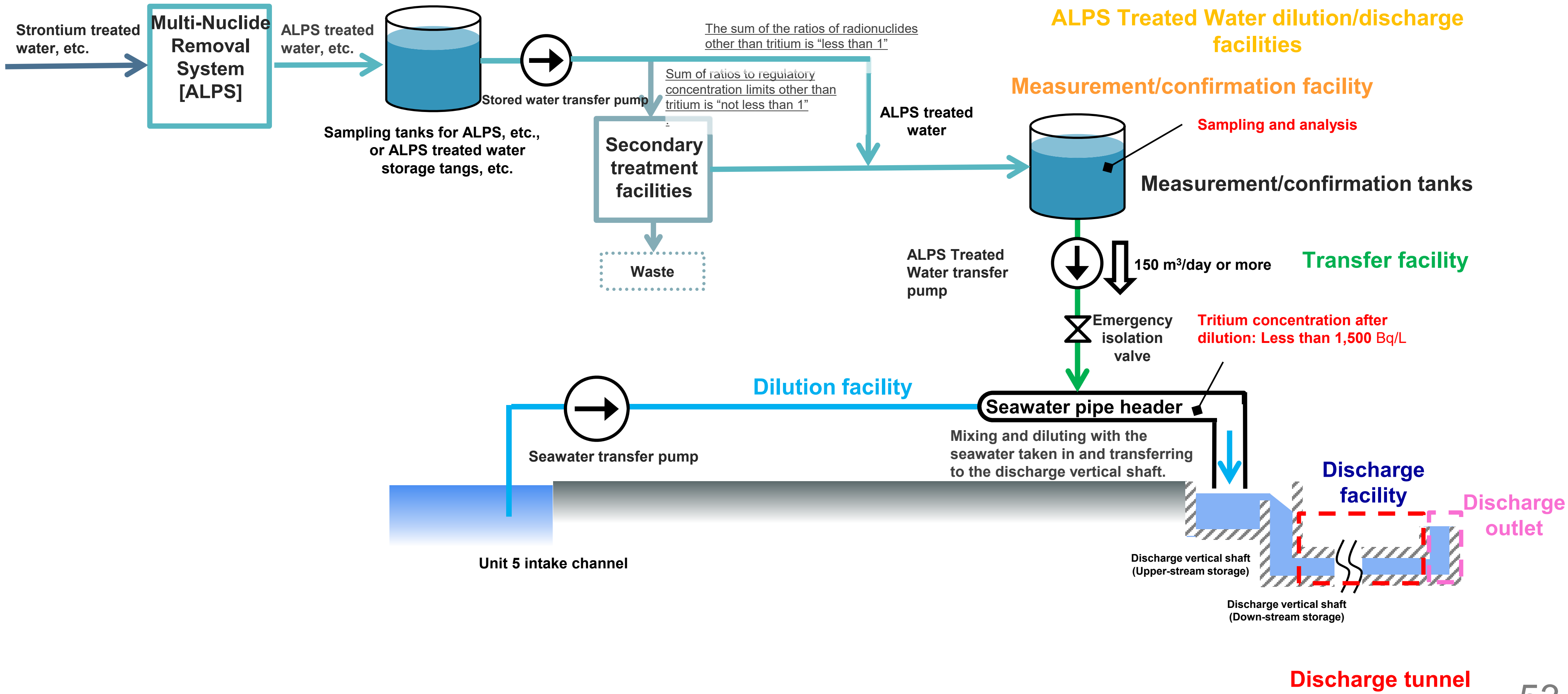
Facility overview

Selection of the alignment of the discharge tunnel

Selection of the construction method of the discharge tunnel

Discharge tunnel design (structure)

- The followings sumerizes the structure and strength, protection against natural phenomena, and reliability of the discharge tunnel.

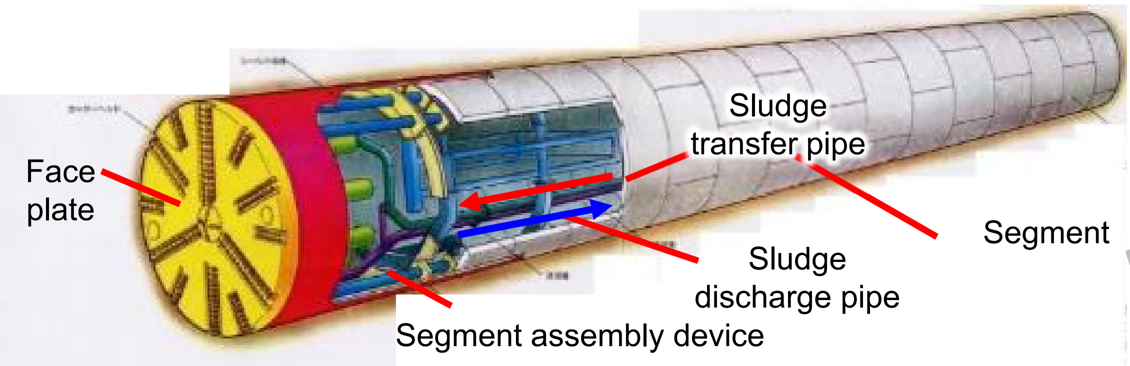


Overview of the structural design

- Water flows through the bedrock layer to minimize the leakage risk and to ensure a highly earthquake-resistant structure.
- A shield method is adopted and double-layer seals are installed in the reinforced concrete segment to ensure water cut-off performance.
- The tunnel body (segment) is designed considering the impacts of typhoons (high waves) and storm surges (sea level rise).

Construction of tunnel (shield method)

- As there are many discharge tunnels constructed by the shield method, this secure construction will minimize the possibility of trouble.
- The slurry shield method* is adopted this time



Schematic diagram of a shield machine

Segment

* Shield method is a hydraulic transport mechanism, applying a predetermined pressure to the mud water stabilized the face (excavation face at the top-end of the tunnel) against the soil water pressure of the natural ground, and through circulating the mud water with the excavated soil the excavated soil is transported in the form of hydraulic transportation.

1.1.3 Overview of the discharge tunnel structure

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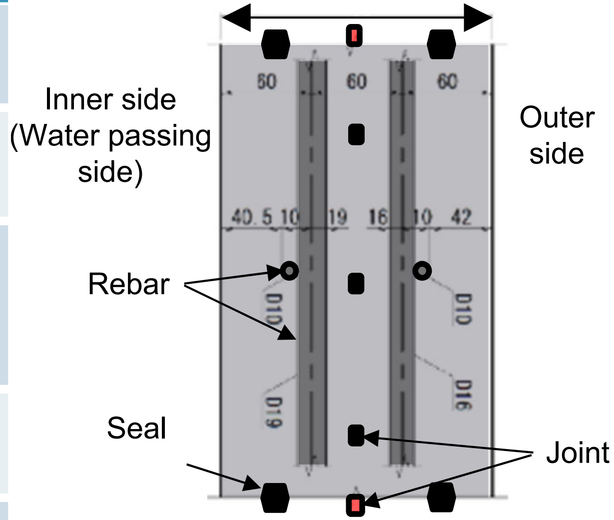
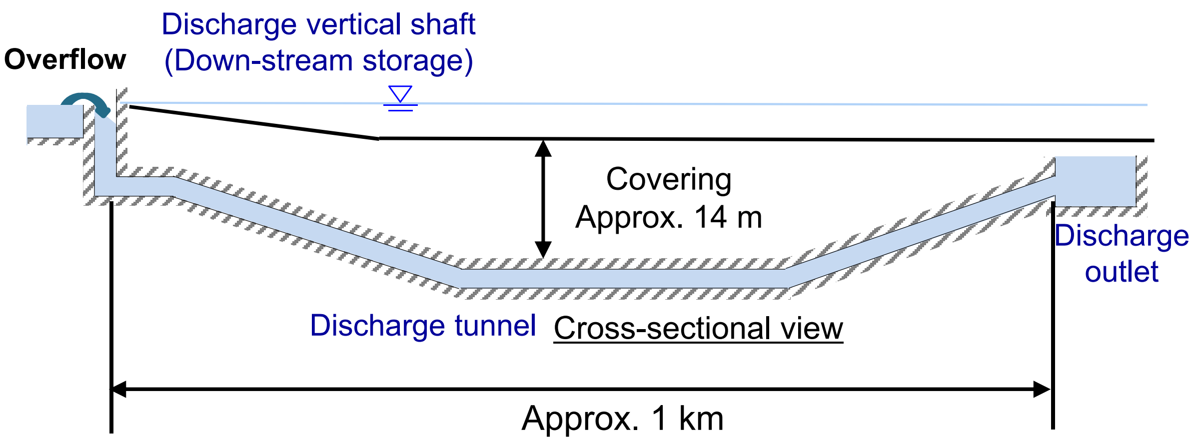
Dimensions of the discharge tunnel (made of reinforced concrete)

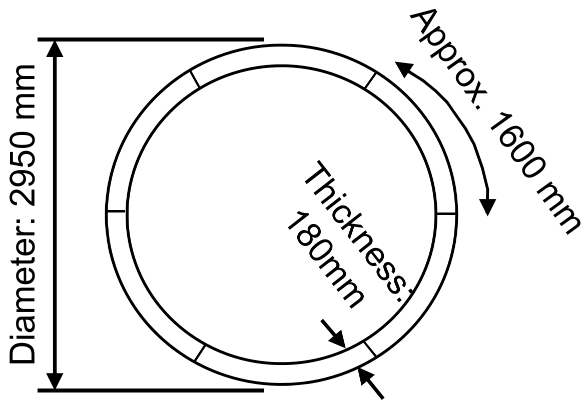
Specifications	Dimensions
Discharge tunnel	Diameter 2,950 mm (inner diameter 2,590 mm) x Length about 1 km
Segment (1 ring)	Diameter 2,950 mm x Thickness 180 mm x Width 1,000 mm
Segment (1 piece)	Length (outer arc length) approx. 1,600 mm x Thickness 180 mm x Width 1,000 mm
Material	Made of reinforced concrete
Maximum covering	Approx. 14 m



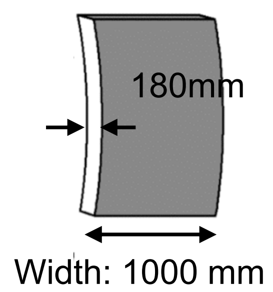
Detailed view of segments



General drawing of discharge tunnel



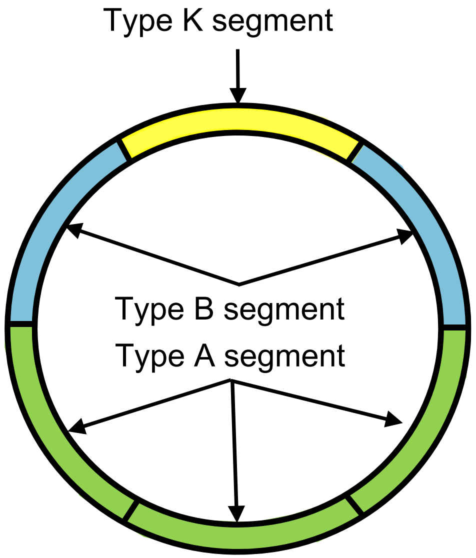
Segments (1 ring) diagram



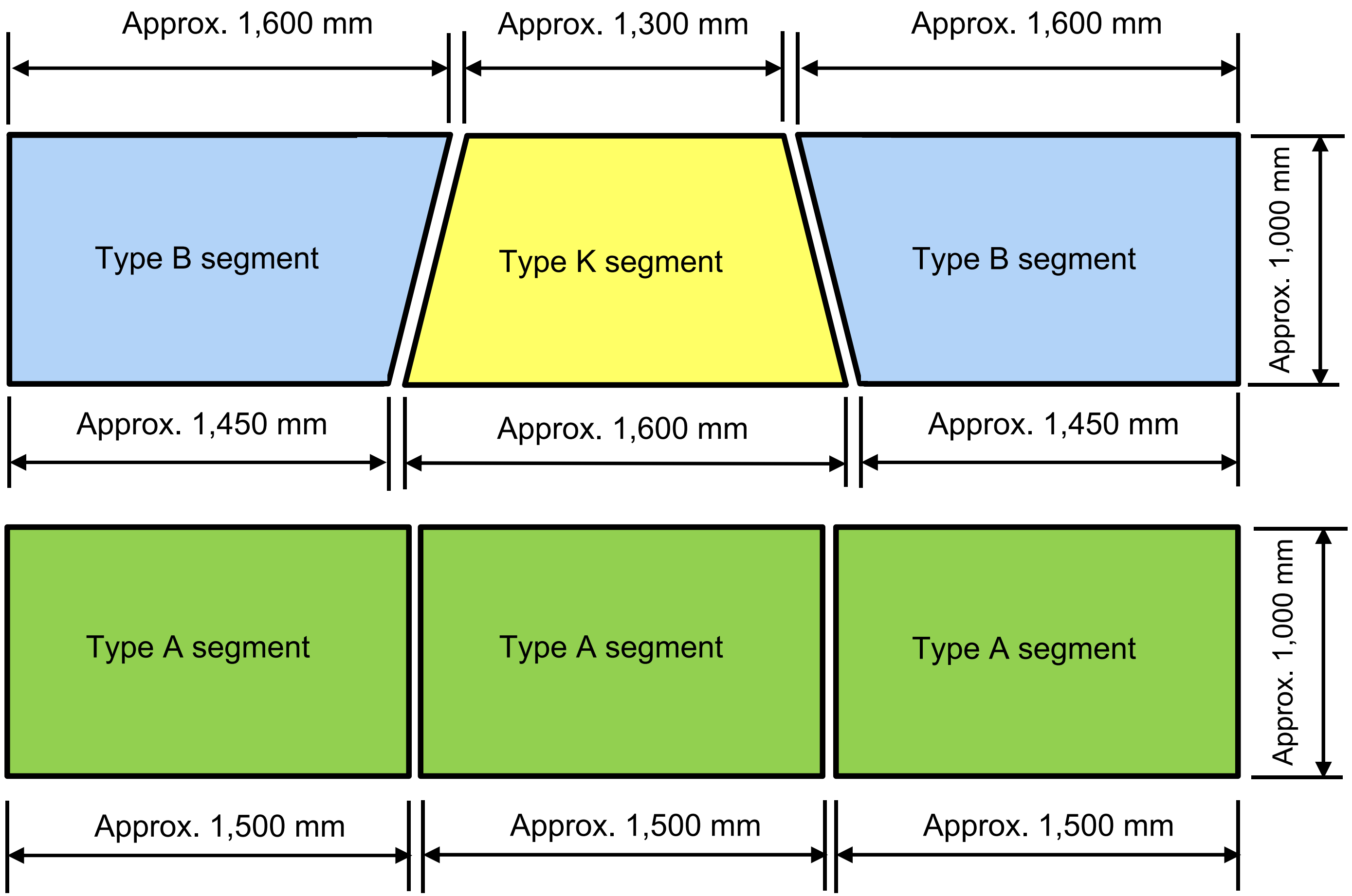
Segments (1 piece) diagram

Segment pieces and dimensions

- The segment pieces have three kinds of pieces, type A, type B, and type K.
- The diagram below shows a development view of segments; the dimension shows images of projection length of each segment viewed from above.



Configuration of segment pieces



Segment development view

Discharge method: Facility overview/design

Facility overview

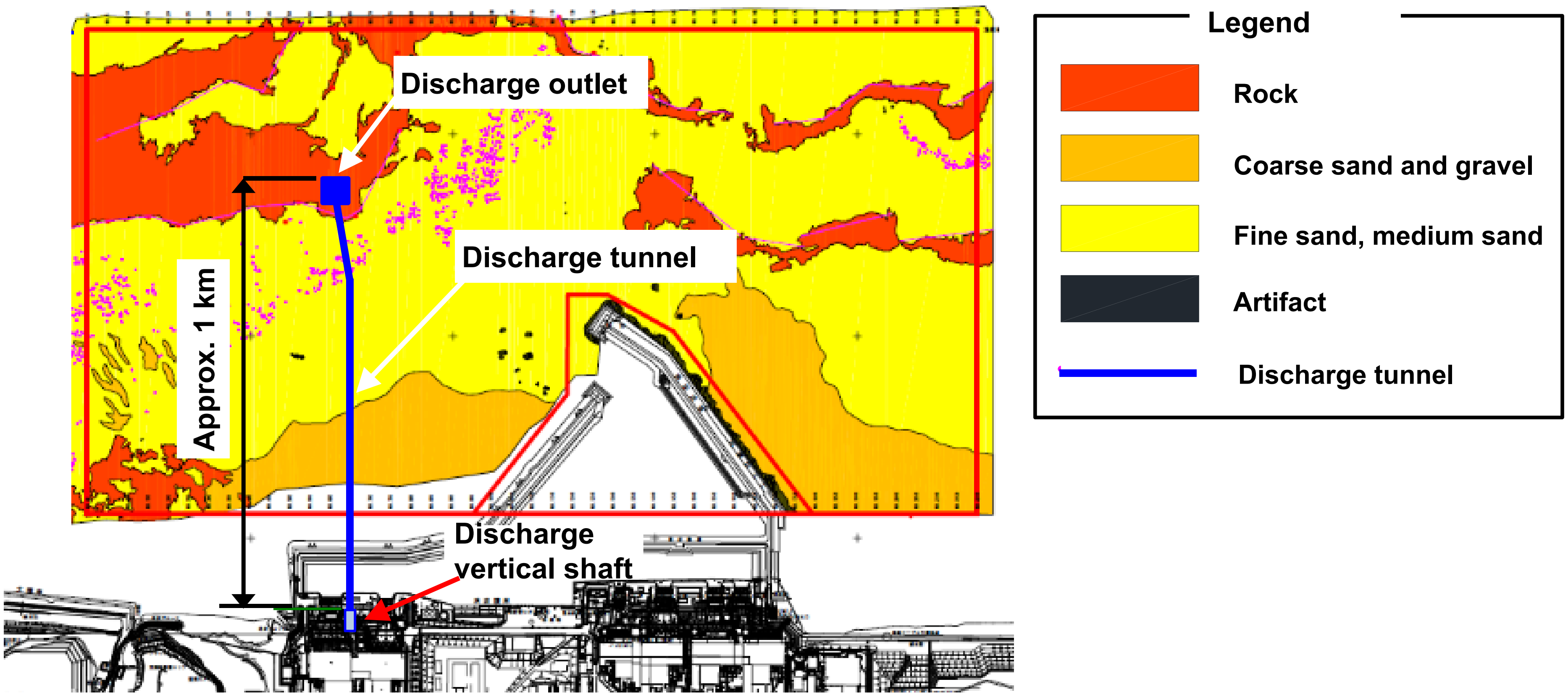
Selection of the alignment of the discharge tunnel

Selection of the construction method of the discharge tunnel

Discharge tunnel design (structure)

Grounds for the selection of the horizontal alignment of the discharge tunnel

- Based on the geological and sea area survey data, we evaluate a horizontal alignment on the precondition that a discharge outlet is installed at a stable bedrock outcrop.
- The horizontal alignment of the discharge tunnel was examined so that the discharge vertical shaft and the discharge outlet will be in a straight line as much as possible. The discharge tunnel alignment is provided with a curved section (R = 500 m).
(The discharge outlet was located about 20 m north of the discharge vertical shaft.)



Estimated geological plane view

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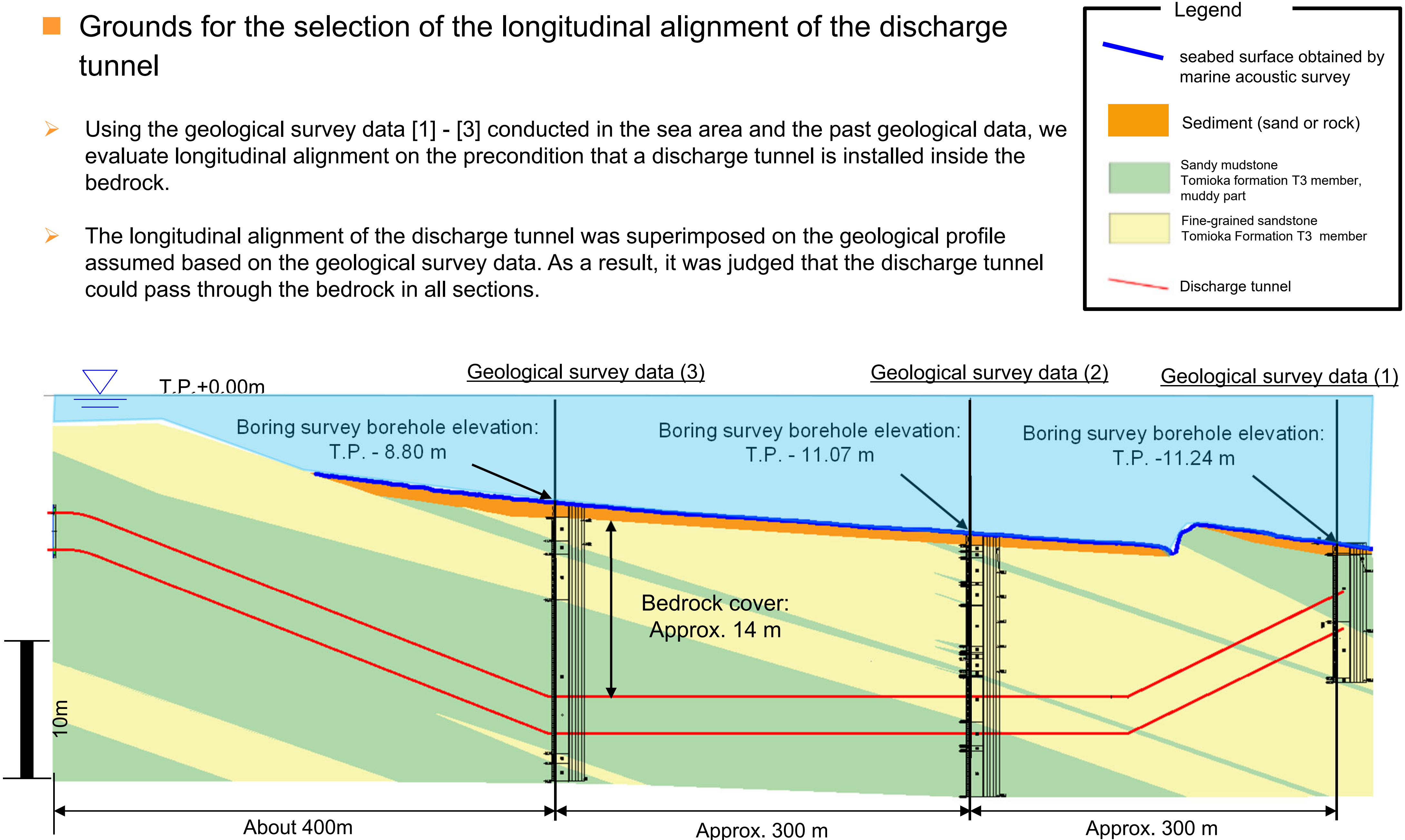
Grounds for the selection of the longitudinal alignment of the discharge tunnel

- Using the geological survey data [1] - [3] conducted in the sea area and the past geological data, we evaluate longitudinal alignment on the precondition that a discharge tunnel is installed inside the bedrock.
- The longitudinal alignment of the discharge tunnel was superimposed on the geological profile assumed based on the geological survey data. As a result, it was judged that the discharge tunnel could pass through the bedrock in all sections.



Assumed geological profile

[Supplement] Purpose and details of boring survey

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Purpose of the boring survey

- A survey is conducted for the safe discharge tunnel work.
- Based on the draft guideline* for the safe and secure construction of shield tunnel work by the Ministry of Land, Infrastructure, Transport and Tourism, the survey was conducted as below:

  Survey points: Three points according to Tunnel Standard Specifications [Common Edition], Explanation/[Shield Method Edition], Explanation

  Survey depth: The depth is set at 1D as a standard from the bottom end level of the tunnel in design (it is sufficient to secure a certain level of cover for the design).

Main survey items and results

Main survey items	Survey results
Geology	Tomioka Formation T_3 member
Standard penetration test (N-value)*	The tunnel construction site has an N-value of 50 or above.
Status of flammable gas	No gas detection
Intensity of ground (uniaxial compressive strength)	3,000 kN/m^2 or more (equal to or higher than the physical properties for analysis in the application for reactor installation permit)
Grain size analysis	Mainly sandy fine-grained soil (reflected in the design of sludge production during sludge discharge)

*Standard penetration test
The purpose is to check that the bedrock is homogeneous, and after we confirmed that N-value was 50 or above, we measured N-value at the bottom end of the survey point.

(*) (Reference) Description related to the geological survey in the draft guidelines for the safe and secure construction of shield tunnel work.

In a geological survey for shield tunneling work, the boring survey should be carried out under an appropriate plan to grasp the geological conditions and changes in the ground to be drilled, taking into consideration topography and geography and history, etc. In addition, necessary investigations should be conducted on the situation of groundwater and its changes, the situation of combustible gas, etc. Regarding geology that we should pay attention to, information on the geological risks due to uncertainties in the distribution range and properties should be incorporated into the design and the execution of the construction without fail.

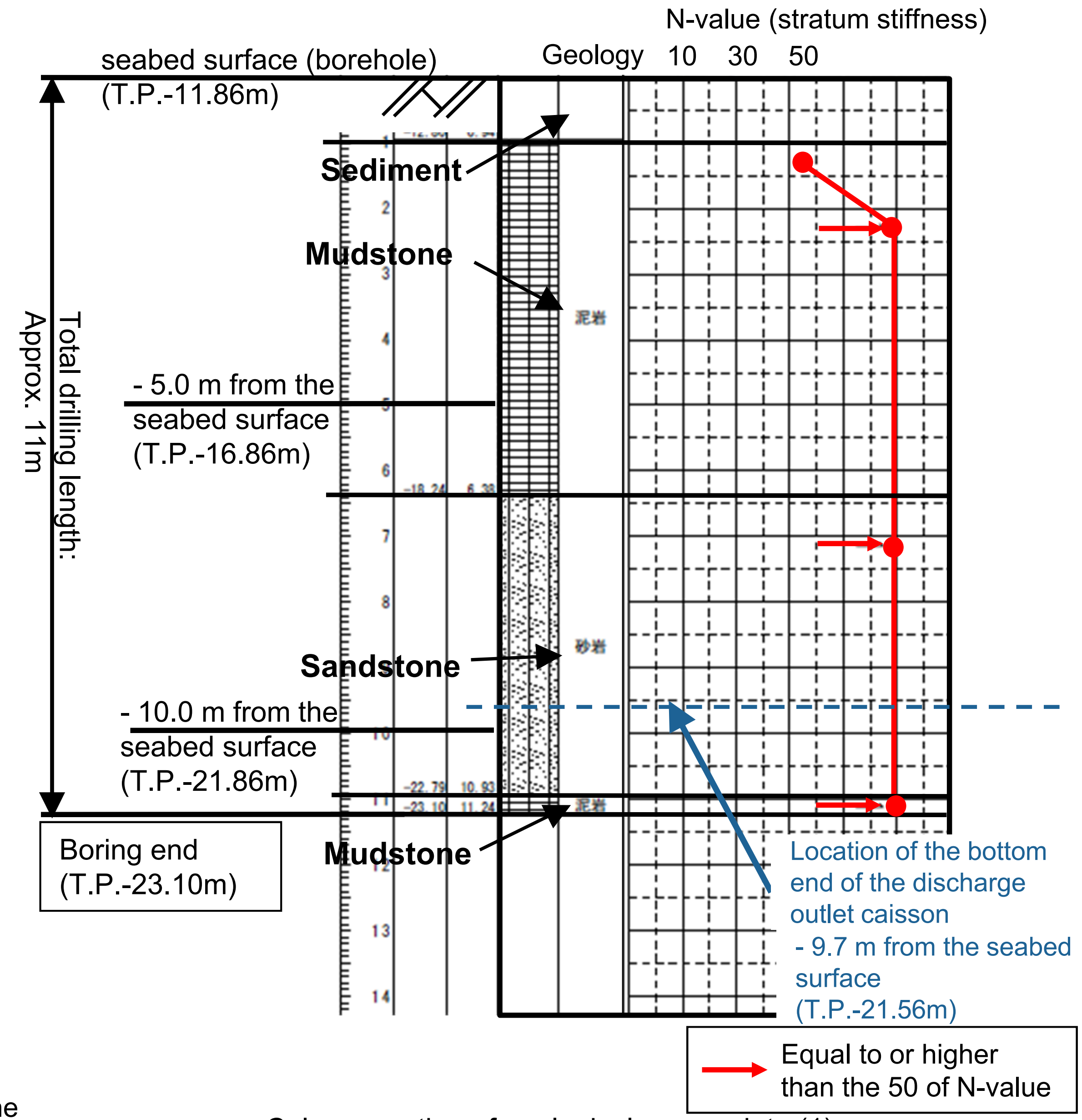
(*) (Reference) Description of geological survey in the report of the Subcommittee on Safety Measures concerning the Construction of Shield Tunnel (June 2016, the Ministry of Health, Labour and Welfare Labour Standards Bureau).

Given a submergence accident in the subsea shield tunnel (Mizushima Accident), when the topography, strata, and geology of the natural ground to be drilled are not sufficiently clear, examine the implementation of boring surveys, and try to grasp the factors leading to the disaster.

[Reference] Geological survey data [1]

- The figure right shows the geological survey data (1)
  - The total drilling length of about 11 m from the borehole mouth (T.P. - 11.86 m) to the boring end (T.P -23.10 m) was investigated.
  - The point (1) of the geological survey data indicates the location of installing the discharge outlet and the discharge tunnel reaching point. We confirmed that installation inside the bedrock (sandstone and mudstone in Tomioka) is possible.

[Location of the bottom end of the discharge outlet: Approx. -10 m from the seabed surface]



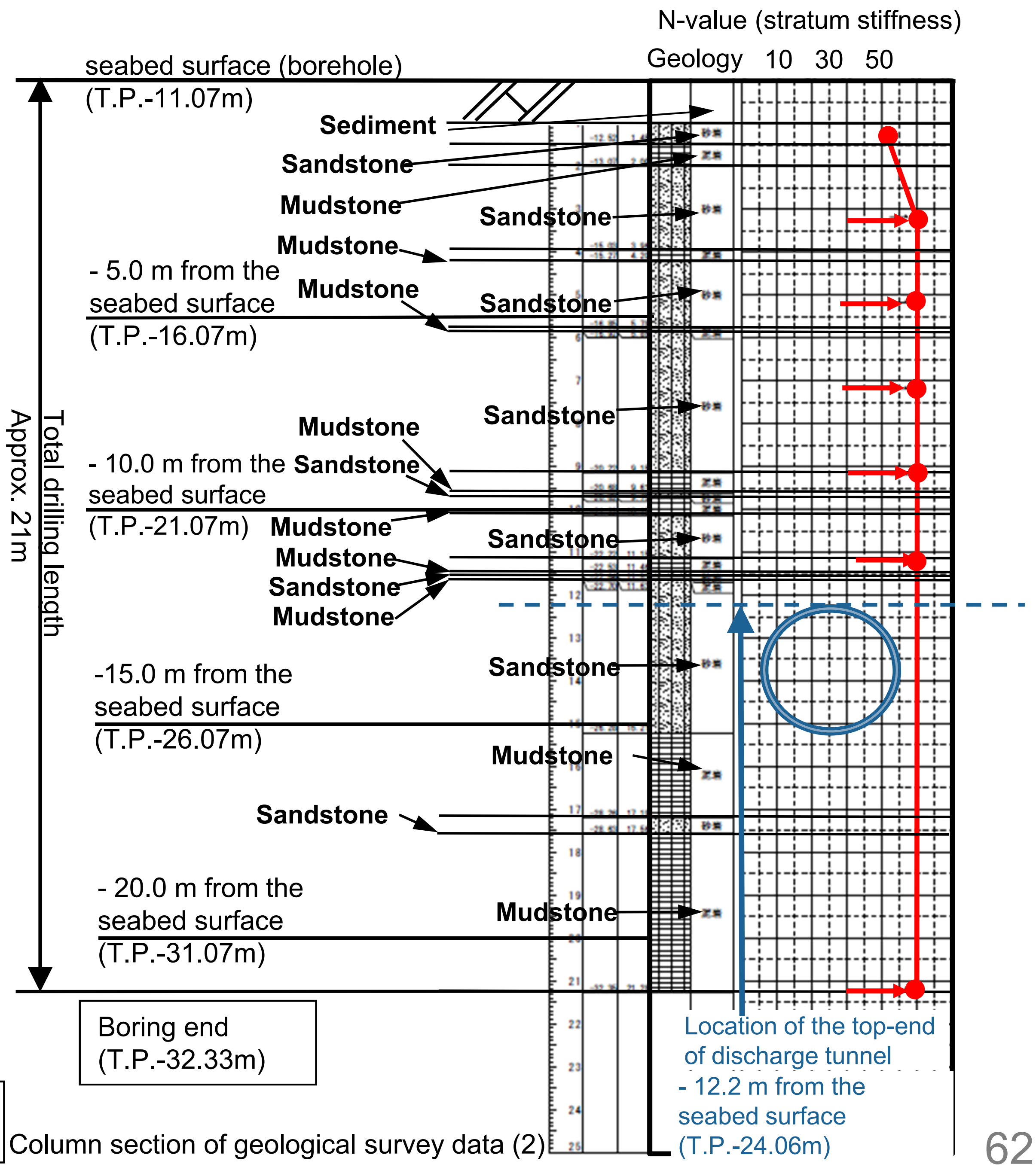
Column section of geological survey data (1)

*About the N-value
- This value is obtained by the standard penetration test (JIS A 1219) and indicates the hardness and softness of the stratum.
- The higher this value, the harder the stratum. The N-value of the Kanto loam layer is about 3 - 5, and the soft alluvial cohesive soil is about 0 - 2. For the foundation of a medium to a high-rise building, the bearing stratum is usually N-value of 30 - 50 or more.

[Reference] Geological survey data [2]

- The figure right shows the geological survey data (2). The location of the discharge tunnel is also indicated.
  - The total drilling length of about 21 m from the borehole mouth (T.P. -11.07 m) to the boring end (T.P. - 32.35m) was investigated.
  - It was confirmed that at the geological survey data (2) point, to install a discharge tunnel inside the bedrock (sandstone, mudstone in Tomioka formation) is enable.

[Location of top-end of the discharge tunnel: Approx. - 12 m from the seabed surface]



Column section of geological survey data (2)

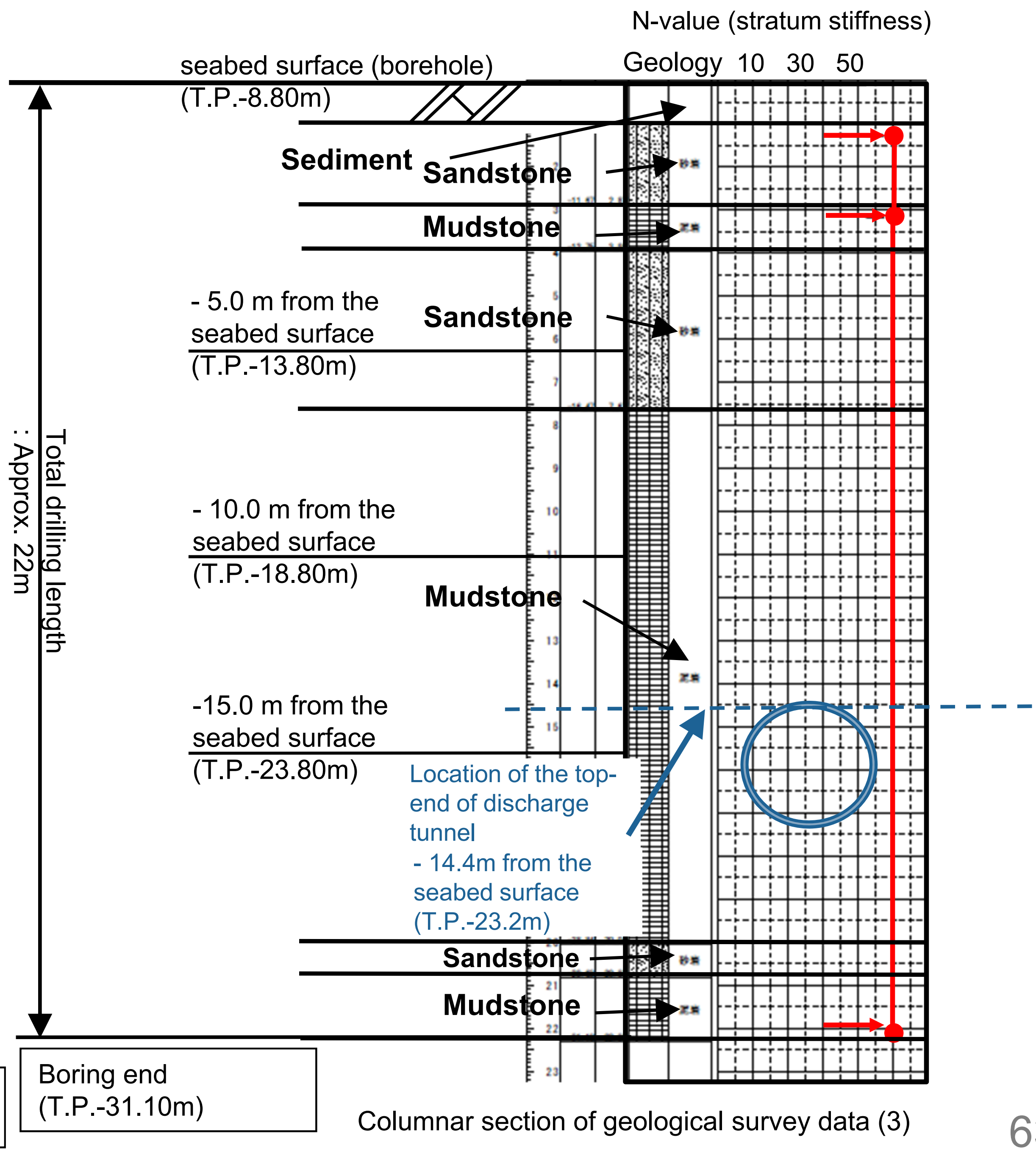
[Reference] Geological survey data [3]

- The figure right shows the geological survey data [3]. The location of the discharge tunnel is also shown in the figure.

  - The total drilling length of about 22 m from the borehole mouth (T.P. - 8.80 m) to the boring end (T.P. - 31.10 m) was investigated.

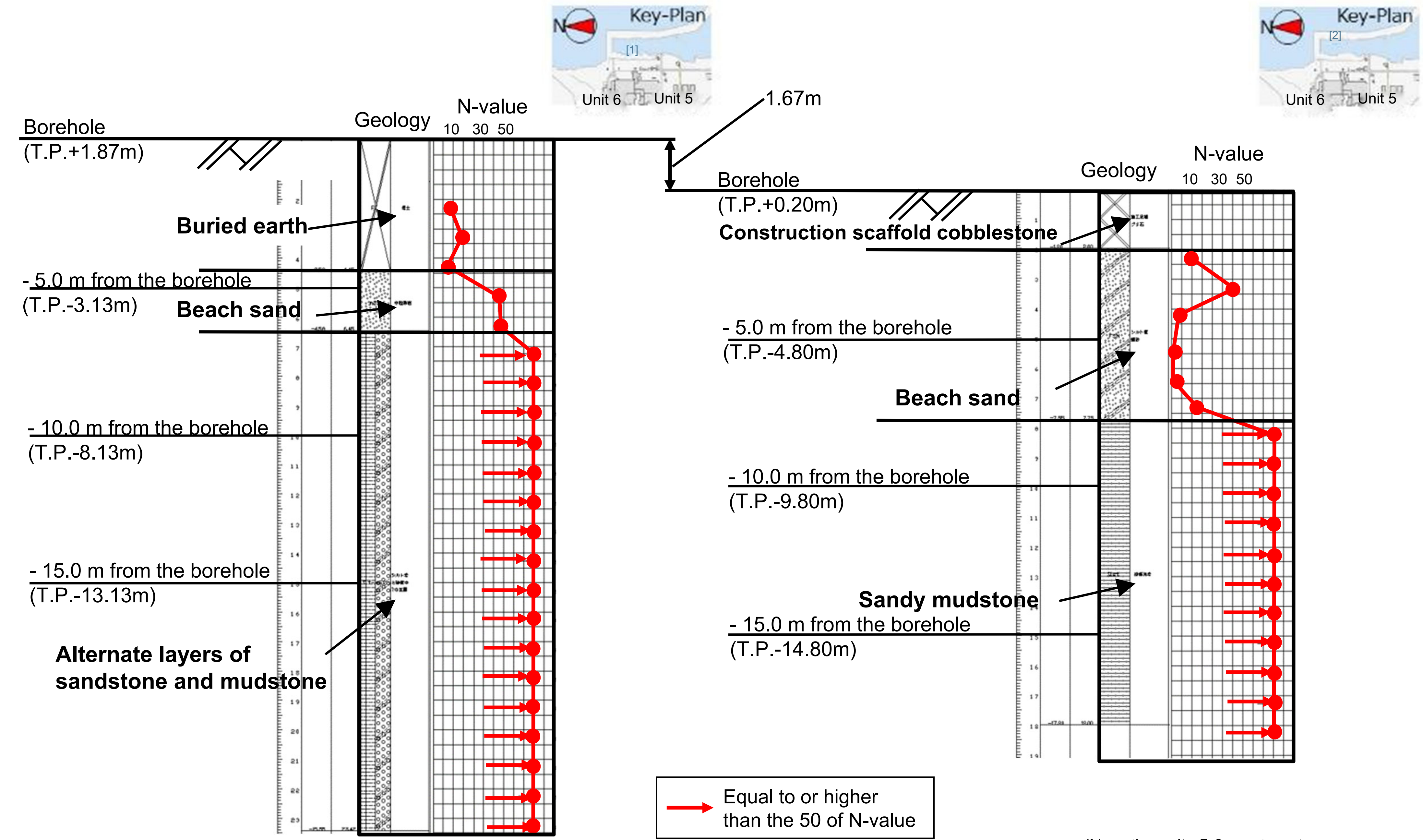
  - It was confirmed that at this geological survey data [3] point, it is possible to install a discharge tunnel inside the bedrock (mudstone in Tomioka formation).

[Location of top-end of the discharge tunnel: Approx. - 14 m from the seabed surface]



Columnar section of geological survey data (3)

[Reference] The past geological survey data near the units 5-6 revetment



(Near the units 5-6 revetment(1))

(Near the units 5-6 revetment (2))

*North breakwater side

[Reference] Confirmation of consistency between past geological survey data and current geological survey data

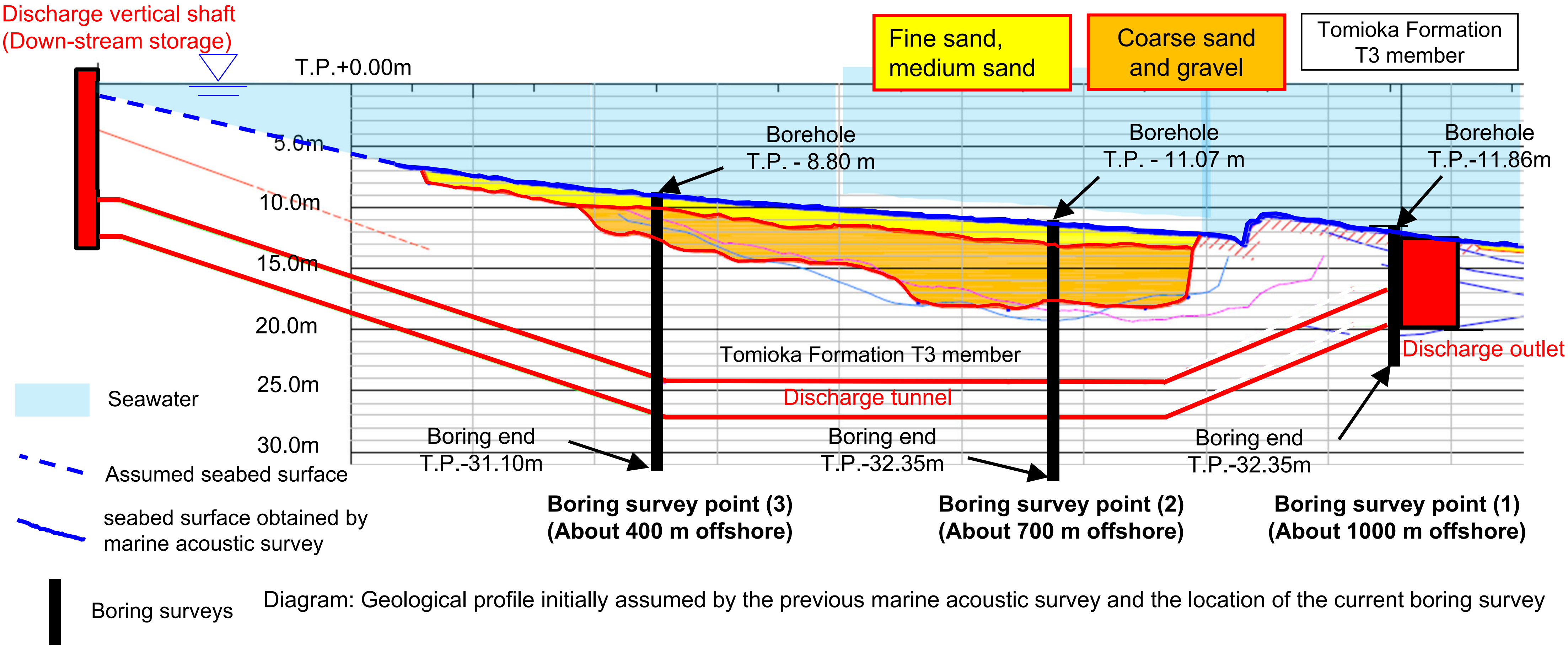


Diagram: Geological profile initially assumed by the previous marine acoustic survey and the location of the current boring survey

[Geological profile with an initially assumed geological section by the past marine acoustic survey and the result of the geological survey by the current marine boring]

- ✓ As shown in the above diagram, in the geologic formation based on the previous marine acoustic survey, it was assumed that fine sand, medium sand, coarse sand, and gravel were deposited on the surface layer. Underneath that, there was a Tomioka formation T3 member.
- ✓ This time, a boring survey was conducted at the point (1) (1,000 m offshore), the point (2) (700 m offshore), and the point (3) (400 m offshore). As a result, at points (2) and (3), it was confirmed that the sedimentary layer containing mainly the surface layer's sand was thinner than what had been assumed by the acoustic survey results. It was also confirmed that at all points, geologic formation is alternating layers of sandstone and mudstone (Tomioka Formation T_3 member), and there is a consistency with the previous marine acoustic survey. Therefore, it was judged that building the discharge tunnel can be safely carried out.

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Material published by TEPCO Geology and Geological Structure on the Fukushima Daiichi and Daini Nuclear Power Stations, page 5 (August 10, 2012)

htT.P.s://www.tepco.co.jp/cc/direct/images/120810d.pdf

Geological stratigraphy within the site

- The geological feature within the Fukushima Daiichi NPS site consists of the Tomioka Formation of the Neogene-Pliocene, terrace deposits of the Quaternary-Pleistocene, and alluvium of the Quaternary-Holocene. Under the Tomioka Formation, sedimentary rocks of the Paleogene to the Neogene-Miocene are distributed.
- The Tomioka Formation is disconformable to the lower strata.

Geological age		Name of stratum			Major lithofacies and facies	
Quaternary		Alluvium			Dark green-gray to brown clay and sand, unconsolidated	
Quaternary		Terrace deposit			Yellow brown sand and sand, partially consolidated	
Neogene-level	Pliocen	Entire Sendai Formation	Tomioka Formation	T_3 member	Sandy mudstone to mudstone, pumice grains, and tuff are intercalated. Sandstone intercalated in the upper part.	
Neogene-level	Pliocen	Entire Sendai Formation	Tomioka Formation	T_2 member	Muddy sandstone, pumice grains, and tuff are intercalated.	
Neogene-level	Pliocen	Entire Sendai Formation	Tomioka Formation	T_1 member	A lot of muddy sandstone, pumice grains, and tuff are intercalated.	
Neogene-level	Miocene	Taga Group		Top	Muddy sandstone	
Neogene-level	Miocene	Taga Group		Bottom	Muddy sandstone	Pumice grains, scoroa grains, and tuff, etc. intercalated.
Neogene-level	Miocene	Yunagaya Group			Alternate layer of mudstone, sandstone and mudstone	
The Paleogene	The Oligocene	Shiramizu Group			Hard muddy sandstone to mudstone	

Disconformable

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The Japanese version shall prevail.

Discharge method: Facility overview/design

Facility overview

Selection of the alignment of the discharge tunnel

Selection of the construction method of the discharge tunnel

Discharge tunnel design (structure)

1.3.1 Selection of the construction method of the discharge tunnel (1/2)

Tunnel construction method

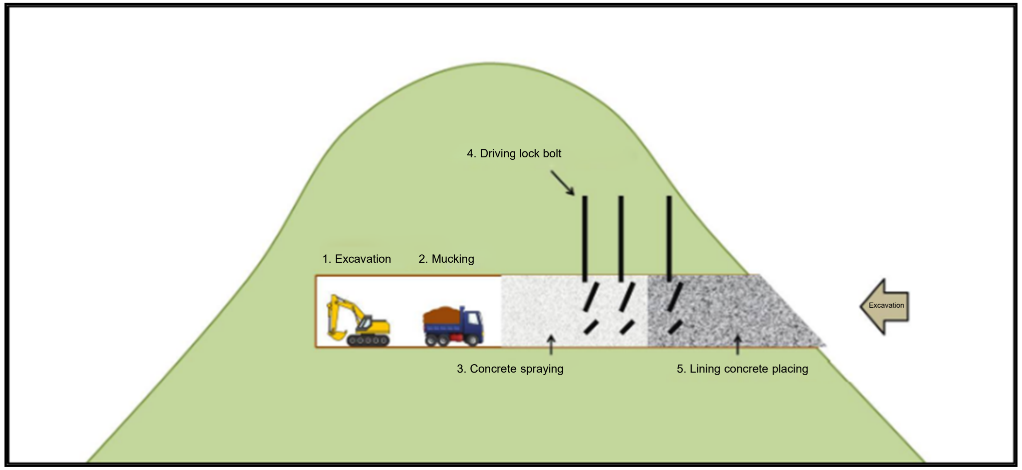
- For tunneling methods suitable for this location, it is assumed there are two types of tunneling methods; "mountain tunnel" and "shield tunnel."

Features of the mountain tunnel

- The mountain tunnel method is used for hard ground, such as bedrock, where the natural ground does not collapse even if the tunnel is excavated.
- When the natural ground is excavated, it tends to collapse under pressure. However, if the ground is hard, the ground around the tunnel supports each other (it is called the arch effect), so the tunnel does not collapse.

Demerits of the mountain tunnel method

- If a tunnel is excavated on soft ground, the tunnel will collapse because of weak ground. Thus, the mountain tunnel method cannot be applied to soft ground.



Mountain tunnel method

htT.P.s://bonperson-civil.com/moutaintunnel-natm/
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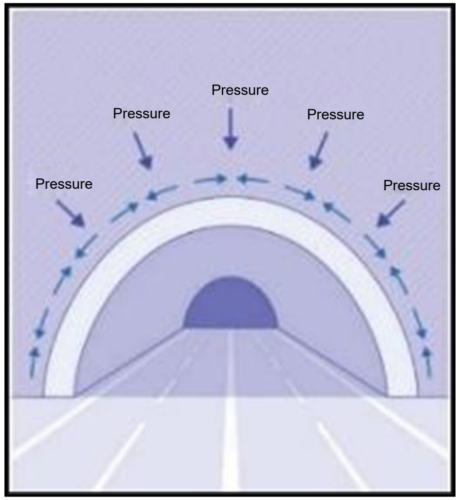

Image diagram of arch effect

htT.P.s://www.pacific.co.jp/magazine/2018/04/post-27.html quote

2-1 (1) [5] Structure and strength of equipment, protection against natural phenomena such as earthquakes and tsunamis, etc.
1.3.1 Selection of the construction method of the discharge tunnel (2/2)

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Features of the shield tunnel

- The shield tunneling method is digging a tunnel with an excavating machine called a shield machine.
- The tunnel is made by assembling pieces called “segments” made of reinforced concrete and steel in a round form.
- Since the tunnel is excavated while supported by the shield machine and segments, it is applicable to soft ground.

Points to be noted for the shield tunnel method

- If we reduce the thickness of the segments on soft ground where the natural ground may collapse, there will be a risk that a tunnel may collapse because the segments will not withstand the earth pressure of the surrounding ground. A submergence accident emerged in the past, which is presumed to be caused by reducing the thickness of the segments.

Grounds for selecting a shield tunnel

- <u>The ground on which the discharge tunnel is constructed is soft rock. Thus, although the mountain tunnel method can be used, but in to place the tunnel in the seabed more safely, we will employ the shield tunnel method.</u>

Shield method (Tokyo Electric Power Co., Inc., 2009)
East-West Joint Gas Pipeline Tunnel at the Transverse Section of Tokyo Bay: Approx.18 km

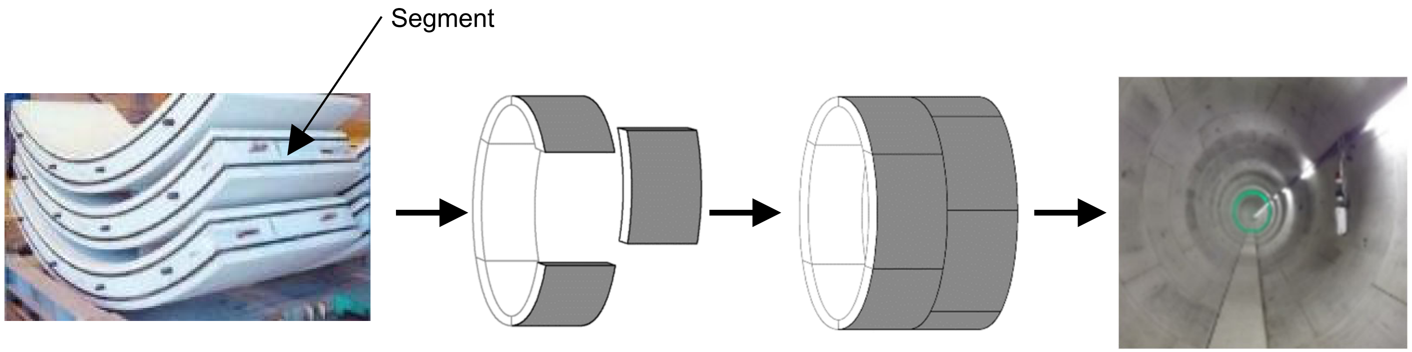
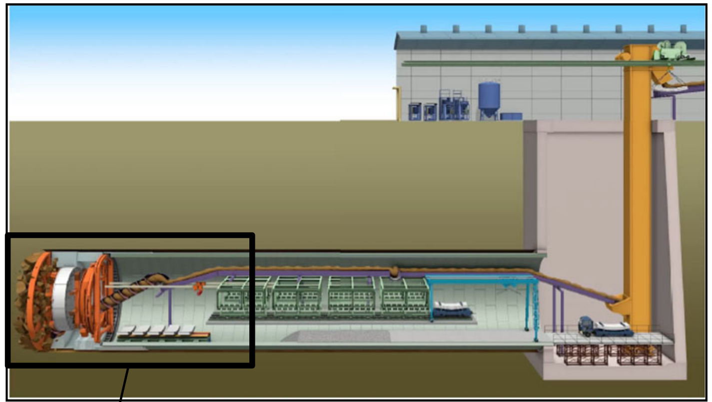


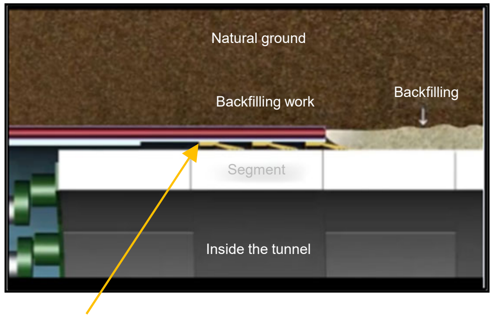
Image drawing of shield tunnel assembly

[Reference] Overview of shield machine

Structure of shield machine



Drawing image of the shield construction method



Drawing image of gap between segments and natural ground *)

*) Source: htT.P.s://m.youtube.com/watch?time_continue=2&v=qBihbM14zwE&feature=emb_logo

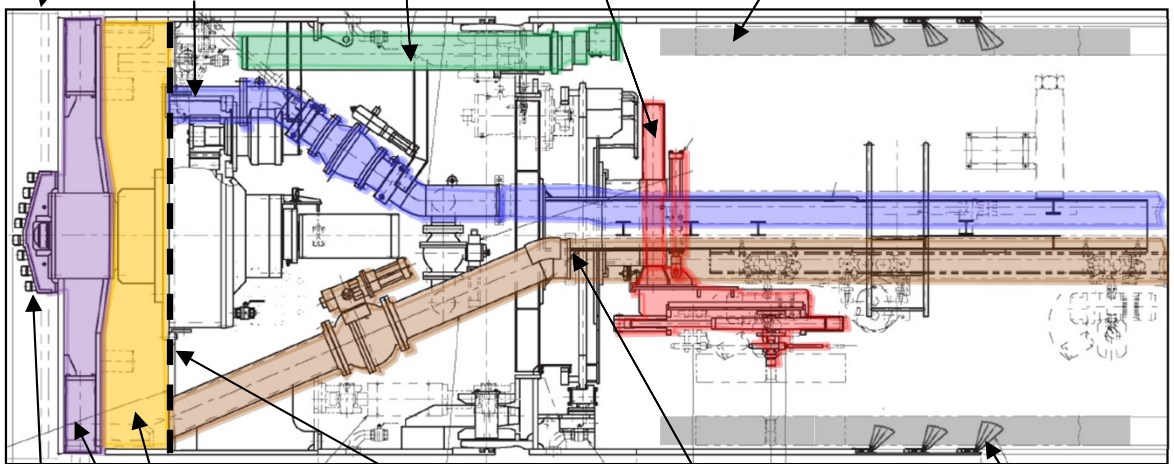


Image drawing of the shield machine

The Japanese version

Description of each part of the shield machine

Name	Description
Segment	A framework of the discharge tunnel. It is assembled by an erector.
Sludge transfer pipe	Pipe that feeds mud water into the cutter chamber and stabilizes the cutter head at its pressure.
Sludge discharge pipe	Pipe that pressure-feeds the excavated soil accumulated in the cutter chamber and the mud water sent from the mud feed pipe to the outside
Erector	Apparatus for assembling segments into a prescribed shape.
Tail seal	It prevents the inflow of the backfilling material from the outer surface of segments and the groundwater accompanied by the earth and sand.
Shield jack	It takes a reaction force from the segments and propels a shield.
Cutter bit	Blade using particular metal for cutting or crushing the natural ground; it is provided on the front of the cutter head.
Cutter head	Portion with a cutting mechanism, such as the cutter bit on the front face of the shield.
Cutter chamber	The part where mud water and excavated soil fed by the sludge transfer pipe are mixed.
Partition wall	Wall for holding the pressure of sludge or mud water for stabilizing the cutter head.

[Reference] Considerations for designing and constructing a discharge tunnel

- In the design and construction of the discharge tunnel, we checked guidelines such as Report of the Council for the Improvement of Safety of Shield Tunnel Construction Technology (the Ministry of Land, Infrastructure, Transport and Tourism), and considerations were given as below:

Item	Considerations
Seabed survey	In planning the alignment of the seabed shield tunnel, the depth of the seabed, the thickness of the sedimentation, and bedrock position will be determined based on the result of the marine survey to ensure that the tunnel alignment fits inside a stable bedrock layer.
Measures for the shape, dimensions, and division of segments	Regarding the width (1000 mm) and thickness (180 mm) of the segments, compared to the/// previous results, it is sufficiently safe in terms of shapes and dimensions. Segments are divided into six pieces, and the number of divisions is set by considering the damage to the segments at the time of assembly without increasing the arc length and the weight of one piece.
Rebar volume of RC segments and seal measures	Safe rebar volume is used for the RC segment, considering the impact of the execution of work. Seals (water cut-off material) applied to the segments are water expansion seals that have been used in undersea tunnels. Water cut-off performance can be ensured with one seal layer on the segment’s outer side, but seals with the same performance will also be placed on the inner side to ensure adequate water cut-off.

[Reference] Measures for the considerations for designing and constructing a discharge tunnel (1/2)

Considerations	Specific measures
Measures for curve construction	The tunnel alignment is made mainly of straight lines without a sharply curved section, unsymmetrical earth pressure may act on the segment ring. Therefore, the tunnel alignment is made mainly of straight lines without a sharply curved section. The alignment of some curved sections is gentle with a curve radius of 500 m or more, equipped with the articulated mechanism. By independently controlling the tunneling jack, the accuracy of alignment management is enhanced, and damage in the segments is also reduced.
Shield machine design	The tail seal of the shield machine should be capable of preventing the inflow of underground water, backfilling material, etc., into the tunnel during the construction. The tail seal of the three-stage structure ensures good water cut-off and durability. In addition, the cutter bit has an excellent safe excavation performance for the bedrock layer, which is the target ground, and the cutter drive unit ensures the durability necessary for the tunneling distance.
Adoption of the stable joint structure	When joints without clamping force are used for segments, an aperture or unevenness during assembly will be generated, resulting in water leakage. Therefore, we will use a joint structure having a high clamping force, which has been applied to many shield tunnel works in the past, for the segment joints, and verify its performance by joint bending test.
Execution of the shield construction	Slurry type shield is chosen for this work. We will continuously measure the amount of excavated earth and sand to be discharged by pump transportation with a densimeter and a flow meter, ensuring the management of the amount of sludge for discharge so as to secure the stability of the surrounding ground. As for the management of backfilling work, we will manage both grouting pressure and injection rate to ensure the stability of the segments and the natural ground.

[Reference] Measures for the considerations for designing and constructing a discharge tunnel (2/2)

Considerations	Specific measures
Salt contamination countermeasures in RC segments (1)	To construct a discharge tunnel by using blast furnace cement (class B) as a material of RC (made of reinforced concrete) segment and assembling a safe RC segment capable of sufficiently withstanding even severe salt damage environment of the ocean. Concrete using blast furnace cement has a high chloride shielding property and is more durable than general concrete (using ordinary Portland cement only).
Salt contamination countermeasures in RC segments (2)	RC segment rebars are provided with salt damage measures by installing proper rebar covering.

Discharge method: Facility overview/design

Facility overview

Selection of the alignment of the discharge tunnel

Selection of the construction method of the discharge tunnel

Discharge tunnel design (structure)

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

1.4.1 Compliance assurance to the matters for which measures should be taken

“14. Design considerations [1]Applied codes and standards ”

- Design, selection of materials, fabrication and inspection of Structures, Systems and Components (SSCs) with safety function shall conform to those codes and standards which are considered to be appropriate taking into account importance of their safety function, respectively,

- Design, selection of materials, and fabrication are evaluated comply with the following:
  - Design of Civil Engineering Structures of Thermal and Nuclear Power Plants (enlarged and revised edition), Electric Power Civil Engineering Association
  - Concrete Standard Specifications (Design Edition); Established in 2017), Japan Society of Civil Engineers
  - Concrete Standard Specifications (Structural Performance Examination Edition); established in 2002), Japan Society of Civil Engineers*
  - Tunnel Standard Specifications [Common Edition] and Explanation/[Shield Method Edition], Explanation (established in 2016), Japan Society of Civil Engineers
  - Tunnel Standard Specifications for Excavating Methods and Explanation (established in 2016)
  - Technical Standards and Explanations of Port Facilities 2018: The Ports and Harbors Association of Japan
  - Specifications for Highway Bridges and Explanation I, Common Edition, 2017, Japan Road Association
  - Specifications for Highway Bridges and Explanation IV, Lower Structure Edition, 2017, Japan Road Association
  - Common Ditch Design Guideline 1986, Japan Road Association
  - Guide to Tunnel Lining Structural Design under Internal Water Pressure (established in 1999), (Advanced Construction Technology Center) *
  - Seismic Countermeasures Guideline and Explanation for Sewerage Facilities - 2014 Edition, Japan Sewage Works Association*
  - Public Works Research Institute Materials: Seismic Design Methods and Guidelines for Large-Scale Underground Structures (Draft) - March 1992, Public Works Research Institute, the Ministry of Construction, and Seismic Research Institute, Earthquake Disaster Prevention Department*
  - Earthquake-resistance calculation examples for sewage facilities, Conduit Facility Edition, 2015 ver., Japan Sewage Works Association*
  - Standard Segment for Shielding Work (established in 2001) co-edited by Japan Society of Civil Engineers and Japan Sewage Works Association*

*Red: Applied to discharge tunnel design (structure).

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

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

1.4.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [2] Design considerations for natural phenomena" (earthquakes)

- Structures, systems, and components having safety functions shall be classified in terms of seismic design in consideration of the importance of their safety functions and the impacts on the safety the loss of their function might have in the event of an earthquake, and shall be designed to sufficiently withstand the design seismic load that is considered to be appropriate.

- The upper-stream storage of the ALPS Treated Water dilution/discharge facilities, which treats the drainage water from the said facilities (the water diluted with seawater and in which the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1), was classified Seismic Class "C", according to the impact of radiation to the public in the event of loss of function of any facilities (Implementation Plan: II-2-50-Attachment 5-1)

[Evaluation method]

✓ Conforming to the Common Ditch Design Guideline, and Seismic Countermeasures Guideline and Explanation for Sewerage Facilities, etc. (conforming to Seismic Class "C")

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

1.4.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [2] Design considerations for natural phenomena" (natural phenomena other than earthquakes)

- SSCs with safety function shall be designed so that the safety of the facilities may not be impaired by postulated natural phenomena other than earthquake (such as tsunami, heavy rain, typhoon and tornado, etc.). SSCs with safety function of especially high importance shall be designed taking into account appropriate combination of conditions considered to be severest among predictable natural phenomena or natural load together with accident load.

- Tsunami (Implementation Plan: II-2-50-8)
  - The design should also take into account the effects of sea-level rise due to tsunami.
- Typhoon (storm surges) (Implementation Plan: II-2-50-8)
  - The design should also take into account the effects of sea-level rise due to typhoons (storm surges).

[Evaluation method]

- ✓ Consideration is given to the sea-level rise against a tsunami equivalent to the Japan Trench tsunami.
- ✓ Consideration is given to waves equivalent to the design wave height (50-year-probability significant wave height: 7.0 m, period: 15.0 seconds).

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

1.4.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [4] Design considerations for fire"

- The facilities shall be designed so that safety may not be impaired by fire, by combining appropriately protective measures such as fire prevention, fire detection, fire extinguishing and mitigation of fire effect.

- Fire (Implementation Plan: II-2-50-5)
  - To avoid fire occurrence, ALPS Treated Water dilution/discharge facilities use non-flammable or flame-retardant materials as much as it is practically possible.

[Evaluation method]

✓ No concern about fire is expected due to its RC structure.

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

1.4.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations (8) Design considerations for reliability"

- SSCs with safety function and monitoring function shall be designed so that their adequately high reliability may be ensured and maintained.

- Structure (Implementation Plan: II-2-50-7)
  - Discharge facility is grounded to bedrock so that the structure will not be easily affected by an earthquake. The discharge tunnel is to be installed inside the bedrock using the shield method in consideration of the risk of advancing the seabed and its durability during the service period. Water cut-off performance is secured by providing a sealing material on a lining plate made of reinforced concrete constituting a discharge tunnel.
- Considerations for integrity (Implementation Plan: II 2-50-7)
  - The structure is established by confirming that this facility is within the allowable stress intensity for stationary, wave, and earthquake loads. It also has been confirmed that there is no structure uplift. In addition, the crack width and salt damage to be generated in the reinforced concrete framework are examined, and it has been confirmed that the durability during the service period is ensured by setting proper rebar cover. The reinforced concrete framework shall be designed in a conservative manner such that it does not require maintenance during the service period. (Periodic inspection is carried out based on the long-term inspection plan.)

*Red: Applied to discharge tunnel design (structure).

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

1.4.1 Compliance assurance to the matters for which measures should be taken

"14. Design Considerations (8) Design considerations for reliability" (continued)

- By examining the discharge facility as per the table below, the durability of the facility has been confirmed during the service period.

Examination items for the discharge facility

Examination item		Discharge vertical shaft (Down-stream storage)	Discharge tunnel	Discharge outlet	Contents of examination
In normal times	Structure	○	○	○*	It should be within allowable stress intensity.*1
	Structure (High wave)		○*	○	It should be within allowable stress intensity.*1
	Crack	○	○	○	The crack width should equal or less than the allowable crack width. *2
	salt damage	○	○	○	Chloride ion concentration at the position of steel materials should not reach the corrosion limit of steel materials.*2
	Uplift	○		○	There should be no uplift.
At the time of the earthquake		○	○	○	It should be within allowable stress intensity against earthquakes.*3

*1. Safety: The stress intensity of the material caused by the action of the load should be within the allowable stress intensity.
*2. Durability: During the design service period, the performance of the structure should not deteriorate due to corrosion of steel materials caused by cracks or intrusion of chloride ions.
*3: Seismic resistance: Examination should be performed with Seismic class C.

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

Document 1-1 (partly revised), the 3rd Review Meeting on the Implementation Plan Regarding the Handling of ALPS Treated Water

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Stress intensity examination

- Of the materials used for the Discharge facility, concrete should be ordinary concrete (Ordinary Portland Cement, blast furnace cement B type), and the design-basis strength should be 24N/mm², 30N/mm², and 42N/mm². The rebar should be SD345.
- Verify whether the stress intensity of the material caused by the action of the load is within the allowable stress intensity.

Allowable stress intensity of concrete *Red: Applied to discharge tunnel design (structure).

Design basis strength of concrete	Long-term		Short-term		Remarks
	Compression (N/mm²)	Shear (N/mm²)	Compression (N/mm²)	Shear* (N/mm²)	
24N/mm²	9.0	0.45	13.5	0.675	Discharge vertical shaft (Down-stream storage)
30N/mm²	11.0	0.50	16.5	0.75	Discharge outlet
42N/mm²	16.0	0.73	24.0	1.095	Discharge tunnel

Allowable stress intensity of rebar

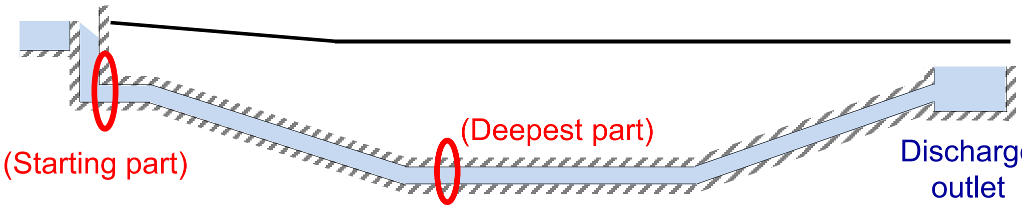
Material used	Long-term	Short-term
	Tension (N/mm²)	Tension (N/mm²)
SD345	200	300

1.4.3 Compliance assurance to the matters for which measures should be taken (results of stress intensity examination [1[)

- The result of stress intensity examination revealed the possession of the proof stress.

Load combination

Load for study	In normal times	At the time of the earthquake
Dead load	○	○
Loading load	○	○
Earth pressure	○	○
Internal water pressure (including waves)	○	○
External water pressure (including waves)	○	○
Seismic inertial force		○



Areas for study

- The operating stress is compared with the allowable stress. The results of examining the part where the ratio of the operating stress to the allowable stress is maximum, and the load case are shown in the table below.
- It has been confirmed that it is within the allowable stress intensity (operating stress/allowable stress intensity < 1.00) for stationary and seismic loads.

Results of examining the stress intensity of the lining plate (segment)

Areas for study	Load case	Target material	Stress	Operating stress (N/mm^2)	Allowable stress (N/mm^2)	Operating stress/ Allowable stress
Lining plate (Starting part)	In normal times	Rebar	Bending moment	78*	200	0.39
Lining plate (deepest part)	In normal times	Rebar	Bending moment	91*	200	0.46

The Japanese version shall prevail.

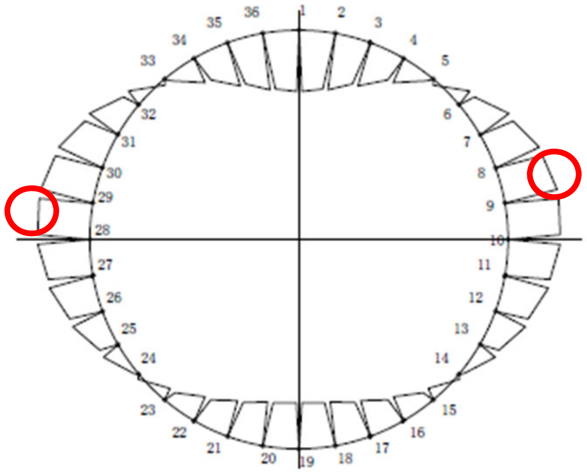
*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

Results of examining the stress intensity at areas for study

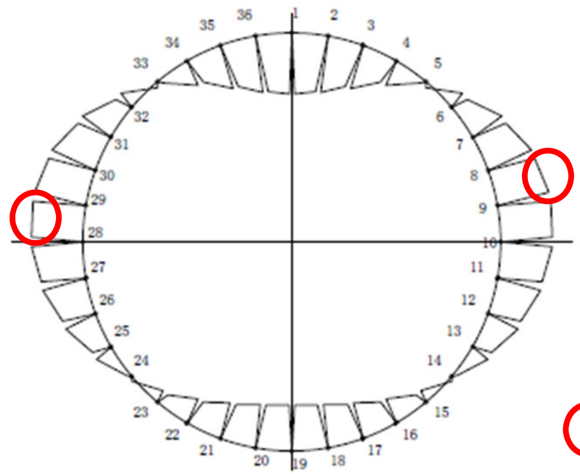
Results of examining the stress intensity of the lining plate (segment)

Areas for study	Stress intensity examination (Operating/Allowance)
	Bending moment
Lining plate (Starting part)	0.39
Lining plate (deepest part)	**0.46**

*Red: maximum value for stress intensity examination



Starting part: Section force diagram (bending moment)



○: Examination of stress intensity, maximum position

Deepest part: Section force diagram (bending moment)

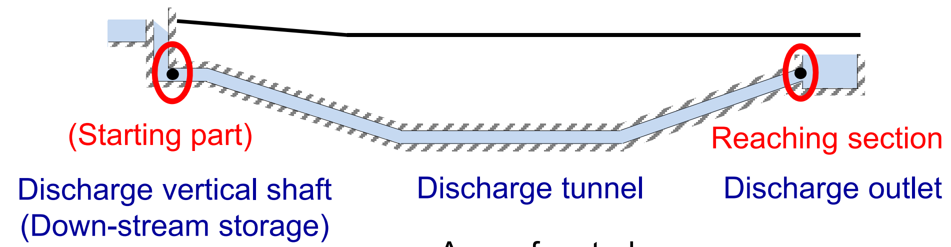
Results of examining the displacement during earthquake

- We examined the horizontal displacement at the starting part (the connection between the down-stream storage and the discharge tunnel) and the reaching part (the connection between the discharge outlet caisson and the discharge tunnel) equivalent to extraction during an earthquake and confirmed that it is safe.
- To be more specific, horizontal displacement at the position (● in the figure below) of the joint of the discharge tunnel during the earthquake was assumed to be the sum of the displacement volume caused by ground inflection and the extraction volume caused by ground strain. As such, it was judged that there would be no significant impact during an earthquake.

Results of examining the horizontal displacement

Areas for study	Displacement by inflection*1 : Δ1 (mm)	Amount extracted*2 : Δ2 (mm)	Total horizontal displacement (mm)
(Starting part)	**2.9**	**0.3**	**3.2**
Reaching section	1.0	0.1	1.1

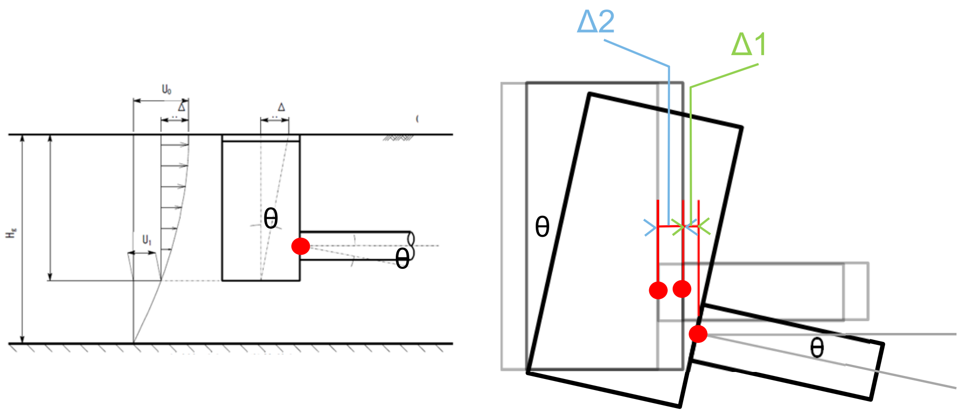
*Red: maximum displacement value



Areas for study

*1. Assuming that the discharge vertical shaft and the discharge tunnel will be inflected by only θ at the time of an earthquake, it was converted into horizontal displacement at the position ●.

*2. It was obtained based on the ground strain at the position of ●.



Example: Image drawing of displacement at the connection portion

Study case

Areas for study	Load patterns	Tunnel condition	Earth pressure	External water level
Lining plate (Starting part)	In normal times	No water	2D	G. L. ± 0.00
		When internal water pressure is acted on (long-term*1)		
		When internal water pressure is acted on (short-term*2)		
		No water	0.175D	
		When internal water pressure is acted on (long-term)		
		When internal water pressure is acted on (short-term)		
	At the time of the earthquake	No water*3	2D	
			0.175D	
Lining plate (deepest part)	In normal times	No water	2D	H.W.L(T.P.+0.757m)
		When internal water pressure is acted on (long-term)		L.W.L(T.P.-0.778m)
		When internal water pressure is acted on (short-term)		
		No water	0.175D	H.W.L(T.P.+0.757m)
		When internal water pressure is acted on (long-term)		L.W.L(T.P.-0.778m)
		When internal water pressure is acted on (short-term)		
	At the time of the earthquake	No water*	2D	H.W.L(T.P.+0.757m)
			0.175D	L.W.L(T.P.-0.778m)

Red:
Critical case of lining plate (starting part)

Blue:
Critical case of lining plate (deepest part)

*1) Inner water level T.P. + 6.40 m obtained based on the significant wave height of the 50-year-probability

*2) Inner water level T.P. + 9.30 m obtained based on the maximum wave height of the 50-year-probability

*3) The most severe case during an earthquake.

[Reference] Approach to loads acting on a discharge tunnel

- Regarding this ground, as a result of calculating a height at which the ground above the top-end of the tunnel loosens, it was confirmed that the ground does not loosen.
- However, the ground's earth pressure (load by earth) was determined at a value when the ground within the range of twice the outer tunnel diameter (about 6 m) collapsed from the top-end of the tunnel to a vertically upward direction. Based on this, it was confirmed that segments were intact.
- Inner water pressure was determined by setting the internal water level at T.P. + 9.30 m obtained from the maximum wave height of the 50-year-probability.

*Standard segments for shield construction, page 95

A range where soil collapse would not pose a challenge in terms of design. (Shaded part)

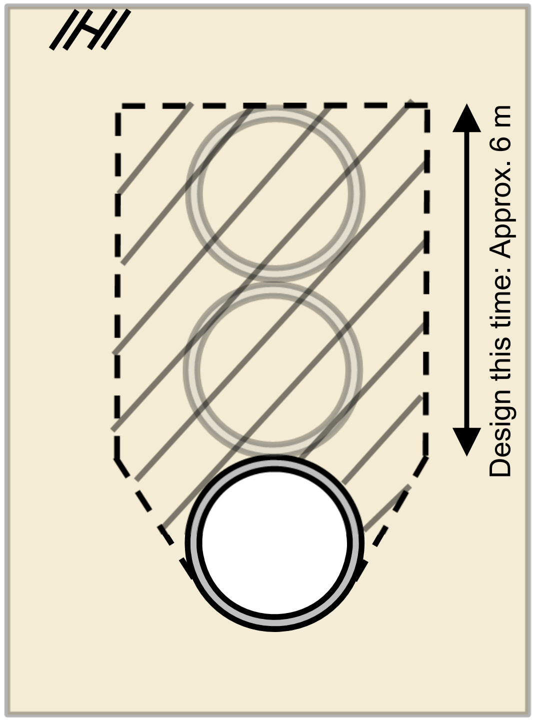


Image drawing of a range where the earth pressure is expected in design

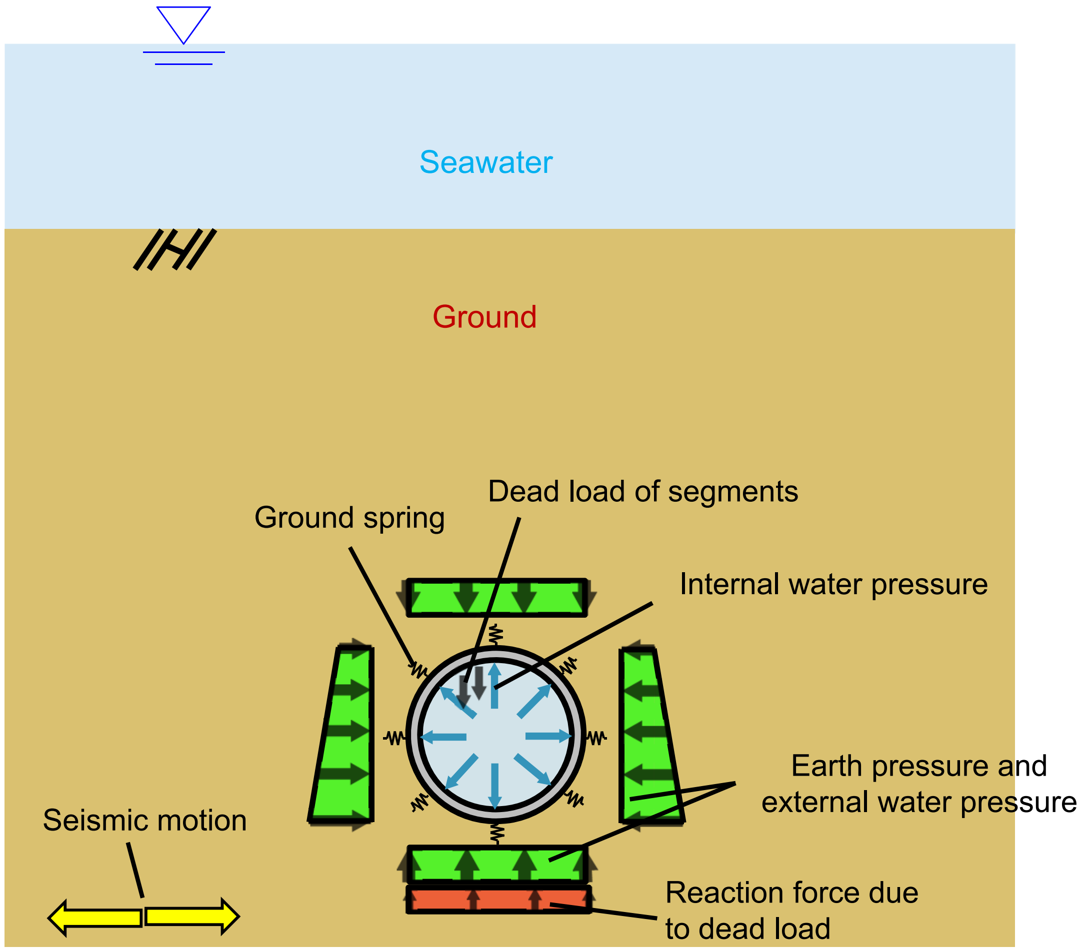


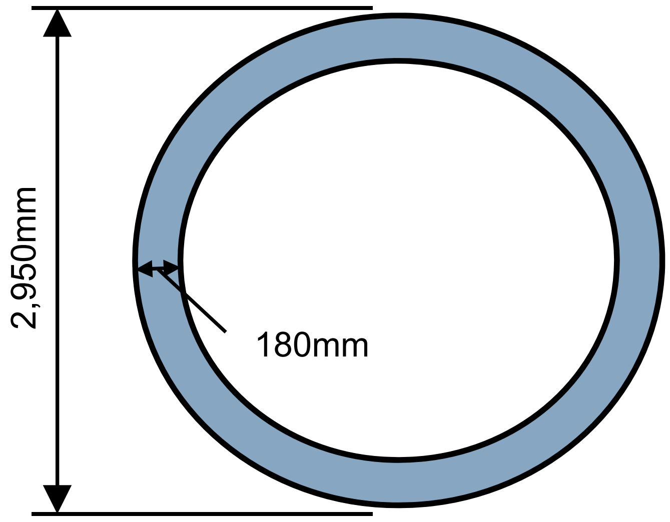
Image drawing of design load

Segment height (thickness) and outer diameter

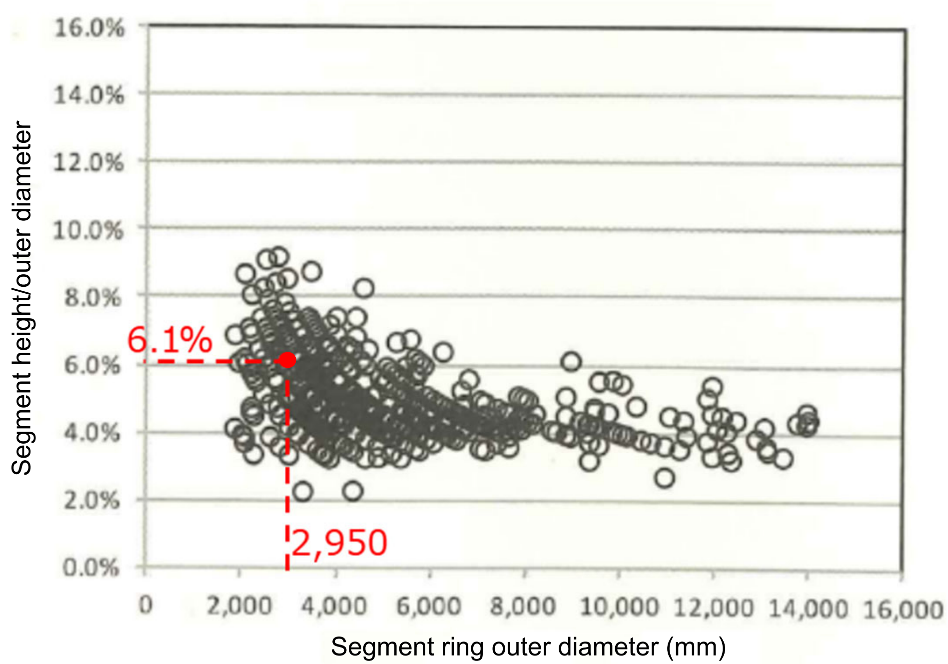
- The segment height (thickness) ratio of 180 mm to the outer segment diameter of 2,950 mm is 6.1%. *

Segment dimensions

Dimensions	Outer diameter (mm)	Height (thickness) (mm)	Height (thickness)/Outer diameter
Segment	2,950	180	6.1%



Segment sectional view



Segment height (thickness)/Outer diameter and outer diameter; Scatter diagram*

*Tunnel Standard Specifications [Common Edition] and Explanation/[Shield Method Edition], Explanation (Established in 2016), P. 84, Explanation Chart 2.5.1: Results of segment height (thickness) made of reinforced concrete

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

1.4.5 Compliance assurance to the matters for which measures should be taken (durability evaluation (crack width))

Examination of crack width

- The crack width is examined by the following formula to confirm that the crack width “w” of the concrete surface is equal to or less than the limit value w_a of the crack width against corrosion of steel materials.

  $w / w_a \leq 1.0$

Crack Width w

$$w = 1.1 \cdot k_1 \cdot k_2 \cdot k_3 \{4c + 0.7(c_s - \phi)\}\left[\frac{\sigma_{se}}{E_s} + \varepsilon'_{csd}\right]$$

Where:

k_1: Coefficient representing the effect of crack width on the surface shape of steel materials. In general, it is 1.0 for deformed bars.

k_2: Coefficient by which the quality of the concrete affects the crack width based on the following formula:

$$k_2 = \frac{15}{f'_c + 20} + 0.7$$

f'_c: Compressive strength of concrete (N/mm^2), generally using design compressive strength f'_{cd}

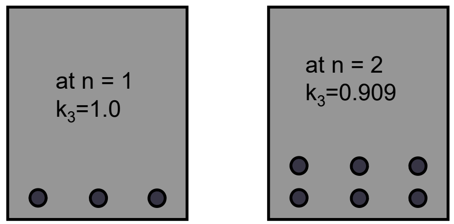
k_3:Coefficient representing the effect of the number of stages “n” of tensile steel materials based on the following formula:

$$k_3 = \frac{5(n+2)}{7n+8}$$

c: Cover (mm), c_s: Center spacing of steel material (mm), φ: Steel material diameter (mm),

σ_{se} :Increase in stress intensity in the rebar (N/mm^2);

ε'_{csd}: Strain to take account of increase in crack width due to shrinkage and creep of concrete



Schematic diagram of the relationship between the number of tensile steel material stages n and k_3

(When examining the corrosion of steel materials, the value of ε'_{csd} is about 150×10^{-6}.)

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

1.4.6 Compliance assurance to the matters for which measures should be taken (durability evaluation (salt damage))

Examination for salt damage

- Confirm that the chloride ion concentration at the position of steel materials does not reach the corrosion limiting concentration of steel materials during the design service life.
- The limit value of crack width against corrosion of steel materials is determined according to environmental conditions, covering, and type of steel materials.
- The environmental conditions should be severe corrosive environment, and the crack width limit should be 0.0035c*(mm).(c: Pure covering)

	Examination formula	
Calculation formula of design diffusion coefficient	$D_d = \gamma_c \cdot D_k + \lambda \cdot \left(\frac{w}{l}\right) \cdot D_0$	
Calculation formula of the chloride ion concentration design value at the position of steel materials	$C_d = \gamma_{cl} \cdot C_0 \cdot \left\{1 - erf\left(0.1 \cdot C_d / 2 \cdot \sqrt{D_d \cdot t}\right)\right\} + C_i$	
Examination formula of the chloride ion concentration at the position of steel materials	The design value of chloride ion concentration at the position of steel materials is equal to or less than the corrosion limiting concentration of steel materials.	$\gamma_i \cdot \frac{C_d}{C_{lim}} \leq 1.0$

D_d: Design diffusion coefficient
D_k: Characteristic value of diffusion coefficient for chloride ion of concrete (cm^2/year)
D_0: Coefficient representing the effect of cracks on the transfer of chloride ion in concrete (cm^2/year). ~~In general, it is 200 cm^2/year.~~
*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan
400 cm^2/year
w: Crack width (mm)
w_a: Limit value of crack width for corrosion of steel materials (mm)
w/l: Ratio of crack width to crack spacing
C_d: Design value of the chloride ion concentration at the position of steel materials

- As a result of examining crack width and salt damage of a discharge tunnel, it has been confirmed that durability during the service period is ensured.

[Examination of crack width]

The bending crack width generated in a discharge tunnel is compared with the allowable bending crack width. The examination result of the portion where the ratio of the generated bending crack width to the allowable bending crack width is maximum is shown in the table below.

Examination results of crack width

Areas for study	Generated bending crack width (mm)	Allowable bending crack width (mm)	Generated bending crack width/Allowable bending crack width
Lining plate (Starting part)	0.135*	0.177	0.76
Lining plate (deepest part)	0.148	0.177	0.84

[Examination for salt damage]

Chloride ion concentration in a discharge tunnel is compared with the corrosion limiting concentration of rebars. The results of examining the portion where the ratio of chloride ion concentration at the position of rebars to the corrosion limiting concentration of rebars is the maximum are shown in the table below.

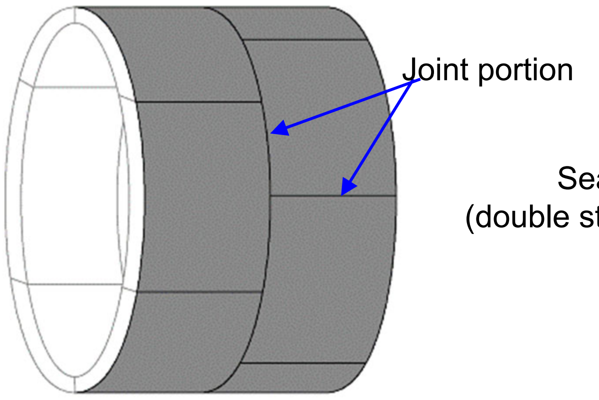
Results of examination for salt damage

Areas for study	Chloride ion concentration at the position of rebars (kg/m^3)	Corrosion limiting concentration of rebars (kg/m^3)	Concentration of chloride ion at the position of rebars/Corrosion limiting concentration of rebars
Lining plate (Starting part)	1.97	2.19	0.90
Lining plate (deepest part)	2.16	2.19	0.98

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

[Supplement] Water cut-off for segments

- Leakage from the shield tunnel (water coming in and out from the outside and inside) is limited to the joint of the segments.
- Water leakage from the joint is cut off by applying seals (rubber that expands into the water, exhibiting the cut-off capability).
- Seals are usually installed only in one layer, but this time, because of the internal water pressure acting on them, they are applied to two layers in the circumferential direction and in the extending direction (the whole circumference) of the discharge tunnel to ensure water cut-off.
- It was confirmed that there is no water leakage through the seals, considering the contact surface stress of the seals, the amount of apertures, and the amount of unevenness.



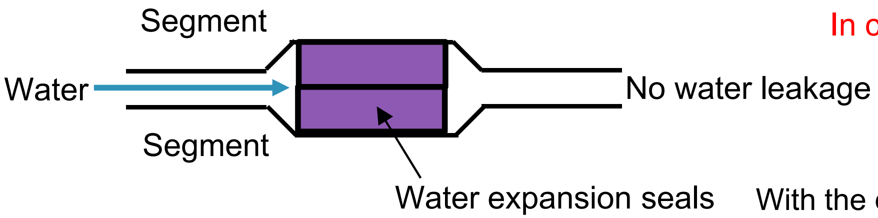
Assumed leakage point

Segments made of reinforced concrete

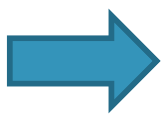
Seal	Specifications
Thickness	Approx. 4 mm
Width	Approx. 17 mm
Material	Chloroprene synthetic rubber system

Specifications of seal

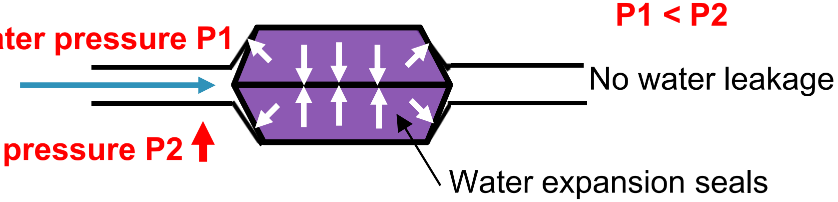
[Principle of water cut-off]



When assembling segments



With the deformation of the ground, etc., even if an aperture is generated between segments, the water channel will be blocked by the water expansion of the seal.



Cut-off state due to water expansion

[Supplement] Joints of segments (1/2)

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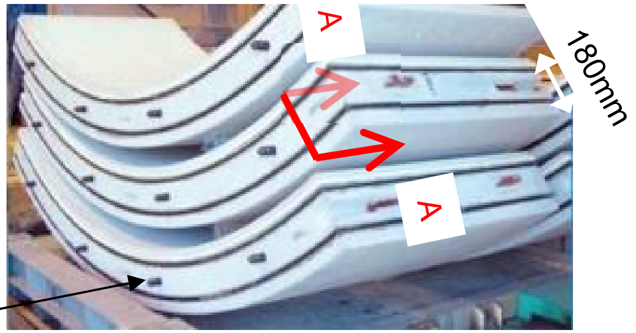
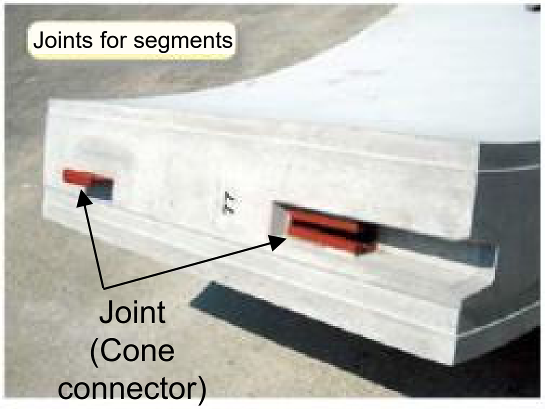
Joints for segments

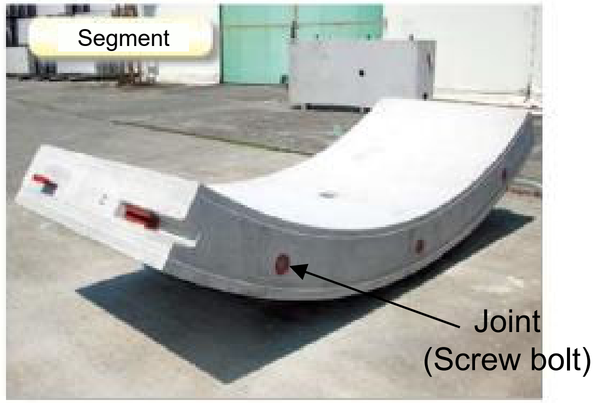
- There are two types of joints between segments: joints in the circumferential direction of the segments (cone connector joint) and those in the extension direction of the discharge tunnel (screw bolt joint).



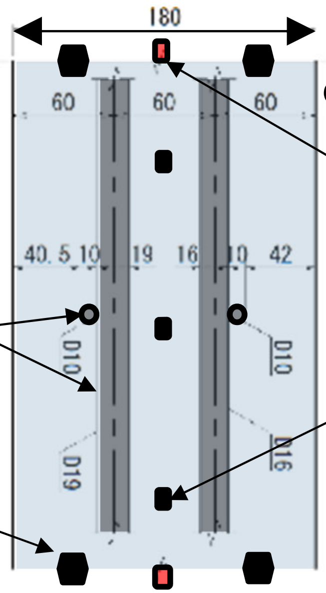
Segments made of reinforced concrete



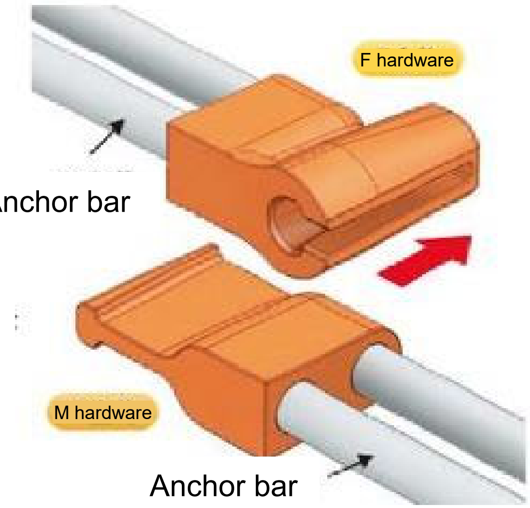
Joints in the circumferential direction (cone connector)



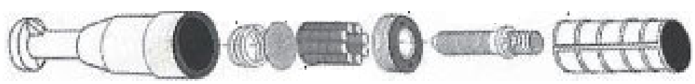
Joints in extension direction (Screw bolt)



A-A cross-sectional view

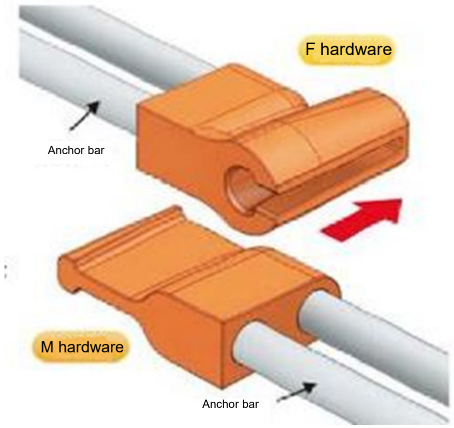
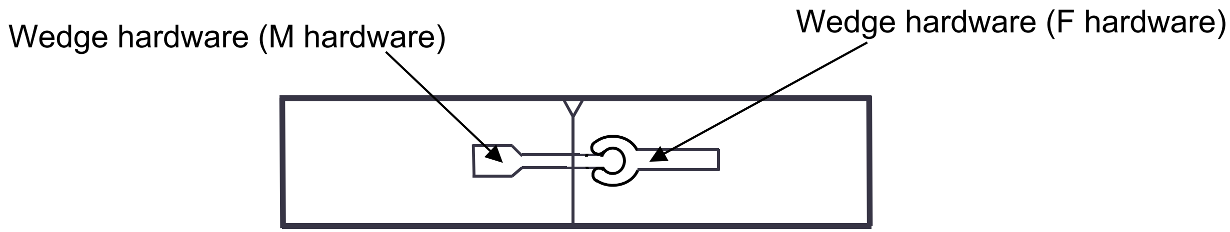
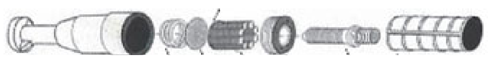
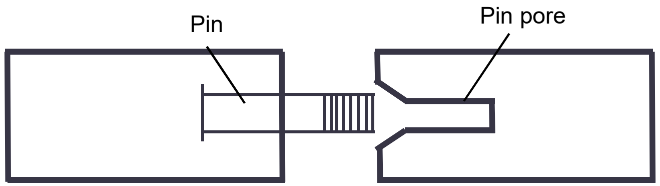
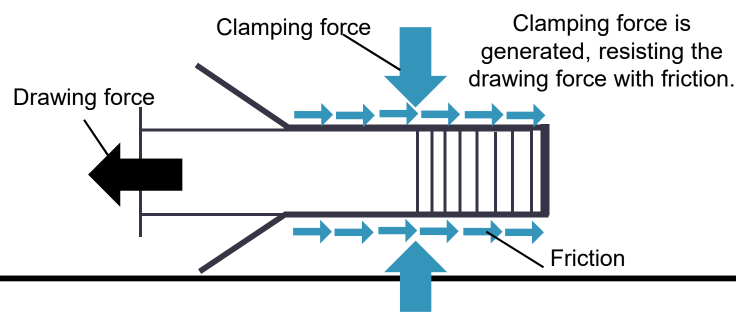


Cone connectors in details



Screw bolts in details

Structural features of the joint

Joint types	Features
 Cone connector joint (Wedge joint structure)	➢ Using the wedge effect, segments are clamped by pulling together to each other. ➢ Joints have high rotational rigidity, making it difficult to transform segments. ➢ Wedges are driven in the axial direction of the tunnel so that joints will not be exposed in the tunnel. 
 Screw bolt joint (Pin insertion joint structure)	➢ Segments are clamped by pressing them together, resulting in higher work efficiency. ➢ Setting a proper margin between the pin and the pin pore size, it is possible to resist the drawing force with the frictional force.  

Design of Discharge facility*

Discharge tunnel: Facility overview/design

Discharge outlet caisson: Facility overview/design

Responses to the findings in the 8th Review Meeting

* This report describes the examination results that the design complies with the standards and criteria for general civil engineering structures and has sufficient safety, durability, earthquake resistance, etc.

Discharge outlet caisson: Facility overview/design

Facility overview

Design of discharge outlet caisson (structure)

2.1.1. Discharge outlet caisson; facility overview

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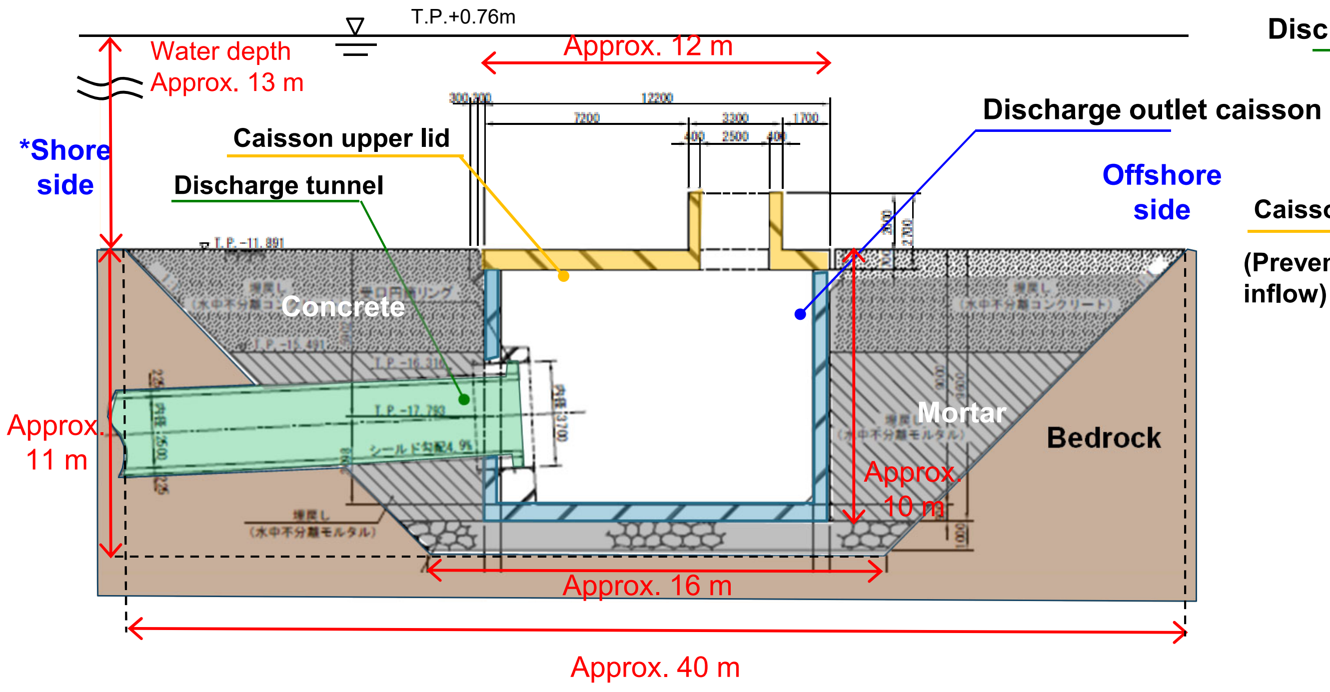
Specifications of discharge outlet caisson

Framework dimensions	Width approx. 9 m x Length approx. 12 m x Height approx. 10 m

Specifications of the caisson upper lid

Dimensions	Width approx. 9 m x Length approx. 12 m x Height approx. 1 m



Sectional view of discharge outlet

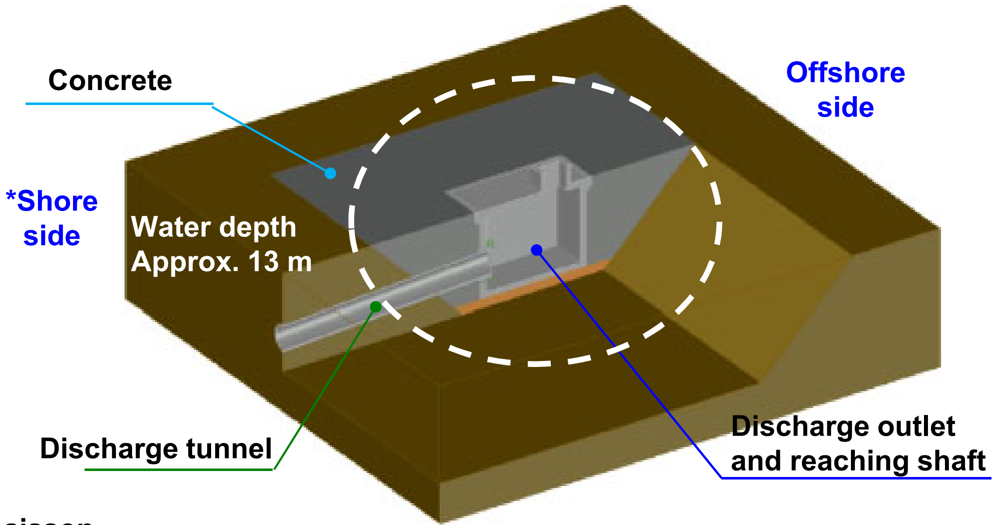


Image drawing of the discharge outlet

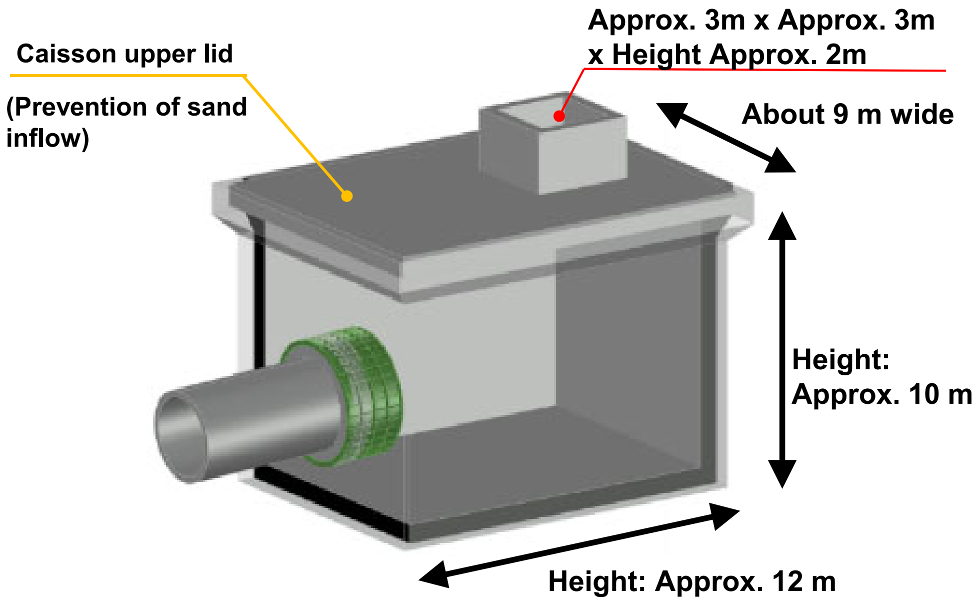


Image drawing of the discharge outlet (magnified view)

[Reference] Image drawing of discharge outlet caisson

- "Reaching pipe" will be installed inside the discharge outlet caisson to have the shield machine reach.
- To ensure that the shield machine reaches the discharge outlet caisson accurately, the measurement turret will also be installed in advance to manage information related to the location of the discharge caisson and the shield machine.
- The shield machine will eventually be pulled out of the sea with the reaching pipe.

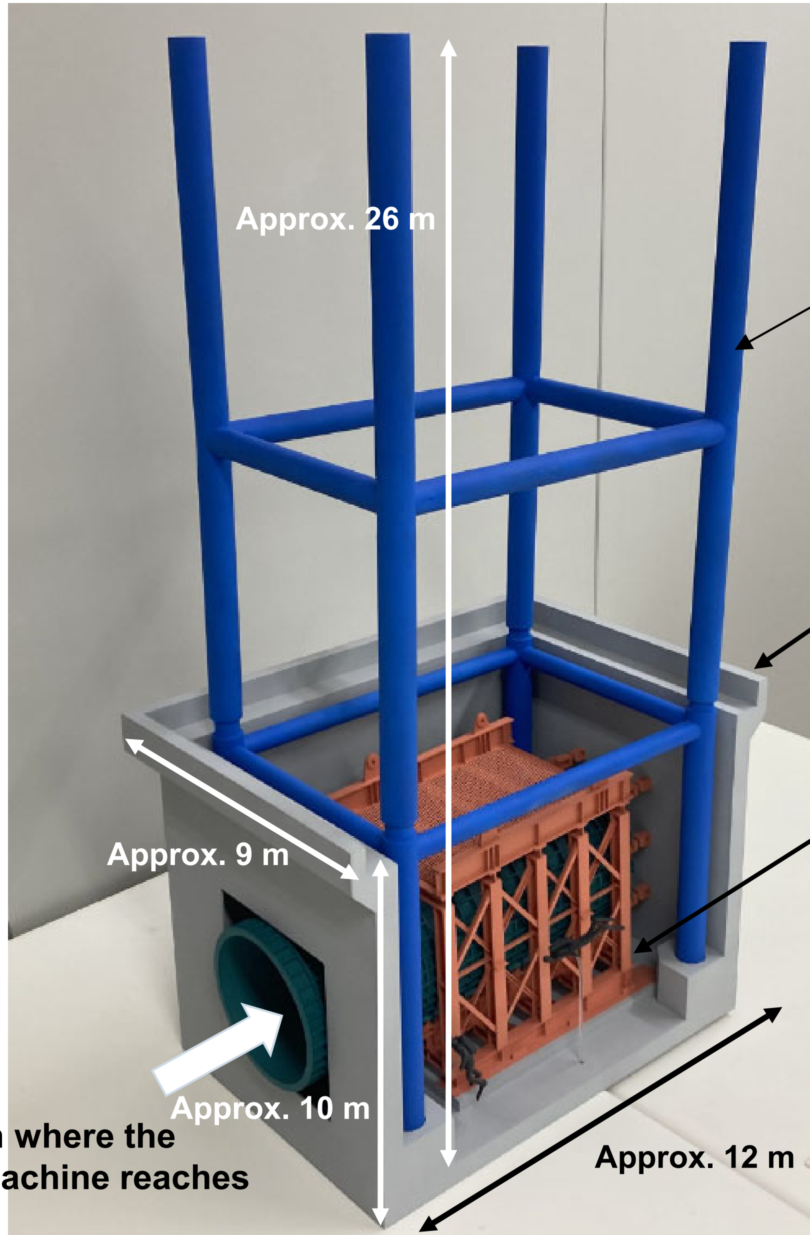


Image drawing of discharge outlet caisson

Discharge outlet caisson: Facility overview/design

Facility overview

Design of discharge outlet caisson (structure)

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

2.2.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [1] Applied codes and standards"

- Design, selection of materials, fabrication and inspection of SSCs with safety function shall conform to those codes and standards which are considered to be appropriate taking into account importance of their safety function, respectively.

- Design, selection of materials, and manufacturing are evaluated in accordance with the following:
  - Design of Civil Engineering Structures of Thermal and Nuclear Power Plants (enlarged and revised edition), Electric Power Civil Engineering Association
  - Concrete Standard Specifications (Design Edition); Established in 2017), Japan Society of Civil Engineers
  - Concrete Standard Specifications (Structural Performance Examination Edition); established in 2002), Japan Society of Civil Engineers*
  - Tunnel Standard Specifications [Common Edition] and Explanation/[Shield Method Edition], Explanation (established in 2016), Japan Society of Civil Engineers
  - Tunnel Standard Specifications for Excavating Methods and Explanation (established in 2016)
  - Technical Standards and Explanations of Port Facilities 2018: The Ports and Harbors Association of Japan
  - Specifications for Highway Bridges and Explanation I, Common Edition, 2017, Japan Road Association
  - Specifications for Highway Bridges and Explanation IV, Lower Structure Edition, 2017, Japan Road Association
  - Common Ditch Design Guideline 1986, Japan Road Association
  - Guide to Tunnel Lining Structural Design under Internal Water Pressure (established in 1999), (Advanced Construction Technology Center) *
  - Seismic Countermeasures Guideline and Explanation for Sewerage Facilities - 2014 Edition, Japan Sewage Works Association*
  - Public Works Research Institute Materials: Seismic Design Methods and Guidelines for Large-Scale Underground Structures (Draft) - March 1992, Public Works Research Institute, the Ministry of Construction, and Seismic Research Institute, Earthquake Disaster Prevention Department*
  - Earthquake-resistance calculation examples for sewage facilities, Conduit Facility Edition, 2015 ver., Japan Sewage Works Association*
  - Standard Segment for Shielding Work (established in 2001) co-edited by Japan Society of Civil Engineers and Japan Sewage Works Association *

*Red: Applied to discharge outlet design

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

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

2.2.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [2] Design considerations for natural phenomena" (earthquakes)

- SSCs with safety function shall be provided with appropriate seismic categories considering the importance of their safety function and possible safety impact caused by loss of function due to earthquake, and be designed to sufficiently withstand design seismic load considered to be appropriate.

➢ Based on the fact that Discharge facility will treat the drainage water from ALPS Treated Water dilution/discharge facilities (water diluted with seawater and in which the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1), the facilities are classified as Seismic Class "C" due to the impact of radiation to the public due to loss of functions of facilities.

(Implementation Plan: II-2-50-Attachment 5-1)

[Evaluation method]

✓ It should be Seismic Class "C," and the examination should be carried out using horizontal design seismic coefficient of kh = 0.2.

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

2.2.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [2] Design considerations for natural phenomena" (natural phenomena other than earthquakes)

- SSCs with safety function shall be designed so that the safety of the facilities may not be impaired by postulated natural phenomena other than earthquake (such as tsunami, heavy rain, typhoon and tornado, etc.). SSCs with safety function of especially high importance shall be designed taking into account appropriate combination of conditions considered to be severest among predictable natural phenomena or natural load together with accident load.

- Tsunami (Implementation Plan: II-2-50-8)
  - Since inundation against tsunami is inevitable, specifications with wave pressure resistance should be provided according to the recoverability .
- Typhoon (storm surges) (Implementation Plan: II-2-50-8)
  - The design should also take into account the effects of sea-level rise due to typhoons (storm surges).

[Evaluation method]

- ✓ Wave pressure resistance performance is evaluated against a tsunami equivalent to the Japan Trench tsunami.
- ✓ Consideration is given to waves equivalent to the design wave height (50-year-probability significant wave height: 7.0 m, period: 15.0 seconds).

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

2.2.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations [4] Design considerations for fire"

- The facilities shall be designed so that safety may not be impaired by fire, by combining appropriately protective measures such as fire prevention, fire detection, fire extinguishing and mitigation of fire effect.

- Fire (Implementation Plan: II-2-50-8)
  - In order to avoid fire occurrence, non-flammable or flame-retardant material should be used as much as it is practically possible. The fire risk is extremely low because the inside of the facilities are filled with seawater.

[Evaluation method]

✓ No concern about fire is expected due to the underwater facility.

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

2.2.1 Compliance assurance to the matters for which measures should be taken

"14. Design considerations (8) Design considerations for reliability"

- SSCs with safety function and monitoring function shall be designed so that their adequately high reliability may be ensured and maintained.

- Structure (Implementation Plan: II-2-50-7)
  - Discharge facility is grounded to bedrock so that the structure will not be easily affected by an earthquake. The discharge tunnel is to be installed inside the bedrock. The shield method is adopted in consideration of the risk of advancing the seabed and its durability during the service period. Water cut-off performance is secured by providing a sealing material on a lining plate made of reinforced concrete constituting a discharge tunnel.

- Considerations for integrity (Implementation Plan: II 2-50-7)
  - The structure is established by confirming that it is within the allowable stress intensity for stationary, wave, and earthquake loads. It has also been confirmed that there is no structure uplift.In addition, the crack width and salt damage to be generated in the reinforced concrete framework are examined, and it has been confirmed that the durability during the service period is ensured by setting proper rebar cover. During the service period, the reinforced concrete framework should be designed conservatively until maintenance is not required. (The periodic inspection is carried out based on the long-term inspection plan.)

*Red: Applied to the design of discharge outlet caisson

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

2.2.1 Compliance assurance to the matters for which measures should be taken

"14. Design Considerations (8) Design considerations for reliability" (continued)

- By examining Discharge facility as per the below table, it has been confirmed that durability during the service period will be ensured.

Examination items for Discharge facility

Examination item		Discharge vertical shaft (Down-stream storage)	Discharge tunnel	Discharge outlet	Contents of examination
In normal times	Structure	○	○	○*	It should be within allowable stress intensity.*1
	Structure (High wave)		○*	○	It should be within allowable stress intensity.*1
	Crack	○	○	○	The crack width should equal or less than the allowable crack width. *2
	salt damage	○	○	○	Chloride ion concentration at the position of steel materials should not reach the corrosion limit of steel materials.*2
	Uplift	○		○	There should be no uplift.
At the time of the earthquake		○	○	○	It should be within allowable stress intensity against earthquakes.*3

*1. Safety: The stress intensity of the material caused by the action of the load should be within the allowable stress intensity.
*2. Durability: During the design service period, the performance of the structure should not deteriorate due to corrosion of steel materials caused by cracks or intrusion of chloride ions.
*3: Seismic resistance: Examination should be performed with Seismic class C.

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

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

2.2.2 Compliance assurance to the matters for which measures should be taken (allowable stress intensity of primary materials)

- Stress intensity examination
  - Of the materials used for the Discharge facility, concrete should be ordinary concrete (Ordinary Portland Cement, blast furnace cement B type), and the design-basis strength should be 24N/mm², 30N/mm², and 42N/mm². The rebar should be SD345.
  - Verify whether the stress intensity of the material caused by the action of the load is within the allowable stress intensity.

*Red: Applied to the design of discharge outlet caisson

Allowable stress intensity of concrete

Design basis strength of concrete	Long-term		Short-term		Remarks
	Compression (N/mm²)	Shear (N/mm²)	Compression (N/mm²)	Shear* (N/mm²)	
24N/mm²	9.0	0.45	13.5	0.675	Discharge vertical shaft (Down-stream storage)
30N/mm²	11.0	0.50	16.5	0.75	Discharge outlet
42N/mm²	16.0	0.73	24.0	1.095	Discharge tunnel

Allowable stress intensity of rebar

Material used	Long-term	Short-term
	Tension (N/mm²)	Tension (N/mm²)
SD345	200	300

- As a result of stress intensity examination, it was confirmed that the proof stress is ensured.

Load combination

Areas for study	In normal times	At high wave	At the time of the earthquake
Dead load	○	○	○
Water pressure (buoyancy)	○	○	○
Pressure from the head loss	○	○	○
Wave force		○	
Seismic inertial force			○
Dynamic water pressure			○

- The operating stress is compared with the allowable stress. The results of examining the part where the ratio of the operating stress to the allowable stress is maximum and the load case are shown in the table below.
- It has been confirmed that it is within the allowable stress intensity (operating stress/allowable stress intensity < 1.00) for stationary, wave, and seismic loads.

Results of stress intensity examination

Areas for study	Load case	Target material	Stress	Operating stress (N/mm^2)	Allowable stress (N/mm^2)	Operating stress/ Allowable stress
Base	In normal times*	Concrete	Shear force	0.23	0.50	0.46
Sidewall	In normal times*	Concrete	Shear force	0.24	0.50	0.48

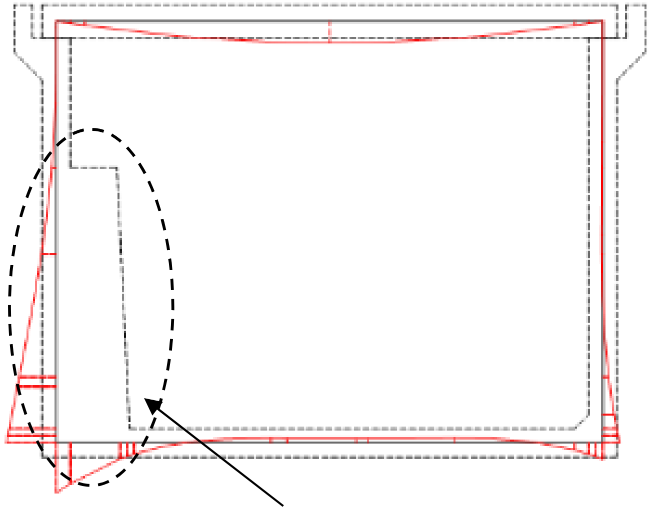
*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

Location where the maximum stress is generated

Results of stress intensity examination (constantly)

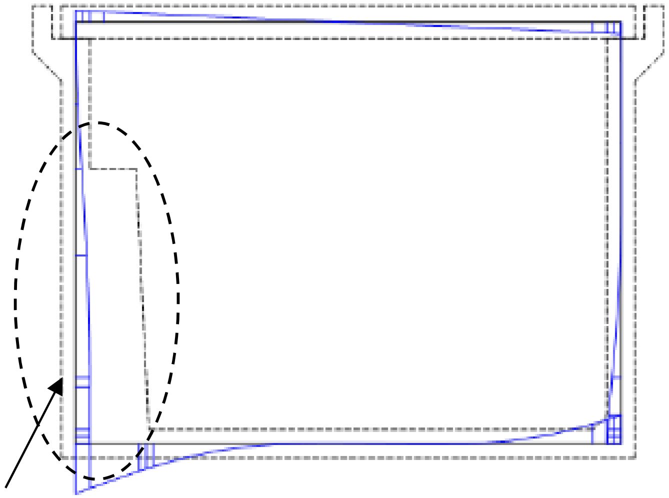
Areas for study	Stress intensity examination (Operating/Allowance)	
	Bending moment	Shear force
Base	0.41	0.46
Sidewall	0.41	0.48

*Red: maximum value for stress intensity examination

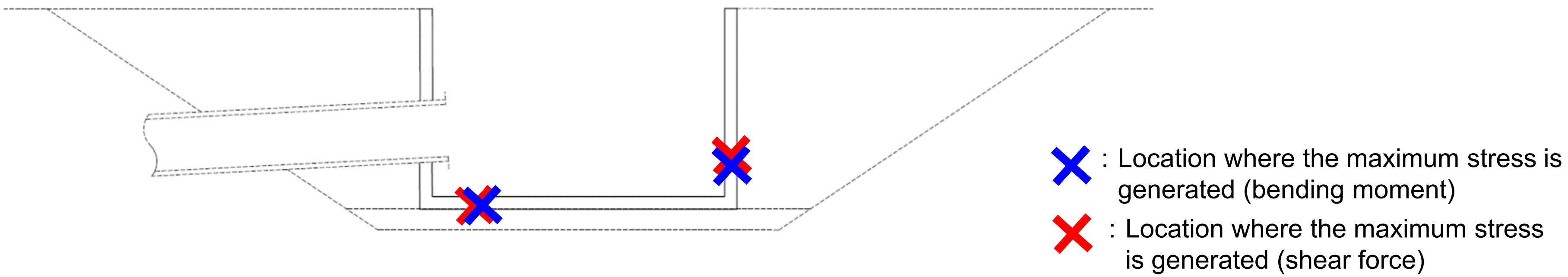


The thickness of the member is increased to reinforce the opening.

Section force diagram (bending moment)



Section force diagram (shear force)



Cross-sectional view

2.2.5 Compliance assurance to the matters for which measures should be taken (durability evaluation (crack width))

Examination of crack width

- The crack width is examined by the following formula to confirm that the crack width "w" of the concrete surface is equal to or less than the limit value w_a of the crack width against corrosion of steel materials.

  $w / w_a \leq 1.0$

Crack Width w

$$w = 1.1 \cdot k_1 \cdot k_2 \cdot k_3 \{4c + 0.7(c_s - \phi)\} \left[\frac{\sigma_{se}}{E_s} + \varepsilon'_{csd} \right]$$

Where:

k_1: A coefficient representing the effect of crack width on the surface shape of steel materials. In general, it is 1.0 for deformed bars.

k_2: A coefficient by which the quality of the concrete affects the crack width based on the following formula:

$$k_2 = \frac{15}{f'_c + 20} + 0.7$$

f'_c: A compressive strength of concrete (N/mm^2), generally using design compressive strength f'_{cd}

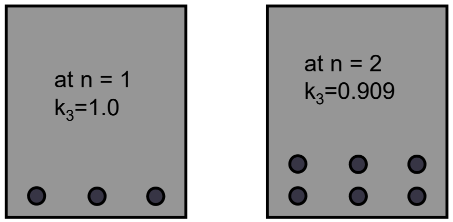
k_3: A coefficient representing the effect of the number of stages "n" of tensile steel materials based on the following formula:

$$k_3 = \frac{5(n+2)}{7n+8}$$

c: Cover (mm), c_s: Center spacing of steel material (mm), φ: Steel material diameter (mm),

σ_{se}: Increase in stress intensity in the rebar (N/mm^2);

ε'_{csd}: Strain to take account of increase in crack width due to shrinkage and creep of concrete



Schematic diagram of the relationship between the number of tensile steel material stages n and k_3

(When examining the corrosion of steel materials, the value of ε'_{csd} is about 150×10^{-6}.)

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

2.2.6 Compliance assurance to the matters for which measures should be taken (durability evaluation (salt damage))

Examination for salt damage

- Confirm that the chloride ion concentration at the position of steel materials does not reach the corrosion limiting concentration of steel materials during the design service life.
- The limit value of crack width against corrosion of steel materials is determined according to environmental conditions, covering, and type of steel materials.
- The crack width limit should be 0.0035c (inner side) to 0.004c (outer side) (mm)*. (c: Pure covering)

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

	Examination formula
Calculation formula of design diffusion coefficient	$D_d = \gamma_c \cdot D_k + \lambda \cdot \left(\frac{w}{l}\right) \cdot D_0$
Calculation formula of the chloride ion concentration design value at the position of steel materials	$C_d = \gamma_{cl} \cdot C_0 \cdot \left\{1 - erf\left(\frac{0.1 \cdot C_d}{2 \cdot \sqrt{D_d \cdot t}}\right)\right\} + C_i$
Examination formula of the chloride ion concentration at the position of steel materials	The design value of chloride ion concentration at the position of steel materials is equal to or less than the corrosion occurrence limiting concentration of steel materials. $\gamma_i \cdot \frac{C_d}{C_{lim}} \leq 1.0$

D_d: Design diffusion coefficient
D_k: Characteristic value of diffusion coefficient for chloride ion of concrete (cm^2/year)
D_0: Coefficient representing the effect of cracks on the transfer of chloride ion in concrete (cm^2/year). ~~In general, it is 200 cm^2/year.~~
*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan
400 cm^2/year
w: Crack width (mm)
w_a: Limit value of crack width for corrosion of steel materials (mm)
w/l: Ratio of crack width to crack spacing
C_d: Design value of the chloride ion concentration at the position of steel materials
γi: Structure coefficient. In general, it is 1.0.cc

2.2.7 Compliance assurance to the matters for which measures should be taken (durability evaluation (results of evaluating durability))

- As a result of examining crack width and salt damage of a discharge outlet caisson, it has been confirmed that durability during the service period is ensured.

[Examination of crack width]
The bending crack width generated in a discharge outlet is compared with the allowable bending crack width. The examination result of the portion where the ratio of the generated bending crack width to the allowable bending crack width is maximum is shown in the table below.

Examination results of crack width

Areas for study	Generated bending crack width (mm)	Allowable bending crack width (mm)	Generated bending crack width/Allowable bending crack width
Base	0.262	0.400	0.66
Sidewall	0.302	0.400	0.76

[Examination for salt damage]
Chloride ion concentration in a discharge outlet is compared with the corrosion limiting concentration of rebars. The results of examining the portion where the ratio of chloride ion concentration at the position of rebars to the corrosion limiting concentration of rebars is the maximum are shown in the table below.

*According to the Technical Standards and Explanations of Port Facilities 2018: The Ports and Harbors Association of Japan.

Results of examination for salt damage

Areas for study	Chloride ion concentration at the position of rebars (kg/m^3)	Corrosion limiting concentration of rebars (kg/m^3)	Concentration of chloride ion at the position of rebars/Corrosion limiting concentration of rebars
Base	1.93	2.00	0.97
Sidewall	1.95	2.00	0.98

Examination of uplift

Uplift is examined by the following formula.

$Fs = W/U$
$U = Vw \cdot \gamma w$

U: Buoyancy (kN)
W: Vertical load (kN/m)
Vw: Capacity equal to or less than the underground water level (m^3)
γw: Unit weight of water (seawater) (kN/m^3)

Safety factor for uplift

	When in service	
Applicable conditions	In normal times	At high wave
Uplift safety factor	1.20	

- As a result of checking the uplift of a discharge outlet caisson, it has been confirmed that durability during the service period is ensured.

The following table shows the results of examining the uplift of a discharge vertical shaft (down-stream storage).

Examination results for uplift

	At high wave
Calculated value	1.99*
Uplift safety factor	1.20

*Optimizing description in Attachment 5 of Chapter II 2.50 of the Implementation Plan

Design of Discharge facility*

Discharge tunnel: Facility overview/design

Discharge outlet caisson: Facility overview/design

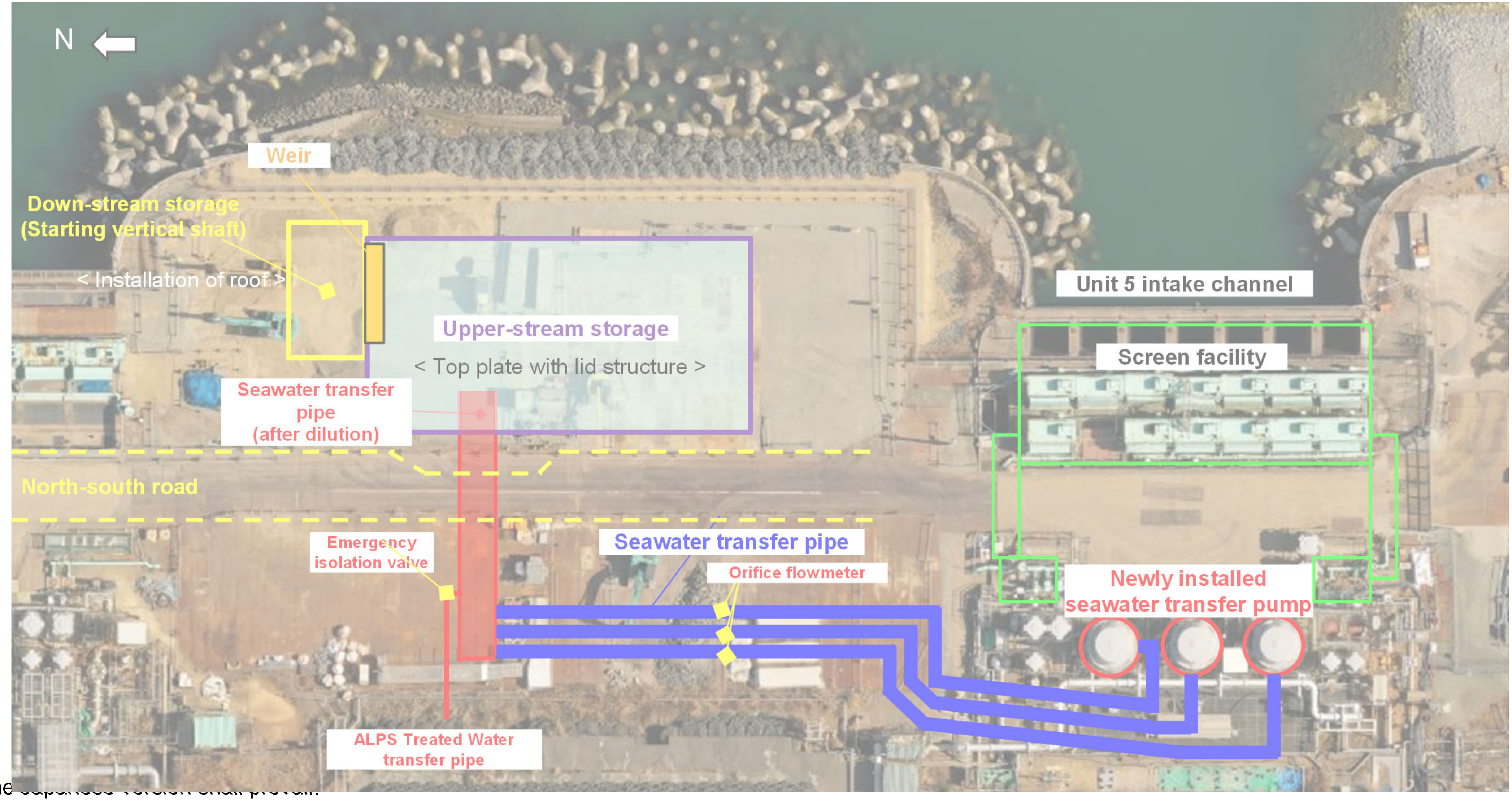
Responses to the findings in the 8th Review Meeting

- Natural disaster countermeasures are mentioned as the merits of determining the structure of the discharge vertical shaft. Explain mitigation in disaster damage risk (it will be inundated, but the direct wave force will be mitigated) with the actual layout.
- It was explained that the durability of the discharge vertical shaft (down-stream storage) is ensured by using shear reinforcement, but the details of calculation should be explained as well.

* This report describes the examination results that the design complies with the standards and criteria for general civil engineering structures and has sufficient safety, durability, earthquake resistance, etc.

3.1 Layout of Dilution facility and Discharge facility (excluding discharge tunnel and outlets)

- From the perspective of natural disaster countermeasures, placing water storage in front of the seawater transfer pipe (orifice flow measurement range) can reduce the risk of damage at times of storm surge and frequent tsunamis (about 2 m (about once every 10 years)). (it may be flooded but can mitigate the direct wave forces)



3.2 Evaluation result of shear force of discharge vertical shaft (down-stream storage)

TEPCO

Results of examining the stress intensity (shearing force) in a discharge vertical shaft (down-stream storage)

- The stress intensity of the discharge vertical shaft (down-stream storage) was examined, and the result was that the shear stress acting on the concrete exceeded the allowable stress.

Results of stress intensity examination (shear force)

Areas for study	Operating stress (N/mm^2)	Allowable stress (N/mm^2)	Operating stress/ Allowable stress
Base	0.52	0.45	1.16
Sidewall	0.72	0.45	1.60

Results of examining shear reinforcement

- Although the shear force acting on the concrete exceeds the allowable stress, for the excess portion, the shearing strength is secured by arranging shear reinforcement.
- Regarding the evaluation method, by converting the shear force borne by the shear reinforcement into the required cross-sectional area of the rebar, we will check that the gross-area-sectional area of the shear reinforcement to be arranged ensures the required cross-sectional area of the rebar.
- As shown in the table below, it was confirmed that the gross cross-sectional area exceeds the required cross-sectional area.

Results of evaluating the shear reinforcement

Areas for study	Gross cross-sectional area (cm^2)	Required cross-sectional area (cm^2)	Required cross-sectional area/gross cross-sectional area
Base	661.9	446.8	0.68
Sidewall	1290.2	738.8	0.57

The following slides are for reference.

[Reference] Overview of the ALPS Treated Water Dilution/Discharge Facilities

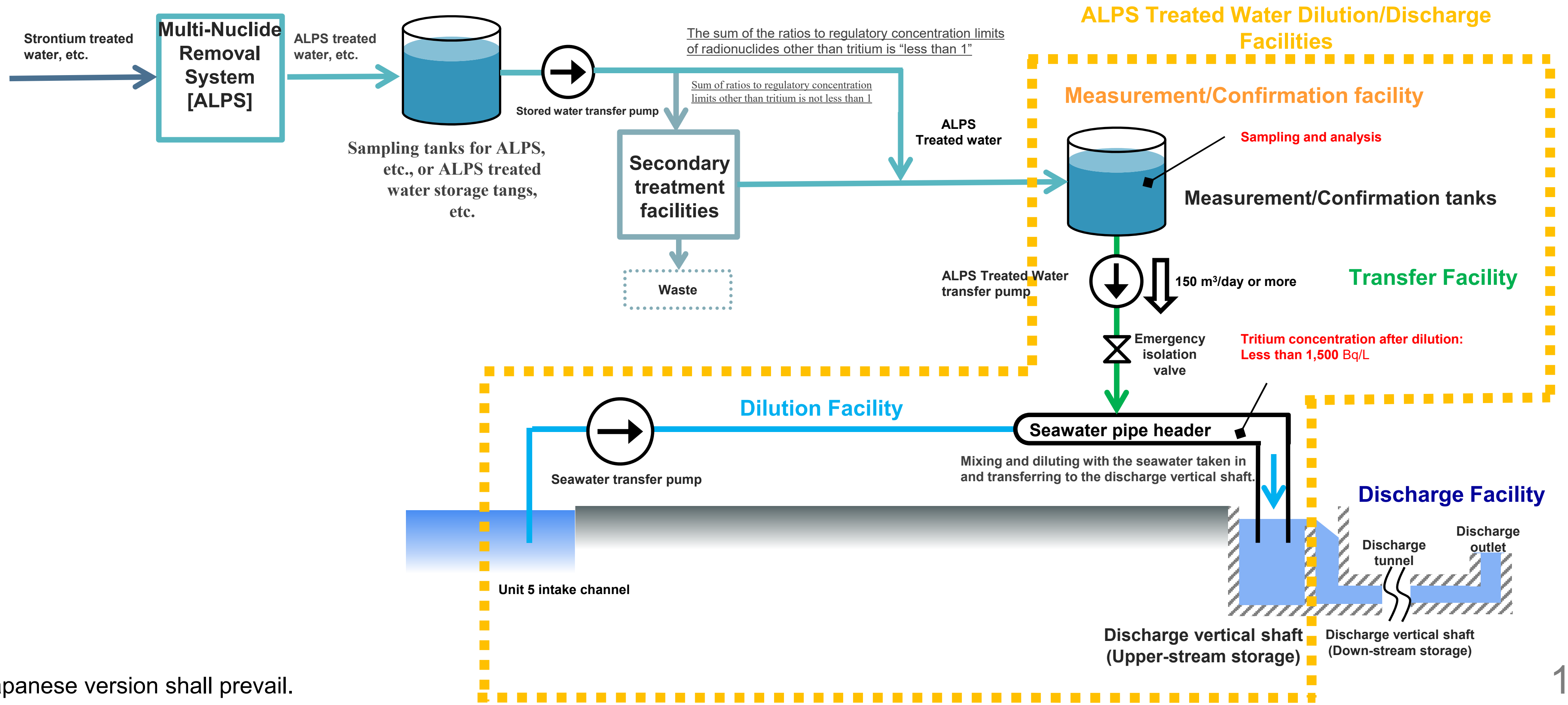
TEPCO

Objective

The facilities ensure that the water treated by Multi-Nuclide Removal System (ALPS) until the radionuclide concentration becomes sufficiently low is the ALPS Treated Water (that is the water in which sum of the ratios to regulatory concentration limits other than tritium is less than 1), and dilute the treated water with seawater, then discharge it into the sea.

Facilities Overview

The Measurement/Confirmation Facility homogenizes the concentration of radionuclides all tanks of the tank group in the status of measurement/ confirmation, and then collects and analyzes samples to ensure that the water is ALPS treated water. Thereafter, the Transfer Facility sends the ALPS Treated Water to the seawater pipe header, and then the Dilution Facility dilutes the water with seawater taken in by the seawater transfer pump at the unit 5 intake channel until tritium concentration in it becomes less than 1,500 Bq/L, and discharge the water to the Discharge Facility.



[Reference] Overview of the ALPS Treated Water Dilution/Discharge Facilities (Measurement/Confirmation facility)

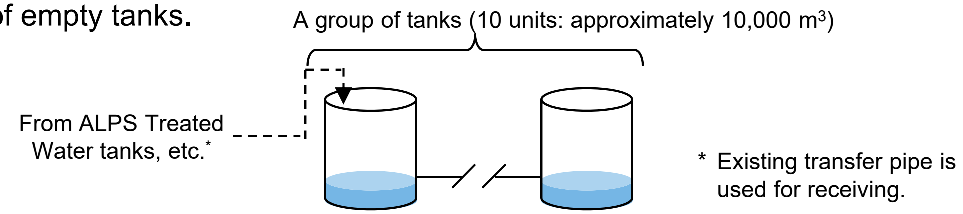
TEPCO

Measurement/Confirmation facility

- K4 area tanks (approx. 30 000 m^3 in total) are reused for the Measurement/Confirmation tanks, and each group from A to C consists of 10 tanks (approximately 1,000 m^3 per unit).
- Each tank group takes the following steps (1) to (3) in rotation, and in the (2) Measurement/Confirmation process, water is circulated and stirred to become homogenized, and then sampled for analysis.

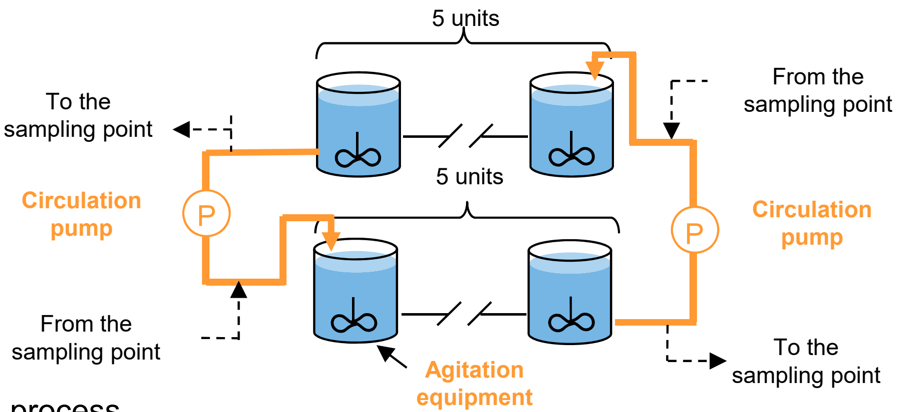
(1) Receiving process

ALPS Treated Water from ALPS Treated Water storage tanks, etc., is transferred into a group of empty tanks.



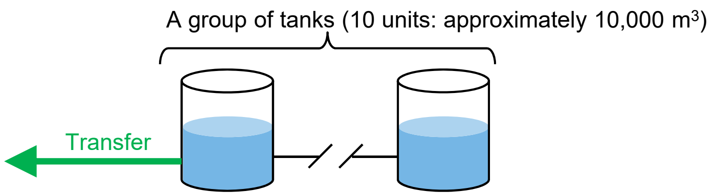
(2) Measurement/Confirmation process

After the quality of water in the tank group is homogenized by the agitation equipment and circulation pumps, the water is sampled to check if it meets the discharge standard.

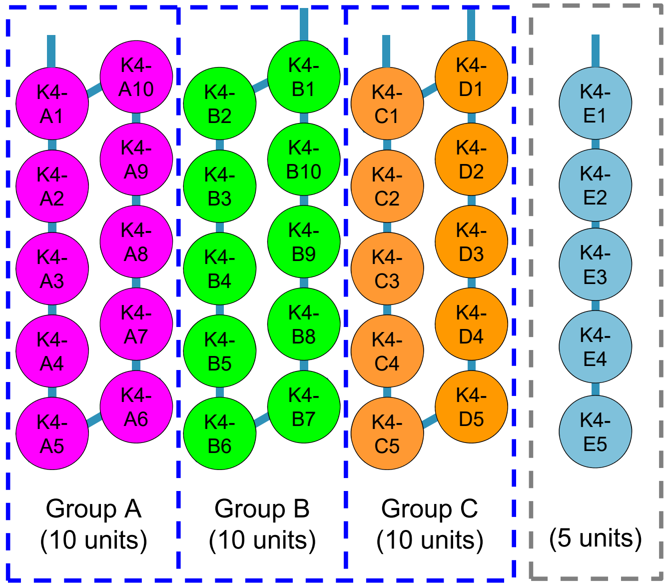


(3) Discharge process

After confirming that the ALPS Treated Water satisfies the discharge standard, the water is transferred to the Dilution Facility by the Transfer Facility.



K4 area tank groups: (35 units)



Chapter 2.50 ALPS Treated Water Dilution/Discharge facility

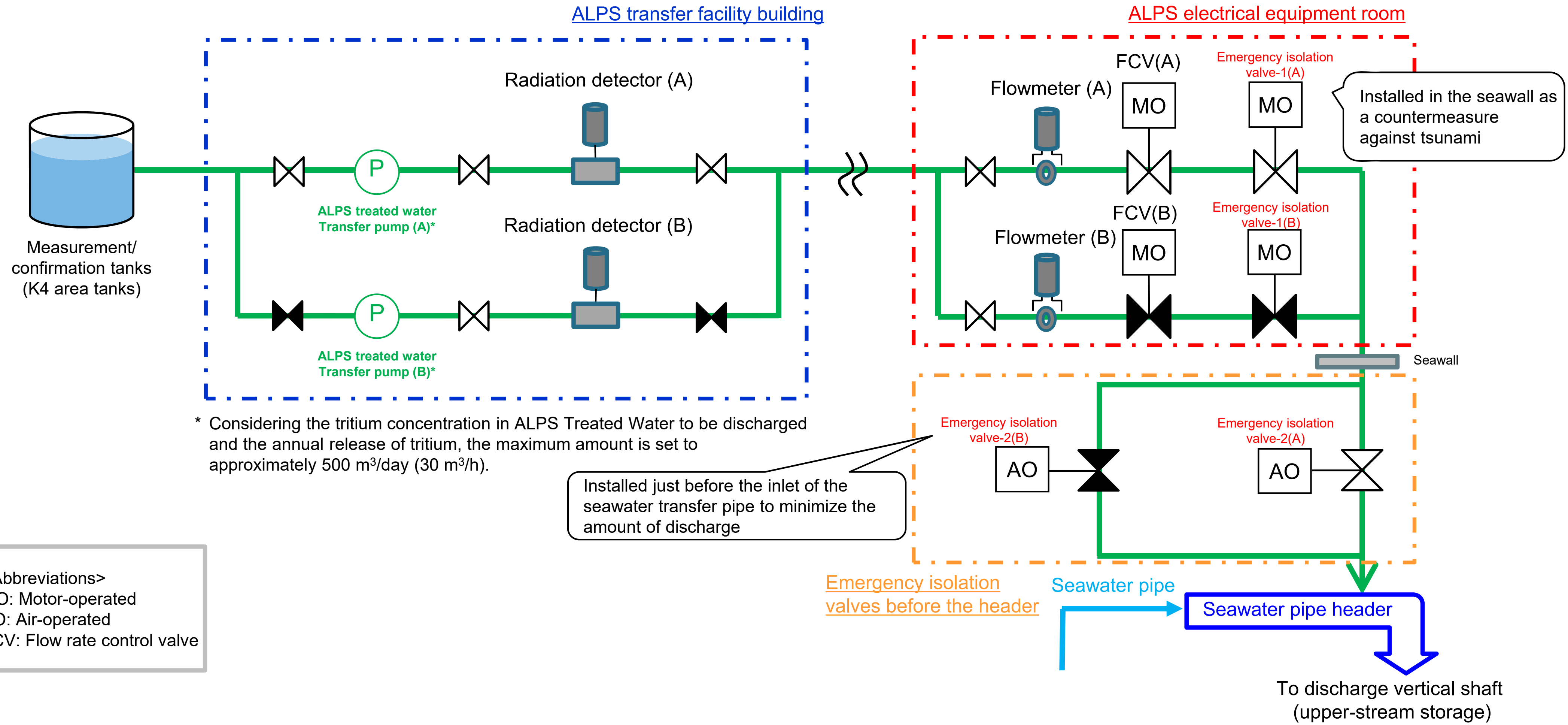
Chapter 2.5 ALPS Treated Water tanks

	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

[Reference] Overview of the ALPS Treated Water dilution/discharge facilities (Transfer facility)

Transfer Facility

- The Transfer Facility consists of ALPS Treated Water transfer pumps and transfer pipes.
- Two ALPS Treated Water transfer pumps are prepared, a unit in operation and the other backup unit, to transfer ALPS Treated Water from Measurement/Confirmation tanks to the Dilution Facility.
- Emergency isolation valves are provided both before the seawater piping header and in the seawall as a countermeasure against tsunami so that the transfer can be stopped immediately when an abnormality occurs.



* Considering the tritium concentration in ALPS Treated Water to be discharged and the annual release of tritium, the maximum amount is set to approximately 500 m^3/day (30 m^3/h).

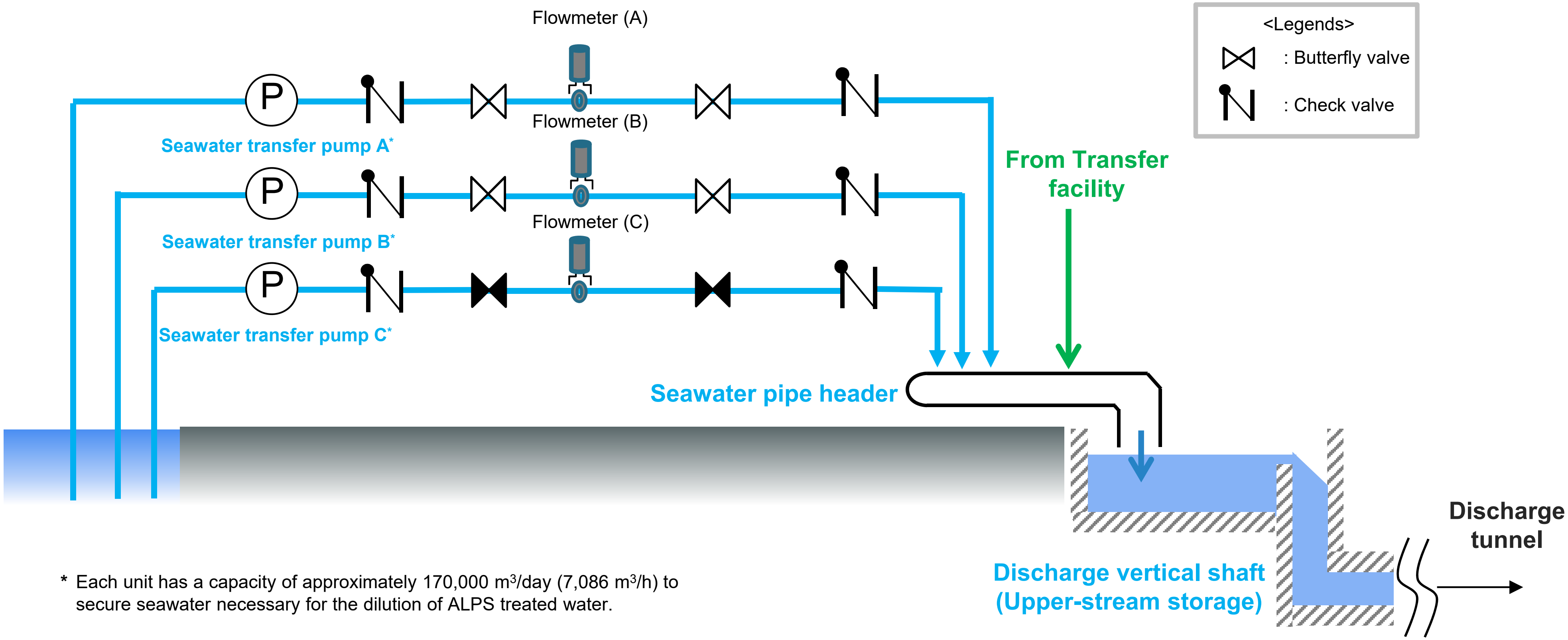
<Abbreviations>
MO: Motor-operated
AO: Air-operated
FCV: Flow rate control valve

[Reference] Overview of the ALPS Treated Water dilution/discharge facilities (Dilution facility)

TEPCO

Dilution facility

- Consisting of seawater transfer pumps, seawater pipe (including a header pipe), a discharge guide, and a discharge vertical shaft (upper-stream storage), the dilution facility dilutes the ALPS Treated Water with seawater, transfer it to the discharge vertical shaft (upper-stream storage), and discharge it to the Discharge facility.
- The seawater transfer pumps have a capacity that can dilute ALPS Treated Water transferred by the Transfer facility 100 times or more.



* Each unit has a capacity of approximately 170,000 m³/day (7,086 m³/h) to secure seawater necessary for the dilution of ALPS treated water.

[Reference] Overview of Related facility (Discharge facility)

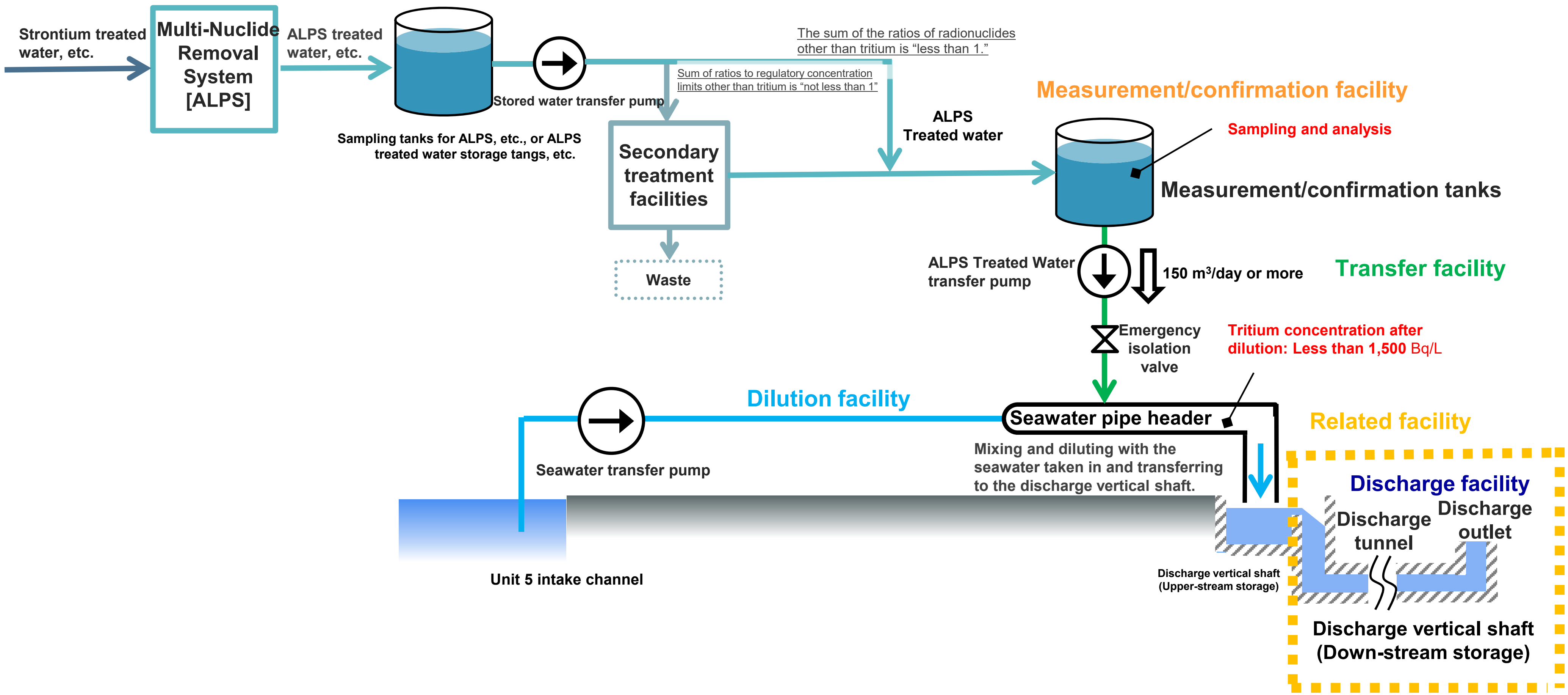
TEPCO

Objective

Drainage water is discharged from the ALPS Treated Water dilution/discharge facilities (water diluted with seawater that satisfies the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1) into the sea from a location approximately 1 km away from the coast.

Facility overview

The Discharge facility consist of a discharge vertical shaft (down-stream storage), a discharge tunnel, and a discharge outlet to achieve the above objective.

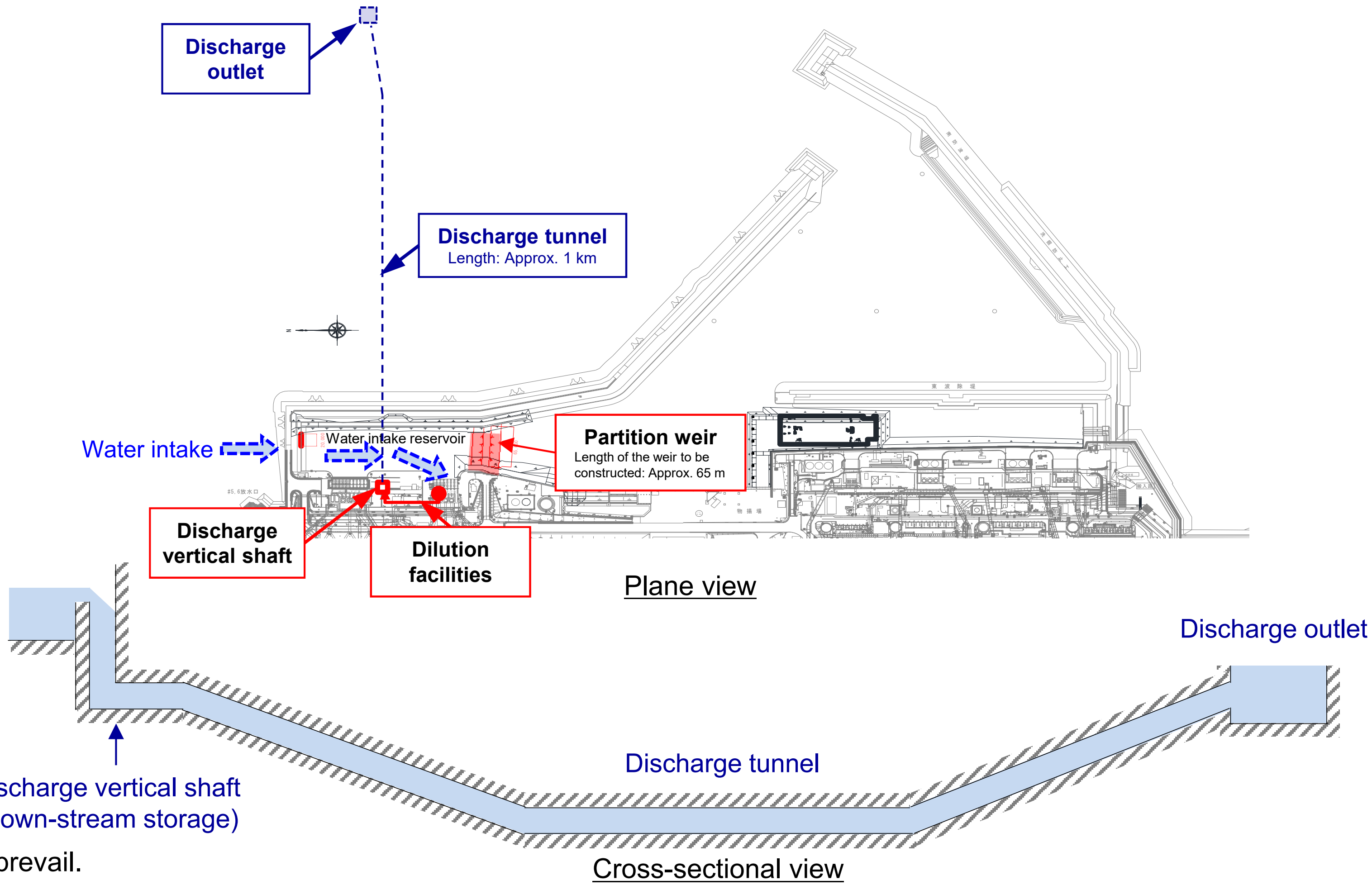


[Reference] Overview of Related facility (Discharge facility) (1/2)

TEPCO

Discharge Facility

- Discharge Facility has a design so that they can transfer water flowing out over the partition wall in the discharge vertical shaft to the outlet, which is approximately 1 km away from the shore, by using the water head difference between water in the discharge vertical shaft (down-stream storage) and the sea surface. In addition, the design concept includes friction losses in the Discharge Facility and elevation of water surface.



[Reference] Overview of Related facility (Discharge facility) (2/2)

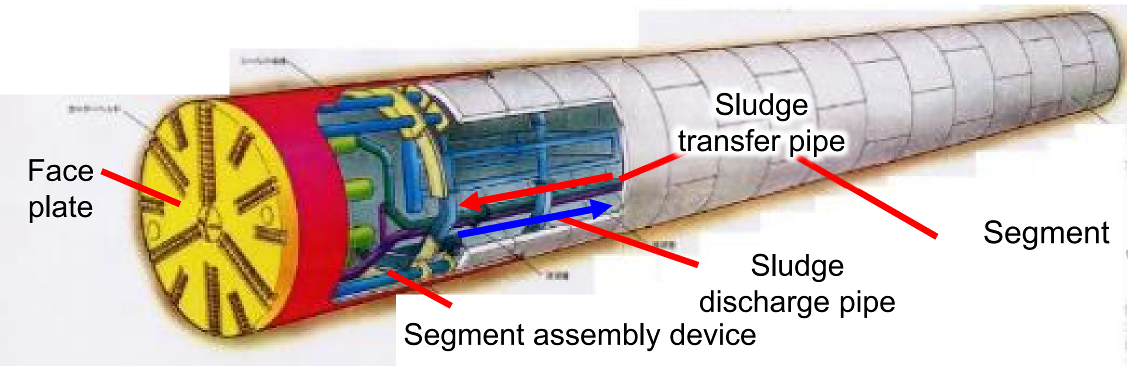
TEPCO

Overview of the structural design

- Water is made to flow through the bedrock layer to minimize the leakage risk and to ensure a highly earthquake-resistant structure.
- A shield method is adopted and double-layer seals are installed in the reinforced concrete segment to ensure water cut-off performance.
- The tunnel body (segment) is designed considering the impacts of typhoons (high waves) and storm surges (sea level rise).

Construction of tunnel (shield method)

- As there are many discharge tunnels constructed by the shield method, secure construction will minimize the possibility of trouble.



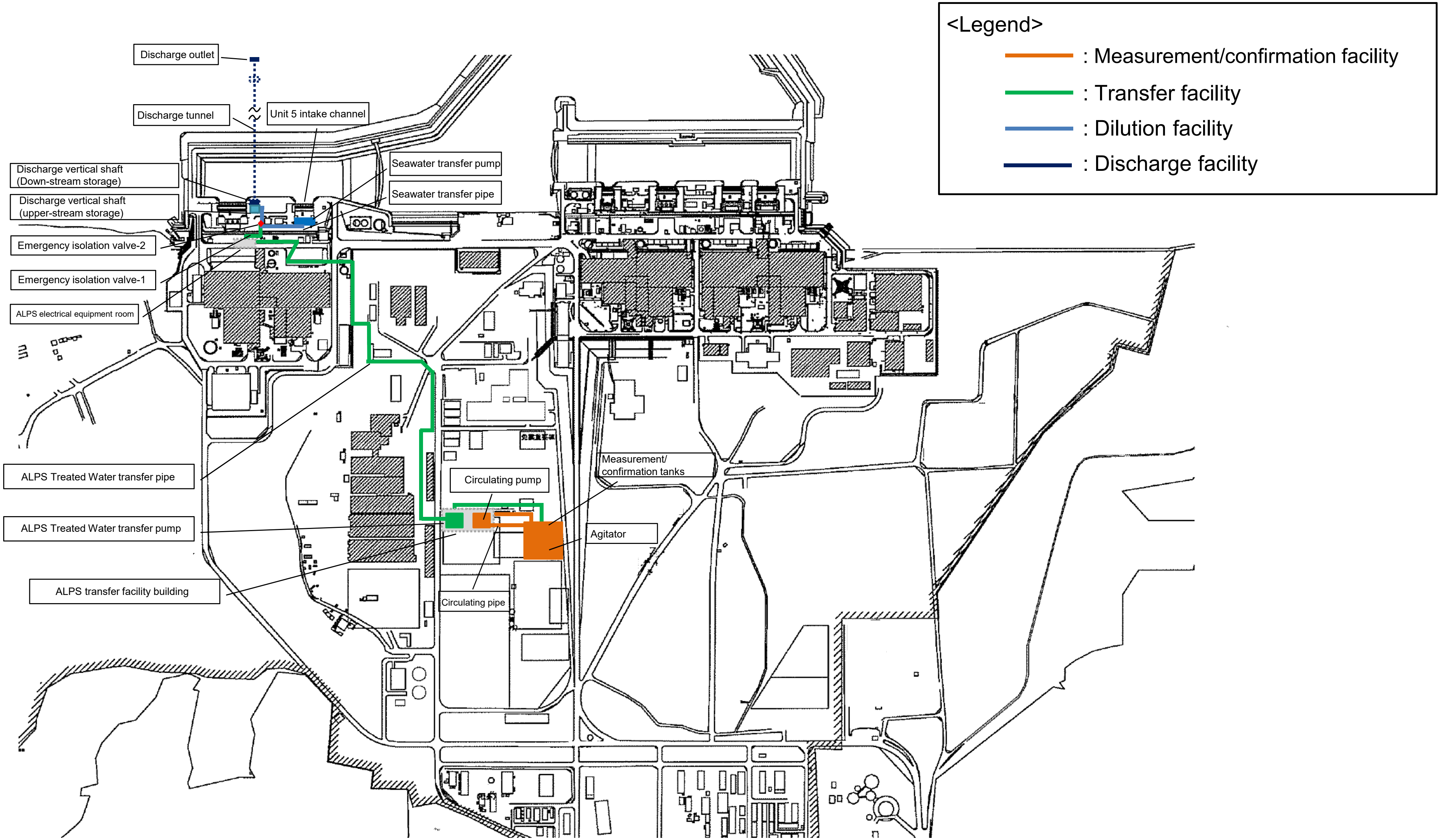
*The slurry shield method is adopted this time.

Schematic diagram of a shield machine

Segment

[Reference] Layout plan of ALPS Treated Water dilution/discharge facilities and Related facility

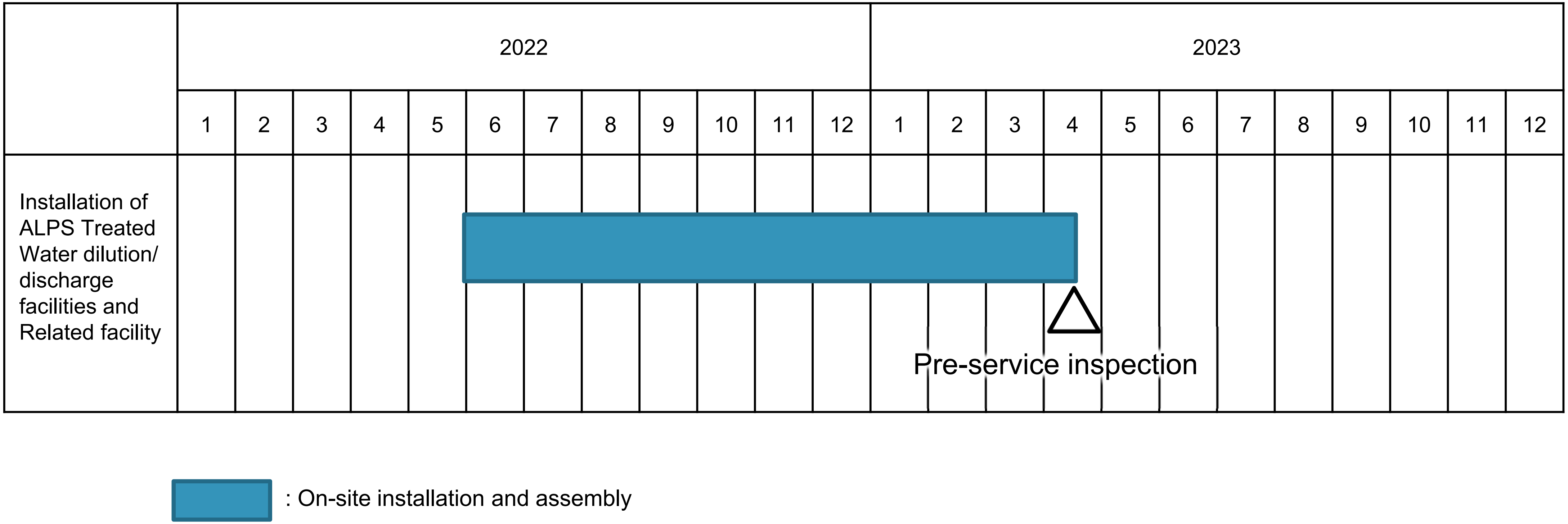
- The layout of ALPS Treated Water dilution/discharge facilities and Related facility is as follows. (Implementation Plan: II-2-50-Attachment 1-2)



[Reference] Installation schedule for ALPS Treated Water dilution/discharge facilities and Related facility

TEPCO

- Once the approval is granted after review by the Nuclear Regulatory Authority, the on-site installation and assembly of the facilities will commence, and completion is scheduled for around mid-April 2023. (Implementation Plan: II-2-50-Attachment 6-1)



The Japanese version shall prevail.

[Reference] Required function of the ALPS Treated Water dilution/discharge facilities

TEPCO

[1] The discharge capacity into the sea must be larger than the amount of contaminated water generated (increase due to inflow of groundwater and rainwater).

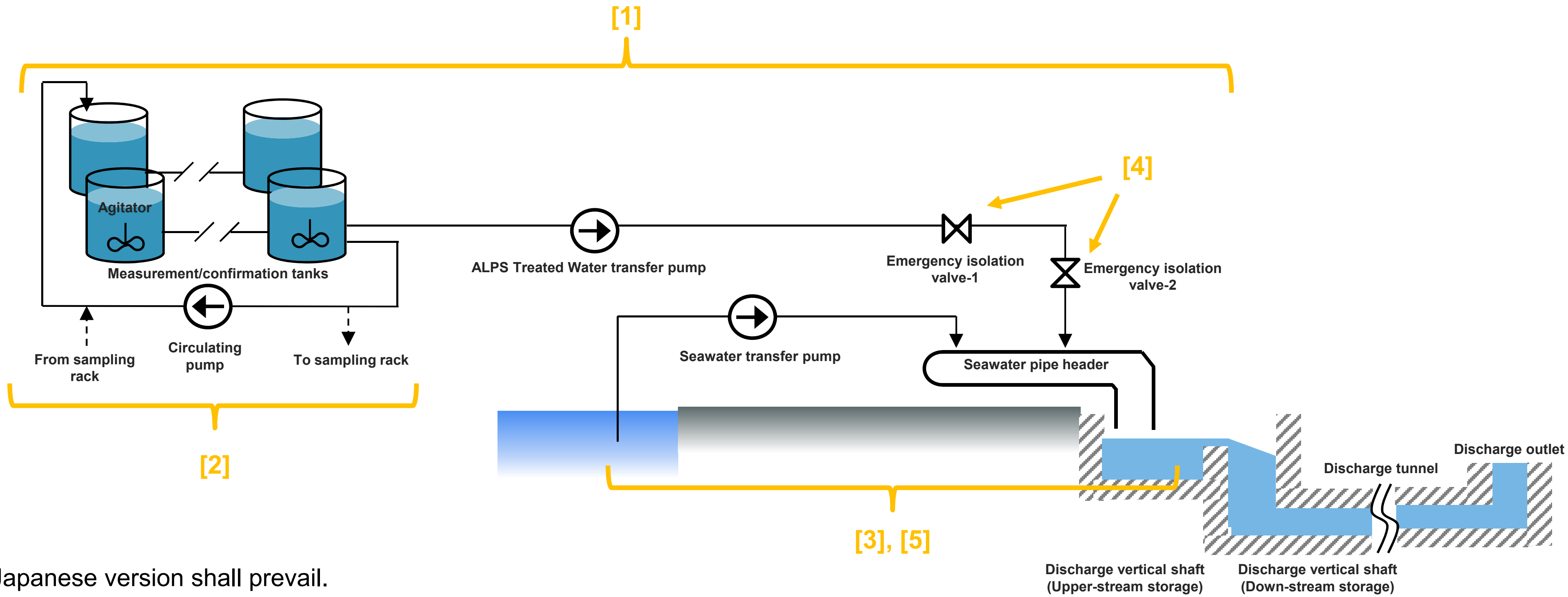
[2] To ensure that the undiluted water before discharge is ALPS treated water, the facilities must be able to homogenize the concentration of radioactive materials in a tank and a tank group and collect samples.

[3] The facilities must dilute ALPS Treated Water with seawater and discharge it into the sea.

[4] The facilities must be equipped with functions to immediately stop the discharge of ALPS Treated Water into the sea in the event of an abnormality.

[5] The facilities must be capable of diluting ALPS Treated Water 100 times or more with seawater so that the tritium concentration in the diluted water becomes sufficiently below the regulatory concentration limit (60,000 Bq/L).

(Implementation Plan: II-2-50-1)



[Reference] Required functions of the Discharge facility (1/2)

[1] The facilities should be able to discharge the water from the ALPS Treated Water dilution/discharge facilities (water diluted with seawater so that the sum of the ratios to regulatory concentrations limits of all radionuclides including tritium is less than 1) into the sea from a location approx. 1 km away from the coast.

(Implementation Plan: II-2-50-7)