(Provisional Translation)

Evaluation of the Tokyo Electric Power Company's Report Regarding Tank Area In-Dike Rainwater Leakage at the Fukushima Daiichi Nuclear Power Station

Nuclear Regulation Authority (NRA)
March 30, 2016

1. Outline

At around 12:10 on September 11, 2015, a subcontractor employee who was patrolling the contaminated water storage system (hereinafter referred to as "tank patrol") found rainwater (hereinafter referred to as "in-dike rainwater") leaking from a joint of the H4 north tank area foundation's circumferential dike (hereinafter referred to as "inner dike"). Also at around 17:35 on September 14, 2015, a contractor employee found in-dike rainwater leaking from the H6 tank area inner dike. In each area, work for stopping the leakage using water-stopping material and temporary measures such as water level reduction by transferring the in-dike rainwater were carried out. As a result, the leakage stopped. The locations and situations of the leakage are summarized in Figure 1 and Table 1.

On September 15, 2015, the NRA received a report from the Tokyo Electric Power Company (hereinafter referred to as "TEPCO") based on the provision of Article 62-3 of the Reactor Regulation Act. On December 22, 2015, the NRA received from TEPCO a report stating the causes of and measures against said events (hereinafter referred to as "the report," which was partially corrected as of February 26, 2016) and assessed it.

Moreover, as in similar events, in-dike rainwater leaked from the H5, C east and C west tank areas' inner dikes on September 9, 2015 and from the H1 east tank area's inner dike on September 30, 2015. The report also included measures against these cases of leakage.

The report from TEPCO:
http://www.nsr.go.jp/activity/bousai/trouble/houkoku/00000041.html (Japanese only)

2. Summary of the report from TEPCO

(1) Assessment of radioactive leakage and environmental impact

① H4 north tank area

On the basis of the volume of in-dike rainwater leakage (about 924 L) and total beta nuclide concentration (1,200 Bq/L), leaked radioactivity was estimated at about 1.2×10^6 Bq (see Table 2).

Since no leakage was found from the circumferential dike (hereinafter referred to as "outer dike") that surrounds the H4 north tank area's inner dike and because the stop valve of the outer dike had been closed before the events occurred, it was judged that no leakage water outflowed into a drainage channel. Since a side-ditch drainage radiation monitor installed in the drainage channel C

did not show a significant difference before and after the leakage, no environmental impact is considered to have occurred (see Figure 2).

② H6 tank area

Based on the volume of in-dike rainwater leakage (about 300 L) and total beta nuclide concentration in the in-dike rainwater (300 Bq/L), the radioactivity of the leaked water was estimated to be about 9.0×10^4 Bq (see Table 2).

Since the leaked water did not reach the drainage pit, it was judged that leaked water outflow into drainage channel did not take place. In addition, the readings of side-ditch drainage radiation monitor installed in drainage channel C did not show any significant variation before and after the leakage, thus there was no impact on the environment.

(2) Results of investigation of the causes

○ Inadequate level-raising (elevation) structure of the inner dike (see Figure 3)

On August 19, 2013, in response to RO concentrated water leakage in H4 north tank area, a structure for immediately making the concrete inner dike taller by adding a steel dike was adopted. The structure had a joint and mounting bolt sections between the concrete dike and the steel dike, a factor which increased the risk of water leakage from them.

○ Inappropriate pipe penetration structure (see Figure 4)

When installing pipes after the inner dike was installed, it was necessary to quickly complete the pipe installation to avoid the stagnation of contaminated water treatment, and therefore a structure where pipes penetrated the inner dike was adopted. The construction started without clarifying detailed specifications of some penetrations, thus the validity of the structure was not checked using design-stage drawings.

○ Inadequate verification of validity after water stoppage

When checking the condition of the elevated inner dike and water-stopping measure for pipe penetrations, a leak test using filtrate water was judged to be difficult because of the increased risk of raising the contaminated water volume. Instead, a visual check was performed. However, neither the reinforcement of the structure and construction method nor validity check was carried out in place of a filling water test.

○ Inadequate seepage prevention effect of polyurea (see Figures 3 and 4)

It is estimated that leakage from the H4 north, H6 and H1 east tanks' areas was due to sections where the seepage prevention effect of polyurea that was sprayed entirely over the floor and inner surfaces of the inner dike was inadequate, from which in-dike rainwater seeped through the steel dike and leaked out from sections with inadequate water-stopping work.

(3) Countermeasures

① A measure applied to the elevated inner dike's joint and mount bolts
Polyurea will be sprayed to both the inside and outside of the inner dike boundary.

② Measures applied to the inner dike's pipe penetrations
Water-stopping material will be applied to the inner and outer surfaces of the inner dike's pipe penetrations and localized water-filling tests will be performed to check for leakage.

③ A measure applied to future pipe laying
As a principle, no pipes will be made to penetrate the inner dike. If penetrating pipes are required in the future, the water-stopping structure will be doubled and localized water-filling tests will be carried out in principle.

④ Enhancement of patrols by the Facility Management Division and of inspections by the Facility Maintenance Division
The strict checking of the inner dike boundary will be ensured through tank patrols based on a tank walkdown manual. The conditions of joints and paint of the inner dike will be checked through annual inspections. Pipe penetrations will be checked through annual condition monitoring.

3. NRA's assessment of and future responses to the report

(1) Environmental impact

As a result of analyzing the readings from a side-ditch drainage radiation monitor installed in drainage channel C, which is downstream of the H4 north and H6 tank areas, as well as radioactivity at the port entrance, no significant total beta nuclide concentration difference before and after the leakage indicating leaked water outflow into the outside of the port was observed (see Figure 2). Therefore, no seawater contamination is considered to have occurred that posed health and environment concerns.

As for leakage from the H5, C east and C west tank areas, its radiation level was almost the same as or lower than that of the drainage channel C water, and as for leakage from the H1 east tank area, the leakage volume was trivial and leakage into the outer dike clearly did not occur, which suggests that no seawater contamination is considered to have happened that posed health and environment concerns.

(2) Exposure dose

With regard to workers who were engaged in tank patrols, water-stopping work, in-dike rainwater transfer, etc. their gamma radiation effective doses and beta radiation equivalent doses (skin) were well below the annual exposure limits (50 mSv for effective dose and 500 mSv for equivalent dose [skin]), which indicates that the level of radiation that workers were exposed to was not of concern (see Table 3).

(3) Countermeasures

① A measure applied to the elevated inner dike's joint and mount bolts
Polyurea will be applied to the inner dike boundary from outside, which will enhance water-stopping effect and reduce the risk of leakage.

② Measures applied to the inner dike's pipe penetrations
Pipe penetrations will be provided with water-stopping means both from inside and outside and localized water-filling tests will be carried out, which will reduce the risk of leakage.

③ Measures for future pipe-laying work
The decision to make the inner dike free of pipe penetrations, which tend to be leakage weak points, can be regarded as appropriate. The policy that if pipe penetrations become necessary in the future, the water-stopping structure will be doubled and localized water filling tests will be carried out which is considered to reduce the risk of leakage .

④ Enhancement of walkdown by the Facility Management Division and of inspections by the Facility Maintenance Division
Well-focused checking of the inner dike boundary through tank patrol is required by a guide for tank walkdown, which will ensure leakage detection.

Regarding the inner dike's joint and paint conditions, additional measures such as their inspections with no rainwater inside the inner dike are scheduled*, which can be regarded to ensure measures for checking their integrity. As for pipe penetrations, their conditions will be monitored annually, which will ensure measures for checking the integrity of water-stopping materials.

* In FY 2014, an inspection was carried out with standing rainwater in the inner dike. At that time, no abnormality was found at the section where the leakage occurred this time.

As for pipe penetration work, it was found in the 2nd operational safety inspection in FY 2015 that TEPCO had not verified the validity of pipe penetration work even when such verification was required if post-construction water-filling test was impossible. This negligence was found to correspond to an implementation plan violation. In the 3rd operational safety inspection in FY 2015, corrective actions taken by TEPCO in response to the violation notification were checked.

Judging from the above, the NRA evaluates that TEPCO will take the measures confirmed by the NRA in TEPCO's report and implement operational safety inspection, thereby taking appropriate measures to prevent the recurrence of leakage from the tank area inner dike. Also in the future, the NRA will further check the state of each measure taken by TEPCO by means such as operational safety inspections.

Table 1. In-dike rainwater leakage from each tank area (prepared by the Secretariat of NRA on the basis of the TEPCO report and a document regarding interviews with TEPCO)

Location of leakage	Date when leakage was found	Leakage situation	Emergency measure	Date when leakage was stopped
H4 north tank area	Around 12:10, Sept. 11	・Found during tank patrol by a contractor employee ・Leakage from a mount bolt hole of the joint between concrete dike and steel dike ・Pencil-size leakage ・Stop valve for the outer dike drainage pit had been closed before the leakage occurred.	・Water-stopping cement ・Water accumulated in the outer dike was transferred to the inner dike (15:55 to 22:00, September 11). ・In-dike rainwater was transferred to H6 tank area inner dike (19:50 to 22:45, Sept. 11).	14:12, Sept. 11
	Around 11:30, Sept. 12	・Found by a TEPCO employee during site patrol ・Leakage from a mount bolt section of the joint between concrete dike and steel dike ・Leakage of about 1 drop per 10 seconds ・Stop valve for the outer dike drainage pit had been closed before the leakage occurred. ・No water accumulated on the nearby floor	・Leakage was stopped using water-stopping material.	12:07, Sept. 12
H6 tank area	Around 17:35, Sept. 14	・Found during site patrol by a contractor employee ・Leakage from a pipe penetration of steel dike and from two joints for joining steel plates ・Leaked water did not reach outer dike drainage pit. Stop valve had been closed before the leakage occurred.	・Water stoppage using water-stopping material and cement (18:30, Sept. 14 to 3:00, Sept. 15 ・Collection of leaked water using water-absorbing sandbags (19:25 to 21:38, Sept. 14) ・Transfer of in-dike rainwater to rainwater tank (20:08, Sept. 14 to 1:12, Sept. 15)	7:25, Sept. 15
H5 tank area	Around 10:40, Sept. 9	・Leakage from a joint for joining the inner dike with steel dike and installing pipes ・Leakage with a width of two pencils ・When the leakage occurred, a stop valve of drainage pit in outer dike was open.	・Stop valve of drainage pit in outer dike was closed (10:45, Sept. 9) ・Sandbags and drain pans were applied to the leaking section and leaked water was collected. ・Transfer of in-dike rainwater and water accumulated in outer dike ・Water stoppage using water-stopping material	20:55, Sept. 9
C east tank area	Around 17:38, Sept. 9	・Leakage from each pipe penetration of inner dike's concrete dike section ・Leakage with a width of a pencil ・When the leakage occurred, the stop valve of drainage pit in outer dike was in a closed state.	・Water stoppage using water-stopping material ・Transfer of in-dike rainwater and water accumulated in outer dike	20:20, Sept. 9
C west tank area				22:25, Sept. 9
H1 east tank area	Around 7:48, Sept 30	・Leakage from four mount bolts of the inner dike's steel dike section ・Water oozed out. ・"Wetting" rather than leakage, with no leakage into outer dike	・Water stoppage using water-stopping material (completed at 9:35, Sept. 30) ・Wiping of wet sections	9:35, Sept. 30

Local layout drawing

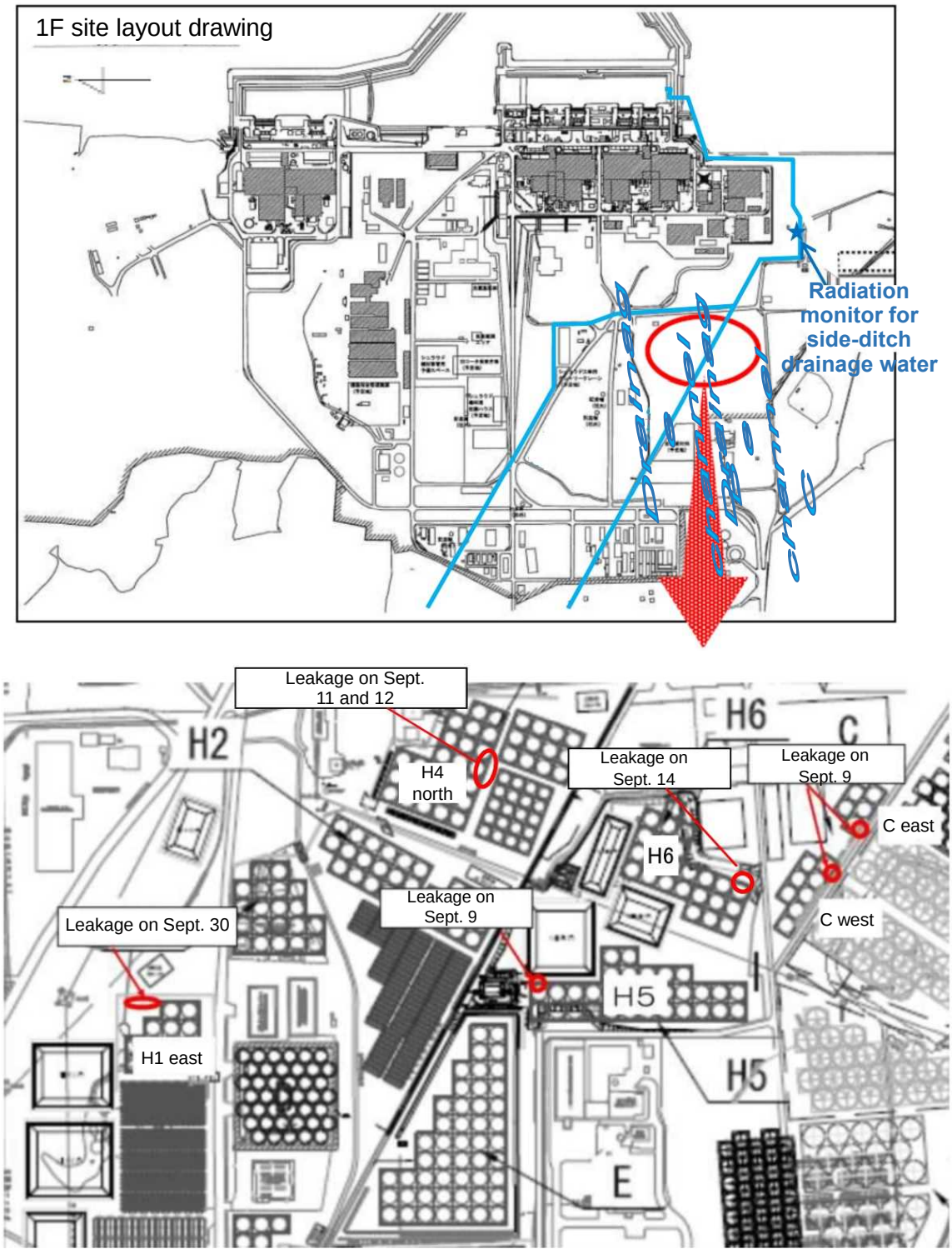
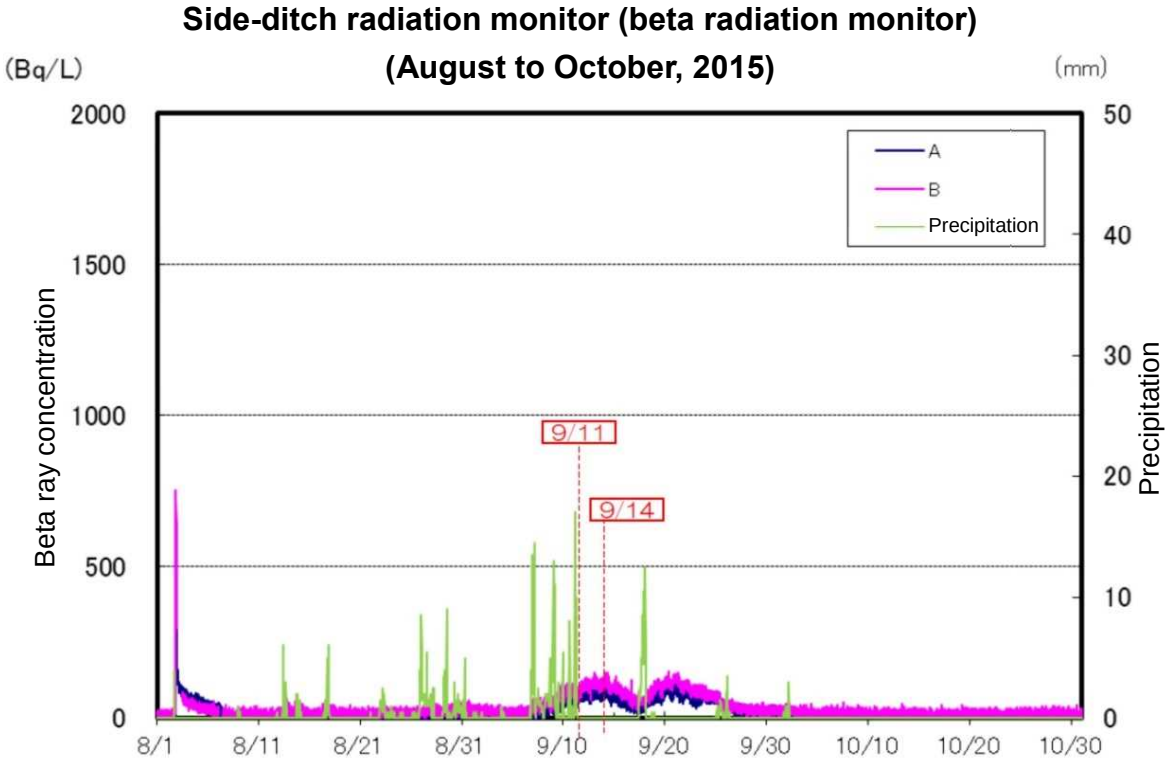


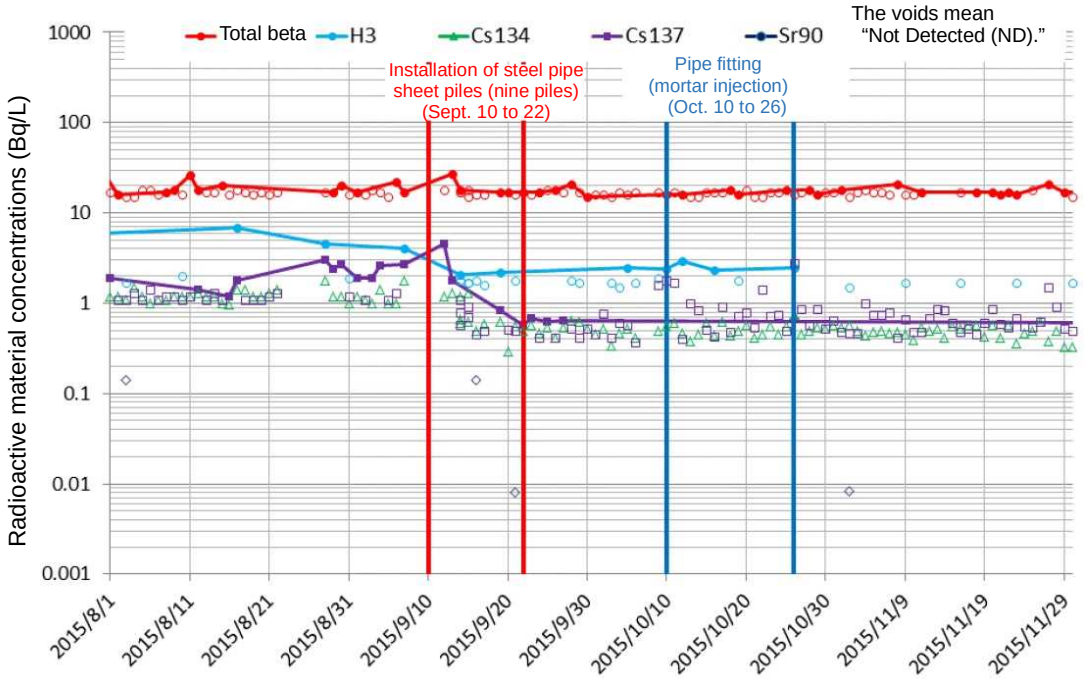
Figure 1. Layout drawing of tank area where rainwater in dike leaked (excerpt from the TEPCO report, with partial revision)

Table 2. Volume of in-dike rainwater leakage from each tank area and radioactive concentrations (prepared by the Secretariat of NRA on the basis of the TEPCO report)

Location of leakage	Volume of leakage	Radioactive concentration (Bq/L)	Notice-based concentration limit ratio	Environmental impact
H 4 north tank area	About 924 L About 1.2×10^{6} Bq (total beta)	^{134}Cs: ND (0.92) ^{137}Cs: 3.6 ^{90}Sr: 740 ^{3}H: 160 Total beta: 1,200	25	None ・No leakage was found by patrol. ・Outer dike's stop valve: Closed
H6 tank area	About 300 L About 9.0×10^{4} Bq (total beta)	^{134}Cs: ND (0.64) ^{137}Cs: 1.7 ^{90}Sr: 160 ^{3}H: ND (92) Total beta: 300	5.4	None ・Leaked water remained in the vicinity. ・Outer dike's stop valve: Closed
H5 tank area	About 63 L About 2.1×10^{3} Bq (total beta)	^{134}Cs: ND (0.58) ^{137}Cs:ND(0.73) ^{90}Sr: 17 ^{3}H: ND (91) Total beta: 34	0.57	Not significant ・When leakage occurred, outer dike's stop valve was in a closed state. ・Outer dike's stop valve: Closed
C east tank area	About 3200 L 8.0×10^{4} Bq to 9.6×10^{4} Bq (total beta)	^{134}Cs: ND (0.59) ^{137}Cs: ND (0.71) ^{90}Sr: 16 ^{3}H: ND (93) Total beta: 30	0.53	None ・Outer dike's stop valve: Closed ・Leaked water remained in the vicinity. ・Outer dike's stop valve: Closed
C west tank area		^{134}Cs: ND (0.6) ^{137}Cs: ND (0.72) ^{90}Sr: 15 ^{3}H: ND (93) Total beta: 25	0.50	
H1 east tank area	Wetting rather than leakage (unmeasurable)	^{134}Cs: ND (1.1) ^{137}Cs: 1.2 ^{90}Sr: 560 ^{3}H: 220 Total beta: 860	19	None ・Trivial (wet level) and no leakage outside the outer dike



(a) Radiation monitor readings of side-ditch drainage water (excerpt from the TEPCO report)



(b) Results of seawater monitoring at the port entrance (prepared by the Secretariat of the NRA)

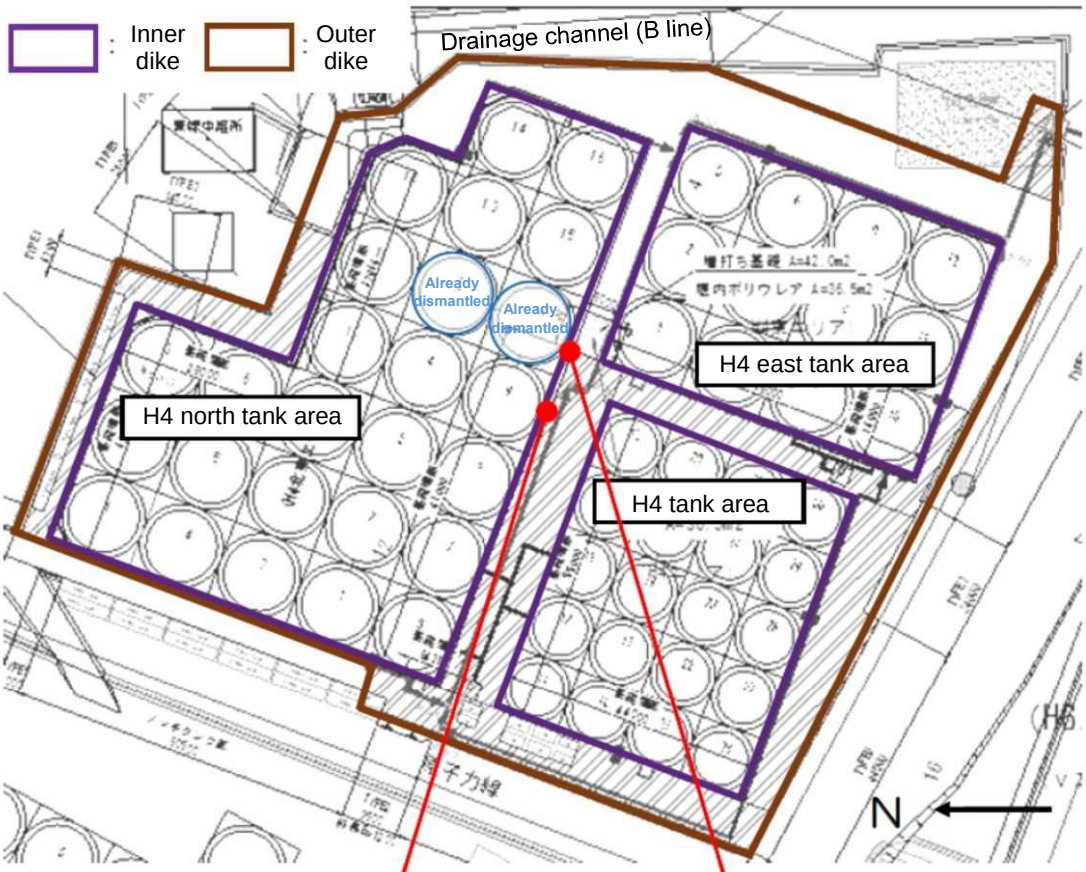
Figure 2. Side-ditch drainage water radiation monitor readings and seawater monitoring results

Table 3. Exposure assessment
(excerpt from the TEPCO report, with partial revision)

Differences in workers' exposure doses		Effective dose (gamma radiation)		Equivalent dose (skin) (beta radiation)	
		Annual dose limit: 50 mSv		Annual dose limit: 500 mSv	
		Average dose per area access (mSv)	Maximum dose per area access (mSv)	Average dose per area access (mSv)	Maximum dose per area access (mSv)
Tank patrol					
Before leakage (Sept. 2 to 8, 2015)		0.02	0.04	0.0	0.0
Date when leakage was found	H5, C east and C west tank areas (Sept. 9, 2015)	0.02	0.03	0.0	0.0
	H4 north tank area (Sept. 11, 2015)	0.02	0.02	0.0	0.0
	H6 tank area (Sept. 14, 2015)	0.03	0.04	0.0	0.0
	H1 east tank area (Sept. 30, 2015)	0.01	0.01	0.0	0.0
After leakage (Oct. 1 to 7, 2015)		0.01	0.02	0.0	0.0
Emergency measures					
H4 north	Leaking water stoppage (Sept. 11, 2015)	0.01	0.02	0.0	0.0
	Leaking water stoppage (Sept. 12, 2015)	0.01	0.02	0.0	0.0
	Transfer of water accumulated in outer dike and in-dike rainwater	0.02	0.02	0.0	0.0
H6	Leaking water stoppage (Sept 14 to 15, 2015)	0.02	0.04	0.0	0.0
	Sandbag installation and accumulated water collection (Sept. 14, 2015)	0.02	0.03	0.0	0.0
	Installation of sandbags (Sept. 15, 2015)	0.02	0.02	0.0	0.0
	Transfer of in-dike rainwater (Sept. 14 to 15, 2015)	0.00	0.01	0.0	0.0

Reference 1

- **H4 north tank area**



①

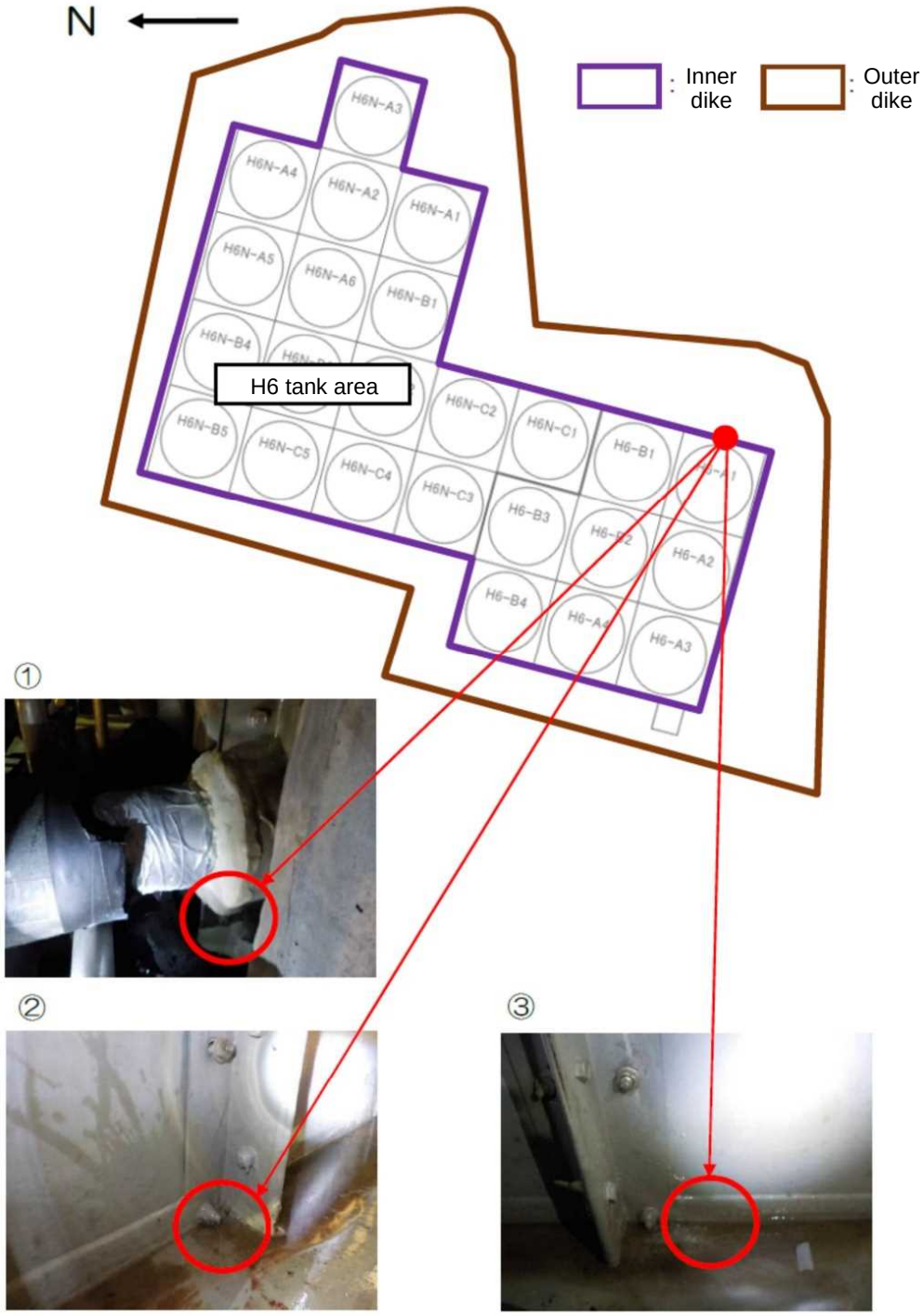
<Leakage found on Sept. 11>
①Pencil-size leakage occurred from the bolt hole.
* No damage or dent was found.

②

<Leakage found on Sept. 12>
②Leakage at a rate of one drop per 10 seconds from the bolt section
* No damage or dent was found.

Figure A. Situation of leakage at the H4 north tank area (excerpt from the TEPCO report)

- **H6 tank area**



<Leakage found on Sept. 14>
①:Leakage from a pipe penetration of steel dike
②and ③:Leakage from these two joints
(Leak level is unknown for any of these cases.)
* No damage or dent was observed.

Figure B. Situation of H6 tank area leakage
(excerpt from the TEPCO report)

Reference 2

Table. List of accident and failure-related reports based on the provision of Article 62-3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors received from TEPCO regarding its Fukushima Daiichi Nuclear Power Station

	Trouble	Date of occurrence	Report	Current situation
1	Leakage from the RO concentrated water storage tank	Aug. 19, 2013	June 30, 2014 Corrected on Oct. 31, 2014	Discussed at NRA Dec. 10, 2014
2	Leakage from the RO-treated water storage tank	Oct. 2, 2013	Dec. 6, 2013 Corrected on Oct. 31, 2014	Discussed at NRA April 15, 2015
3	Leakage from the RO-3 contaminated water treatment facility desalination system (reverse osmosis membrane system)	Oct. 9, 2013	December 6, 2013 Corrected on Oct. 31, 2014	Discussed at NRA Apr. 15, 2015
4	Leakage from the double strainer differential manometer for the water transfer pipes of the desalination system	Feb. 6, 2014	June 30, 2014 Corrected on Oct. 31, 2014	Discussed at NRA Apr. 15, 2015
5	Leakage from the RO-concentrated water storage tank (H6 area's C1 tank)	Feb. 19, 2014	January 23, 2015 Corrected on Apr. 13, 2015	Discussed at NRA Apr. 15, 2015
6	Inflow of water that accumulated in the process main building into the incineration building	Apr. 11, 2014	June 30, 2014 Corrected on Dec. 12, 2014	Discussed at NRA Apr. 15, 2015
7	Leakage from 4,000-ton square steel tank cluster	June 2, 2014	Dec. 17, 2014 Corrected on Apr. 20, 2015	Discussed at NRA Apr. 28, 2015
8	Leakage from a connection valve between A5 tank and A6 tank in the G4 South Tank Area	Sept. 4, 2014	Apr. 28, 2015 Corrected on June 5, 2015	Discussed at NRA June 17, 2015
9	Leakage from piping transferring treated water at the Multi-nuclide Removal System (Advanced Liquid Processing System: ALPS)	Dec. 17, 2014	June 3, 2015	Discussed at NRA July 15, 2015
10	Alarm set off from a side-ditch effluent radiation monitor	Feb. 22, 2015	July 3, 2015 Corrected on Aug. 10, 2015	Discussed at NRA Sept. 2, 2015
11	Leakage from contaminated-water transfer hose	May 29, 2015	Aug. 28, 2015 Corrected on Dec. 16, 2015	Discussed at NRA Jan. 20, 2016
12	Tank area in-dike rainwater leakage	Sept. 15, 2015	Dec. 22, 2015	Discussed at NRA March 30, 2016