FY2016

Results of the Radioactive Material Monitoring in the Water Environment

March 2018

Ministry of the Environment

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Note: ND stands for “Not detectable” in this report.

Outline

Following is an outline of the results of monitoring for radioactive material carried out in FY2016 based on the Water Pollution Control Act. Monitoring locations are as shown in Figure 1 and Figure 2.

1. National Radioactive Material Monitoring in the Water Environment in the Whole of Japan (FY2016)

○ Monitoring commenced in FY2014 at 110 public water areas and groundwater locations in 47 prefectures in Japan for the purpose of clarifying the distribution of radioactive materials in those areas nationwide (hereinafter referred to as "Nationwide Monitoring").

○ The total β radioactivity and the detected γ-ray emitting nuclides were within past measurement trends[1]. Detection limits differ by nuclide and sampling location, but overall were around 0.001 to 0.1 Bq/L in water and around 1 to 100 Bq/kg in sediments[2,] (“Bq/kg” of sediment indicates “dried sediment” in this report, and the same shall apply to Radioactive Material Monitoring performed in Fukushima prefecture and the surrounding areas, and other national radioactive material monitorings performed.).

○ There were locations where the value of K-40 and total β radioactivity were elevated in both public water areas and groundwater, but these levels were thought to have been influenced by seawater or soil / rocks.

○ As for other naturally occurring radionuclides, Pb-212 was detected in higher concentrations at some locations for groundwater than in past results. Pb-212 is in the thorium series, and generally occurs naturally in soil / rocks.

○ At some public water area monitoring locations, the artificial radionuclides Cs-134 and Cs-137 were detected exceeding their detection limits, but their values were within the past measurement trends.

○ It is appropriate to continue this monitoring the following fiscal year onward in order to clarify the distribution of radioactive materials in the water environment.

2. Radioactive Material Monitoring in the Water Environment in and around Fukushima Prefecture (FY2016)

○ In response to the accident at the Tokyo Electric Power Company’s Fukushima Daiichi NPS (hereinafter referred to as the "Fukushima NPS Accident"), monitoring has been conducted continuously since August 2011 at around 600 locations for public water areas and around 400 locations for groundwater in and around Fukushima prefecture for the purpose of clarifying the distribution of the accident-derived radioactive materials in the water environment (hereinafter referred to as "Post-Earthquake Monitoring").

○ A summary of the radioactive cesium measurement results after the commencement of the FY2016 monitoring is as follows.

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[1] "Within the past measurement trends" means that the results of the latest monitoring survey are evaluated from a technical perspective as not displaying extreme deviation from the results of past similar monitoring surveys.

[2] See Table 3.1-1, Table 3.1-2, and Table 3.1-3 in Part 1 of this report for the details of the detection limits.

<Public water areas>

1) Water (detection limit: 1 Bq/L for both Cs-134 and Cs-137)

- At most locations, radioactive cesium was not detectable, although several locations showed a positive result for these radionuclide.

2) Sediments (detection limit: 10 Bq/kg for both Cs-134 and Cs-137)

[Rivers]

- Overall, the levels of both Cs-134 and Cs-137 were 200 Bq/kg or less at most locations, though they were detected in relatively higher levels at some limited locations, such as those within 20 km of Tokyo Electric Power's Fukushima Daiichi Nuclear Power Plant. Changes in activity concentrations were observed as a decreasing trend at most locations.

[Lakes]

- Overall, the levels of both Cs-134 and Cs-137 were 3,000 Bq/kg or less at most locations, though they were detected in relatively high levels at some limited locations, such as those within 20 km of the power plant. Activity concentrations were observed to be decreasing or unchanged, except for some locations which showed fluctuations.

[Coastal areas]

- Overall, the levels of both Cs-134 and Cs-137 were 200 Bq/kg or less at most locations. Changes in activity concentrations were observed generally as decreasing or unchanged at most locations except for several locations that showed fluctuations.

< Groundwater >

- Radioactive cesium was not detected in groundwater at any surveyed locations in FY2016 (detection limit: 1 Bq/L for both Cs-134 and Cs-137).

○ The results concerning radionuclides other than radioactive cesium were as follows.

•Sr-89: Was not detected at any surveyed groundwater locations.

•Sr-90: Was detected in collected sediments at several public water area locations, but basically remained at relatively low levels; was not detectable at any surveyed groundwater locations.

○ Measured activity concentrations have fluctuated at some locations. There is a possibility that this is due to the effects of the Fukushima nuclear accident, but the fluctuations could also be due slight differences in sampling locations and the properties of individual samples. Therefore, it is appropriate to continue this monitoring on an ongoing basis over the following fiscal years.

3. Other Radioactive Material Monitoring Conducted Nationwide (FY2016)

○ The results of the Monitoring of Environmental Radioactivity Levels (hereinafter referred to as "Monitoring of Levels"), which has been conducted by the Nuclear Regulation Authority for the purpose of clarifying the existence or nonexistence of the influence of nuclear facilities, etc. nationwide, were almost all within the past measurement trends.

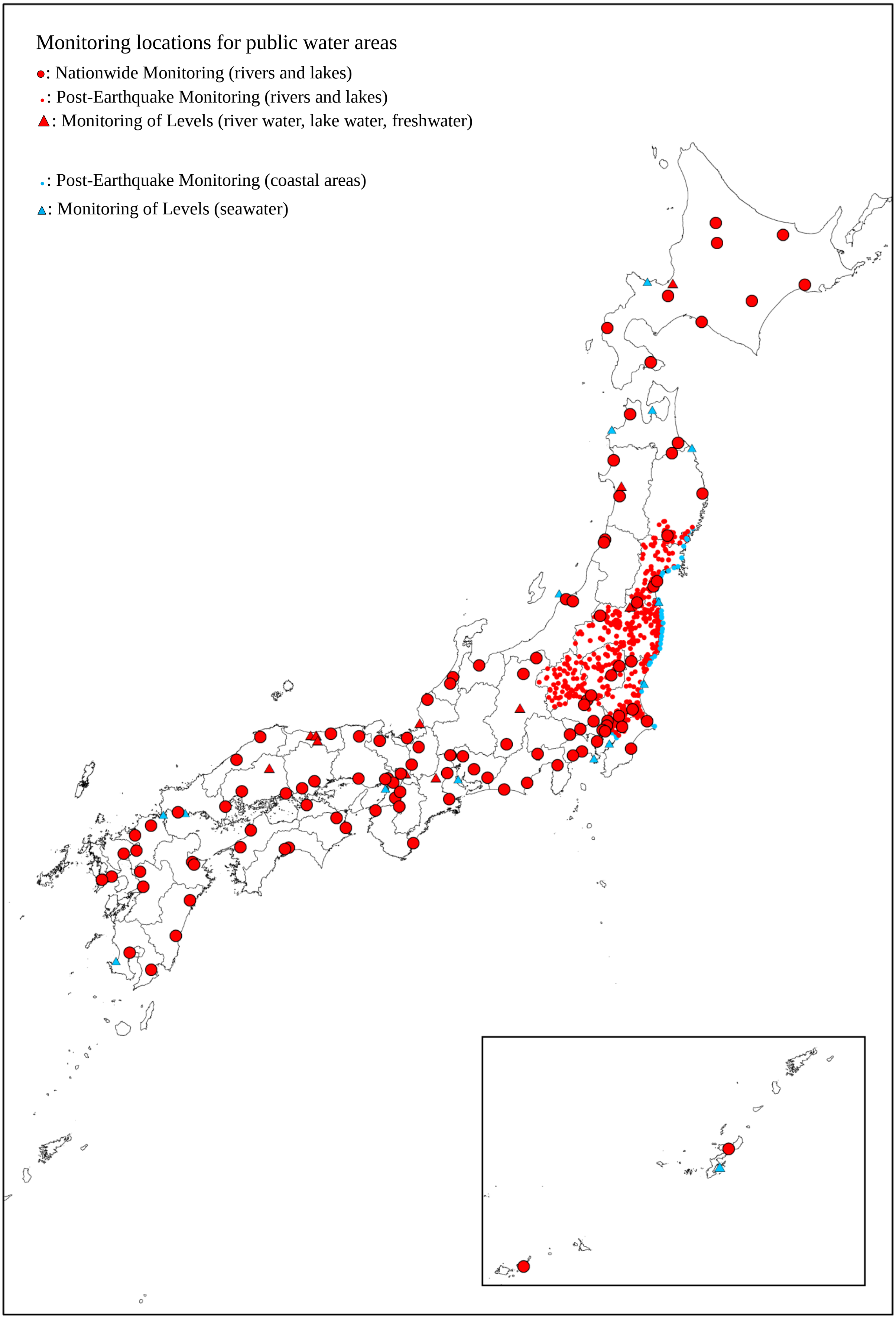


Figure 1 Locations for monitoring radioactive materials (public water areas)

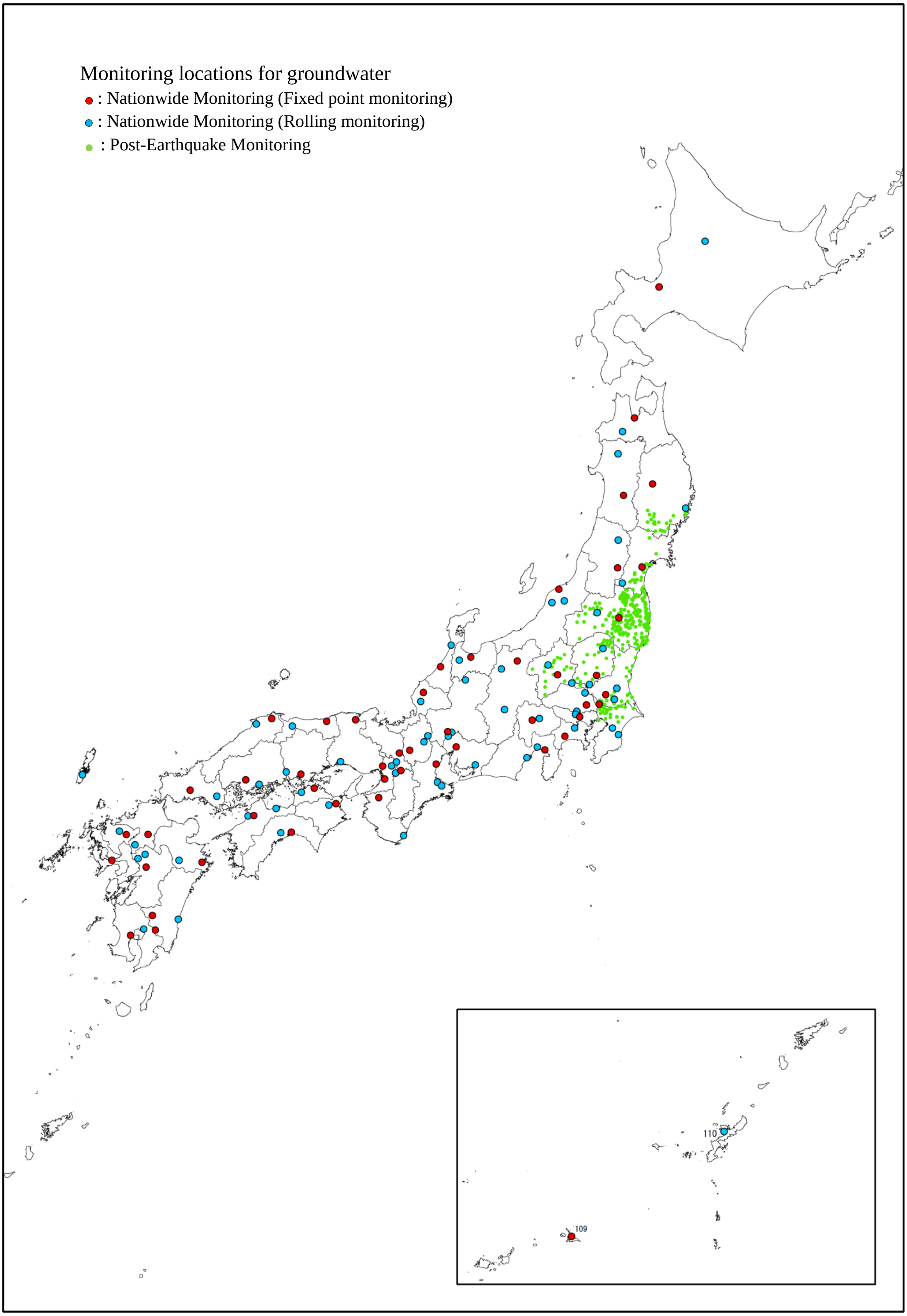


Figure 2 Locations for monitoring radioactive materials (groundwater)

Part 1: National Radioactive Material Monitoring in the Water Environment in the Whole of Japan (FY2016)

1 Objective and Details

1.1 Objective

In response to the the Fukushima NPS Accident, during which radioactive materials were discharged causing environmental pollution, the Water Pollution Control Act was amended. It was decided that the Minister of the Environment should monitor pollution caused by radioactive materials in public water areas and groundwater and release the results from the perspective of preserving the health and living environment of the people.

Based on the above, this monitoring aims to clarify the distribution of radioactive materials in public water areas and groundwater nationwide.

1.2 Details

(1) Monitoring locations

・Public water areas: 110 locations (rivers: 107 locations; lakes: 3 locations)

・Groundwater: 110 locations

Monitoring locations were selected based on the following policy with a view to ensuring balanced nationwide monitoring (specific locations are as shown in Tables 1.2-2 and 1.2-3 and Figures 1.2-1 and 1.2-2).

(i) Public water areas

・At least one sampling location was selected in each prefecture, and additional locations were added according the area and population of each prefecture.

・Locations within each prefecture were selected based on the following policy:

a) Select representative rivers (including lakes) within each prefecture in the same numbers listed above, taking into account the area and population in their basins.

b) Regarding rivers selected as explained in a), select locations from among those monitored for hazardous materials, etc. conducted under the Water Pollution Control Act, selected with consideration of water utilization points. Within a single river, give priority to a location in the lower reaches (including lakes located downstream).

c) As this monitoring does not aim to clarify the influence of specific sources, exclude locations close to those subject to Environmental Monitoring around Nuclear Facilities, etc. (Radiation Monitoring Grants) in principle.

(ii) Groundwater

・Two sampling locations were chosen in each prefecture, and one more location was added for each prefecture in which the amount of groundwater utilized had been large over the past several years.

・Sampling locations for continuous monitoring of environmental standard items were selected based on the following policy:

a) Select regional representative wells (such as wells built for monitoring or major wells with an especially large amount of water yield) taking into consideration the amount of utilization of groundwater from each groundwater basin and water vein (hereinafter referred to as "groundwater basins, etc.").

b) Prioritize wells owned or managed by local governments, etc. in consideration of the convenience of coordination in case any additional survey is required.

c) Select one location for continuous fixed point monitoring from among the locations selected in the manner above, taking into account that location’s level of utilization and the representativeness of that groundwater basin in the wider area. Perform rolling monitoring at the remaining locations (for 5 years in principle).

d) As this monitoring does not aim to clarify the influence of specific sources, exclude locations close to those subject to Environmental Monitoring around Nuclear Facilities, etc. (Radiation Monitoring Grants), in principle.

(2) Targets

・Public water areas: Water and sediments (for lakes, survey water both at the surface layer and bottom layers)
(Additionally, as a reference, radioactive concentrations in soil and ambient dose rates in the environment (river beds, etc.) surrounding the sampling locations are to be measured.)

・Groundwater: Water
(Additionally, as a reference, ambient dose rates near the sampling locations are to be measured.)

(3) Frequencies and periods

・Public water areas : Once a year
However, monitoring was conducted four times a year at two locations (one location in eastern and western Japan, respectively) in order to check any annual variation.

・Groundwater : Fixed point monitoring was conducted once a year, and rolling monitoring was conducted once every five years for each location in principle.

FY2016 monitoring periods are as shown in Table 1.2-4.

(4) Conducted analyses

The following analyses were conducted for collected samples:

・Measurement of total β radioactivity concentrations.

・γ-ray spectrometry measurement using a germanium semiconductor detector (In principal, all detectable radionuclides, including artificial radionuclides and major naturally occurring radionuclides, were analyzed).

(5) Comparison with the past measurement trends

Obtained values were compared with the past measurement trends, and if any deviation was suspected, the validity of the measured values was rechecked (potential number transcription errors, incorrect calibration of equipment, etc.).

Because this monitoring has just commenced, there are no accumulated data for some locations. Therefore, results from similar environmental monitoring surveys conducted so far will be used for comparison for the time being. Specifically, results from the Monitoring of Environmental Radioactivity Levels and Monitoring of the Surrounding Environment conducted by the Nuclear Regulation Authority, as well as the results from the Radioactive Material Monitoring in the Water Environment in and around Fukushima Prefecture conducted by the Ministry of the Environment were utilized. When making comparisons, due consideration was given to the possibility that the values of Cs-137 and other accident-derived radionuclides would have increased after the Fukushima NPS Accident.

Essentially, nationwide data for the past two decades were used for comparison. Considering the influence of the Fukushima NPS Accident and informed by actual measurements, “two years after the accident” was assumed to be a steady state, and therefore, data from between March 11, 2011 to March 10, 2013 were excluded.

(6) Measures to be taken when a value deviating from the past measurement trends was detected

The following measures were taken when a value deviating from the past measurement trends was detected (see Figure 1.2-3).

(6)-1 Release of preliminary values

Any value that is suspected to deviate from the past measurement trends should be immediately evaluated professionally by the chair and the deputy chair, and if it is judged highly urgent (when it has been confirmed that the value is highly likely to deviate from the past measurement trends, and additional detailed analyses are considered to be necessary), a preliminary report should be released as promptly as possible.

In such a case, the following related data should be compiled as basic data for professional evaluation. Members of the Evaluation Committee other than the chair and the deputy chair should be informed of the relevant information together with the professional evaluation by the chair and the deputy chair (see Table 1.2-1 for the chair and other committee members).

(i) Results of the measurement concerning water and sediments (γ-ray spectrometry and total β radioactivity concentrations), and ambient dose rates

(ii) Sampling dates, sampling locations (maps, water depth, river width, etc.), sampling methods, and sampling circumstances (photos)

(iii) Weather data for about one week close to the measurement date (the amount of precipitation, in particular)

(iv) Ambient dose rates measured for the last month or so at neighboring points

(v) Changes in detected values of a relevant radionuclide compared to the past

(6)-2 Detailed analyses and release of the results

For data for which the preliminary report was released as explained in (6)-1 above, the following detailed analyses are to be conducted and the results are to be released.

・Specific analyses to identify radionuclides (including measurement of individual radionuclides through radiochemical analyses)

・Additional measurements in the surrounding areas of the relevant surveyed location

(7) Disclosure of measurement results

The measurement results data are made publicly available on the following Ministry of the Environment website:

http://www.env.go.jp/en/water/rmms/surveys.html

Table 1.2-1 List of members of the Evaluation Committee on Radioactive Material Monitoring in the Water Environment

IIMOTO Takeshi (Deputy chair)	Professor, Division for Environment, Health and Safety, the University of Tokyo
ISHII Nobuyoshi	Principal Researcher, Environmental Transfer Parameter Research Team, The Fukushima Project Headquarters, National Institute of Radiological Sciences, National Institutes for Quantum and Radiological Science and Technology
TOKUNAGA Tomochika	Professor, Department of Environment Systems, Graduate School of Frontier Sciences, the University of Tokyo
HAYASHI Seiji	Research Group Manager & Head of Environmental Assessment Section, Fukushima Branch, National Institute for Environmental Studies
FUKUSHIMA Takehiko (Chair)	Director of the Center, Ibaraki Kasumigaura Environmental Science Center

Table 1.2-2 List of locations for the FY2016 Nationwide Monitoring (public water areas) (No. 1)

No.	Prefecture	Property	Sampling location		
			Water area	Location	Municipality
1	Hokkaido Prefecture	River	Ishikari River	Domestic water intake at Ishikari River in Asahikawa City	Asahikawa City
2		River	Ishikari River	Intake at the Shirakawa water purification plant in Sapporo City	Sapporo City
3		River	Teshio River	Nakashibetsu Bridge (Intake at the Higashiyama water purification plant in Shibetsu City)	Shibetsu City
4		River	Tokoro River	Tadashi Bridge	Kitami City
5		River	Kushiro River	Intake at the Aikoku water purification plant in Kushiro City	Kushiro City
6		River	Tokachi River	Nantai Bridge	Obihiro City
7		River	Sarugawa River	Sarugawa Bridge (Tomigawa)	Hidaka Town
8		River	Matsukura River	Mitsumori Bridge (Before the confluence with Torasawa River)	Hakodate City
9		River	Shiribeshi-toshibetsu River	Intake at the Kitahiyama simple water plant in Kitahiyama Town	Setana Town
10	Aomori Prefecture	River	Iwaki River	Tsugaru-ohashi Bridge	Nakadomari Town
11		River	Mabechi River	Shiriuchi Bridge	Hachinohe City
12	Iwate Prefecture	River	Mabechi River	Fugane Bridge	Ninohe City
13		River	Heigawa River	Miyako Bridge	Miyako City
14		River	Kitakami River	Chitose Bridge	Ichinoseki City
15	Miyagi Prefecture	River	Abukuma River	Iwanuma (Abukuma Bridge)	Iwanuma City
16		River	Natori River	Yuriage-ohashi Bridge	Natori City
17	Akita Prefecture	River	Yoneshiro River	Noshiro Bridge	Noshiro City
18		River	Omono River	Kurose Bridge	Akita City
19	Yamagata Prefecture	River	Mogami River	Ryou Bridge	Sakata City
20		River	Akagawa River	Shinkawa Bridge	Sakata City
21	Fukushima Prefecture	River	Agano River	Shingo Dam	Kitakata City
22		River	Abukuma River	Taisho Bridge (Fushiguro)	Date City
23		River	Kujigawa River	Takachihara Bridge	Yamatsuri Town
24	Ibaraki Prefecture	Lake	Lake Kasumigaura	Center of the lake	Miho Village
25		River	Kokai River	Fumimaki Bridge	Toride City
26	Tochigi Prefecture	River	Nakagawa River	Shinnaka Bridge	Nakagawa Town
27		River	Kinugawa River	Kinugawa Bridge (Hoshakuji Temple)	Utsunomiya City
28	Gunma Prefecture	River	Tonegawa River	Toneozeki Weir	Chiyoda Town/Gyoda City (Saitama Prefecture)
29		River	Watarase River	Watarase-ohashi Bridge	Tatebayashi City
30	Saitama Prefecture	River	Arakawa River	Kuge Bridge	Kumagaya City
31		River	Arakawa River	Akigase Intake Weir	Saitama City/ Shiki City
32		River	Edogawa River	Nagareyama Bridge	Nagareyama City (Chiba Prefecture) / Misato City
33	Chiba Prefecture	River	Tonegawa River	Kakozeki Weir	Tonosho Town
34		River	Ichinomiya River	Nakano Bridge	Ichinomiya Town
35		Lake	Lake Inbanuma	Lower area of water supply intake	Sakura City
36	Tokyo Metoropolis	River	Edogawa River	Shinkatsushika Bridge	Katsushika City
37		River	Tamagawa River	Haijima raw water supply point	Akishima City
38		River	Sumida River	Ryogoku Bridge	Chuo City / Sumida City
39		River	Arakawa River	Kasai Bridge	Koto City / Edogawa City
40	Kanagawa Prefecture	River	Tsurumi River	Rinko Tsurumigawa Bridge	Yokohama City
41		River	Sagami River	Banyu Bridge	Hiratsuka City
42		River	Sakawa River	Sakawa Bridge	Odawara City
43	Niigata Prefecture	River	Shinano River	Heisei-ohashi Bridge	Niigata City
44		River	Agano River	Oun Bridge	Niigata City
45	Toyama Prefecture	River	Jinzu River	Hagiura Bridge	Toyama City
46	Ishikawa Prefecture	River	Saigawa River	Okuwa Bridge	Kanazawa City
47		River	Tedori River	Hakusangoguchi Dike	Hakusan City
48	Fukui Prefecture	River	Kuzuryu River	Fuseda Bridge	Fukui City
49		River	Kitagawa River	Takatsuka Bridge	Obama City
50	Yamanashi Prefecture	River	Sagami River	Katsuragawa Bridge	Uenohara City
51		River	Fujikawa River	Nanbu Bridge	Nanbu Town
52	Nagano Prefecture	River	Shinano River	Ozeki Bridge	Iiyama City
53		River	Saigawa River	Koichi Bridge	Nagano City
54		River	Tenryu River	Tsutsuji Bridge	Iida City

Table 1.2-2 List of locations for the FY2016 Nationwide Monitoring (public water areas) (No. 2)

No.	Prefecture	Property	Sampling location		
			Water area	Location	Municipality
55	Gifu Prefecture	River	Kisogawa River	Tokai-ohashi Bridge（Naruto）	Kaizu City
56		River	Nagara River	Tokai-ohashi Bridge	Kaizu City
57	Shizuoka Prefecture	River	Kanogawa River	Kurose Bridge	Numazu City
58		River	Ooi River	Fujimi Bridge	Yaizu City / Yoshida Town
59		River	Tenryu River	Kaketsuka Bridge	Iwata City / Hamamatsu City
60	Aichi Prefecture	River	Shonai River	Mizuwake Bridge	Nagoya City
61		River	Yahagi River	Iwazutenjin Bridge	Okazaki City / Toyota City
62		River	Toyogawa River	Eshima Bridge	Toyokawa City
63	Mie Prefecture	River	Suzuka River	Ogura Bridge	Yokkaichi City
64		River	Miyakawa River	Watarai Bridge	Ise City
65	Shiga Prefecture	River	Adogawa River	Joan Bridge	Takashima City
66		Lake	Lake Biwako	Karasakioki-Chuo	—
67	Kyoto Prefecture	River	Yuragawa River	Yuragawa Bridge	Maizuru City
68		River	Katsura River	Before the confluence of three tributaries of Katsura River	Oyamazaki Town
69	Osaka Prefecture	River	Inagawa River	Gunko Bridge	Itami City (Hyogo prefecture)
70		River	Yodogawa River	Sugaharashirokita-ohashi Bridge	Osaka City
71		River	Ishikawa River	Takahashi	Tondabayashi City
72	Hyogo Prefecture	River	Kakogawa River	Kakogawa Bridge	Kakogawa City
73		River	Mukogawa River	Hyakkenbi	Takarazuka City
74		River	Maruyama River	Kaminogo Bridge	Toyooka City
75	Nara Prefecture	River	Yamato River	Fujii	Oji Town
76		River	Kinokawa River	Okura Bridge	Gojo City
77	Wakayama Prefecture	River	Kinokawa River	Shinrokkaizeki Weir	Wakayama City
78		River	Kumano River	Kumano-ohashi Bridge	Shingu City
79	Tottori Prefecture	River	Sendai River	Gyotoku	Tottori City
80	Shimane Prefecture	River	Hiikawa River	Kandatsu Bridge	Izumo City
81		River	Gonokawa River	Sakurae-ohashi Bridge	Gotsu City
82	Okayama Prefecture	River	Asahikawa River	Otoite Weir	Okayama City
83		River	Takahashi River	Kasumi Bridg	Kurashiki City
84	Hiroshima Prefecture	River	Ota River	Water supply intake in Hesaka	Hiroshima City
85		River	Ashida River	Kominomi Bridge	Fukuyama City
86	Yamaguchi Prefecture	River	Nishiki River	Domestic water intake for the city	Iwakuni City
87		River	Koto River	Suenobu Bridge	Ube City
88	Tokushima Prefecture	River	Yoshino River	Takase Bridge	Ishii Town
89		River	Nakagawa River	Nakagawa Bridge	Anan City
90	Kagawa Prefecture	River	Dokigawa River	Marugame Bridge	Marugame City
91	Ehime Prefecture	River	Shigenobu River	Deai Bridge	Matsuyama City
92		River	Hijikawa River	Hijikawa Bridge	Ozu City
93	Kochi Prefecture	River	Kagami River	Kachuzeki Weir	Kochi City
94		River	Niyodo River	Hatazeki Weir (1) Center of flow	Ino Town
95	Fukuoka Prefecture	River	Onga River	Hinode Bridge	Nogata City
96		River	Nakagawa River	Shiobara Bridge	Fukuoka City
97		River	Chikugo River	Senoshita	Kurume City
98	Saga Prefecture	River	Kasegawa River	Kase Bridge	Saga City
99	Nagasaki Prefecture	River	Honmyo River	In front of Tenma Park	Isahaya City
100		River	Uragami River	Ohashizeki Weir	Nagasaki City
101	Kumamoto Prefecture	River	Kikuchi River	Shiroishi	Nagomi Town
102		River	Midori River	Uesugizeki Weir	Kumamoto City
103	Oita Prefecture	River	Oita River	Funaichi-ohashi Bridge	Oita City
104		River	Oono River	Shirataki Bridge	Oita City
105	Miyazaki Prefecture	River	Gokase River	Miwa	Nobeoka City
106		River	Oyodo River	Shinaioi Bridge	Miyazaki City
107	Kagoshima Prefecture	River	Kotsuki River	Iwasaki Bridge	Kagoshima City
108		River	Kimotsuki River	Matase Bridge	Kanoya City
109	Okinawa Prefecture	River	Genka River	Water intake	Nago City
110		River	Miyara River	Omoto water intake	Ishigaki City

Table 1.2-3 List of locations for the FY2016 Nationwide Monitoring (groundwater) (No. 1)

No.	Prefecture	Property	Municipality	District	Monitoring method
1	Hokkaido Prefecture	Groundwater	Sapporo City	Kitasanjonishi, Chuo Ward	Fixed point monitoring
2		Groundwater	Asahikawa City	Nagayama	Rolling monitoring
3	Aomori Prefecture	Groundwater	Aomori City	Shinmachi	Fixed point monitoring
4		Groundwater	Hirosaki City	Kamisukimachi	Rolling monitoring
5	Iwate Prefecture	Groundwater	Morioka City	Motomiya	Fixed point monitoring
6		Groundwater	Kamaishi City	Shinmachi	Rolling monitoring
7	Miyagi Prefecture	Groundwater	Sendai City	Honcho, Aoba Ward	Fixed point monitoring
8		Groundwater	Shichikashuku Town	Seki	Rolling monitoring
9	Akita Prefecture	Groundwater	Daisen City	Niiyaji	Fixed point monitoring
10		Groundwater	Kitaakita City	Wakigami	Rolling monitoring
11	Yamagata Prefecture	Groundwater	Yamagata City	Hatagomachi	Fixed point monitoring
12		Groundwater	Shinjo City	Torigoe	Rolling monitoring
13	Fukushima Prefecture	Groundwater	Koriyama City	Asahi	Fixed point monitoring
14		Groundwater	Aizuwakamatsu City	Kozashimachi	Rolling monitoring
15	Ibaraki Prefecture	Groundwater	Tsukuba City	Kenkyugakuen	Fixed point monitoring
16		Groundwater	Ishioka City	Higashiohashi	Rolling monitoring
17		Groundwater	Ami Town	Hanawa	Rolling monitoring
18	Tochigi Prefecture	Groundwater	Shimotsuke City	Machida	Fixed point monitoring
19		Groundwater	Ohtawara City	Honcho	Rolling monitoring
20		Groundwater	Nogi Town	Tomonuma	Rolling monitoring
21	Gunma Prefecture	Groundwater	Maebashi City	Shikishimacho	Fixed point monitoring
22		Groundwater	Ota City	Hosoyacho	Rolling monitoring
23		Groundwater	Nakanojo Town	Isemachi	Rolling monitoring
24	Saitama Prefecture	Groundwater	Saitama City	Mikura, Minuma Ward	Fixed point monitoring
25		Groundwater	Tokorozawa City	Miyamotocho	Rolling monitoring
26		Groundwater	Kazo City	Hanasakikita	Rolling monitoring
27	Chiba Prefecture	Groundwater	Kashiwa City	Funato	Fixed point monitoring
28		Groundwater	Chosei Village	Kaneda	Rolling monitoring
29		Groundwater	Ichihara City	Higashikuniyoshi	Rolling monitoring
30	Tokyo Metoropolis	Groundwater	Koganei City	Kajinocho	Fixed point monitoring
31		Groundwater	Higashiyamato City	Nakahara	Rolling monitoring
32	Kanagawa Prefecture	Groundwater	Hadano City	Imaizumi	Fixed point monitoring
33		Groundwater	Zama City	Sagamigaoka	Rolling monitoring
34	Niigata Prefecture	Groundwater	Niigata City	Nagata, Chuo Ward	Fixed point monitoring
35		Groundwater	Gosen City	Muramatsu Ko	Rolling monitoring
36		Groundwater	Tsubame City	Akibacho	Rolling monitoring
37	Toyama Prefecture	Groundwater	Toyama City	Funahashikitamachi	Fixed point monitoring
38		Groundwater	Tonami City	Saiwaicho	Rolling monitoring
39	Ishikawa Prefecture	Groundwater	Hakusan City	Kuramitsu	Fixed point monitoring
40		Groundwater	Hakui City	Asahimachi A	Rolling monitoring
41	Fukui Prefecture	Groundwater	Fukui City	Ote	Fixed point monitoring
42		Groundwater	Echizen City	Hachiman	Rolling monitoring
43	Yamanashi Prefecture	Groundwater	Showa Town	Saijyoshinden	Fixed point monitoring
44		Groundwater	Yamanashi City	Ono	Rolling monitoring
45	Nagano Prefecture	Groundwater	Nagano City	Tsurugamidoricho	Fixed point monitoring
46		Groundwater	Omachi City	Omachi	Rolling monitoring
47		Groundwater	Ina City	Nishiharuchika	Rolling monitoring
48	Gifu Prefecture	Groundwater	Gifu City	Kanoshimizucho	Fixed point monitoring
49		Groundwater	Kagamihara City	Nakasakuramachi	Rolling monitoring
50		Groundwater	Hida City	Kawaicho	Rolling monitoring
51	Shizuoka Prefecture	Groundwater	Numazu City	Hara	Fixed point monitoring
52		Groundwater	Fuji City	Iwamoto	Rolling monitoring
53		Groundwater	Shizuoka City	Kurihara, Suruga Ward	Rolling monitoring
54	Aichi Prefectur	Groundwater	Nagoya City	Kawaharatori, Showa Ward	Fixed point monitoring
55		Groundwater	Ichinomiya City	Okucho	Rolling monitoring
56		Groundwater	Toyokawa City	Hiraocho	Rolling monitoring

Table 1.2-3 List of locations for the FY2016 Nationwide Monitoring (groundwater) (No. 2)

No.	Prefecture	Property	Municipality	District	Monitoring method
57	Mie Prefecture	Groundwater	Suzuka City	Inoucho	Fixed point monitoring
58		Groundwater	Matsusaka City	Toyoharacho	Rolling monitoring
59		Groundwater	Ise City	Nakazucho	Rolling monitoring
60	Shiga Prefecture	Groundwater	Moriyama City	Miyakecho	Fixed point monitoring
61		Groundwater	Maibara City	Shiori	Rolling monitoring
62		Groundwater	Taga Town	Nakagawara	Rolling monitoring
63	Kyoto Prefecture	Groundwater	Kyoto City	Kamihonnojimaecho, Nakagyo Ward	Fixed point monitoring
64		Groundwater	Yawata City	Tozudoden	Rolling monitoring
65	Osaka Prefecture	Groundwater	Sakai City	Daisennakamachi, Sakai Ward	Fixed point monitoring
66		Groundwater	Neyagawa City	Koyamotomachi	Rolling monitoring
67	Hyogo Prefecture	Groundwater	Itami City	Kuchisakai	Fixed point monitoring
68		Groundwater	Toyooka City	Saiwaicho	Fixed point monitoring
69		Groundwater	Tatsuno City	Ibocho	Rolling monitoring
70	Nara Prefecture	Groundwater	Nara City	Sakyo	Fixed point monitoring
71		Groundwater	Ikoma City	Arisatocho	Rolling monitoring
72	Wakayama Prefecture	Groundwater	Kinokawa City	Takano	Fixed point monitoring
73		Groundwater	Nachikatsuura Town	Ichiya	Rolling monitoring
74	Tottori Prefecture	Groundwater	Tottori City	Saiwaicho	Fixed point monitoring
75		Groundwater	Hoki Town	Kobayashi	Rolling monitoring
76	Shimane Prefecture	Groundwater	Matsue City	Nishikawatsucho	Fixed point monitoring
77		Groundwater	Izumo City	Himebara(2)	Rolling monitoring
78	Okayama Prefecture	Groundwater	Kurashiki City	Fukui	Fixed point monitoring
79		Groundwater	Ibara City	Sasakacho	Rolling monitoring
80	Hiroshima Prefecture	Groundwater	Hiroshima City	Kamisenocho, Aki Ward	Fixed point monitoring
81		Groundwater	Takehara City	Shimonocho	Rolling monitoring
82	Yamaguchi Prefecture	Groundwater	Yamaguchi City	Ouchimihori	Fixed point monitoring
83		Groundwater	Iwakuni City	Shutomachi Shimokubara	Rolling monitoring
84	Tokushima Prefecture	Groundwater	Tokushima City	Fudohoncho	Fixed point monitoring
85		Groundwater	Yoshinogawa City	Kamojimacho Jogejima	Rolling monitoring
86	Kagawa Prefecture	Groundwater	Takamatsu City	Bancho	Fixed point monitoring
87		Groundwater	Marugame City	Kanakuracho	Rolling monitoring
88	Ehime Prefecture	Groundwater	Matsuyama City	Hiraimachi	Fixed point monitoring
89		Groundwater	Masaki Town	Nishikoizumi	Rolling monitoring
90		Groundwater	Niihama City	Kubotacho	Rolling monitoring
91	Kochi Prefecture	Groundwater	Kochi City	Kerako	Fixed point monitoring
92		Groundwater	Ino Town	Hakawa	Rolling monitoring
93	Fukuoka Prefecture	Groundwater	Kurume City	Tanushimarumachi Akinari	Fixed point monitoring
94		Groundwater	Miyama City	Setakamachi Shimonosho	Rolling monitoring
95	Saga Prefecture	Groundwater	Saga City	Yamatochoniiji	Fixed point monitoring
96		Groundwater	Karatsu City	Kyuragimachi Amagawa	Rolling monitoring
97	Nagasaki Prefecure	Groundwater	Isahaya City	Eidamachi	Fixed point monitoring
98		Groundwater	Tsushima City	Mitsushimamachi	Rolling monitoring
99	Kumamoto Prefecture	Groundwater	Kumamoto City	Suizenji, Chuo Ward	Fixed point monitoring
100		Groundwater	Tamana City	Hanegi	Rolling monitoring
101		Groundwater	Yamaga City	Koga	Rolling monitoring
102	Oita Prefecure	Groundwater	Saiki City	Kamioka	Fixed point monitoring
103		Groundwater	Taketa City	Tamarai	Rolling monitoring
104	Miyazaki Prefecture	Groundwater	Miyakonojo City	Minamiyokoichicho	Fixed point monitoring
105		Groundwater	Kobayashi City	Minaminishikata	Fixed point monitoring
106		Groundwater	Miyazaki City	Yamasakicho Hamayama	Rolling monitoring
107	Kagoshima Prefecture	Groundwater	Kagoshima City	Tamazatocho	Fixed point monitoring
108		Groundwater	Kirishima City	Kokubukawahara	Rolling monitoring
109	Okinawa Prefecture	Groundwater	Miyakojima City	Hirarahigashinakasonezoe	Fixed point monitoring
110		Groundwater	Motobu Town	Namizato	Rolling monitoring

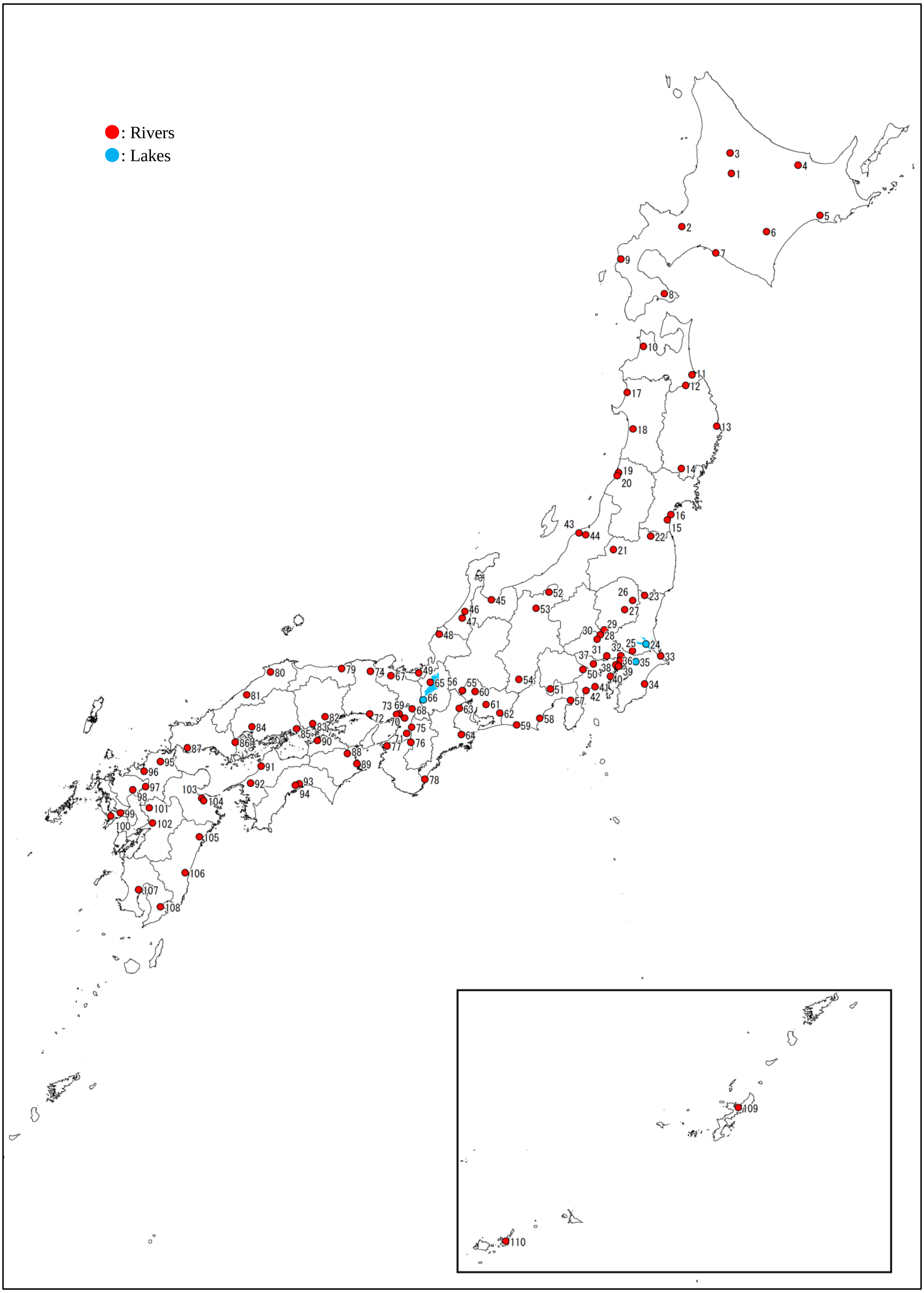


Figure 1.2-1 Map showing locations for FY2016 Nationwide Monitoring (public water areas)

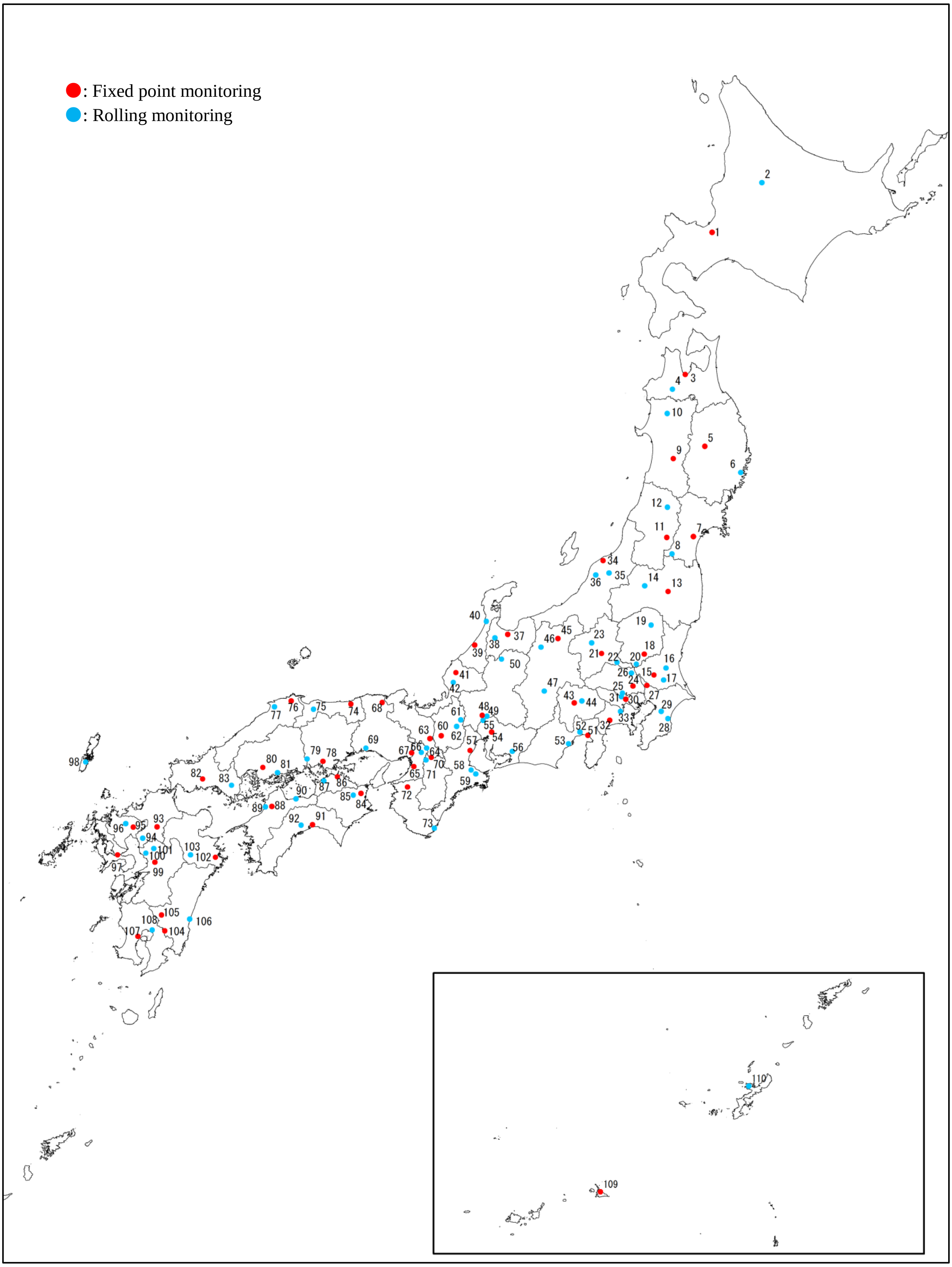


Figure 1.2-2 Map showing locations for FY2016 Nationwide Monitoring (groundwater)

Table 1.2-4 Monitoring points and period by block (FY2016)

Blocks	Prefectures	Public water areas		Groundwater	
		Number of Locations (*1)	Period	Number of locations	Period
Hokkaido block	Hokkaido	9	Aug. 23 to Nov. 7	2	Aug. 22
Tohoku block	Aomori, Iwate, Miyagi, Akita, Yamagata and Fukushima	14	Sep. 2 to Oct. 4	12	Sep 2 to Sep.29
Kanto block	Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Niigata, Yamanashi and Shizuoka	26 (2)	Aug. 24 to Oct 21	27	Aug. 23 to Sep 16
Chubu block	Toyama, Ishikawa, Fukui, Nagano, Gifu, Aichi and Mie	15	Aug 29 to Oct. 14	18	Aug. 29 to Sep. 16
Kinki block	Shiga, Kyoto, Osaka, Hyogo, Nara and Wakayama	14 (1)	Aug. 31 to Oct. 4	14	Aug. 29 to Sep. 9
Chugoku-Shikoku block	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime and Kochi	16	Aug. 22 to Oct. 13	19	Aug. 22 to Oct. 13, Feb. 14 (*2)
Kyushu and Okinawa block	Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima and Okinawa	16	Aug. 22 to Sep. 16	18	Aug. 23 to Sep. 16
Survey to check annual variation	Gunma and Okayama	2	May 24 to Jan. 27	-	-

(*1) Numbers in parentheses designate monitoring locations for lakes; plain numbers are for rivers.

(*2) The groundwater at No. 77 was collected on February 14, and collection from other locations finished by October 13.

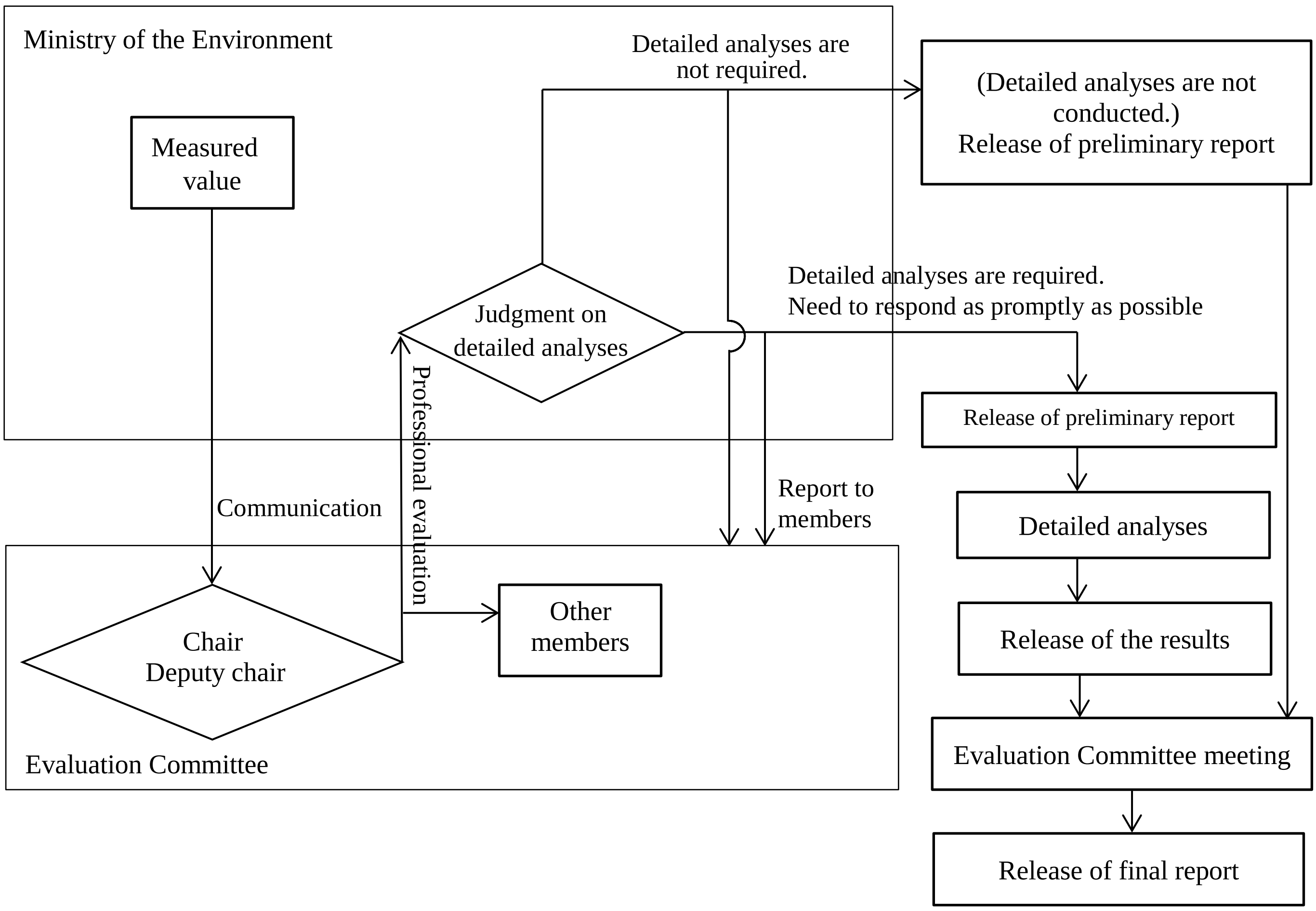


Figure 1.2-3 Procedures for professional evaluation of the results of the Nationwide Monitoring

2 Survey Methods and Analysis Methods

2.1 Survey methods

Samples were collected based on the following guidelines in principle, as outlined below.

- Water Quality Survey Method (September 30, 1971; Notice Kansuikan No. 30 issued by the Director General of the Water Quality Preservation Bureau, Ministry of the Environment)
- Sediment Survey Method (August 8, 2012; Notice Kansuitaisuihatsu No. 120725002 issued by the Director General of the Environmental Management Bureau, Ministry of the Environment)
- Groundwater Quality Survey Method (September 14, 1989; Notice Kansuikan No. 189 issued by the Director General of the Water Quality Preservation Bureau, Ministry of the Environment)
- Environmental Sample Collection Method (1983, Ministry of Education, Culture, Sports Science and Technology (hereinafter referred to as "MEXT")'s Radioactivity Measurement Method Series)
- Sample Pretreatment for Instrumental Analysis Using Germanium Semiconductor Detectors (1982, MEXT's Radioactivity Measurement Method Series)

(1) Public water areas

• Water:

Water samples of around 160 L (hydrochloric acid added) and around 2 L (nitric acid added) were collected at the predetermined points. From the 160 L sample (hydrochloric acid added), 80 L was used for γ-ray spectrometry analyses and the remaining 80 L was preserved for possible detailed analyses. From the 2 L sample (nitric acid added), 1 L was used to measure total β radioactivity concentrations.

Additionally, the transparency (or Secchi disk depth) was measured when collecting water samples, and in the case that transparency was thought to have been affected by rainwater based on comparison to prior measurements, or if there was no past data to compare to, the measured transparency was 50 cm or less and it was suspected that rainwater may have influenced transparency, the water was not used as samples.

• Sediments:

Bottom sediment samples of around 6 L were collected at the predetermined points at a depth of around 10 cm from the surface layer by using an Ekman-Birge grab sampler etc., and 3 L out of the 6 L was used for γ-ray spectrometry analyses.

• Soil:

Soil samples (around 5 cm in diameter) were collected at a depth of around 5 cm at five points within a 3 to 5 meter square (four vertexes and the diagonal intersection point), or, when it was difficult to find an appropriate square to determine five such sampling locations, soil from five points in 3 to 5 meter intervals along a river were collected and were brought back separately. Samples thus collected at the five points were mixed in equal amounts respectively and were used for analyses.

• Ambient dose rates (soil sampling locations):

Ambient dose rates were measured by installing NaI (Tl) scintillation survey meters at a height of 1 m from the ground surface on both banks of a river (or in the case of a lake, installing a NaI (Tl) scintillation survey meter at one point on lake side) so that the meters would face the sampling location of river water (or lake water).

(2) Groundwater

• Water:

Groundwater samples of around 160 L (hydrochloric acid added) and 2 L (nitric acid added) were collected at the predetermined wells, etc. 80 L of the 160 L sample (hydrochloric acid added) was used for γ-ray spectrometry analyses and the remaining 80 L was preserved for possible detailed analyses. 1 L of the 2 L sample (nitric acid added) was used for to measure total β radioactivity concentrations.

When collecting water samples, it was confirmed that water temperature, transparency, pH, and electrical conductivity remained constant by letting the water pass for several minutes, and changes in the transparency, etc. thereafter were recorded as notes.

・Ambient dose rates:

Ambient dose rates were measured by installing NaI (Tl) scintillation survey meters at a height of 1 m from the ground surface near the relevant wells, etc. so that they would face the sampling location of groundwater (or the groundwater layer).

2.2 Analysis methods

For public water areas (water, sediments and soil) and groundwater (water), total β radioactivity concentrations and γ-ray spectrometry with a germanium semiconductor detector were conducted using the methods below. As a general rule, the γ-ray spectrometry measurement covered all detectable radionuclides (including artificial radionuclides and naturally occurring radionuclides). Measurements were described to two significant digits, and the unit of measures were "Bq/L" for water samples from public water areas and groundwater samples, and "Bq/kg" in for sediment samples from public water areas, respectively.

The adopted analysis methods were essentially in line with the MEXT’s Radioactivity Measurement Method Series, and detection limits were set around 0.001 to 0.01 Bq/L for water samples and around 1 to 30 Bq/kg for sediment samples. (However, these detection limits did not apply to radionuclides with short half-lives or those with extremely low γ-ray emission rates.)

・Measurement of total β radioactivity concentrations: The samples were concentrated and dried, and then measurements were taken using a low-background gas-flow proportional counter.

・γ-ray spectrometry measurement: After proper pretreatment, the samples were placed in a U-8 container or a 2L Marinelli beaker and measured using a germanium semiconductor detector. The following 62 types of γ-ray emitting radionuclides (18 naturally occurring radionuclides and 44 artificial radionuclides) were surveyed. The measured results of γ-ray emitting radionuclides were corrected for attenuation, and figures were reported as activity concentration after sampling.

Table 2.2-1 Surveyed γ-ray emitting radionuclides

Naturally occurring radionuclides (18 radionuclides)		Artificial radionuclides (44 radionuclides)				
Ac-228	Ra-224	Ag-108m	Co-58	I-131	Np-239	Te-129m
Be-7	Ra-226	Ag-110m	Co-60	I-132	Ru-103	Te-132
Bi-212	Th-227	Am-241	Cr-51	La-140	Ru-106	Y-91
Bi-214	Th-228	As-74	Cs-134	Mn-54	Sb-124	Y-93
K-40	Th-231	Ba-140	Cs-136	Mn-56	Sb-125	Zn-63
Pa-234m	Th-234	Bi-207	Cs-137	Mo-99	Sb-127	Zn-65
Pb-210	Tl-206	Ce-141	Fe-59	Nb-95	Sr-91	Zr-95
Pb-212	Tl-208	Ce-143	Ga-74	Nb-97	Tc-99m	Zr-97
Pb-214	U-235	Ce-144	Ge-75	Nd-147	Te-129	

3 Results

The outline of detectable radioactive materials at each monitoring location is as follows.

3.1 Detection of total β radioactivity and γ-ray emitting radionuclides

(1) Public water areas

1) Water

The results of the measurements of total β radioactivity and γ-ray emitting radionuclides in water samples from public water areas are as shown in Table 3.1-1 and Figure 3.1-1.

a) Total β radioactivity

The detection rate for total radioactivity was 92.0 % with detected values ranging from not detectable to 2.6 Bq/L: all of which were within the past measurement trends.

b) γ-ray emitting radionuclides

As shown in Table 3.1-1 and Figure 3.1-1, six types of γ-ray emitting radionuclides (four naturally occurring radionuclides and two artificial radionuclides) were detected, while other types of γ-ray emitting radionuclides were not detectable at any of the locations surveyed.

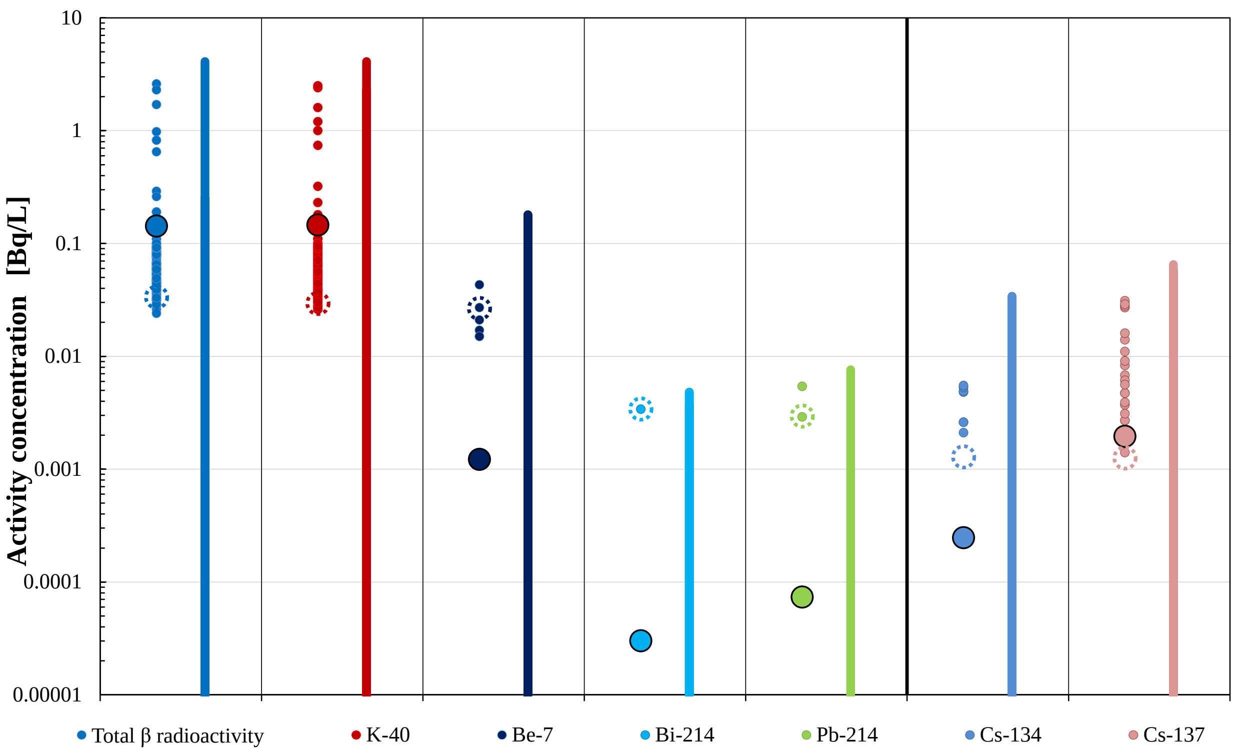
The detection rates of naturally occurring radionuclides were 10 % or less, except for K-40, for which the detection rate was 91.2 %. All of the measured values of naturally occurring radionuclides were within the past measurement trends.

Regarding artificial radionuclides, the detection rate for Cs-134 was 6.2 % and for Cs-137 it was 18.6 %, while the nuclide concentration of Cs-134 was 0.0055 Bq/L or less, Cs-137 was 0.031 Bq/L or less: all of which were within the past measurement trends.

Table 3.1-1 Detection of total β radioactivity and γ-ray emitting radionuclides in water samples from public water areas

Radionuclides			Number of samples	Detection times	Detection rate (%)	Measured values [Bq/L] Range			Measured values [Bq/L] Detection limits			Maximum records [Bq/L] Nationwide Monitoring in FY2014, FY2015	Maximum records [Bq/L] Monitoring of Levels (*1)
Total β radioactivity			113	104	92.0	ND	-	2.6	0.023	-	0.36	4.1	0.25
γ-ray emitting radionuclides	Naturally occurring	Ag-110m	113	103	91.2	ND	-	2.5	0.016	-	0.092	4.1	2.3
		Ba-140	113	6	5.3	ND	-	0.043	0.0077	-	0.087	0.057	0.18
		Be-7	113	1	0.9	ND	-	0.0034	0.0020	-	0.011	0.0037	0.0048
		Bi-214	113	2	1.8	ND	-	0.0054	0.0016	-	0.010	0.0076	No data
	Artificial	Ce-141	113	7	6.2	ND	-	0.0055	0.00078	-	0.0042	0.022	0.034
		Ce-144	113	21	18.6	ND	-	0.031	0.00074	-	0.0043	0.065	0.058

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment conducted in Japan nationwide from FY1997 to FY2016 (excluding data from March 11, 2011 to March 10, 2013)



<Legend> : Detected value
: Mean value (arithmetic mean calculated assuming ND = 0)
: Mean value of detection limits (Arithmetic mean)
: Range of past measured values (Nationwide Monitoring in FY2014 and FY2015, and Monitoring Levels, etc., from FY1997 to FY2016 (excluding data from March 11, 2011 to March 10, 2013))

(*) The vertical axis is logarithmically scaled because the magnitude of detected values varies widely depending on the type of radionuclide.

Figure 3.1-1 Detection of total β radioactivity and γ-ray emitting radionuclides in water samples from public water areas

2) Sediments

The results for total β radioactivity and γ-ray emitting radionuclides in sediment samples from public water areas are as shown in Table 3.1-2 and Figure 3.1-2.

a) Total β radioactivity

Total β radioactivity was detected at all locations surveyed, with detected values ranging from 170 to 1,300 Bq/kg: all of which were within the past measurement trends.

b) γ-ray emitting radionuclides

As shown in Table 3.1-2 and Figure 3.1-2, 11 types of γ-ray emitting radionuclides (nine naturally occurring radionuclides and two artificial radionuclides) were detected, while no other types of γ-ray emitting radionuclides were detectable.

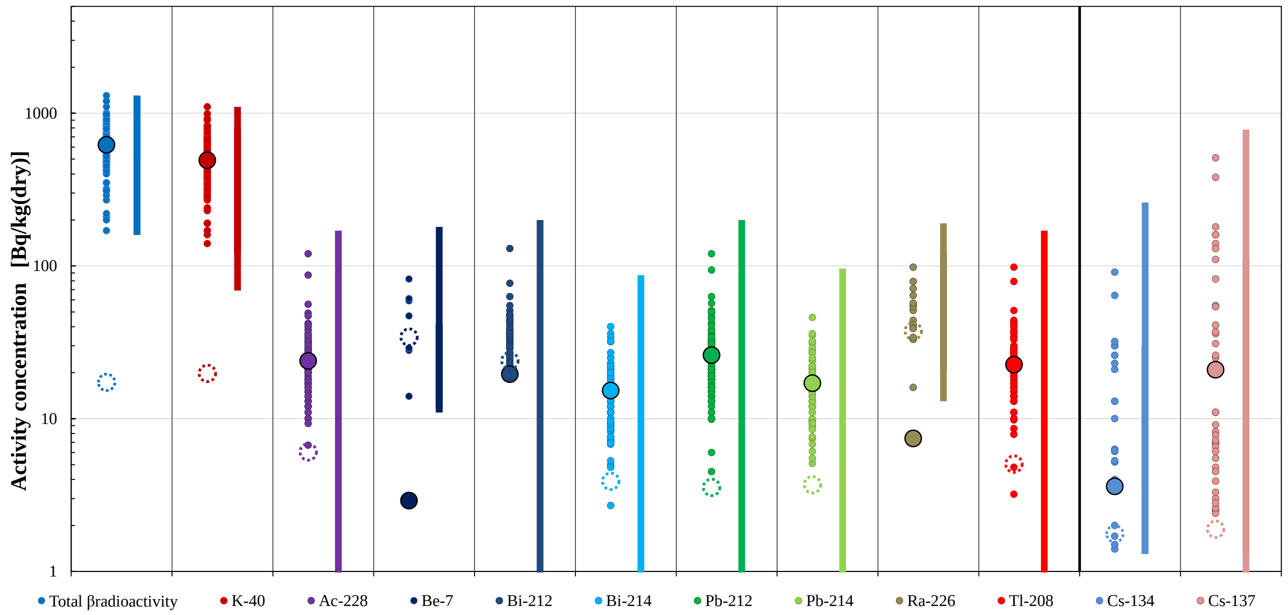
The detection rates of the six naturally occurring radionuclides other than Be-7, Bi-212, and Ra-226 exceeded 95%. All of the detected naturally occurring radionuclides were within the past measurement trends.

As for artificial radionuclides, the detection rates of Cs-134 and Cs-137 were 20.0% and 35.5% respectively, while detected values were 91 Bq/kg or less for Cs-134 and 510 Bq/kg or less for Cs-137: all of which were within the past measurement trends.

Table 3.1-2 Detection of total β radioactivity and γ-ray emitting radionuclides in sediment samples from public water areas

Radionuclides			Number of samples	Detection times	Detection rate (%)	Measured values [Bq/kg]: Range	Measured values [Bq/kg]: Detection limits	Maximum records [Bq/kg]: Nationwide Monitoring in FY2014, FY2015	Maximum records [Bq/kg]: Monitoring of Levels (*1)
Total β radioactivity			110	110	100.0	170 - 1,300	15 - 26	1,300	1,300
γ-ray emitting radionuclides	Naturally occurring	K-40	110	110	100.0	140 - 1100	12 - 38	1,100	800
		Ac-228	110	107	97.3	ND - 120	3.2 - 10	170	No data
		Be-7	110	7	6.4	ND - 82	11 - 160	180	42
		Bi-212	110	59	53.6	ND - 130	11 - 44	200	No data
		Bi-214	110	110	100.0	2.7 - 40	1.9 - 9.5	87	ND
		Pb-212	110	110	100.0	4.5 - 120	1.4 - 6.1	200	No data
		Pb-214	110	110	100.0	5.1 - 46	1.5 - 9.5	96	No data
		Ra-226	110	16	14.5	ND - 98	14 - 73	190	122
		Tl-208	110	110	100.0	3.2 - 98	2.2 - 12	170	No data
	Artificial	Cs-134	110	22	20.0	ND - 91	0.80 - 4.3	260	30
		Cs-137	110	39	35.5	ND - 510	0.82 - 3.5	780	110

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment studies conducted in Japan nationwide from FY1997 to FY2016 (excluding data from March 11, 2011 to March 10, 2013)



<Legend> : Detected value
: Mean value (arithmetic mean calculated assuming ND = 0)
: Mean value of detection limits(Arithmetic mean)
: Range of past measured values (Nationwide Monitoring in FY2014 and FY2015, and Monitoring Levels, etc., from FY1997 to FY2016 (excluding data from March 11, 2011 to March 10, 2013))

(*) Details of the detection of Cs-134 and Cs-137 are explained later.
(*) The vertical axis is logarithmically scaled because the magnitude of detected values varies widely with the type of radionuclide.

Figure 3.1-2 Detection of total β radioactivity and γ-ray emitting radionuclides in sediment samples from public water areas

(2) Groundwater

The measurement results for total β radioactivity and γ-ray emitting radionuclides in groundwater samples are as shown in Table 3.1-3 and Figure 3.1-3.

a) Total β radioactivity

The detection rate of total β radioactivity was 88.2%, with detected values ranging from not detectable to 0.54 Bq/L. Detected values exceeded the range of past measurement records at one location, but they were attributed to K-40, and was considered to be within the past measurement trends.

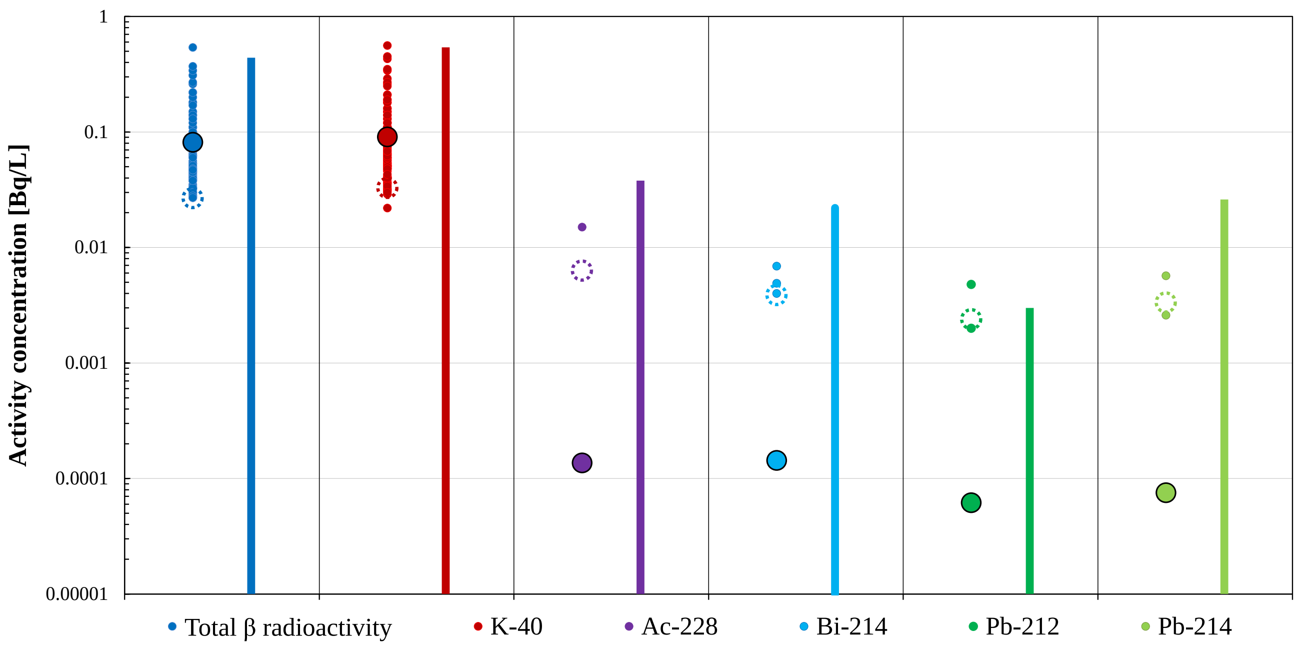
b) γ-ray emitting radionuclides

Five types of γ-ray emitting radionuclides (all naturally occurring radionuclides), as shown in Table 3.1-3 and Figure 3.1-3, were detected, while no other types of γ-ray emitting radionuclides were detected. For naturally occurring radionuclides, the detection rate was less than 3% except for the detection rate of K-40 which was 84.5%. At one location, K-40 slightly exceeded the range of past measurement records, but it is usually contained in natural soil rocks etc (described below). In addition, Pb-212 slightly exceeded the range of past measurement records at one point, but it is a natural species of the thorium series and is usually contained in natural soil rocks etc. Considering that the past detected cases are based on survey results from only a few areas (Shiga prefecture, Niigata prefecture, Nara prefecture; not surveyed in the Monitoring of Environmental Radioactivity Levels), Pb-212 was assumed to be within the past measurement trends.

Table 3.1-3 Detection of total β radioactivity and γ-ray emitting radionuclides in groundwater samples

Radionuclides			Number of samples	Detection times	Detection rate (%)	Measured values [Bq/L]		Maximum records [Bq/L]	
						Range	Detection limits	Nationwide Monitoring in FY2014, FY2015	Monitoring of Levels (*1)
Total β radioactivity			110	97	88.2	ND - 0.54	0.024 - 0.038	0.44	0.33
γ-ray emitting radionuclides	Naturally occurring	K-40	110	93	84.5	ND - 0.56	0.017 - 0.054	0.54	0.41
		Ac-228	110	1	0.9	ND - 0.015	0.0038 - 0.0096	0.038	No data
		Bi-214	110	3	2.7	ND - 0.0069	0.0022 - 0.0059	0.022	No data
		Pb-212	110	2	1.8	ND - 0.0048	0.0013 - 0.0040	0.0030	No data
		Pb-214	110	2	1.8	ND - 0.0057	0.0019 - 0.0050	0.026	No data

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment conducted in Japan nationwide from FY1997 to FY2016 (excluding data from March 11, 2011 to March 10, 2013)



<Legend> : Detected value
: Mean value (arithmetic mean calculated assuming ND = 0)
: Mean value of detection limits(Arithmetic mean)
: Range of past measured values (Nationwide Monitoring in FY2014 and FY2015, and Monitoring of Levels, etc., from FY1997 to FY2016 (excluding data from March 11, 2011 to March 10, 2013))

(*) The vertical axis is logarithmically scaled because the magnitude of detected values varies widely with the type of radionuclide.

Figure 3.1-3 Detection of total β radioactivity and γ-ray emitting radionuclides in groundwater samples

3.2 Discussion regarding detected radionuclides

(1) Detection of naturally occurring radionuclides

1) Correlation between activity concentrations of K-40 and seawater

As explained in 3.1 above, activity concentrations of K-40 were all within the past measurement trend in water samples collected in public water areas. All the locations where relatively high concentrations of K-40 were detected were located in the tide zone and the electrical conductivity (EC) was high (1,330 mS/m at the maximum). Therefore, a comparison was made using all available data to clarify the correlation between activity concentrations of K-40 and EC (see Figure 3.2-1).

As shown in Figure 3.2-1, a positive correlation was found between them.

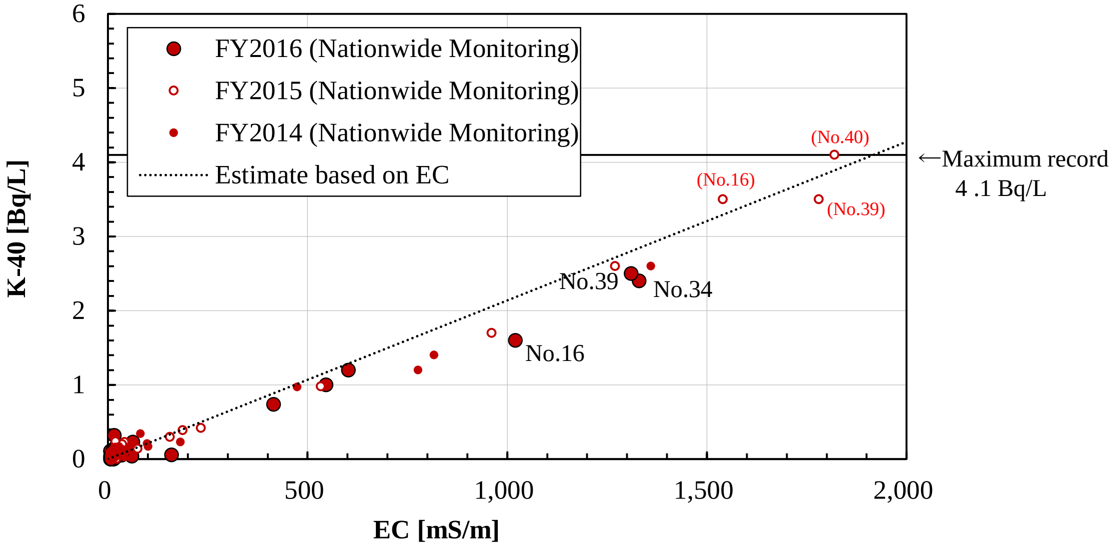


Figure 3.2-1 Correlation between K-40 concentrations and electrical conductivity(EC) in water samples from public water areas

On the other hand, according to the results of the Monitoring of Levels, conducted for 20 years from FY1997 to FY2016 (monitoring of 744 samples collected from 19 prefectures), the average concentration (average) of K-40 was approximately 9.6 Bq/L and the maximum concentration was 15 Bq/L (see Table 3.2-1).

Table 3.2-1 Results of the Monitoring of Levels, etc., concerning K-40 in seawater (*1)

Number of surveys	Detection times	Detection rate (%)	Average (Bq/L)	Maximum (Bq/L)
744	717	96.4	9.6	15

(*1) Results of the Monitoring of Environmental Radioactivity Levels and the Monitoring of the Surrounding Environment conducted in Japan nationwide from FY1997 to FY2016

EC of seawater is generally around 4,500 mS/m, and the estimated activity concentrations of K-40 with possible influence of seawater were obtained by using the following formula based on the measurement results of EC for the relevant river water.

$$\text{(Activity concentration of K-40 in river water)} = \text{(Average activity concentration of K-40 in seawater)} \times \frac{\text{(Measured EC in the river water)}}{\text{(Ordinary values of EC in seawater)}}$$

The estimated activity concentrations of K-40 in the river water are indicated with a dotted line (……) in Figure 3.2-1, and the estimated values agree very well with the measured activity concentrations of K-40. Therefore, the relatively high activity levels of K-40 obtained in the latest measurements are considered to have been caused by the intrusion of seawater.

In the same manner, the correlation between K-40 concentration and EC was also investigated with regard to groundwater samples (see Figure 3.2-2, scales of the vertical and horizontal axes differ from those for Figure 3.2-1). However, no clear correlation was found from the groundwater samples. The concentrations of K-40 in groundwater samples from Site No. 77 (Himebara, Izumo City, Shimane Pref.: 0.56 Bq/L) slightly exceeded the range of past measured values (maximum value: 0.54 Bq/L). This result is considered to reflect the geological charagteristics of the monitoring area, which exhibits relatively high potassium concentrations in the soil (Figure 3.2-3). Accordingly, the K-40 concentration for groundwater samples in the latest monitoring is considered to fall within the past measurement trends.

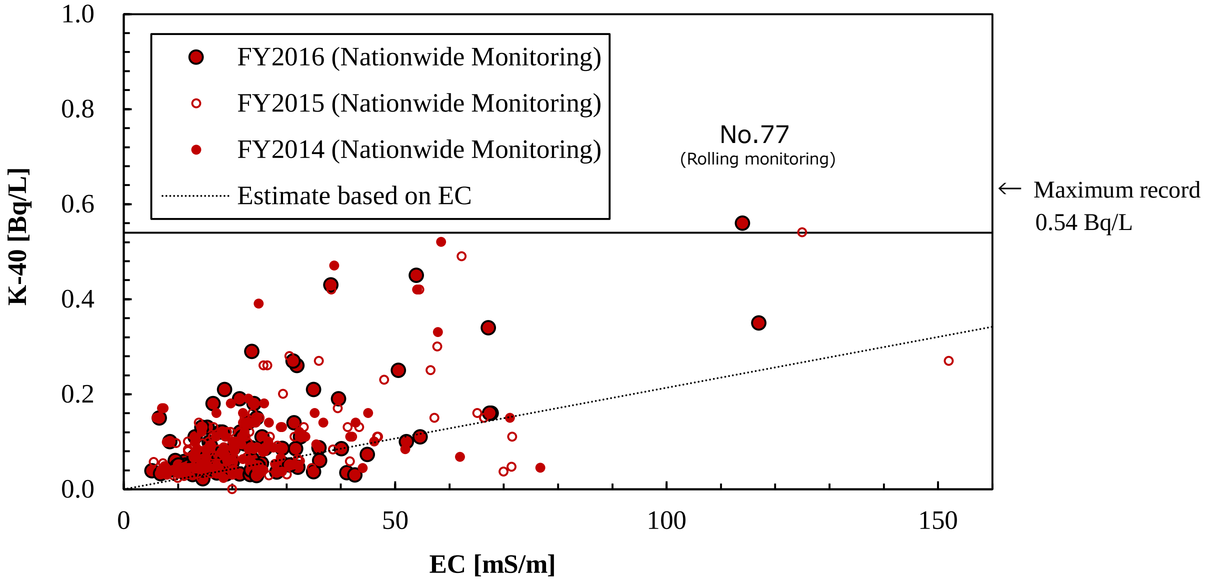
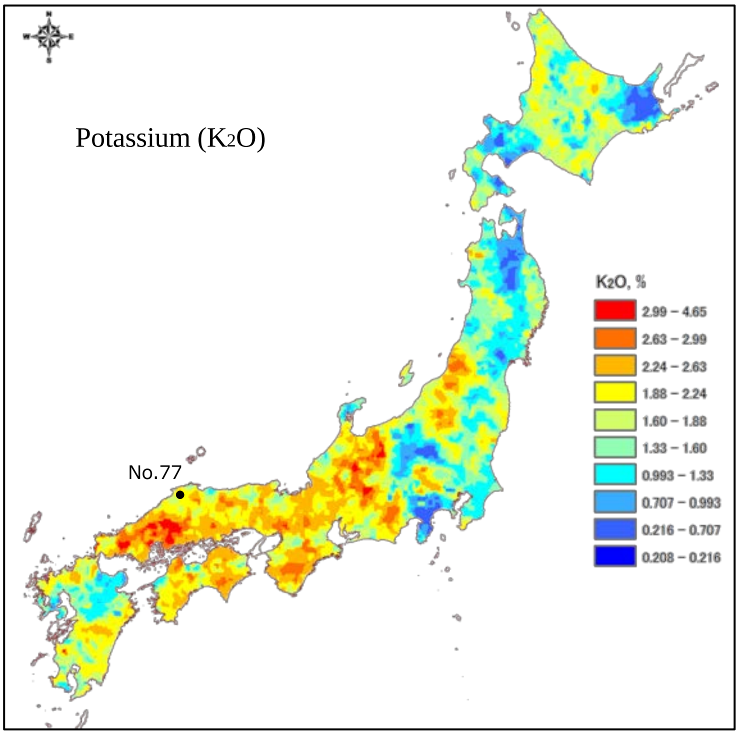


Figure 3.2-2 Correlation between the K-40 concentration and electrical conductivity (EC) in groundwater sample



Reference: Website of the Geological Survey of Japan, AIST
https://gbank.gsj.jp/geochemmap/setumei/radiation/setumei-radiation.htm

Figure 3.2-3 Distribution of potassium (K_2O) in soil in Japan

2) Uranium and thorium series radionuclides

As explained in 3.1 above, uranium and thorium series radionuclides were detected at relatively high concentration levels in sediment samples from public water areas. The detection status is shown in Table 3.2-2.

These naturally occurring radionuclides exist widely within the earth's crust and belong to the same decay series, which implies the existence of some correlations among detected values.

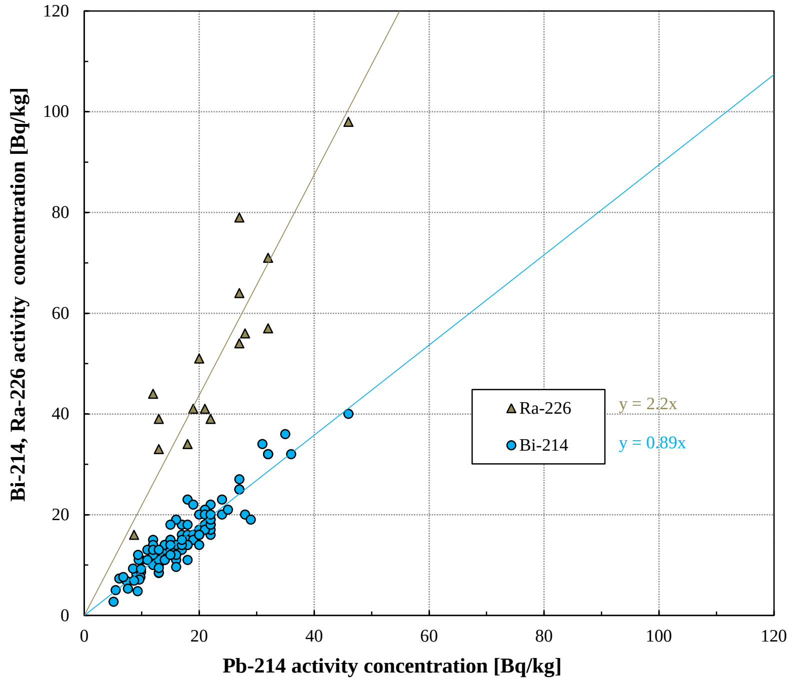
Table 3.2-2 Detection of uranium and thorium series naturally occurring radionuclides

Radionuclides			Number of samples	Detection times	Detection rate (%)	Measured value [Bq/kg]					
						Range			Detection limit		
γ-ray emitting radionuclides	Uranium series	Ra-226	110	16	14.5	ND	-	98	14	-	73
		Pb-214	110	110	100.0	5.1	-	46	1.5	-	9.5
		Bi-214	110	110	100.0	2.7	-	40	1.9	-	9.5
	Thorium Series	Ac-228	110	107	97.3	ND	-	120	3.2	-	10
		Pb-212	110	110	100.0	4.5	-	120	1.4	-	6.1
		Bi-212	110	59	53.6	ND	-	130	11	-	44
		Tl-208	110	110	100.0	3.2	-	98	2.2	-	12

Figure 3.2-4 and Figure 3.2-5 show the correlation among uranium series radionuclides and among thorium series radionuclides, respectively, based on the radionuclides with high detection rate (with instances of non-detection excluded). Figure 3.2-4 and Figure3.2-5 reveals high correlations among uranium series or among thorium series radionuclides. From this information it can be inferred that the radionuclides of the two series reflected the geology of the locations at which they had been detected.

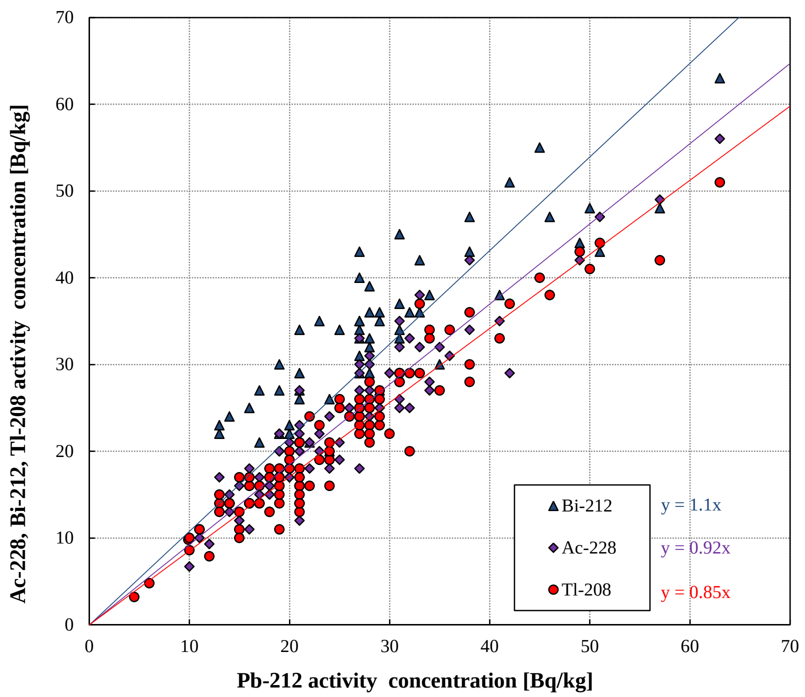
Note that it is generally accepted that granite contains larger amounts of naturally occurring radionuclides than other kinds of rocks and that natural radiation doses correlate to some extent with uranium and thorium series radionuclides (both according to the Geological Society of Japan[3]). For reference, Figure 3.2-6 shows the distribution map of granite in Japan, while Figure 3.2-7 shows the distribution map of natural radiation doses in Japan.

[3] http://www.geosociety.jp/hazard/content0058.html



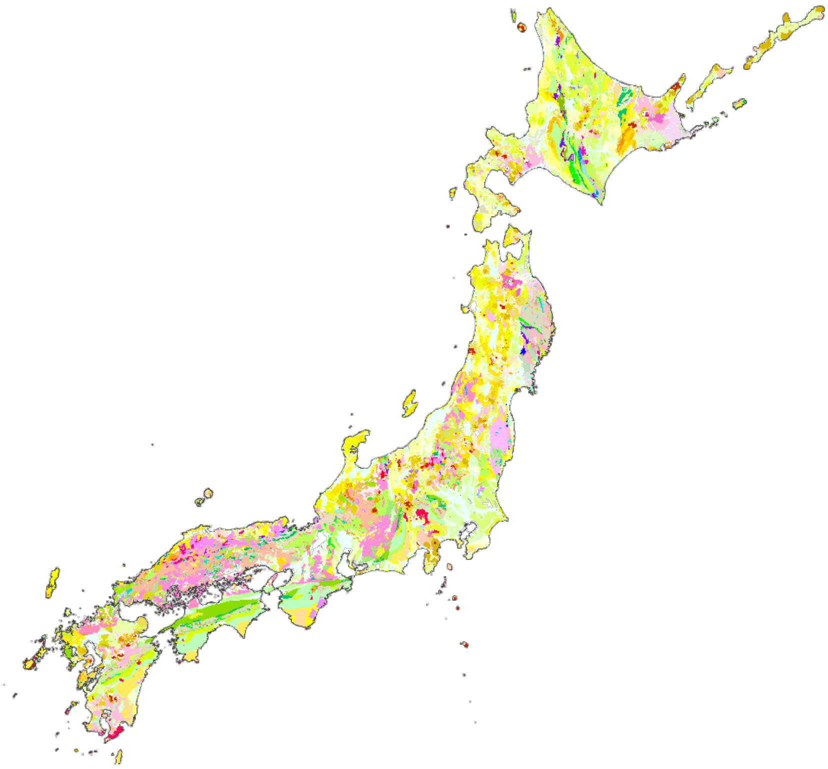
Correlation coefficient	Bi-214	Ra-226
Pb-214	0.93	0.90

Figure 3.2-4 Correlations among uranium series radionuclides



Correlation coefficient	Ac-228	Bi-212	Tl-208
Pb-212	0.97	0.94	0.98

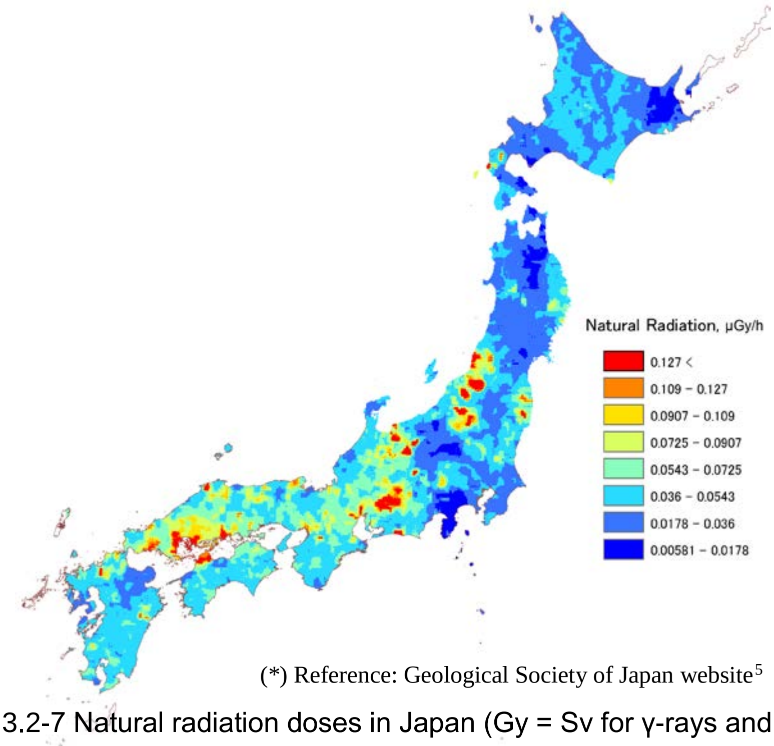
Figure 3.2-5 Correlations among thorium series radionuclides



(*) Reference: Seamless Digital Geological Map of Japan (1:200,000) ® ; AIST website[4]

Figure 3.2-6 Distribution of granite in Japan

(parts highlighted in pink in the Figure are locations where granite exists)



(*) Reference: Geological Society of Japan website[5]

Figure 3.2-7 Natural radiation doses in Japan (Gy = Sv for γ-rays and β-rays)

[4] https://gbank.gsj.jp/seamless/

[5] http://www.geosociety.jp/hazard/content0058.html

(2) Detection of artificial radionuclides

1) Cs-134 and Cs-137 in sediments

Radioactive cesium was detected in sediment samples from public water areas in Hokkaido, Tohoku, Kanto, Chubu, Kinki, and Kyushu blocks (39 locations in total; both Cs-134 and Cs-137 were detected at 22 locations (all in Tohoku and Kanto Blocks); only Cs-137 was detected at 17 locations).

To better clarify the concentration levels of the detected radioactive cesium species, the following comparisons were made:

(i) Wherever Post-Earthquake Monitoring is carried out at the same locations, a direct comparison between data was carried out.

(ii) For locations that do not fall under the category of (i) above but are within the Tokyo Metropolitan Area or other prefectures where Post-Earthquake Monitoring is conducted, collected data was compared with that from other locations in the same prefecture.

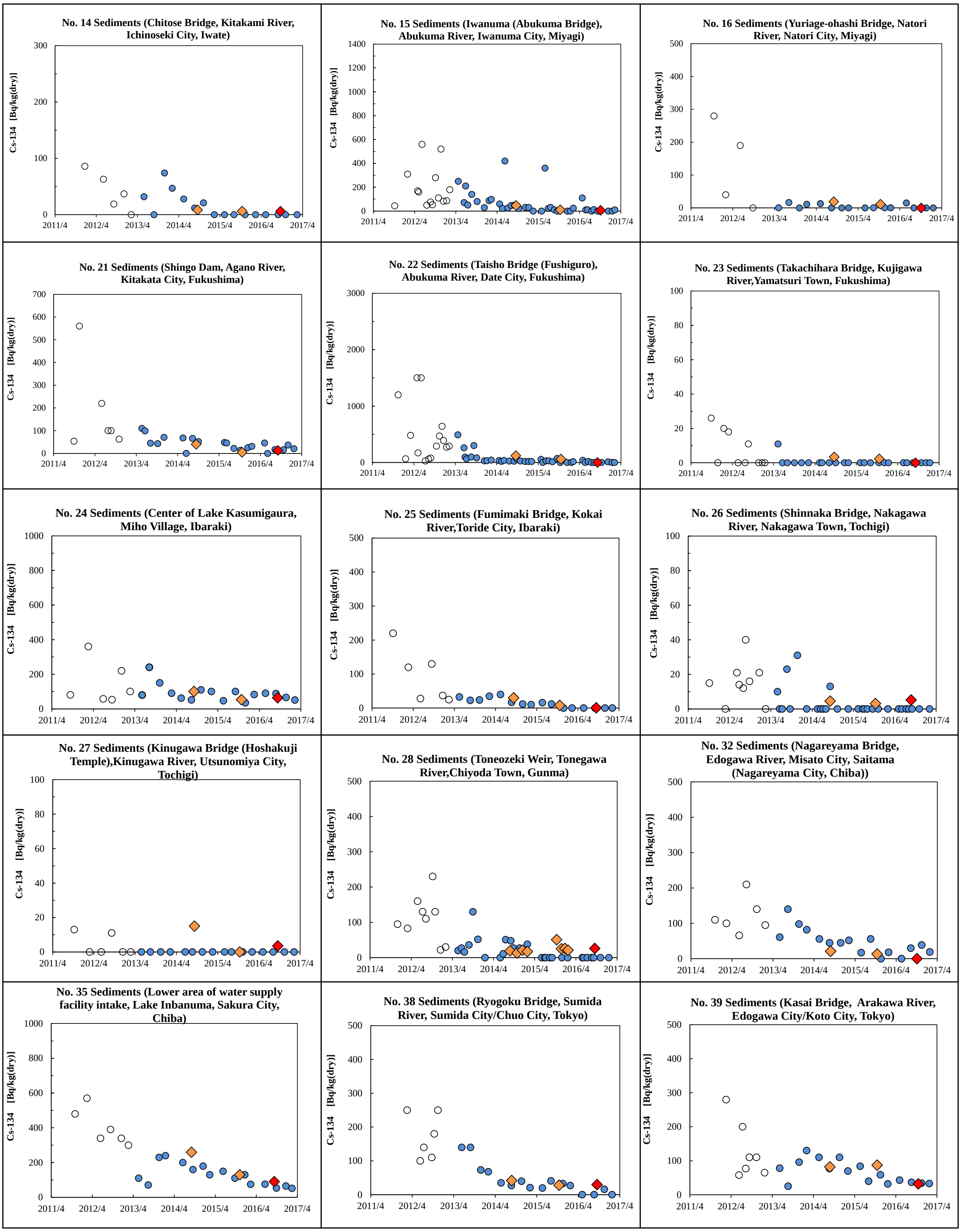
(iii) For locations that do not fall under the categories of (i) and (ii) above, collected data was compared to data from nearby locations obtained via Post-Earthquake Monitoring.

(iv) For locations where measured values did not exceed the range of past measurement records, collected data was compared with data obtained through the Monitoring of Levels and other reports.

(i) Comparison with the past Post-Earthquake Monitoring results for the same locations

Regarding locations where Post-Earthquake Monitoring was also conducted, the measured values in the latest monitoring were compared with the past measurement records for the same locations (see Figure 3.2-8).

All the results of the latest monitoring were found to be within the past measurement trends.



<Legend>

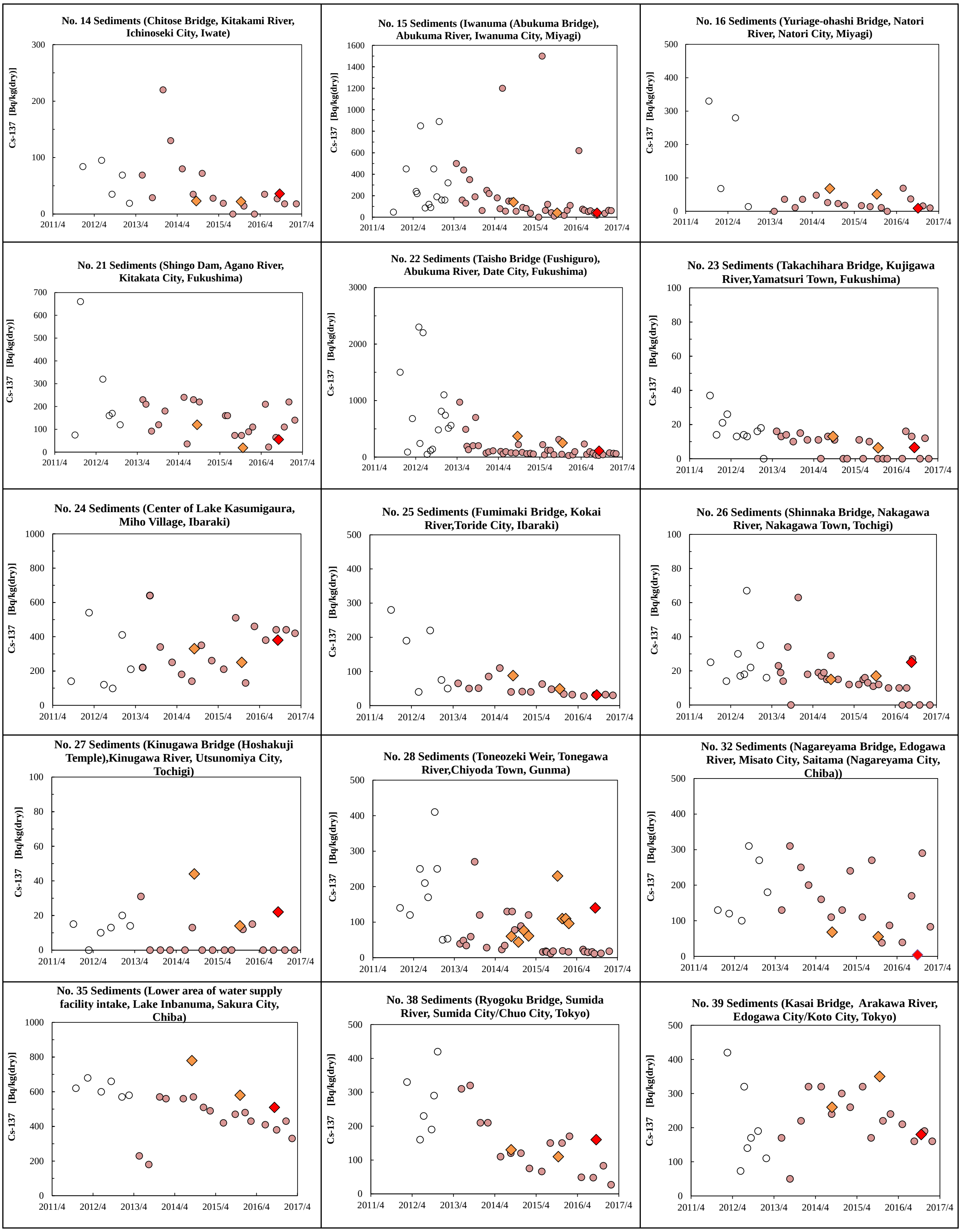
◆: FY2016 Nationwide Monitoring results

◆: FY2014-FY2015 Nationwide Monitoring results

●: Post-Earthquake Monitoring results

○: Post-Earthquake Monitoring results (measurement results from March 11, 2011 to March 10, 2013 which were excluded from the past measured values used as reference data)

Figure 3.2-8 (1) (i) Comparison with past Post-Earthquake Monitoring results for the same locations [Cs-134]



<Legend>

◆: FY2016 Nationwide Monitoring results

◆: FY2014-FY2015 Nationwide Monitoring results

● : Post-Earthquake Monitoring results

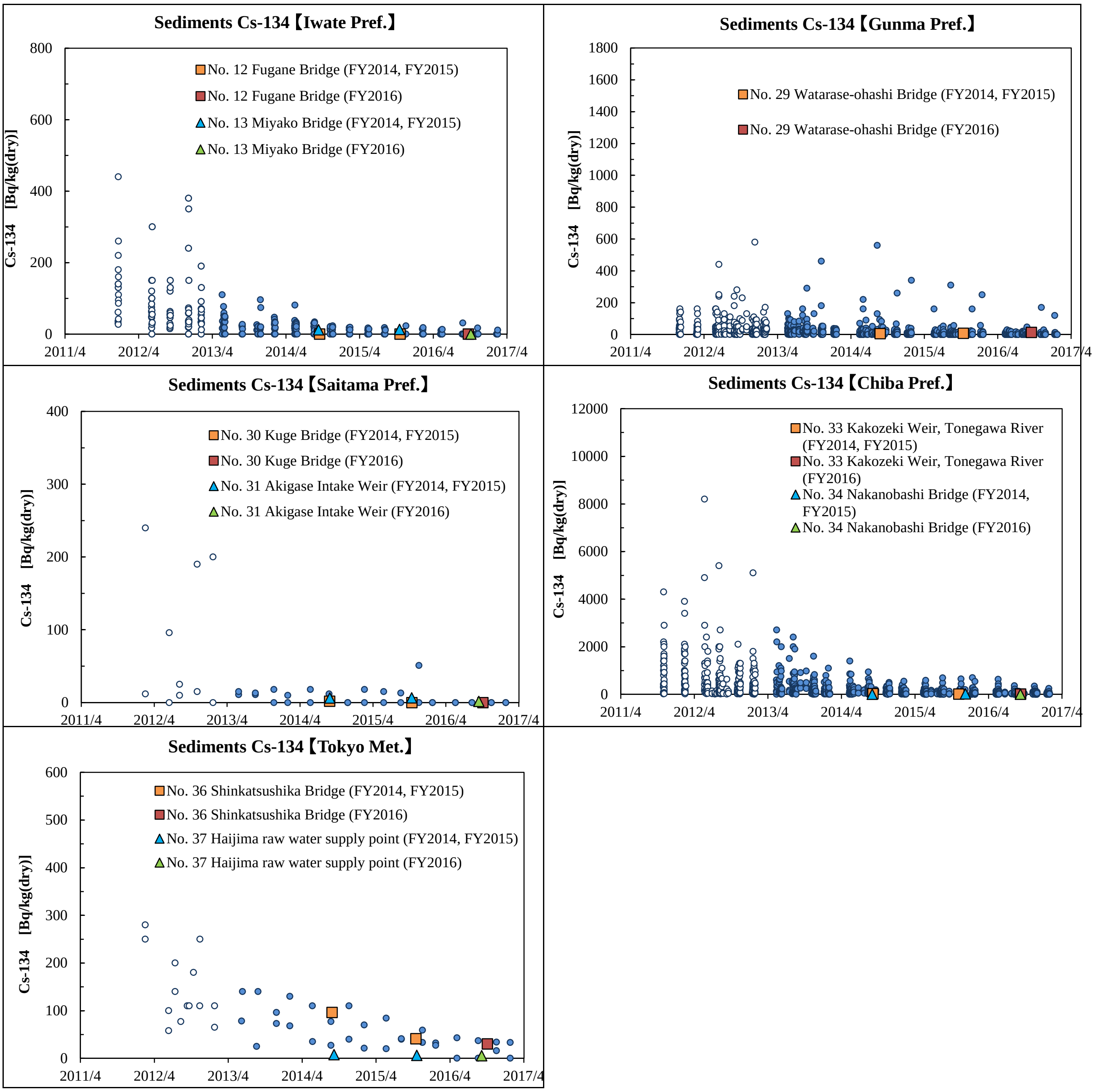
○ : Post-Earthquake Monitoring results (measurement results from March 11, 2011 to March 10, 2013, which were excluded from the past measured values used as reference data)

Figure 3.2-8 (2) (i) Comparison with the past Post-Earthquake Monitoring results for the same locations [Cs-137]

(ii) Comparison with the past Post-Earthquake Monitoring results in the same prefectures

For locations that have not been surveyed by Post-Earthquake Monitoring, the measured values obtained in the latest monitoring were compared with the past Post-Earthquake Monitoring results for locations in the same prefectures (see Figure 3.2-9).

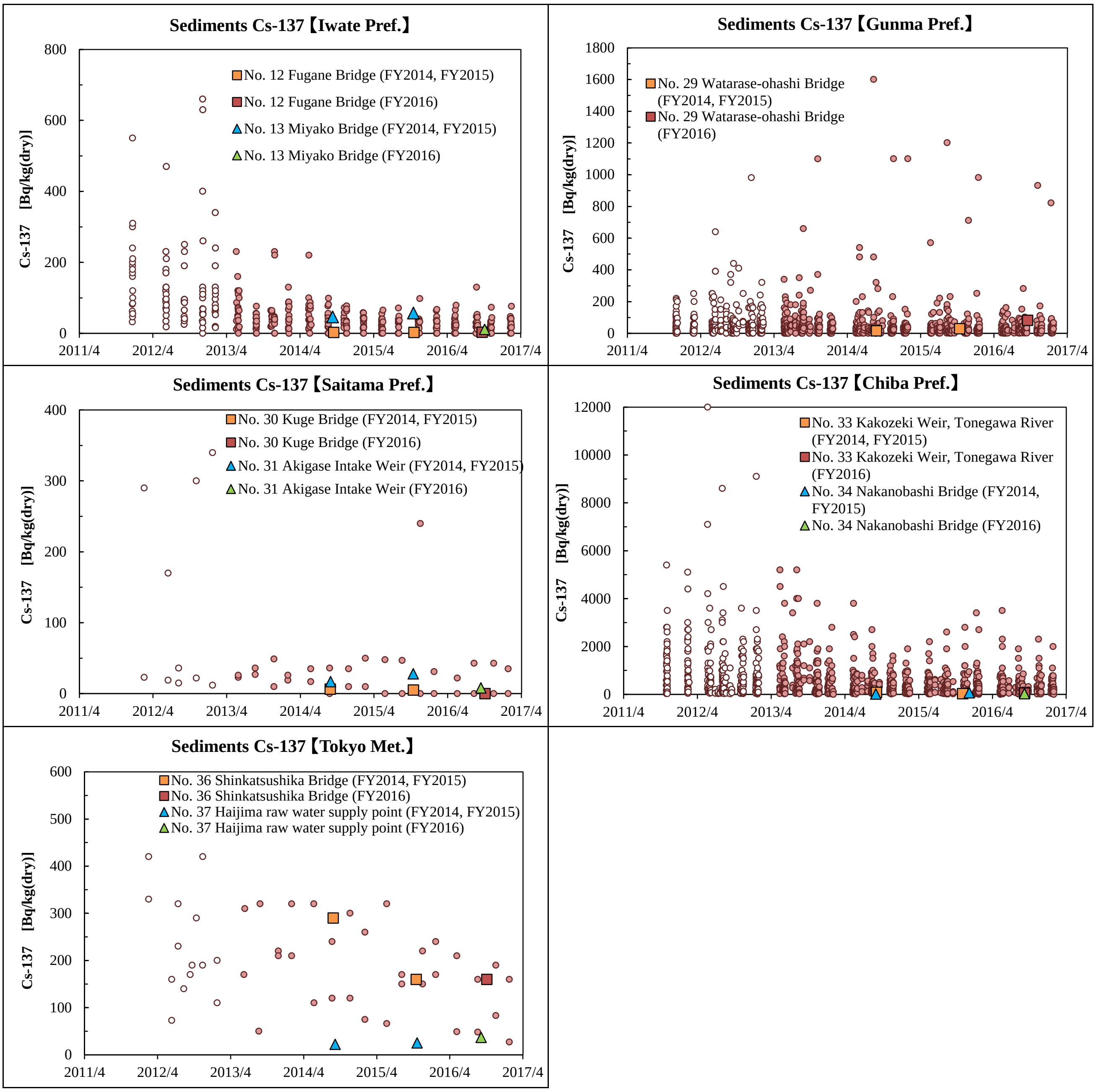
The measured values from the latest monitoring were all found to be within the past measurement trends.



● : Post-Earthquake Monitoring results

○ : Post-Earthquake Monitoring results (measurement results from March 11, 2011 to March 10, 2013 which were excluded from the past measured values used as reference data)

Figure 3.2-9 (1) (ii) Comparison with past Post-Earthquake Monitoring results in the same prefectures [Cs-134]

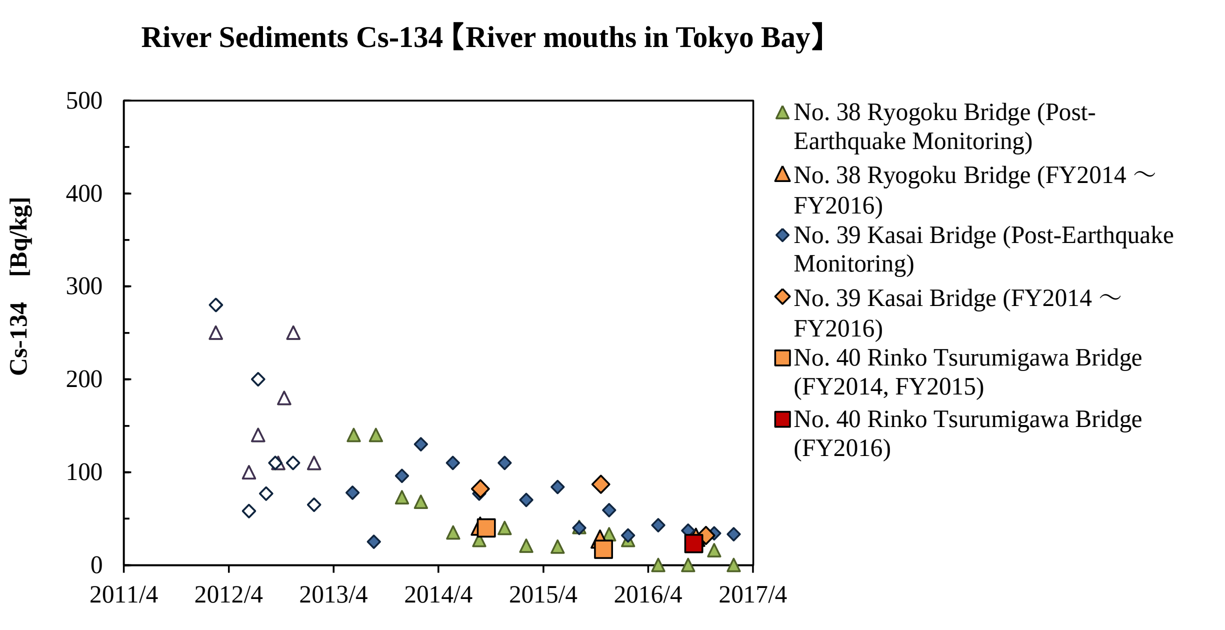


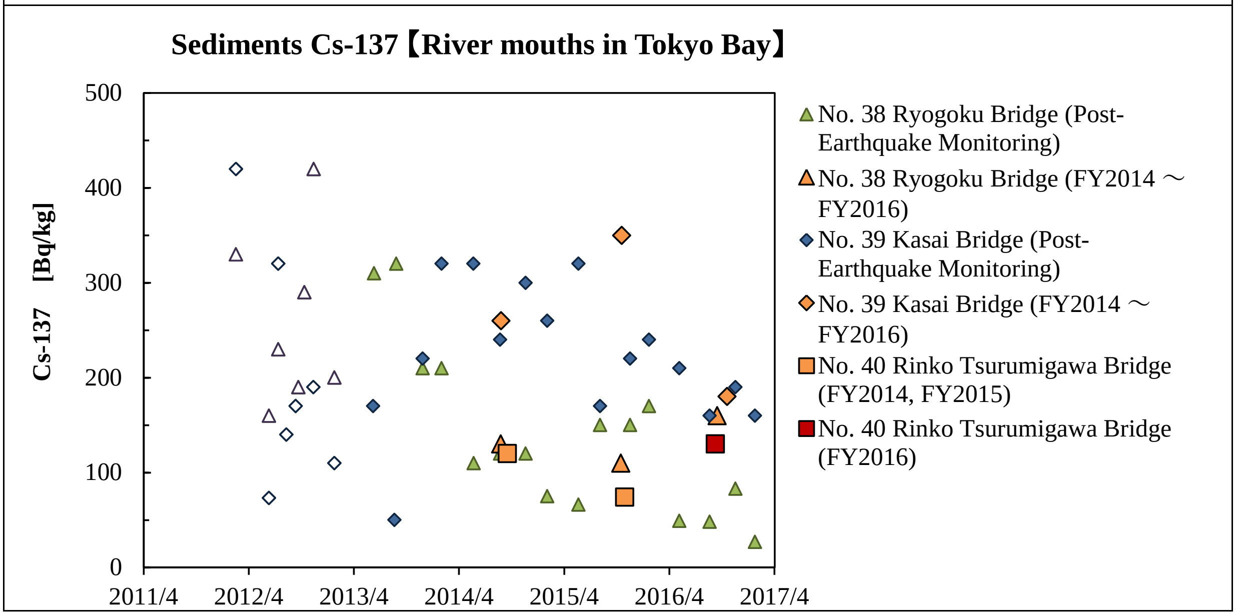
- : Post-Earthquake Monitoring results
- : Post-Earthquake Monitoring results (measurement results from March 11, 2011 to March 10, 2013 which were excluded from the past measured values used as reference data)

Figure 3.2-9 (2) (ii) Comparison with past Post-Earthquake Monitoring results in the same prefectures [Cs-137]

(iii) Comparison with past Post-Earthquake Monitoring results for nearby locations

Regarding Location No. 40 (Rinko Tsurumigawa Bridge, Tsurumi River, Yokohama City, Kanagawa Prefecture), it was considered reasonable to make a comparison with the past data for nearby locations although Post-Earthquake Monitoring had not been conducted in Kanagawa Prefecture. Therefore, a comparison was made with the past data for Location No. 38 (Ryogoku Bridge, Sumida River, Chuo City/Sumida City, Tokyo Metropolis) and Location No. 39 (Kasai Bridge, Arakawa River, Koto City/Edogawa City, Tokyo Metropolis), both of which are located at the mouths of the Sumida River and the Arakawa River to Tokyo Bay (see Figure 3.2-10). As a result, it was found that the measured values for Location No. 40 were within the past measurement trends.





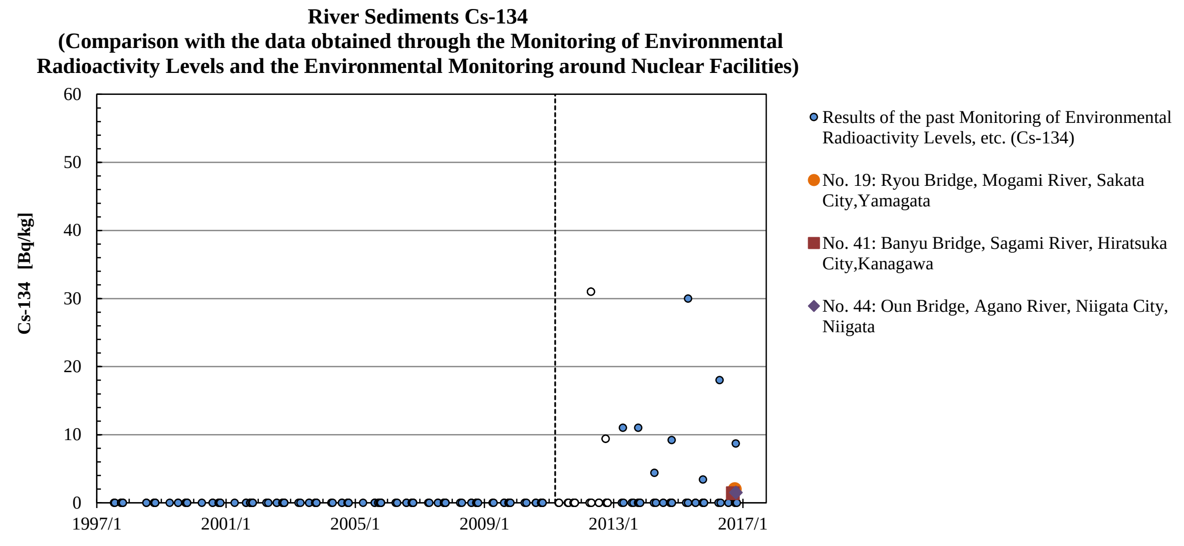
(*) Small white diamonds and triangles show the measurement results from March 11, 2011 to March 10, 2013, which were excluded from the past measured values used as reference.

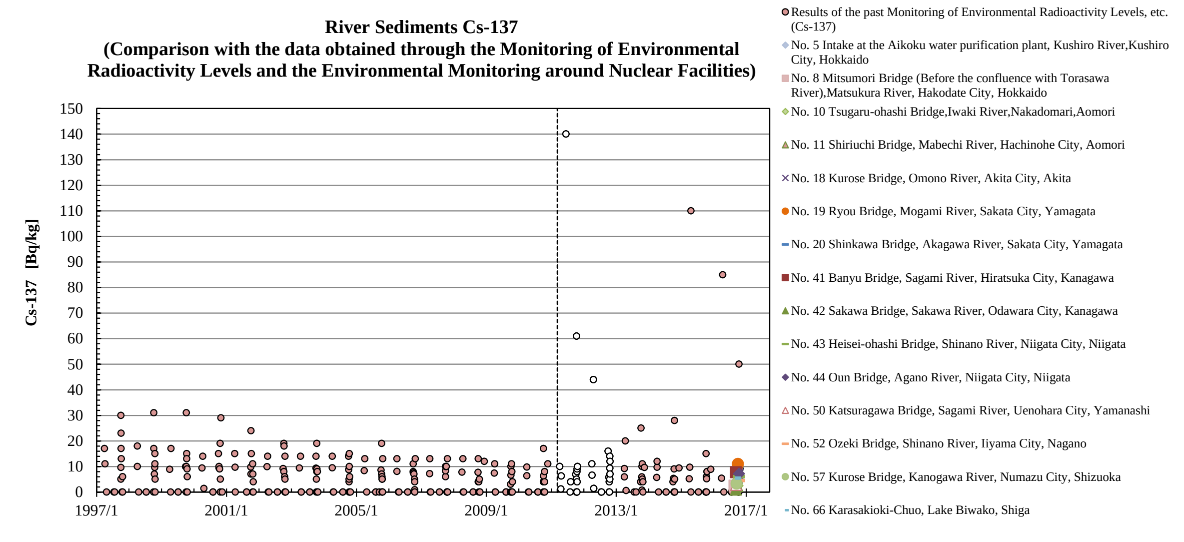
Figure 3.2-10 (iii) Comparison with past Post-Earthquake Monitoring results for nearby locations

(iv) Comparison with the data obtained from the Monitoring of Levels, etc.

For locations where measured values did not exceed the range of past measurement records, the measured values obtained during the latest monitoring were compared with the data obtained through the Monitoring of Environmental Radioactivity Levels, etc. to validate the concentration levels (see Figure 3.2-11).

Cs-134 and Cs-137 were detected at Location No. 19 (Ryou Bridge, Mogami River, Sakata City, Yamagata Prefecture), Location No. 41 (Banyu Bridge, Sagami River, Hiratsuka City, Kanagawa Prefecture), and Site No.44 (Oun Bridge, Agano River, Niigata City, Niigata Prefecture). At other locations , only Cs-137 was detected and the measured values all fell within the past measurement trends.





(*) Upper: Cs-134, Lower: Cs-137

(*) A dotted line shows the day the Great East Japan Earthquake occured (March 11, 2011). White small circles show the measurement results from March 11, 2011 to March 10, 2013, which excluded from the past measured values used as reference.

Figure 3.2-11 (iv) Comparison with the data obtained through the Monitoring of Environmental Radioactivity Levels, etc.

As a reference, a good correlation was confirmed in the activity concentration ratios of Cs-137 and Cs-134 in locations where both Cs-134 and Cs-137 were detected (all in the Tohoku and Kanto blocks). The calculated activity concentration ratio was approximately 5.6 (Cs-137/Cs-134). Assuming that detected Cs-134 and Cs-137 are those discharged due to the Fukushima NPS Accident, this ratio should be approximately equal to the theoretical ratio (approx. 5.6) as of September 2016 after the discharge in March 2011 (see Figure 3.2-12). This suggests that Cs-134 and Cs-137 detected in sediment samples collected in the Tohoku and Kanto blocks were indeed derived from the Fukushima NPS Accident.

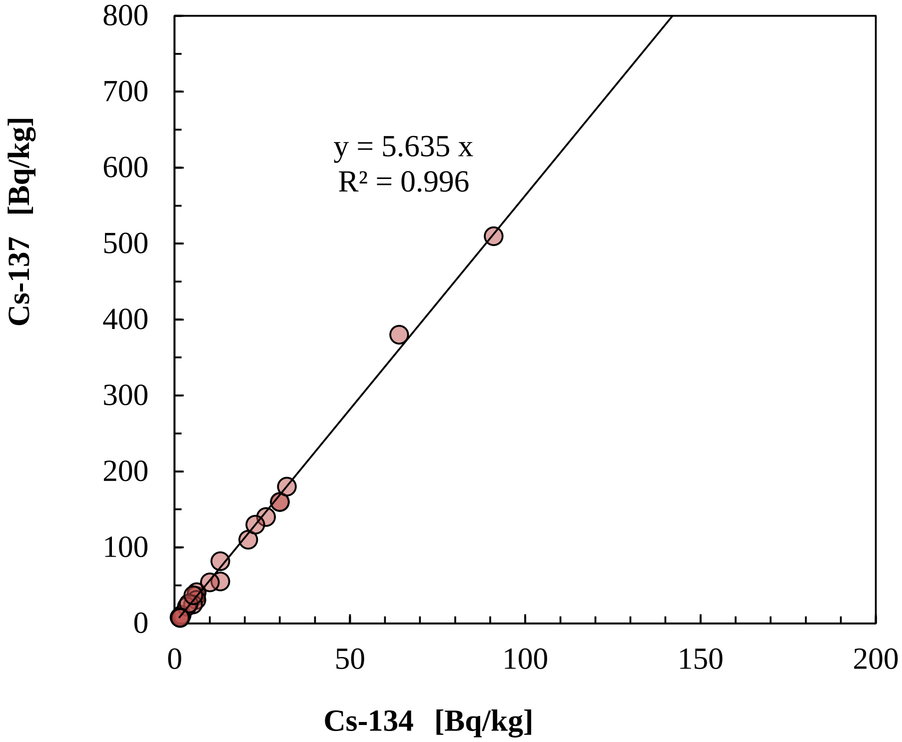


Figure 3.2-12　Concentration ratio (Cs-137/Cs-134) [Sediments (public water areas)]

(Reference: Changes in concentration ratios (Cs-137/Cs-134) over time, accounting for half-life periods)

Radionuclide	Half-life (years)	2011/3	2012/3	2013/3	2014/3	2015/3	2015/11	2016/9
Cs-134	2.0648	1	0.71	0.51	0.36	0.26	0.21	0.16
Cs-137	30.1671	1	0.98	0.96	0.93	0.91	0.90	0.88
Cs137／Cs134		1	1.37	1.87	2.56	3.50	4.28	5.62

(*) The concentration ratio at the time of the latest monitoring (around September 2016) is estimated to be approximately 5.6 (highlighted in yellow in the table above).

Given these facts, Cs-134 and Cs-137 detected in sediment samples from public water areas were mostly derived from the Fukushima NPS Accident, except for some locations for which causal relations were unclear, but the detected values were all within the past measurement trends.

2) Cs-134 and Cs-137 in water

Cs-134 or Cs-137 were detected at 21 out of the 110 locations where water samples from public water areas were collected (a total of 21 locations: both Cs-134 and Cs-137 were detected at seven locations (all in the Tohoku and Kanto blocks) and only Cs-137 was detected at 14 locations). The maximum values were 0.0055 Bq/L for Cs-134 and 0.031 Bq/L for Cs-137. Moreover, these values fell within the range of past measured values from the Monitoring of Environmental Radioactivity Levels (max. 0.034 Bq/L for Cs-134, and max 0.058 Bq/L for Cs-137).

At the seven locations (all in the Tohoku and Kanto blocks) where both Cs-134 and Cs-137 were detected, the concentration ratio (Cs-137/Cs-134) was calculated in the same manner as with the sediment samples and also showed a good correlation. The obtained concentration ratio was approximately 5.6. Assuming that detected Cs-134 and Cs-137 were those discharged due to the Fukushima NPS Accident, this ratio should be close to the theoretical ratio (approx. 5.6) as of September 2016 after the discharge in March 2011 (see Figure 3.2-13). This suggests that Cs-134 and Cs-137 detected in water samples collected in the Tohoku and Kanto blocks were indeed derived from the Fukushima NPS Accident.

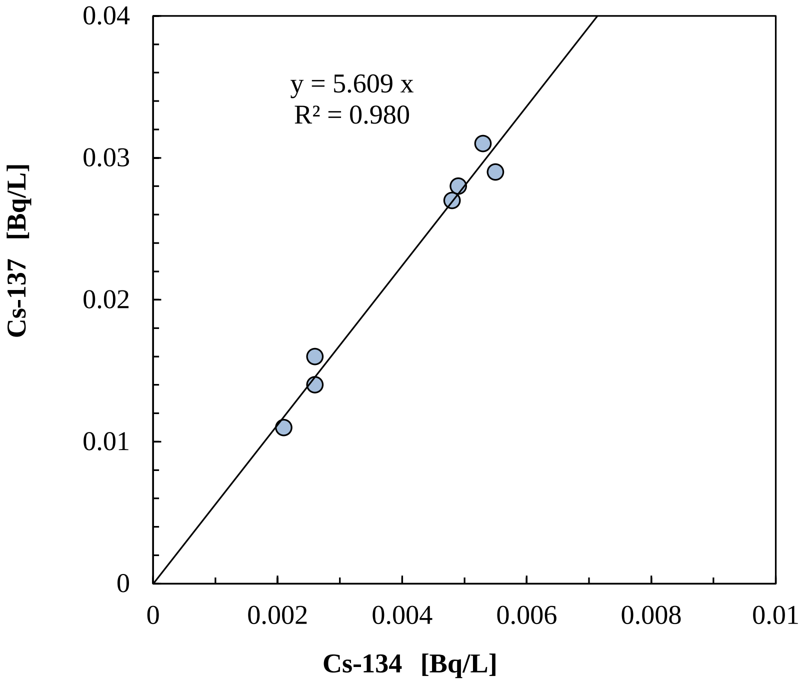


Figure 3.2-13 Concentration ratio (Cs-137/Cs-134) [Water (public water areas)]

3) Cs-134 and Cs-137 in groundwater

Cs-134 and Cs-137 were not detected in groundwater samples collected at any of the 110 locations (detection limit: approx. 0.001 to 0.002 Bq/L).

3.3 Survey to check annual variation

At two locations[6] (both in rivers), namely, Location No. 28 (Toneozeki Weir, Tonegawa River, Chiyoda Town, Gunma Prefecture) and Location No. 83 (Kasumi Bridge, Takahashi River, Kurashiki City, Okayama Prefecture), surveys were conducted four times during the period from May 24, 2016 to January 27, 2017. These two locations had been previously surveyed four times each in FY2014 and in FY2015, and the current analysis includes the results from those prior years.

Radionuclides were detected as shown in Table 3.3-1 and Table 3.3-2. Figure 3.3-1 and 3.3-2 show the changes in radionuclides detected in and after FY2014. Table 3.3-1 and Table 3.3-2 also show the coefficients of variation[7] (= sample standard deviation /average) indicating for the variations in detected values.

The coefficients of variation in water samples ranged from 15% to 26% for total β radioactivity and K-40, and stood at 36% for Cs-137, respectively[8].

The coefficients of variation in sediment samples ranged from 5.2% to 27% for total β radioactivity and naturally occurring radionuclides (Ac-228, Bi-212, Bi-214, Pb-212, Pb-214, Tl-208, and K-40), and from 47 to 51% for radioactive cesium.

For reference, sediment grain size distribution and CS-137 concentration change for Location No. 28 are shown in Figure 3.3-3, and sediment grain size distribution for Location No. 83 is shown in Figure 3.3-4.

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[6] It was decided that one location each would be selected in eastern and western Japan. To make the selection, all 110 locations were first divided into two areas for convenience (Locations No. 1 to No. 55 were classified as eastern Japan and Locations No. 56 to No. 110 were classified as western Japan) and the middle number in each area was selected.

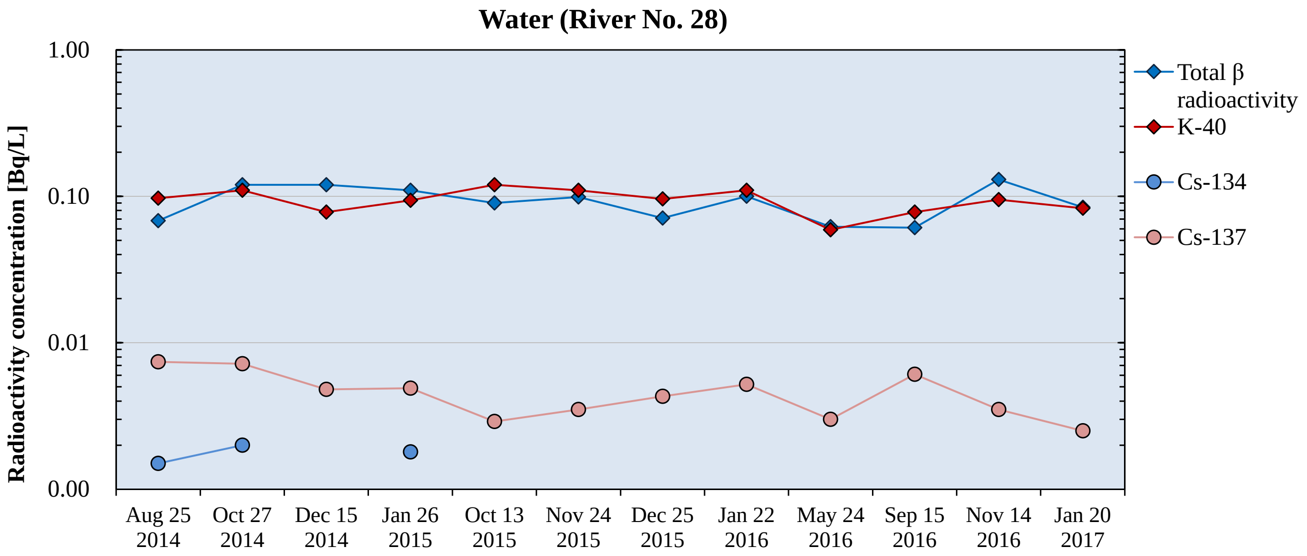
[7] In this report: coefficient of variation = sample standard deviation divided by the average; hereinafter the same shall apply.

[8] Fluctuations in measured radioactivity were reported when sites were sampled multiple times. For instance, the FY2012 survey shows 12 to 16 % fluctuations in the amount of radioactive cesium contained in riverbed sediments (nine samples collected during the same period). At River Site No. 28, radioactive cesium was detected in sediment, and a drop in water transparency probably due to sludge disturbance caused by pleasure boats or winds in the vicinity was observed. This changed the water and bottom sampling locations slightly, and changes in the distribution of sediment grain size was observed. Because the changes in sediment grain size distribution might have affected the concentration of radioactive cesium, the changes in sediment grain size distribution and Cs-137 concentration at River Site No. 28 are graphically summarized in Figure 3.3-3. This revealed that sediment samples with high clay and silt contents tend to have higher Cs-137 concentrations. Accordingly, it was inferred that the fluctuations in the amount of radioactive cesium in samples from River Site No. 28 had occurred due to the changes in the grain size distribution in the sediment samples.

Table 3.3-1 Detection trends for radioactive materials at the same location [River No. 28]

	Radionuclides	FY2014				FY2015				FY2016				Coefficient of variation [%]
		Aug 25	Oct 27	Dec 15	Jan 26	Oct 13	Nov 24	Dec 25	Jan 22	May 24	Sep 15	Nov 14	Jan 20	
Water [Bq/L]	Total β radioactivity	0.068	0.12	0.12	0.11	0.090	0.099	0.071	0.10	0.062	0.061	0.13	0.084	26
	K-40	0.097	0.11	0.078	0.094	0.12	0.11	0.096	0.11	0.059	0.078	0.095	0.083	18
	Cs-134	0.0015	0.0020	<0.0010	0.0018	<0.0022	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0017	<0.0013	-
	Cs-137	0.0074	0.0072	0.0048	0.0049	0.0029	0.0035	0.0043	0.0052	0.0030	0.0061	0.0035	0.0025	36
Sediment [Bq/kg]	Total β radioactivity	410	350	350	380	720	460	490	430	410	460	400	450	22
	K-40	290	330	280	280	290	370	320	320	280	300	250	260	11
	Ac-228	15	9.8	12	15	23	18	22	20	15	21	18	12	26
	Be-7	<24	<36	<38	<25	<76	<68	<44	<28	<54	59	<66	<29	-
	Bi-212	<32	<17	<28	<23	<46	<30	<21	<23	37	29	<30	<30	-
	Bi-214	<12	11	13	13	14	15	16	12	12	13	16	18	15
	Pb-212	18	16	21	16	28	18	16	18	17	21	19	19	18
	Pb-214	11	11	16	11	14	15	17	13	19	17	18	13	19
	Tl-208	16	12	13	14	18	11	15	17	14	21	14	13	19
	Cs-134	19	13	21	17	51	25	26	21	15	26	19	11	47
	Cs-137	60	44	76	61	230	110	110	96	74	140	96	72	51

(*) The coefficients of variation are shown only for radionuclides detected five times or more.



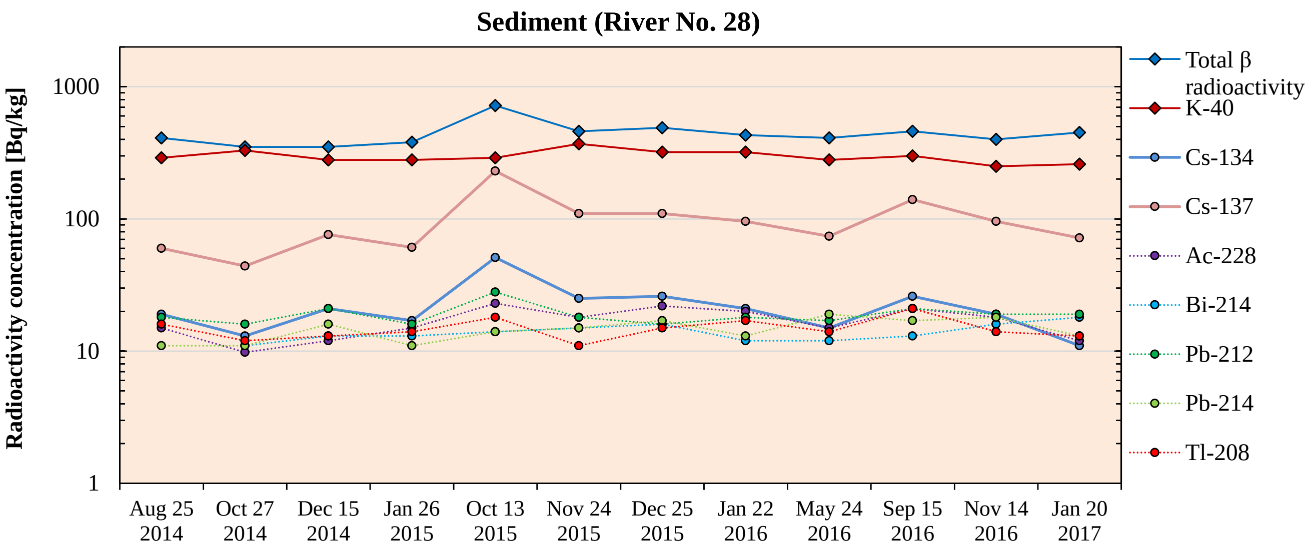
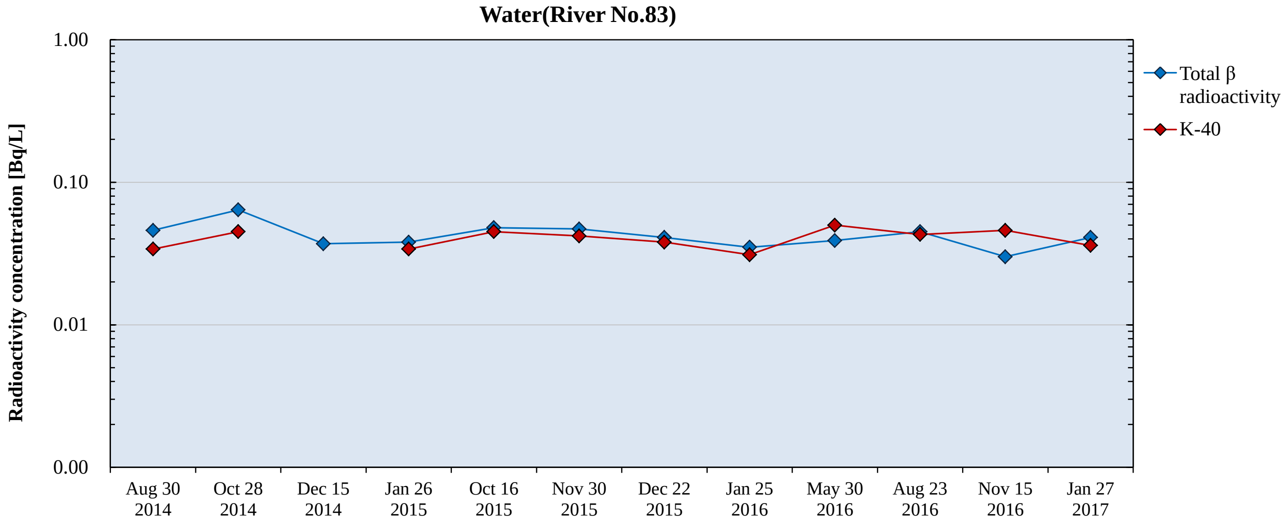


Figure 3.3-1 Changes in detection trends for radioactive materials at the same location [River No. 28]

Table 3.3-2 Detection trends for radioactive materials at the same location [River No. 83]

	Radionuclides	FY2014				FY2015				FY2016				Coefficient of variation [%]
		Aug 30	Oct 28	Dec 15	Jan 26	Oct 16	Nov 30	Dec 22	Jan 25	May 30	Aug 23	Nov 15	Jan 27	
Water [Bq/L]	Total β radioactivity	0.046	0.064	0.037	0.038	0.048	0.047	0.041	0.035	0.039	0.045	0.030	0.041	20
	K-40	0.034	0.045	<0.028	0.034	0.045	0.042	0.038	0.031	0.050	0.043	0.046	0.036	15
	Be-7	<0.024	0.012	<0.0073	<0.0073	<0.024	<0.018	<0.013	<0.0085	<0.011	<0.040	<0.022	<0.0078	-
	Pb-212	<0.0019	<0.0021	<0.0019	0.0013	<0.0019	<0.0015	<0.0015	<0.0014	<0.0017	<0.0015	<0.0015	<0.0014	-
Sediment [Bq/kg]	Total β radioactivity	1000	980	890	920	1000	1000	950	940	930	1100	940	990	5.6
	K-40	870	830	910	770	920	920	840	840	840	900	840	840	5.2
	Ac-228	13	25	12	19	25	21	29	25	17	18	24	15	27
	Bi-212	42	34	23	28	28	<33	37	<34	<35	34	<28	<29	20
	Bi-214	15	21	17	17	16	19	16	19	19	14	18	14	13
	Pb-212	28	28	24	27	28	26	26	27	24	21	22	23	9.7
	Pb-214	21	23	19	15	21	20	22	18	24	16	17	17	15
	Ra-226	50	<42	36	<39	<37	<46	<44	<41	<42	<38	<42	<39	-
	Th-234	<30	<41	30	42	<31	<47	<45	<47	<160	<140	<150	<140	-
	Tl-208	25	20	21	25	23	24	15	19	23	21	21	17	15

(*) The coefficients of variation are shown only for radionuclides detected five times or more.



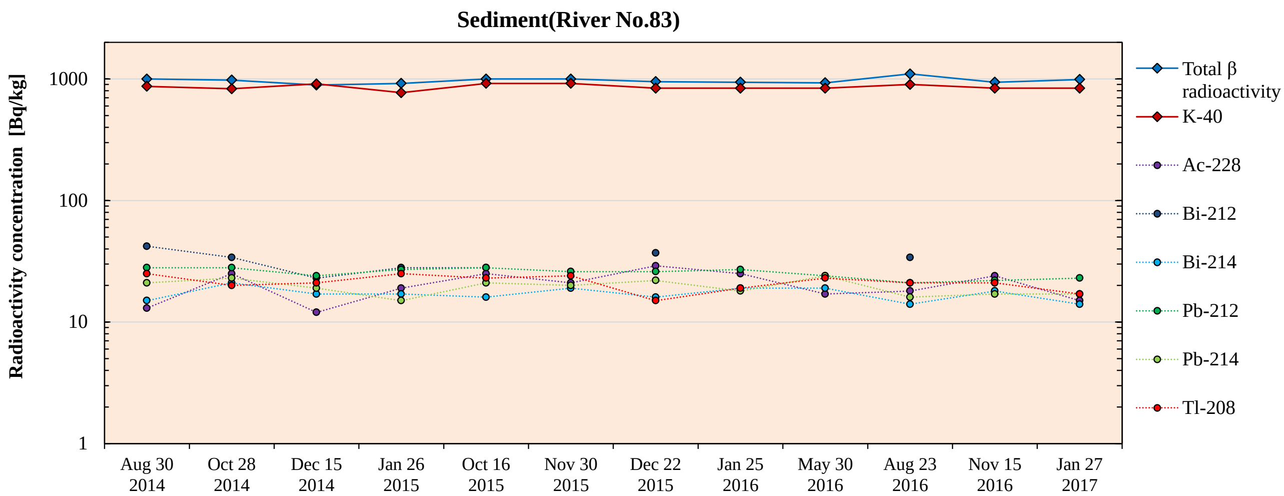


Figure 3.3-2 Changes in detection trends for radioactive materials at the same location [River No. 83]

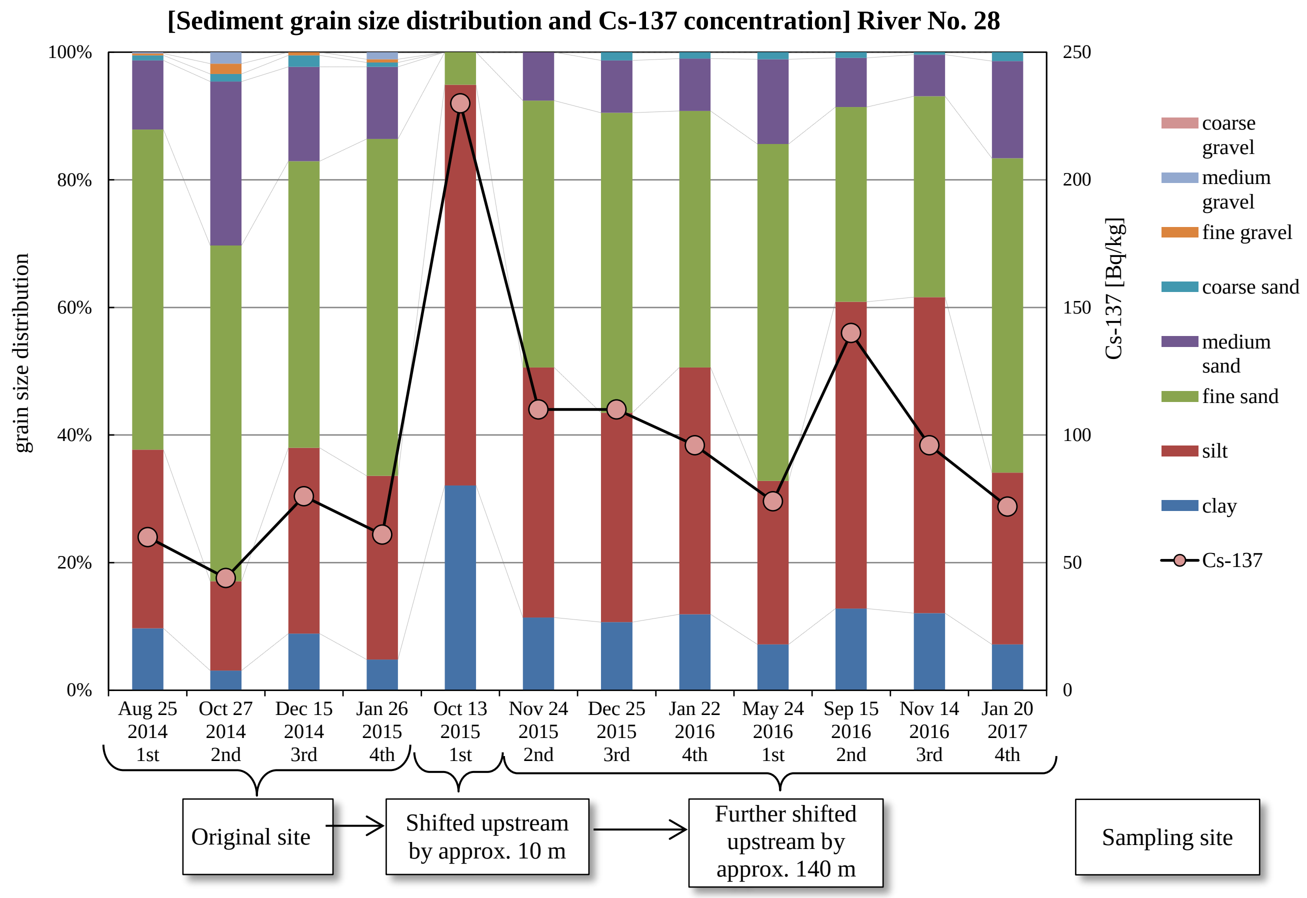


Figure 3.3-3 Changes in sediment grain size distribution and Cs-137 concentration [River No. 28]

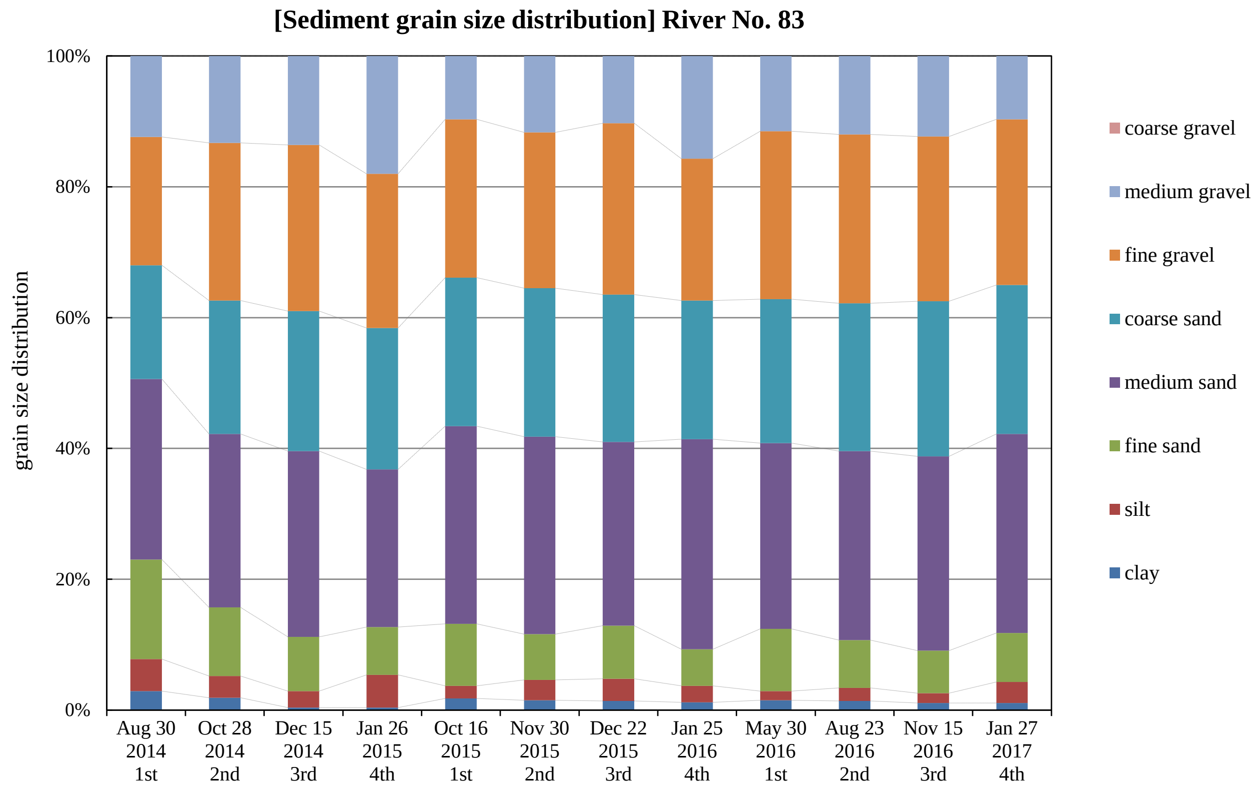


Figure 3.3-4 Changes in sediment grain size distribution [River No. 83]