The image shows a complex industrial facility with large pipes, valves, and machinery. The equipment is primarily grey and white, with several prominent red handwheels on the valves. The setting appears to be an indoor industrial space with a high ceiling and large windows in the background. The floor is covered with a metal grating.

CO₂ injection and monitoring of the Tomakomai CCS Demonstration Project

5th International Workshop on Offshore Geologic CO₂ Storage
19 – 20 May 2022

Daiji Tanase, Japan CCS Co., Ltd.

JCCS

Japan CCS Co., Ltd.

■ Outline of Presentation

- Overview of the project
- Reservoirs and injection & monitoring facilities
- Key results
- Summary

- First large-scale CCS demonstration project in Japan
- Location: Tomakomai City, Hokkaido Prefecture
- Commissioned by: METI, NEDO
- Contractor: JCCS



Photo by University of Texas

➤ Overview of the project

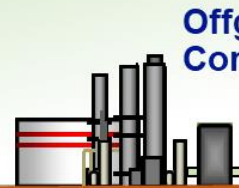
Project scheme and schedule

- ◆ The CO₂ source is a hydrogen production unit of an oil refinery
- ◆ A portion of PSA (Pressure Swing Adsorption) offgas containing approximately 52% CO₂ generated by a hydrogen production unit is transported by 1.4 km pipeline to the CO₂ capture facility.
- ◆ After CO₂ capture and compression, the CO₂ is injected into two offshore subsurface reservoirs

Typical PSA offgas composition

CO ₂	51.6%
H ₂	38.8%
CH ₄	6.6%
CO	2.3%
H ₂ O	0.7%

CO₂ source



Hydrogen production unit of Existing oil refinery

Offgas Containing CO₂

Pipeline 1.4km

Capture

Activated amine process



CO₂ capture capacity = 200,000 tonnes/year

Injection

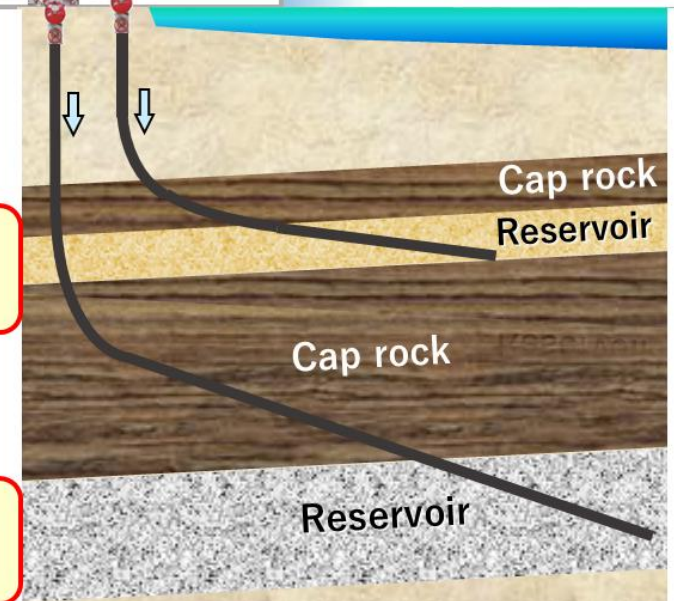
Compressors

Injection wells

2 wells

Storage

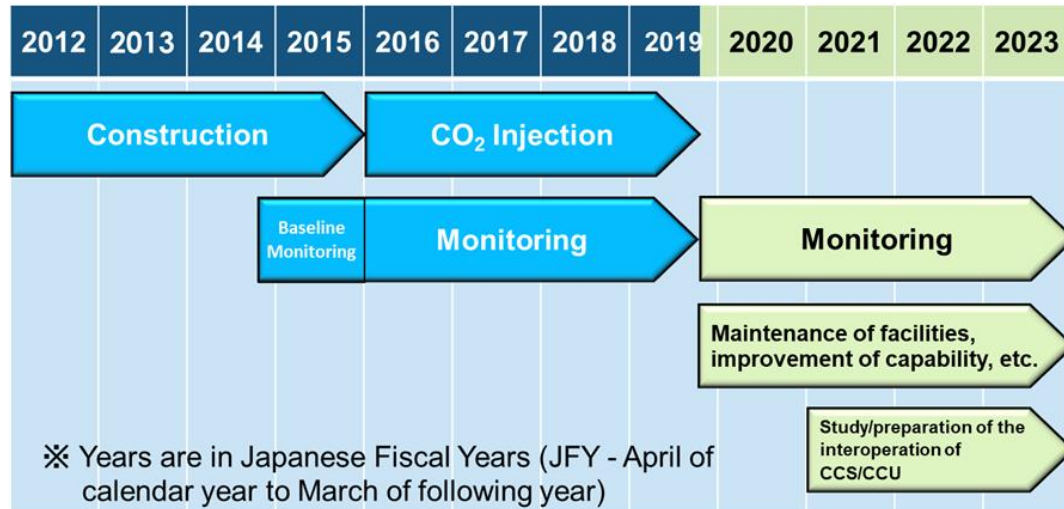
Offshore Tomakomai



Reservoir

Moebetsu Formation : Sandstone layers
1,000 – 1,200m sub-seabed

Takionue Formation : Volcanic rock layers
2,400 – 3,000m sub-seabed

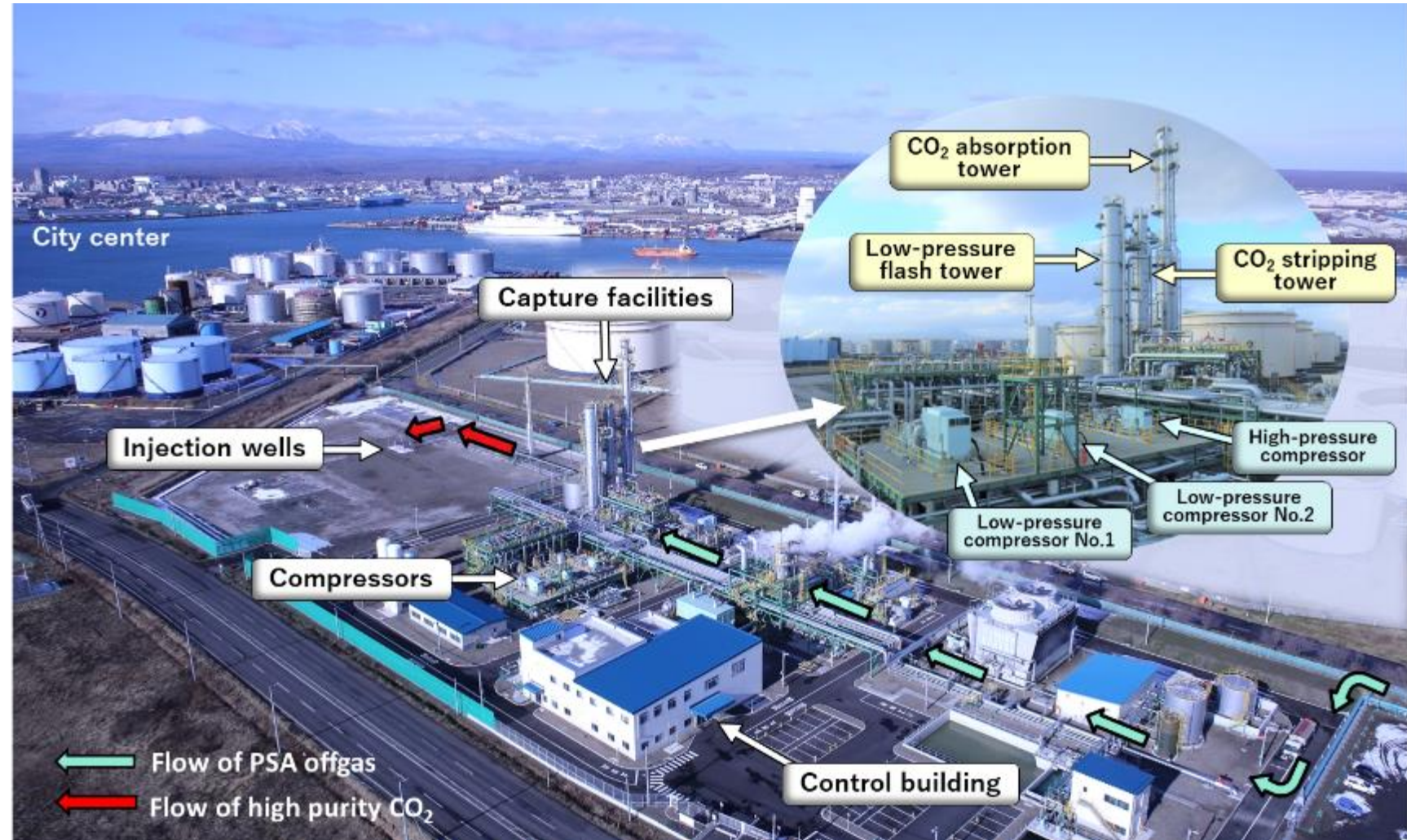


※ Years are in Japanese Fiscal Years (JFY - April of calendar year to March of following year)

Main features of Tomakomai CCS Demonstration Project

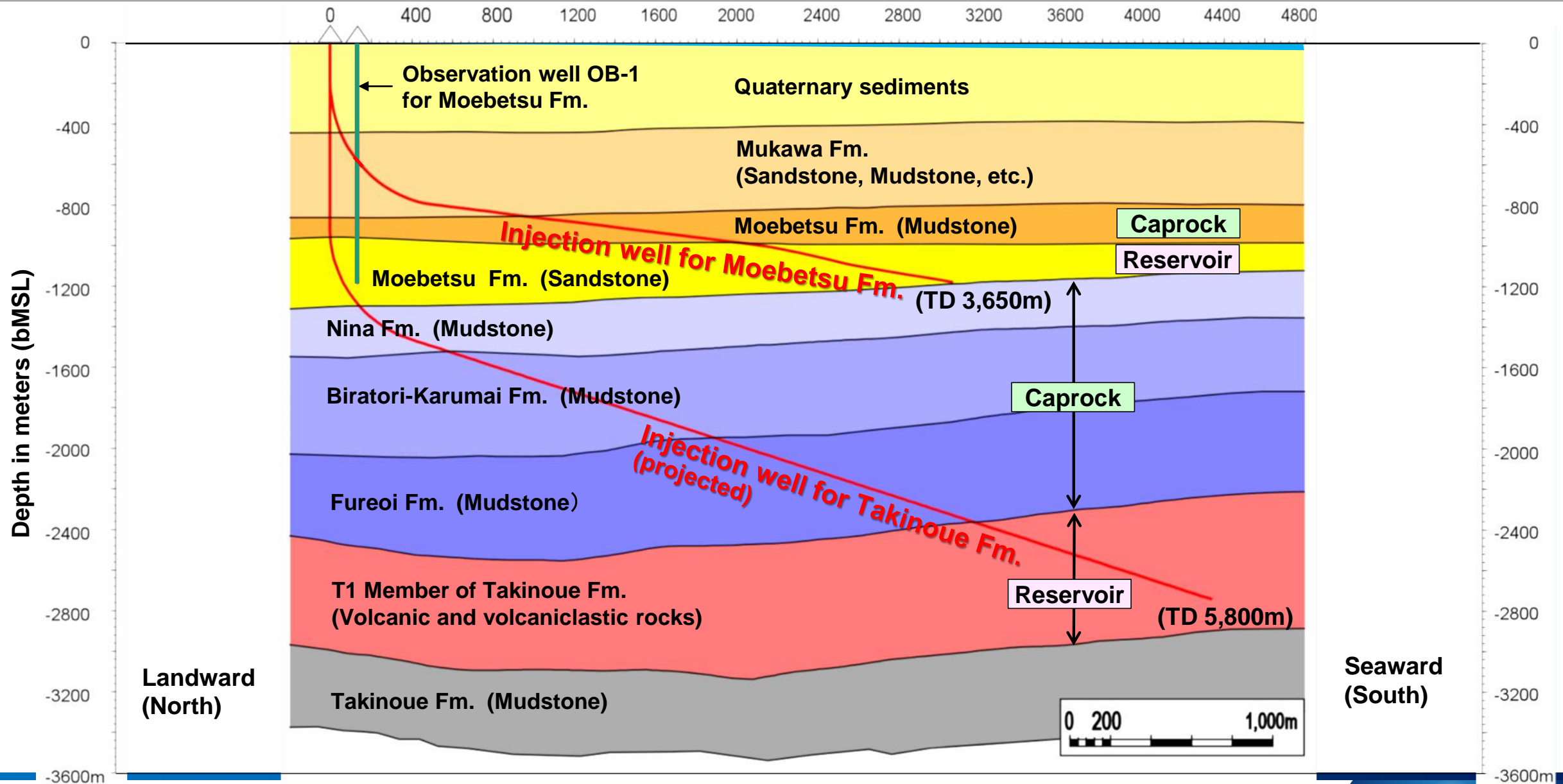
- ◆ World first offshore CCS project in a busy port area of large city
- ◆ CO₂ storage governed by Japanese law reflecting the London Protocol 1996
- ◆ Energy efficient CO₂ capture process
- ◆ Two highly deviated injection wells drilled from onshore targeting two separate sub-seabed reservoirs with injection intervals exceeding 1,100m
- ◆ Extensive onshore and offshore monitoring system for observation of CO₂ behavior in the reservoirs, micro seismicity and natural earthquakes
- ◆ Marine environmental surveys conducted each season

Bird's eye view of capture and injection facilities



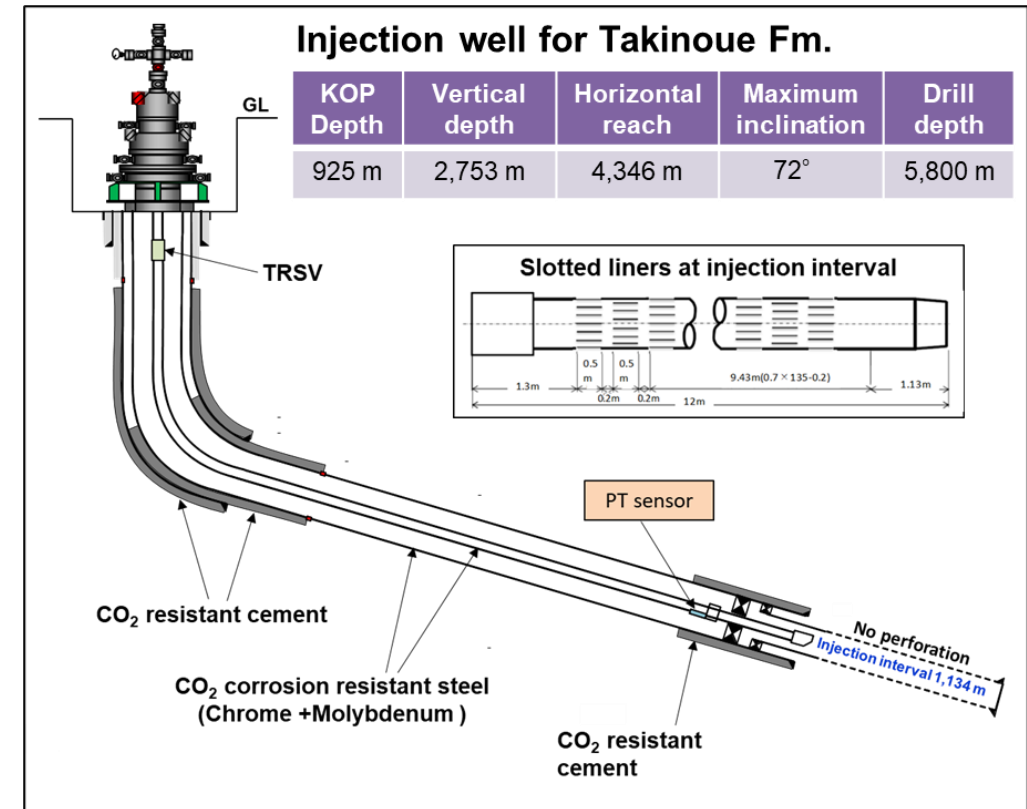
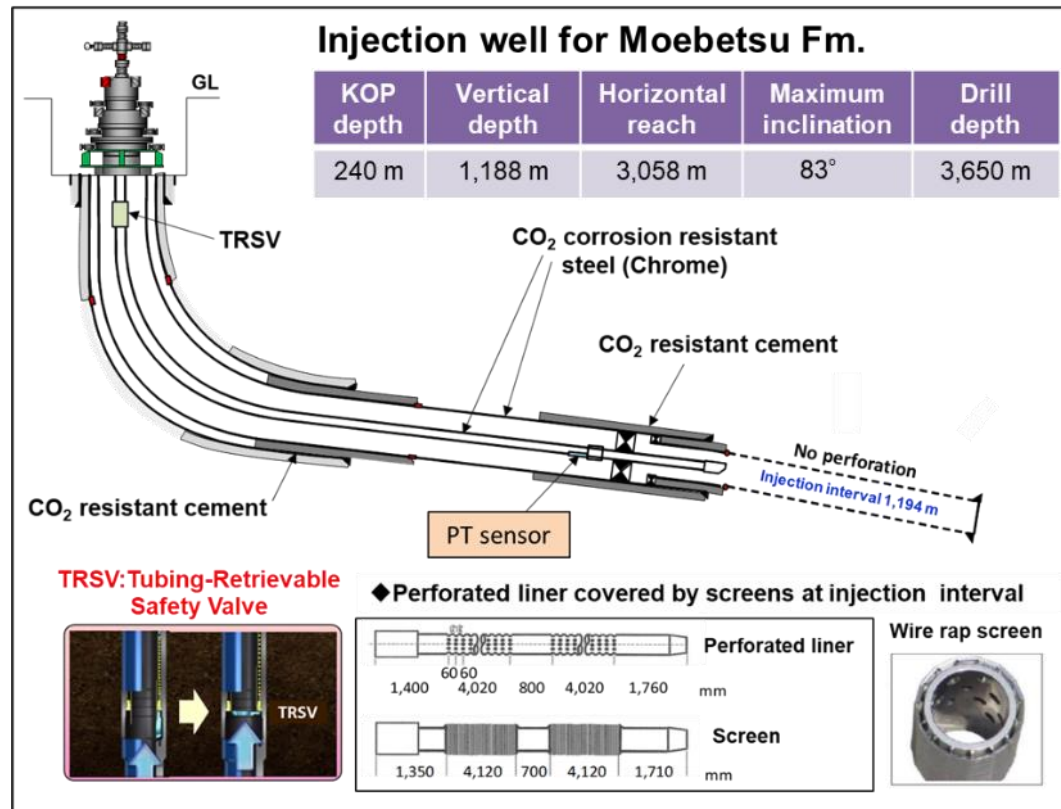
➤ Reservoirs and injection & monitoring facilities

Geological section

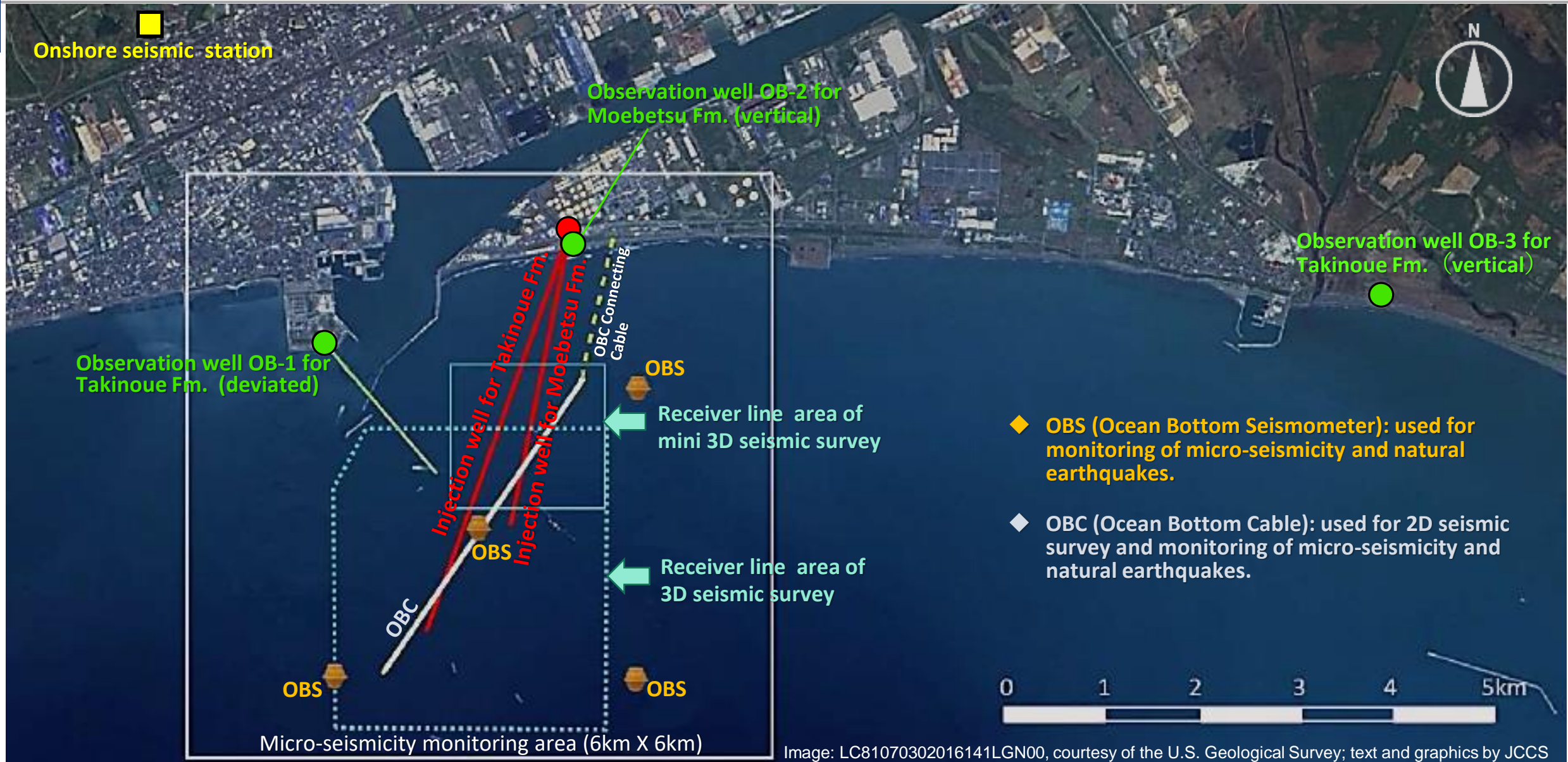


Schematic diagram of geologic layers and injection wells

- ◆ The captured CO₂ is compressed and stored 3-4km offshore in two sub-seabed reservoirs at different depths – Moebetsu and Takinoue formations by two independent injection wells
- ◆ Deviated CO₂ injection wells drilled from onshore to offshore sub-seabed
 - Cost reduction of drilling, operation and maintenance
 - No disturbance on marine environment and harbor operation
- ◆ Injection interval length exceeding 1,100m to enhance injection efficiency

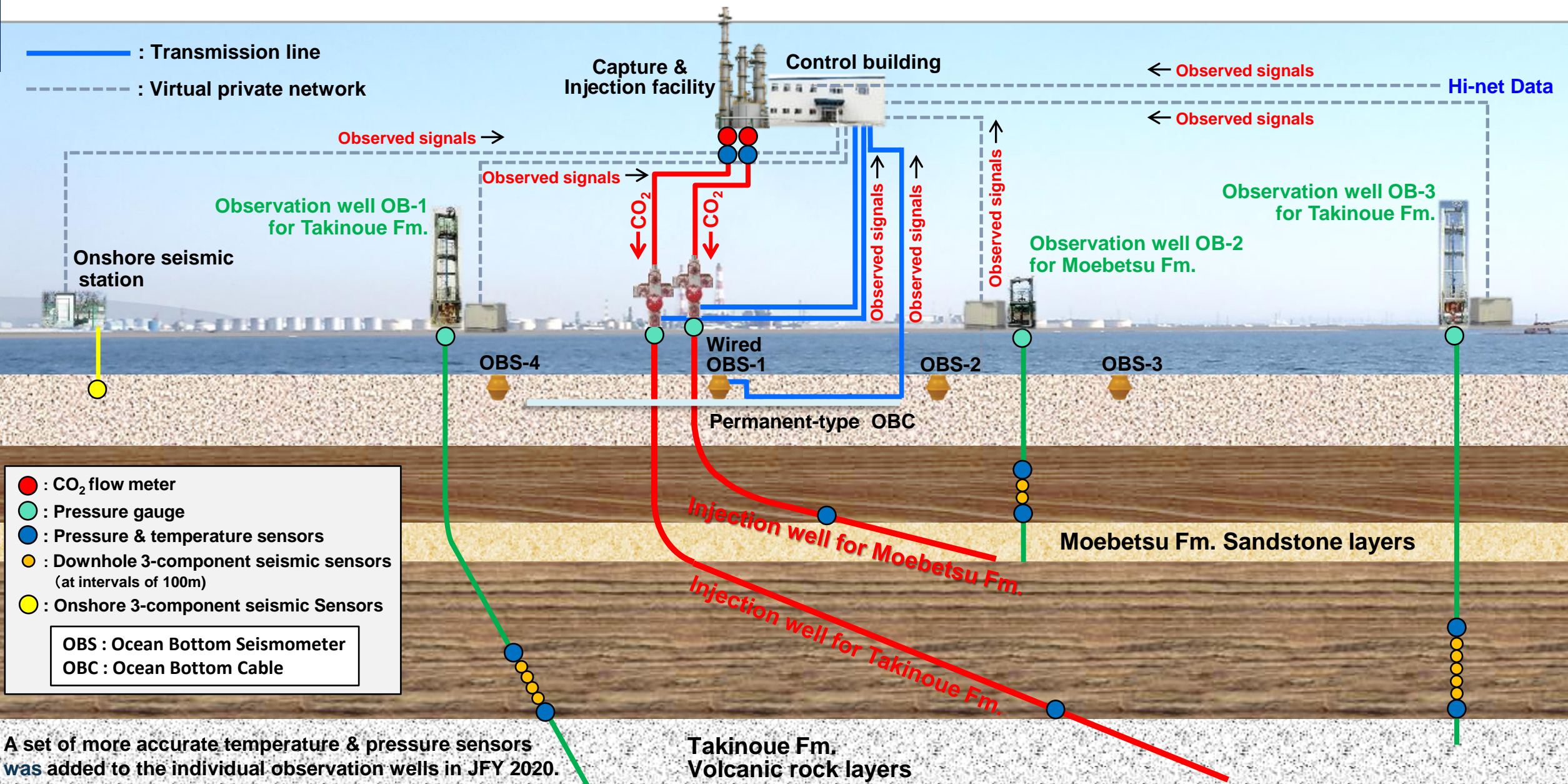


Layout of monitoring system



- ◆ **OBS (Ocean Bottom Seismometer):** used for monitoring of micro-seismicity and natural earthquakes.
- ◆ **OBC (Ocean Bottom Cable):** used for 2D seismic survey and monitoring of micro-seismicity and natural earthquakes.

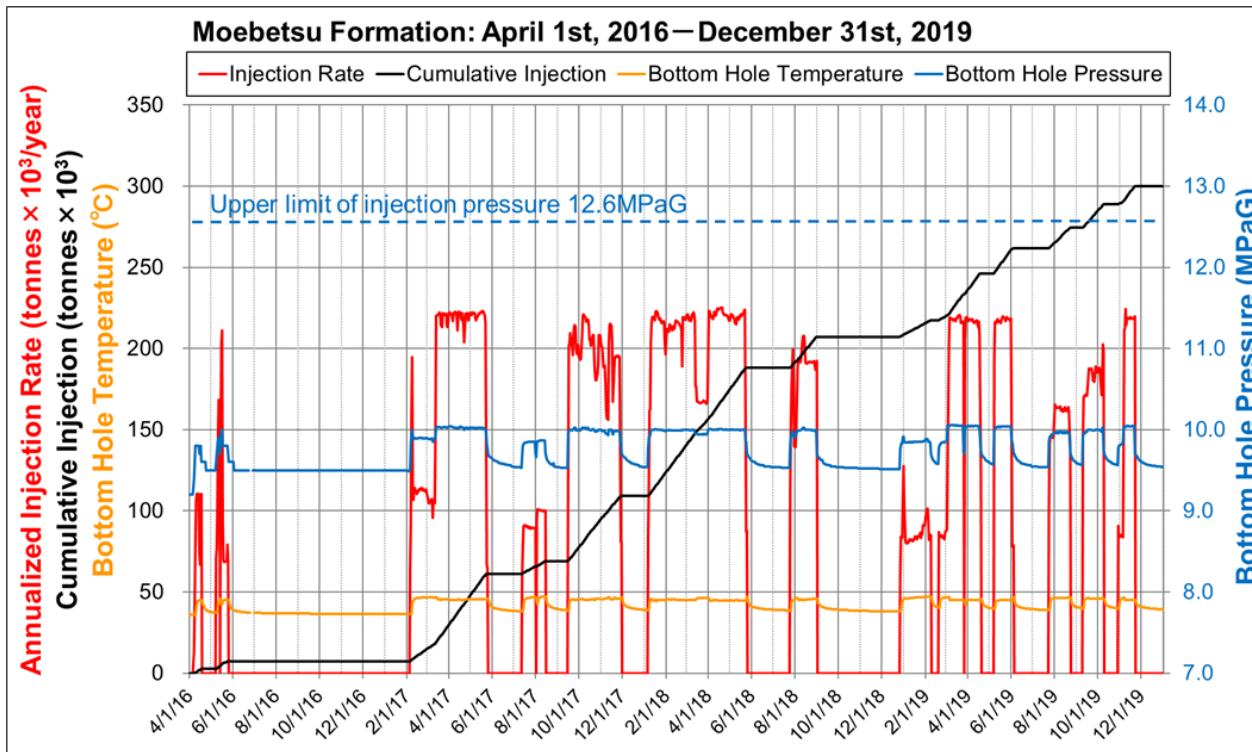
Schematic diagram of deployment of sensors for monitoring



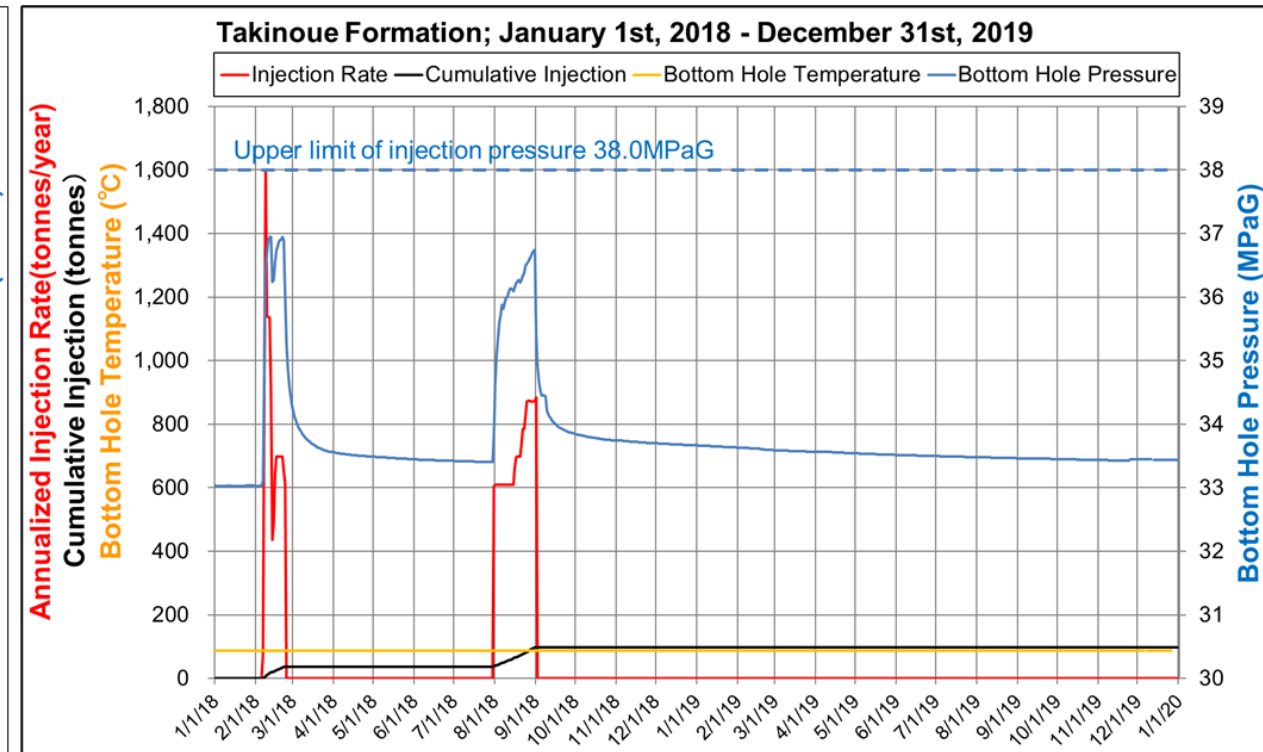
➤ Key results

Results of CO₂ injection

- ◆ Achieved 300,110 tonnes cumulative CO₂ injection into 2 reservoirs at different depths (Moebetsu Formation – 300,012 tonnes, Takinoue Formation – 98 tonnes)
- ◆ The maximum bottomhole pressures recorded by PT set close to reservoir during injection were much lower than the upper limit set to avoid destruction of the overlying cap rock.



Injection record of Moebetsu Formation

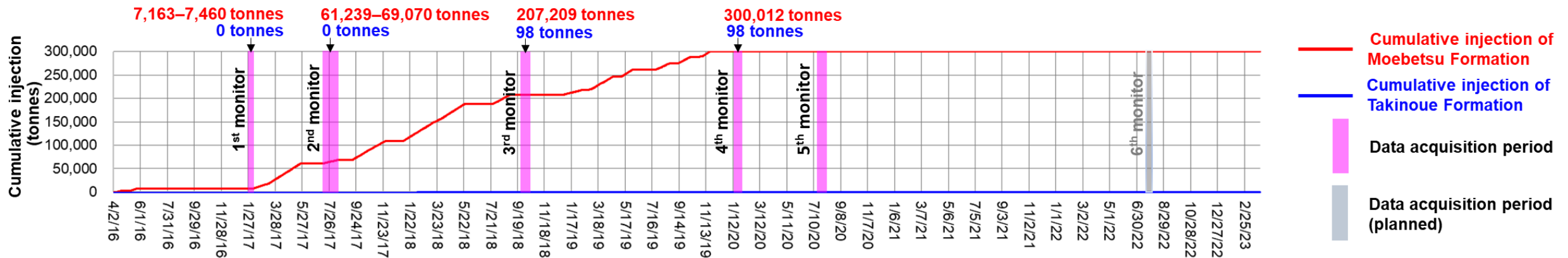


Injection record of Takinoue Formation

Seismic surveys: Results

- ◆ Following the baseline 2D and 3D surveys, five monitor seismic surveys have been carried out, which are a combination of 2D, 3D and 2D plus mini-3D surveys

Type of survey	Fiscal year	Implementation period	Cumulative injection (Moebetsu Formation)	Results
Baseline	3D	JFY 2009	October–December 2009	-
Baseline	2D	JFY 2013	August 2013	-
1st monitor	2D	JFY 2016	January 25–February 6, 2017	No anomalies
2nd monitor	3D	JFY 2017	July 9–August 17, 2017	Anomalies were detected
3rd monitor	2D + mini-3D	JFY 2018	September 26–October 18, 2018	Anomalies evolution was observed
4th monitor	2D + mini-3D	JFY 2019	January 19–February 9, 2020	Anomalies evolution was observed
5th monitor	3D	JFY 2020	July 13–August 6, 2020	Anomalies evolution was observed
6th monitor	mini-3D	JFY 2022	JFY2022	Planned



3D seismic survey results: Comparison of 2nd to 5th time-lapse 3D seismic surveys

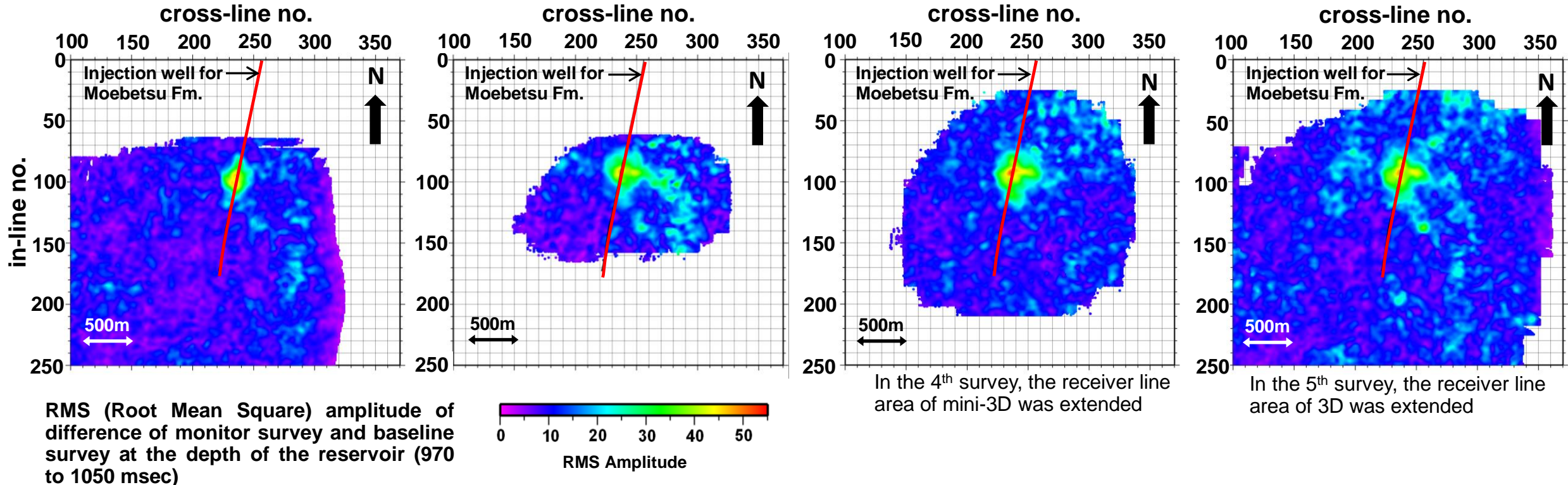
- The 2nd, 3rd, 4th and 5th monitor seismic surveys at cumulative CO₂ injection of approx. 65,000, 207,000 and 300,000 tonnes into the Moebetsu Formation detected anomalies, indicating evolution of the CO₂ plume

2nd monitor survey : 3D
JFY 2017 (61,239–69,070 tonnes)
During CO₂ injection

3rd monitor survey : mini-3D
JFY 2018 (207,209 tonnes)
During CO₂ injection

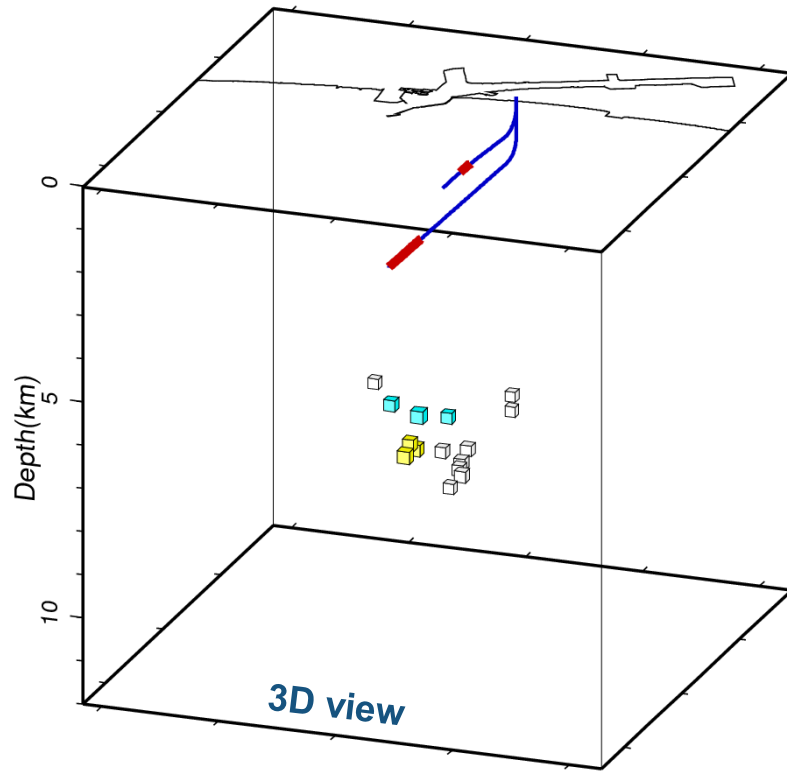
4th monitor survey : mini-3D
JFY 2019 (300,012 tonnes)
58–79 days after termination
of CO₂ injection

5th monitor survey : 3D
JFY 2019 (300,012 tonnes)
233–257 days after termination
of CO₂ injection



Results of micro-seismicity monitoring

◆ No micro-seismicity or natural earthquakes attributable to CO₂ injection were detected in vicinity of injection area between startup of injection and 16th October 2021, including before and after 2018 Hokkaido Eastern Iburi Earthquake

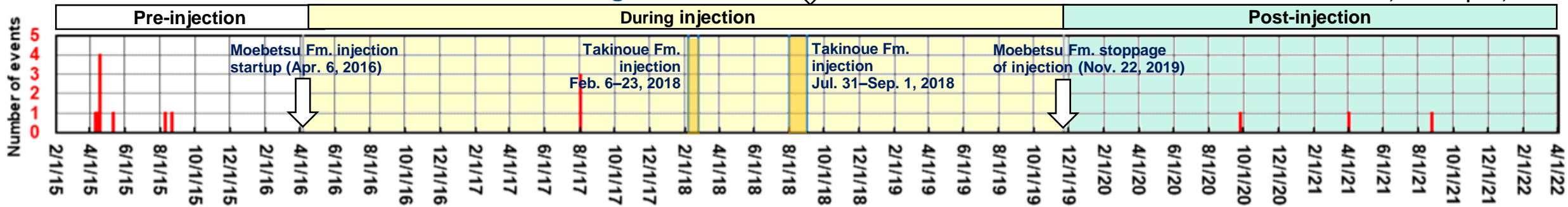


- Pre-injection events
- Events during injection
- Post-injection events

List of events Detectability: Mw > - 0.5

No.	Date	Depth (km)	Mw
1	4/09/2015 15:03	6.64	0.14
2	4/13/2015 14:00	5.97	0.14
3	4/17/2015 07:06	8.17	0.20
4	4/17/2015 07:09	8.19	0.19
5	4/17/2015 07:13	8.33	0.28
6	4/17/2015 07:18	7.57	0.17
7	5/10/2015 08:27	8.59	-0.04
8	8/10/2015 19:08	6.76	0.23
9	8/20/2015 23:20	8.18	0.44
10	8/02/2017 13:35	7.80	0.50
11	8/02/2017 13:36	7.78	0.33
12	8/02/2017 13:55	7.70	0.33
13	9/24/2020 11:53	5.86	0.59
14	4/01/2021 04:23	7.45	0.23
15	8/24/2021 16:03	6.50	0.13

Histogram of events



Marine environmental surveys according to the monitoring plan submitted to MOE

- ◆ Marine environmental surveys, seismic surveys and other monitoring were conducted under the five-year injection permit (FY2016–2020) from Ministry of the Environment (MOE) on the condition of implementation of the “monitoring plan” approved by MOE.

Monitoring Plan

Marine environmental survey

- Seasonal survey at 12 survey points
- Chemical measurements of seawater
- Chemical measurements of sea bottom sediments
- Plankton observation
- Benthos observation

Location and extent of CO₂

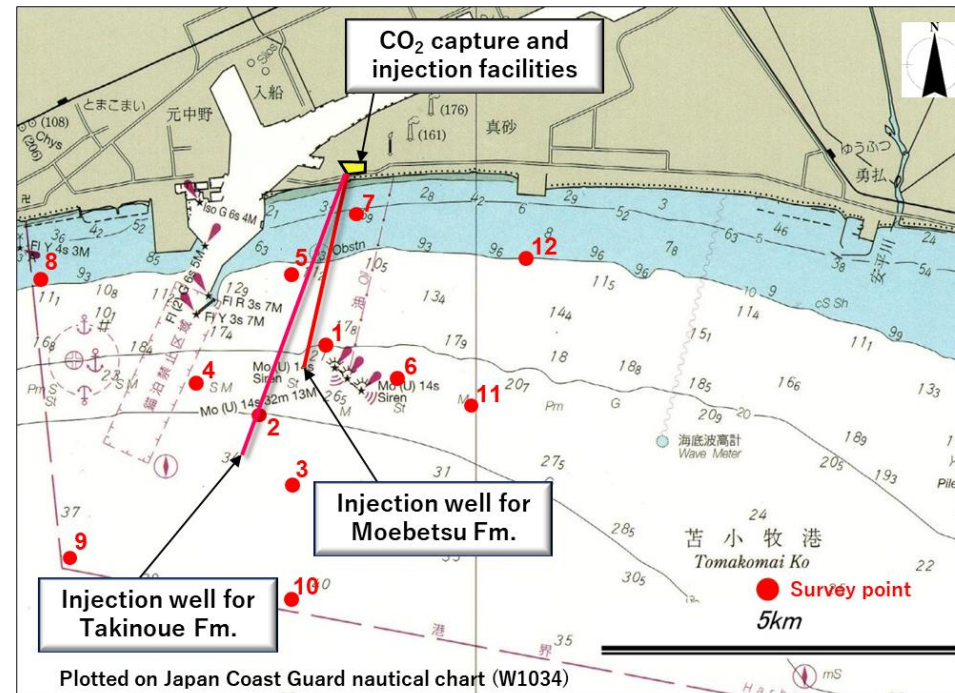
- Seismic survey (once a year)

Conditions of the formations

- Pressure and temperature at the injection wells and the observation wells (continuous observation)

Conditions of CO₂

- Measurement of CO₂ injection rate and injection temperature and pressure (continuous observation)
- CO₂ concentration analysis (gas chromatography analysis: once a year)



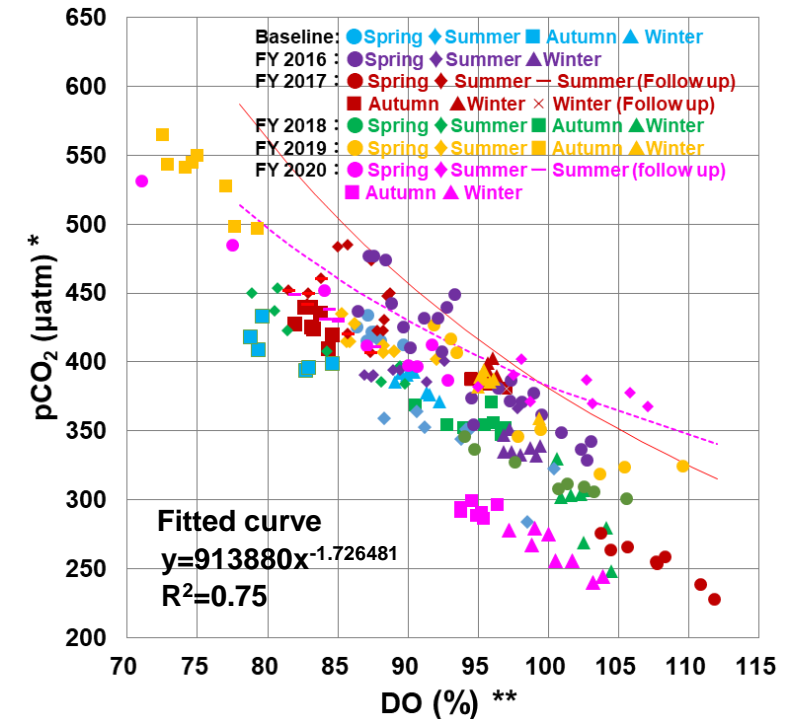
Water sampler



Bottom sampler



ROV



* pCO₂: partial pressure of CO₂ ** DO: dissolved oxygen

— Threshold line Upper limit of 95% prediction interval using data from baseline and Feb. 2017 to Feb. 2018

..... Initial threshold line using baseline data

pCO₂/DO threshold in the monitoring plan (revised on Aug. 31st, 2018)

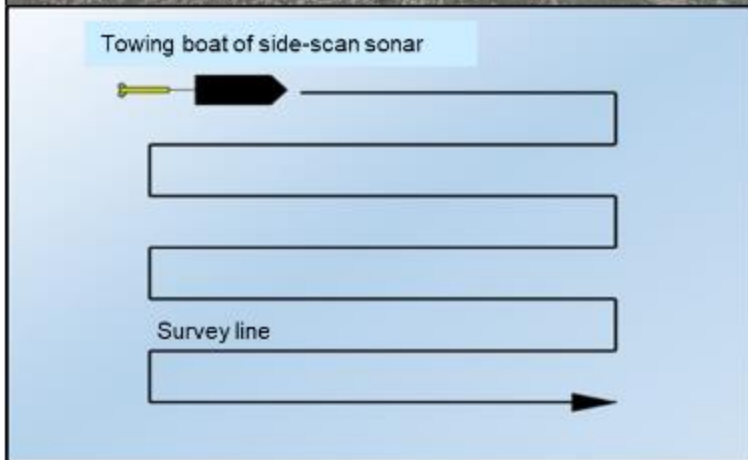
Marine environmental survey: Follow-up survey

◆ Follow-up survey in case of exceedance of the threshold

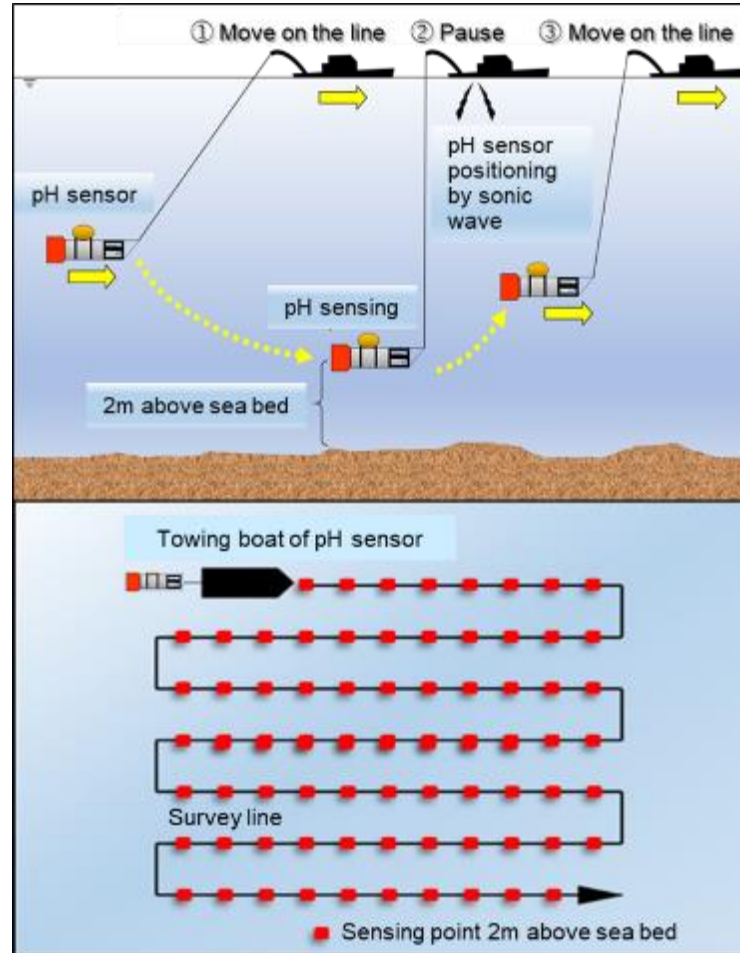
Side-scan sonar surveillance for bubble detection



Side-scan sonar



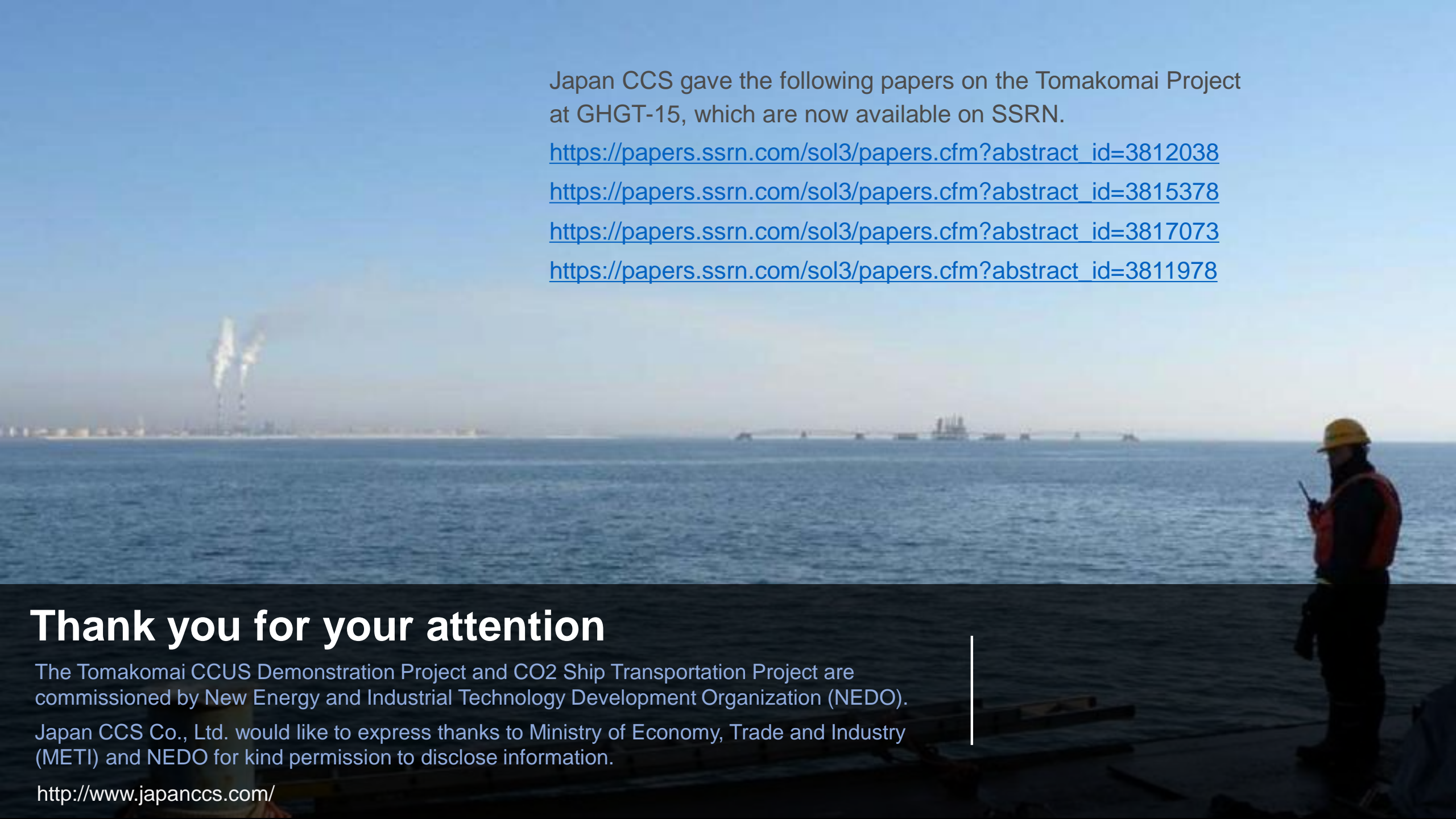
pH sensor surveillance for CO₂ seepage detection



➤ Exceedance of the former threshold line

- June 2016 at 5 survey points
- August 2017 at 5 survey points
- February 2018 at one survey point
- August 2020 at 5 survey points (after the revision of the threshold line)
- ✓ All the results of the follow-up surveys were reported to MOE
- ✓ On each occasion, MOE issued an official statement that there was no seepage or threat of seepage of injected carbon dioxide into the ocean

- ◆ The operation of a full chain CCS system from capture to storage was conducted successfully, and the target of 300,000 tonnes of CO₂ injection into the Moebetsu Formation was achieved. Monitoring operations are being continued
- ◆ No seismicity has been detected in/around the depth range of the reservoirs prior to, during and after injection, including before and after 2018 Hokkaido Eastern Iburi Earthquake
- ◆ 2018 Hokkaido Eastern Iburi Earthquake has not caused any damage to the facilities or reservoirs of the project
- ◆ The 2nd, 3rd, 4th and 5th monitor seismic survey at cumulative CO₂ injection of approx. 65,000, 207,000 and 300,000 tonnes into the Moebetsu Formation detected anomalies, indicating evolution of the CO₂ plume
- ◆ Marine environmental surveys conducted each season have detected no CO₂ seepage

The background image shows a wide expanse of blue water in the foreground. In the distance, there is an industrial facility with several tall chimneys emitting white plumes of smoke or steam. On the right side of the image, a person wearing a yellow hard hat and a high-visibility orange vest is standing on a dark, possibly metallic, surface, looking towards the water. The sky is a clear, light blue.

Japan CCS gave the following papers on the Tomakomai Project at GHGT-15, which are now available on SSRN.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3812038

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3815378

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3817073

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3811978

Thank you for your attention

The Tomakomai CCUS Demonstration Project and CO2 Ship Transportation Project are commissioned by New Energy and Industrial Technology Development Organization (NEDO).

Japan CCS Co., Ltd. would like to express thanks to Ministry of Economy, Trade and Industry (METI) and NEDO for kind permission to disclose information.

<http://www.japanccs.com/>