Summary of IAEA Experts' Meeting on

Groundwater Modelling at TEPCO's Fukushima Daiichi Nuclear Power Station

Tokyo, Japan, 15 – 19 February 2016

An Experts' Meeting on groundwater modelling at the Tokyo Electric Power Company's (TEPCO's) Fukushima Daiichi Nuclear Power Station (NPS) was convened by the IAEA in cooperation with the Ministry of Economy, Trade and Industry (METI) of the Government of Japan in Tokyo, from 15 – 19 February 2016. The IAEA group of experts reviewed the status of groundwater inflow, countermeasures and modelling with METI and TEPCO participants, conducted a site visit to Fukushima Daiichi NPS, and held a technical seminar with METI, TEPCO, and other Japanese hydrology experts covering overall groundwater issues. This document summarizes the findings, observations and considerations highlighted during the Experts' Meeting.

1. Background

The continuing inflow of groundwater into the reactor and turbine buildings at TEPCO's Fukushima Daiichi NPS results in accumulation of significant quantities of contaminated water every day, increasing the need for treatment and on-site storage tanks. Managing this substantial water storage on site poses additional challenges for eventual decommissioning operations. Therefore, problems associated with groundwater are among the most serious challenges that require immediate and comprehensive countermeasures. A number of countermeasures have been taken to control the inflow of groundwater into reactor and turbine buildings and to prevent contaminated water outflow to the ocean. These include a set of pumping wells on the mountain-side to reduce the amount of water flowing towards the reactor buildings (i.e., groundwater bypass system), pumping of sub-drain wells near the buildings, impermeable walls with a soil freezing method (i.e., ice wall) that will soon encompass the area of Units 1 to 4 buildings on all four sides, and seaside impermeable walls with steel piles.

A Technical Meeting on 'Groundwater Contamination following TEPCO's Fukushima Daiichi Nuclear Power Station Accident' was held at the IAEA Headquarters in Vienna in September 2014 to discuss the issues of groundwater inflow and countermeasures. This meeting concluded that the IAEA should consider the following activities to further assist Japan in its efforts at the Fukushima NPS by cooperating in:

i. Fact-finding visit composed of international experts to conduct a field survey and review the modelling of groundwater, particularly for issues related to the calibration and validation of the model.

ii. A workshop or seminar covering overall groundwater issues (both on-site and off-site) to enhance the understanding of the associated challenges, solutions and perspectives and to build confidence in information to be provided, decisions to be made, measures to be taken, and organisations to be responsible.

Subsequently, the 3rd Mission of the International Peer Review of Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4 was conducted in February 2015. One of the advisory points given by the mission team was that TEPCO should consider producing a better calibrated, robust groundwater model, which would

allow TEPCO to continuously evaluate and optimize the performance of various countermeasures taken at the Fukushima Daiichi NPS.

The IAEA Member States adopted Resolution (GC(59)/RES/12) in September 2015 during the 59th IAEA General Conference, wherein the organization of the September 2014 Technical Meeting was noted and the importance of characterization of detailed hydrogeological settings of nuclear power plant sites was highlighted, along with a request to the IAEA to continue taking follow-up actions from the September 2014 Technical Meeting.

Upon METI's request, the Expert Meeting was organized to review the current status of hydrogeological conditions at the NPS site and the groundwater model, to discuss the underlying data and current groundwater model, focusing on the issues related to the calibration and validation of the model, for future improvement of groundwater modelling, and to enhance the understanding of current status, challenges and future perspectives on groundwater issues among the scientific community in Japan.

2. Summary

The IAEA expert group consisted of two staff and three external experts met on 15 and 16 February 2016 with six participants from METI and TEPCO (see the list of the meeting participants in **Attachment 1**). The visit to the Fukushima Daiichi NPS site was conducted by the IAEA experts on 18 February 2016 to obtain first-hand information about the on-site situation, especially that related to groundwater inflow management. The technical seminar was held on 19 February 2016 with additional Japanese hydrology experts (see the list of the technical seminar participants in **Attachment 2**).

In the IAEA, METI and TEPCO meetings on 15-16 February, TEPCO provided a comprehensive overview of the countermeasures against groundwater inflow and contaminated water management at the Fukushima Daiichi NPS. These countermeasures have been undertaken to remove the contamination sources, isolate groundwater from the reactor and turbine buildings, and to prevent uncontrolled leakage of contaminated water to the surrounding environment. The geological features on site and the groundwater simulation model used for evaluating the effectiveness of these countermeasures were also explained by TEPCO.

The participating IAEA experts were impressed by the high quality of the documents and presentations, and of the very detailed understanding demonstrated by the individuals in charge of the countermeasures for contaminated water, and were convinced that:

i. The existing model was able to provide guidelines to define and select the countermeasures.

ii. A future transient model is needed to optimize the operation of existing and future countermeasures (e.g., designing pumping rates or well locations) and to provide a tool that can be used to modify operations in the case of unexpected events.

The meeting participants shared the view that the ice wall, designed to minimize groundwater inflow to reactor and turbine buildings, should be completed as soon as possible, as it would provide a viable mechanism to contain groundwater in the region with highest contamination. The experts pointed out that ideally the ice wall on the up-gradient side of the buildings would be the first portion to be completed (rather than the seaside portion) as this would have the most significant effect on the water levels adjacent to the buildings. It appeared that, if the ice wall can be fully completed and

creates an impervious barrier, and if no groundwater inflows from the bottom of the encompassed area, the groundwater would be contained. They also noted that, in this case, the only pumping of contaminated water that would be necessary would be to remove any water that recharges inside of the ice wall. The IAEA experts stressed that the groundwater level close to the buildings should be maintained above the water level inside the building to avoid additional groundwater contamination; this will require accurate management of this countermeasure.

The IAEA experts agreed that continued efforts to improve measurements at the Fukushima Daiichi NPS need to be made to obtain realistic analysis incorporating the good scientific basis, performance of thorough calibration, and tracking the progress. To improve measurements, the experts stressed that the following items should be taken into account:

i. Install automated pressure transducers to record water levels in all wells on site, especially up-gradient wells on the high elevation area near the western site boundary, preferably in each of the layers (sandstone and alternate layers).

ii. Collect groundwater samples from the groundwater bypass wells and upstream of these wells (mountain-side) and measure groundwater ages in order to characterize the source and velocity of groundwater.

iii. Install automated pressure and temperature transducers inside and outside the ice wall system to estimate any potential leakage, adapt the pumping rates, and monitor the increase in groundwater upstream of the ice wall.

iv. Install pressure transducers to regularly measure water levels in surface water outflows and surrounding the site as feasible; these should be located up-gradient of the area that experiences tidal fluctuations. Periodically measure streamflow at these sites to develop stage discharge relationships. This data will constrain the water mass balance for the system.

v. Conduct detailed transects of simultaneous flow measurements along the streams to evaluate gaining and losing reaches.

vi. Analyse the measurements to better understand how the system works.

vii. Salt concentrations in the groundwater should be measured (electrical conductivity) to evaluate salt water intrusion. Increase in salt concentration may also reduce the efficiency of the water treatment system.

viii. Conduct tracer tests to evaluate any potential leakage through the ice wall.

The meeting participants shared the common view that, at this stage the existing groundwater model has provided sufficient guidelines to define countermeasures to limit water contamination. The participants recognized that most of the countermeasures were already operating or would be in operation soon, and that there would be no immediate needs to revise the modelling. However, they noted that, to optimize these operations and to have a tool that could prepare for unexpected events, it would be recommendable that a new model be developed since a more detailed understanding of the hydrogeological conditions would be needed. The objectives of the new model would be:

- To provide local water balances (inside the ice wall system and at the model scale),
- To provide accurate flow conditions for a transport model;
- To define guidelines for optimal survey of water levels (frequency, and locations);
- To provide an estimate of the duration of the countermeasures.

Some hydrologic considerations, based on the existing model and observations could help in the new model development:

i. Define the boundary of the surface water catchment.

ii. Define the boundary of the groundwater contributing area to the site.

iii. Simulate the spatial and temporal variations in recharge based on climate, land cover and topography data, and use this as input for the groundwater model.

The IAEA experts highlighted the following points which need to be taken into consideration in developing the new model in the future:

i. A smaller area should be defined, based on the hydrogeological conditions and the output of a regional model designed to characterize the dynamics of recharge. The boundary of the local model should be far enough out that the pumping has minimal influence from the boundary.

ii. The area discretized by elements (model mesh) should be optimized. Flat elements and too disordered mesh should be avoided, especially for future transport simulations.

iii. Head dependent flux boundary conditions should be used along the buildings and salt water intrusion should be evaluated.

iv. Model calibration should be transient, with temporally and spatially variable infiltration. The provided porosities should be carefully evaluated, as the values are higher than expected. Geophysical surveys would help in the characterization of the aquifer heterogeneity.

v. Calibration should performed during one period, and the model should be tested on another period.

vi. Sensitivity analyses should be performed, to estimate the model reliability (especially connections between aquifers, infiltration, and anisotropy).

During the visit to Daiichi NPS on 18 February 2016, groundwater seepage on the slopes that have been covered with facing was observed by the IAEA experts. The experts viewed that an appropriate seepage boundary condition would need to be included in the model. They also pointed out that while this seeping water should not be contaminated, seepage through the facing could create geotechnical instability on the slope if horizontal drains are not installed through the facing.

The technical seminar on 19 February 2016 served a good opportunity as a forum where the IAEA experts, METI and TEPCO experts, as well as Japanese hydrology professionals openly exchanged views on the countermeasures taken at the on-site and the groundwater modelling.

Mr Takashi Ozawa, Director General for Contaminated Water and Decommissioning Issues Team & Director General for Nuclear Disaster Management of METI, concluded the Expert Meeting, appreciating the timely organization of the Expert Meeting as several countermeasures had been in place since the Technical Meeting in September 2014. Mr P.K. Aggarwal, Section Head of Isotope Hydrology of the IAEA, indicated the high level of interest within the IAEA and the Member States in general related to the topic of the meeting, and emphasized that upon a request of the Government of Japan, the IAEA would be ready to assist Japan in dealing with challenges associated with the groundwater management issues.

Attachment 1: Meeting Participants

Name	Affiliation
AGGARWAL, Pradeep	Head, Isotope Hydrology Section International Atomic Energy Agency
IZUMO, Akira	Waste Technology Section International Atomic Energy Agency
ACKERER, Philippe	LHyGeS, Université de Strasbourg- CNRS, France
HYNDMAN, David William	Professor and chair, Hydrogeology, Environmental Geophysics, Michigan State University, USA
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Attachment 2: Technical Seminar Participants

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