Numerical Simulation and Particle-Tracking Analysis of the Managed Aquifer Recharge System in Sakon Nakhon Province, Northeast Thailand.

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Dong Khwang is a small village in Sakon Nakhon Province located in the Nam Kam River Basin, which is rich in rainfall with an annual rate ranging from ca. 1,300 to 2,400 mm. Currently, precipitation has changed in intensity, pattern, and frequency due to the effect of climate change. In 2017, this area was hit by a tropical cyclone causing heavy rainfall and considerable flash flooding. Consequently, residential properties, agricultural areas, and businesses were devastated. The storm eventually caused 100-million-baht worth of damage in the province.

The challenge for policymakers is to develop strategies that can provide satisfactory outcomes and long-term solutions. This study drew on examples of the use of managed aquifer recharge (MAR) as an approach primarily to prevent flood-related issues and store stormwater runoff during wet seasons. The MAR system comprises a 5-m-deep settling pond and a 5-m-deep infiltration pond. In addition, a concrete weir was installed to control the inflow of water before entering the settling pond. Recently, a modeling approach is widely known as a scientific and reliable method for the assessment of MAR systems. Here, a groundwater model was developed to simulate MAR and the subsequent movement of groundwater in this area. The MAR model was constructed using a notable 3D finite-difference groundwater-flow model known as MODFLOW, in association with a MODPATH particle-tracking model. The MODFLOW-NWT transient model applied the LAK7 package to account for interactions between an artificial lake and groundwater. Two model scenarios were developed based on the actual MAR methods applied at the demonstration site: (1) An infiltration pond scenario (LAK Package) and (2) an infiltration pond with four additional recharge wells (WEL Package) scenario. A one-year simulation was performed using actual field data followed by a nine-year projection based on annual average data. Groundwater levels, collected from 37 wells, were monitored monthly for model validation.

The results showed that the flow model had an acceptable simulation accuracy with an NRMSE of 8.9%. Under model scenario 1, the annual rate of pond seepage into the aquifer was 85,188 m^3. Particles were initially assigned at the lake bottom. As a result, artificially recharged water can travel in the system for at least ten years, with a maximum travel distance of 722 m (0.21 m/day). In Scenario 2, the runoff was recharged directly into the aquifer. The results showed that an annual recharge rate was higher than Scenario 1, accounting for about 112,600 m^3. The deeper-and-longer flow paths were roughly doubled in distance compared to the first scenario, being up to 1,805 m away from recharge wells with an average rate of 0.49 m/day.

In conclusion, the combination of these two common MAR methods, that has been studied in this work, introduces strategies for flood management and mitigation. Recharge can travel in the groundwater system, on average, from about one year to at least ten years. To maximize its benefits, the system was designed as a multi-purpose facility providing surface water reservoir, recreation, and wildlife habitat along with flood control and groundwater storage.

Keywords: MAR; MODFLOW; Particle Tracking