Reservoir impoundment, hydro-mechanical changes, and increased seismicity near the Xiluodu hydropower dam, Southwestern China

Man Zhang\textsuperscript{1,2}, Shemin Ge\textsuperscript{3}, Qiang Yang\textsuperscript{1}, and Xiaodong Ma\textsuperscript{2}

\textsuperscript{1}Tsinghua University, Department of Hydraulic Engineering, Beijing, China (zhangm17@mails.tsinghua.edu.cn)
\textsuperscript{2}ETH Zürich, Department of Earth Sciences, Zürich, Switzerland (xiaodong.ma@sccer-soe.ethz.ch)
\textsuperscript{3}University of Colorado, Department of Geological Sciences, Boulder, United States (Shemin.Ge@Colorado.edu)

Xiluodu is currently the third largest hydropower station in the world and situates on the upper Yangtze River in Southwestern China. The 285.5 m-high dam lies in the center of a relatively intact and stable tectonic block, triangulated by three large fault zones. The seismicity in the region increased markedly since the reservoir was first impounded in 2013. Previous studies suggest a strong spatial-temporal link between the seismicity and reservoir impoundment. This study attempts at conducting a quantitative analysis integrating the geological and engineering data to constrain the link between the impoundment and the seismicity, which could inform the future seismic evolution in the area.

We first study the characters of the spatial activity of earthquakes in different periods to address the correlation between increased seismicity and reservoir impoundment. Since the impoundment, the earthquakes in this region can be plausibly separated spatially into two groups. The first group (including a M\textsubscript{L} 5.4 and a M\textsubscript{L} 5.5 event) is located within \~10km of reservoir, where a major fault zone is absent. Within this spatial range, earthquakes > M\textsubscript{L} 2.0 are rare three years prior to the impoundment, but more than 1000 events were detected between the initial impoundment in 2013 and September 2014 when the reservoir reached its peak level. Thereafter, the fluctuations of water level were accompanied by continuous seismicity, albeit at a considerably lower rate. The seismicity in this region is strengthened again in 2019. The other group of earthquakes are clustered with several mapped major fault traces. Some of these events quickly followed the water level fluctuation, while some were observed after significant delays. In general, the distances between locations of delayed events and the reservoir gradually increase with time.

To address the influence of impoundment on seismicity, we analyzed the hydrologic and mechanical effects of the impoundment, i.e., the fluid pressure diffusion and the reservoir loading. We computed the spatiotemporal changes of Coulomb stress on known faults resulting from these two effects. The sensitivity analysis of hydraulic and mechanical parameters shows that the changes of Coulomb stress in the area could increase to a level that is relevant to reactivation of faults. While the relationship between the impoundment and increase seismicity warrants further analysis, we hope to inform the regional seismic impact by integrating in-situ stress state, fault geometries, and the coupled hydro-mechanical stress changes.