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学位論文題名	Influence of Climate and Reservoir Operations on the Thermal Structure and Release Water Temperatures of a Monomictic Reservoir （気象と施設運用がダム貯水池の水温成層と放流水温におよぼす影響）
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【論文の内容の要旨】

The temperature and thermal structure of the reservoir govern the turbidity current dynamics and phytoplankton movement, which are greatly related to sedimentation and eutrophication of the water body and its water quality status. Understanding therefore the factors affecting the thermal conditions of the reservoir such as climate and reservoir operation is key to water quality management. Climate warming poses serious impacts such as surface water warming, increased rates of evaporation and enhanced resistance to vertical mixing. On the other hand, reservoir operations as controlled by hydraulic facilities can vary the thermal responses of the water body. For example, conventional deep penstock withdrawal (DPW) promotes warming of the water profile while shallow releases from the selective withdrawal (SW) can strengthen the thermocline. Additionally, vertical curtains (VC) can be installed in the upstream reaches of the reservoir, which can promote surface cooling.

The Ogouchi Reservoir in Japan was chosen as the study site as it had apparently experienced climate warming between 1959 and 2016 and its operation had transitioned into three periods namely, Periods A (DPW, 1957-1991), B (SW and no VC, 1992-2001) and C (SW and VC, 2002-2016). The general objective of the study is to

clarify the effects of climate and the different operations on the thermal structure and outflow temperatures of the reservoir. The long-term data of reservoir temperatures were analyzed and several thermal indices were quantified to describe the thermal stratification. Furthermore, numerical simulation was carried out to determine the effects of the facilities on both the in-reservoir and outflow temperatures, in the hope to recommend the best method of management for these thermal properties.

This dissertation is composed of six chapters.

Chapter 1 is the introduction that provides the research background and the description of the study area. Literatures related to thermal structure and outflow temperatures of reservoirs as affected by climate and management were also reviewed.

Chapter 2 provides the methodology, which includes data analysis and numerical simulation. For the data analysis, the climate and reservoir properties were subjected statistical tests such as Mann-Kendall, Kruskal-Wallis, rank-sum and correlation. Different stratification parameters were also computed to describe quantitatively the reservoir's thermal condition, other than water temperature. For the simulation, Fantom Refined was used to analyze the thermo-hydrodynamics of the reservoir. This simulator uses the equations of continuity and 3-D Navier-Stokes with incompressible and Boussinesq approximation alongside temperature transport, which were discretized based on a collocated finite-volume method. Uniform grids were set in the horizontal and the vertical. The time step, dt was set at 20 s. The hourly river and weather data served as the boundary conditions. The vertical temperature profile and the water level were set as the initial condition. The VC was modeled as an impermeable cell face with its upper edge moving with water level.

Chapter 3 presents the long-term trends of climatic parameters such as air temperature, rainfall and wind speed together with the results of the analysis of the distribution of water temperatures during the three periods. Although annual temperatures were increasing, the surface water temperatures were decreasing due to the shift in facilities. Period A produced warmer profiles and exhibited higher heat content (Q), lower stability by potential energy anomaly (PEA) and weaker stratification by Brunt-Vaisala Frequency 闇), in comparison with Periods B and C. It was found that the varying operations bear a stronger influence on the reservoir's thermal structure than climate change itself

Chapter 4 discusses the seasonal variation of thermal stratification under different operating schemes. Isothermal conditions exist during winter while stratification onsets in spring, intensifies in summer and weakens during autumn. Considering summer stratification, deep hypolimnetic withdrawals through the

penstock intake (Period A) promoted thicker epilimnion resulting in lower values of Schmidt's Stability Index (SSI) and Thermocline Strength Index (TSI). Meanwhile, shallow releases using the SW facility resulted in narrower epilimnion, with larger TSI for no curtain scenario (Period B) and larger SSI for with curtain scenario (Period C). Strongest thermoclines do not necessarily translate to largest magnitudes of thermal stability. Longer duration of stratification is associated with shallow withdrawals (B and C). Depending on the outflow depth and the occurrence of prolonged hot or cold atmospheric conditions, the onset of stratification could be likely shifted early or late.

Chapter 5 covers the application of the Modified Gaussian Method Distribution (MGDM) in the three-dimensional simulation of in-reservoir and outflow temperatures in comparison with the conventional Uniform Distribution Method (UDM). Results showed that MGDM can reproduce the two thermal properties more reasonably than UDM. The simulation results of three cases corresponding to the three periods of operations have confirmed the significant differences in thermal distribution among the periods, as shown in Chapter 4. Furthermore, the SW case without and with the curtain, representing Periods B and C, respectively can mitigate the cold water pollution, which is rather manifested in the case of DPW, representing Period A. Lastly, with the application of MGDM to the 3-D model, simulations were carried out by varying the SW intake levels considering the scenarios of with and without the VC, in order to propose the best combined operation method to regulate the thermal structure and released water temperature of the reservoir.

Chapter 6 provides the summary, conclusions and recommendations for future studies.