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Variation in channel thalweg in the Yichang-Chenglingji Reach of the Middle Yangtze River in response to the Three Gorges Dam operation

Yiwei Lyu, Guangming Tan, Shan Zheng, and Caiwen Shu

Wuhan University, State Key Laboratory of Water Resources and Hydropower Engineering Science, wuhan, China (yiweilv_whu@outlook.com)

The evolution of the pool-riffle sequences in channel thalweg is a critical feature of hydro-morphological adjustments in alluvial rivers and might have important impacts on aquatic habitats, navigation and channel stability. Based on the 220 cross-sectional profiles from 2002 to 2016, spatial statistical analyses and residual depths were performed to quantitatively investigate the temporal variations and spatial distribution of the pool-riffle couplets and channel thalweg in the Yichang-Chenglingji Reach (YCR) of the Middle Yangtze River, which consists of the Yizhi-Zhijiang, Shashi-Gongan and Shishou-Jianli sub-reaches. Results showed that considerable adjustments in the size, morphological diversity and spatial distribution of pool-riffle structures occurred in the YCR, due to the drastic reduction in the sediment loads following the run-on of the Three Gorges Dam (TGD). Specifically, the average depth of the pools in the Yizhi-Zhijiang Reach and the Shishou-Jianli Reach overall presented a nonlinear growth trend, with the average residual depth increasing by 1.4 m and 1.9 m, respectively. However, the average residual depth in the Shashi-Gongan Reach exhibited a decreasing trend, with a reduction of approximately 1.2 m. The longitudinal lengths of the riffles in all three reaches took on shrinkage of different degrees, and the specific percentage of longitudinal river length occupied by riffles (total riffle length/total channel length) decreased by 8%, 9.6% and 5.9% in the three sub-reaches from upstream to the downstream. In addition, the morphological diversity of the thalweg elevation in the Shashi-Gongan Reach and Shishou-Jianli Reach weakened following the TGD operation, while the bed topography in the Yizhi-Zhijiang Reach became more diverse and complex. Furthermore, the pool-riffle structures in the YCR were distributed and rearranged regularly since the dam closure, although the variations in the average pool spacing in the three sub-reaches were quite different. Based on the Delayed Response Model (DRM), quantitative relationships between the average residual depths and the previous four-year hydrological conditions were proposed for all the three sub-reaches and verified using the measurements during 2013-2016, with encouraging results being obtained.