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Rapid infill of Wushe Reservoir, Central Taiwan: Ten years of field observations

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Abstract

Because of high rates of sediment supply, many reservoirs in Taiwan experience significant storage losses and operational difficulties due to sedimentation. The resulting infill often involves the progradation of coarse-grained deltas, at the upstream end of the reservoir, combined with the accumulation of fine-grained bottom deposits near the dam. To better understand these processes, we have monitored for ten years the evolution of a medium sized reservoir subject to rapid infill: the Wushe Reservoir in Central Taiwan. The methods used include ground and airborne photography, topographic surveys, bathymetric sounding, and suspended sediment sampling, all facilitated by the moderate length of the reservoir and its upstream alluviated valley.

Keywords: Reservoir sedimentation; field observations; repeat surveys.

1 Introduction

Located in Nantou County, Central Taiwan, Wushe Dam is used since 1960 to generate hydroelectric power. Its reservoir receives water and sediment from the Choshui and Taluowan Rivers (see Fig. 1). When full, the reservoir is approximately 4 km long. Upstream, the alluviated valley reaches up to the hot spring resort town of Lushan, at a distance of approximately 10 km from the dam. The reservoir and its alluviated valley are thus much shorter than the Shihmen and Tsengwen Reservoirs, the two key reservoirs supplying water to Northern and Southern Taiwan. Because of its small size, the Wushe Reservoir has also been filling more rapidly in response to Taiwan's high sediment supply. It therefore provides a useful scale model, at accelerated time scales, of the processes likely to unfold over the coming decades in Taiwan's larger reservoirs.

As illustrated in Fig. 2, the water discharge supplied to Wushe Reservoir is highly variable. It alternates periods of low flow with periods of high flow dominated by sharp pulses due to typhoons or rain storms. The water level in the reservoir, likewise, fluctuates erratically between 980 and 1005 m a.s.l. in response to river inflows, variations in power production, and periods of low level needed for upgrades and repairs to the dam and intakes. These fluctuations in river discharge and water level, therefore, exert a large influence on the delta prograding into the reservoir. To monitor the evolution of this delta, our research group at National Taiwan University has been conducting repeat surveys of the reservoir and valley since 2009.

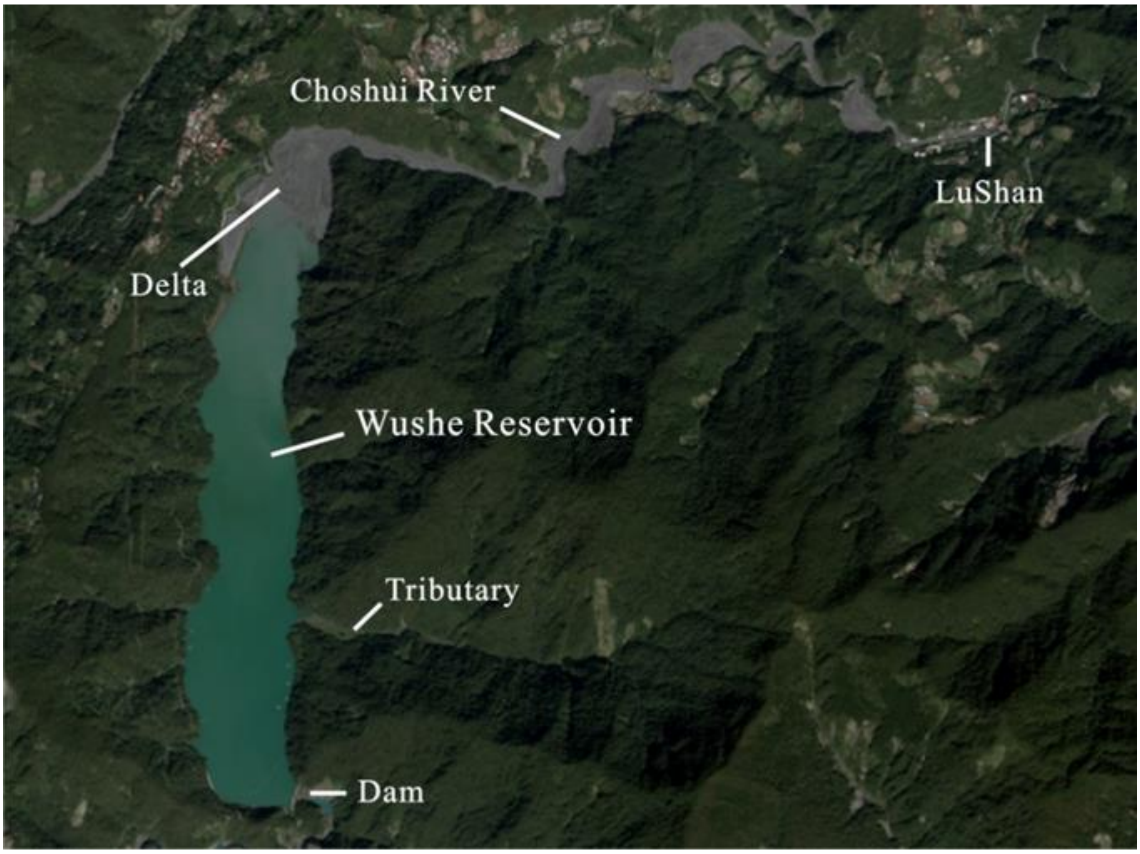

Fig. 1: Study area from Lushan to Wushe Dam (SPOT satellite image).

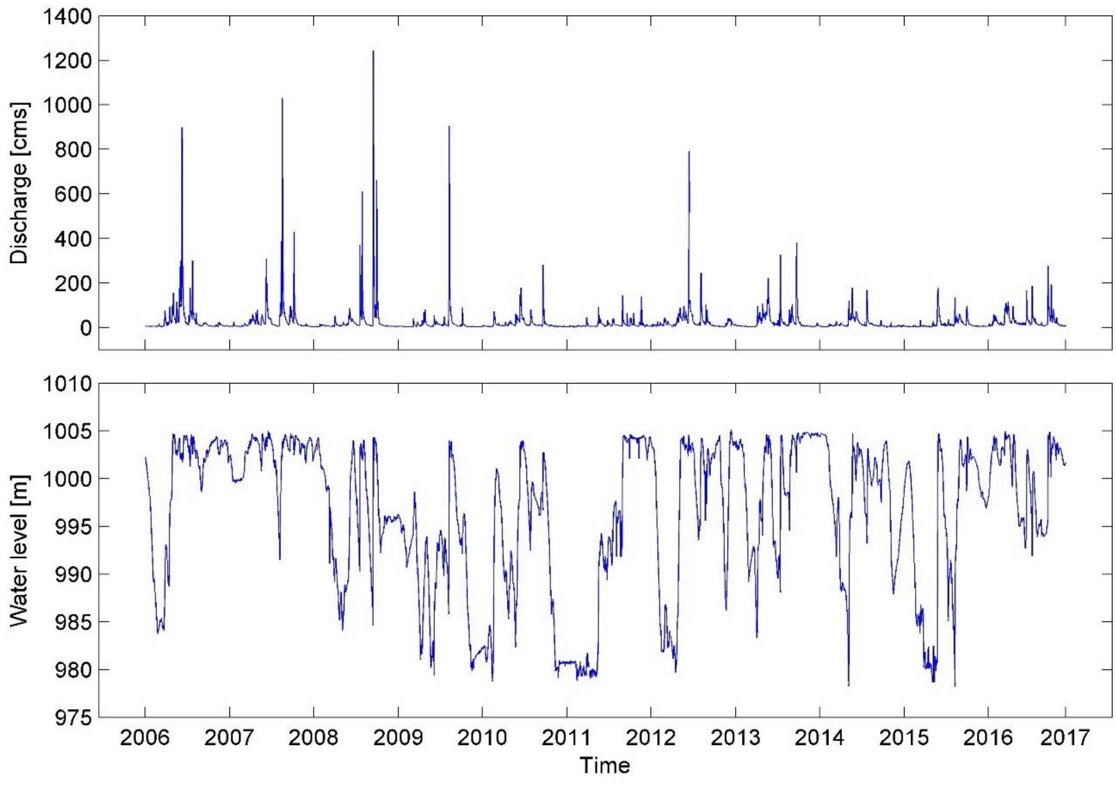

Fig. 2: Ten year records of inflow discharge (top) and water level (bottom) for Wushe Reservoir (data source: Taipower).

2 Survey methods

Since 2009, we have used various tools to conduct repeat surveys of the reservoir delta (see Fig. 3). To measure the subaqueous bathymetry, we have used a small boat, a fish finder echo sounder, and a handheld GPS to acquire acoustic soundings along longitudinal and transverse transects. To measure the subaerial topography, we have used a total station and reflector poles to acquire river and delta long profiles. To connect our measurements to a georeferenced coordinate system, we have used static benchmarks and a pair of Topcon GPS stations. For our most recent surveys, finally, we have used a small unmanned aerial vehicle (UAV) to acquire air photos. These were then calibrated with ground controls to obtain orthophotos and digital terrain models (DTMs) of the subaerial delta surface. The methods used to acquire and process these data are described in detail in Wang (2009), Liu (2010), Ke (2016), Chang (2017) and Huang (2018).

Fig. 3: Tools used for the repeat survey campaigns. Top left, boat used to survey the reservoir bathymetry. Top right, total station used to acquire topography transects. Bottom left, UAV used to acquire high resolution orthophotos and DTMs of the delta surface. Bottom right, GPS station used to position ground controls.

3 Measurements and observations

Selected measurements and observations from our various campaigns are illustrated in Figures 4 to 10. Figure 4, first, shows repeat long profiles of the river and delta, covering approximately 12 km from Lushan to Wushe Dam.

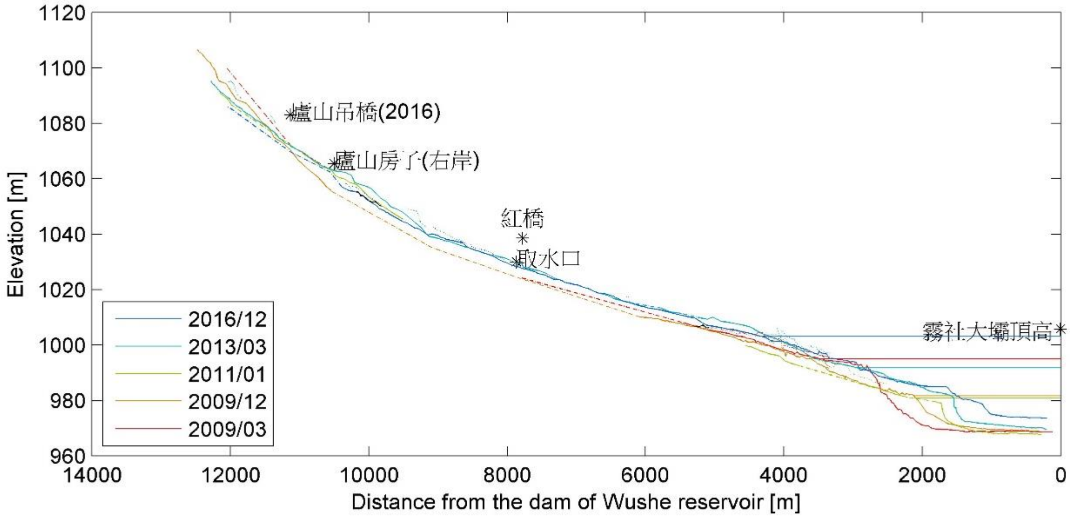

Fig. 4: Repeat surveys of river and delta long profiles from Lushan to Wushe Dam, 2009 to 2016.

Fig. 5: Episodic aggradation and incision events at the Lushan hot spring area. Top left, October 2008. Top right, November 2010. Bottom left, September 2008. Bottom right, March 2018.

At Lushan and upstream (see also Fig. 5), the river bed has undergone cycles of rapid aggradation and incision due to episodic sediment supply from landsliding in the upstream watershed. Downstream (see also Fig. 6 and 7), the delta has steadily prograded into the reservoir, advancing by more than 1 km from 2009 to 2016. The morphology of the delta front, however, has varied significantly in response to water level fluctuations.

Fig. 6: Trunk river and tributary deltas of Wushe Reservoir. Top, plunging hyperpycnal inflow from the trunk river into the reservoir following a rain storm (March 2009). Bottom, steep, coarse-grained foreset of the tributary delta at low reservoir level (December 2009).

Shaped by plunging underflows (Fig. 6, top), the trunk river delta is hyperpycnal in morphology (Lai and Capart, 2009). It has a curved profile of gradually diminishing slope connecting the inclined delta front to nearly flat bottom deposits near the dam. This contrasts with the steep, coarse-grained foreset of the Gilbert-type delta (Ke and Capart, 2015) associated with a side tributary of the reservoir (Fig. 6, bottom). When the reservoir level drops, the trunk river channel elongates and incises delta deposits, picking up suspended sediment from the bed and banks (Figures 7 to 10).

Fig. 7:   Repeat panoramic views of Wushe Reservoir (2006/10, 2009/08, 2016/12, 2018/03).

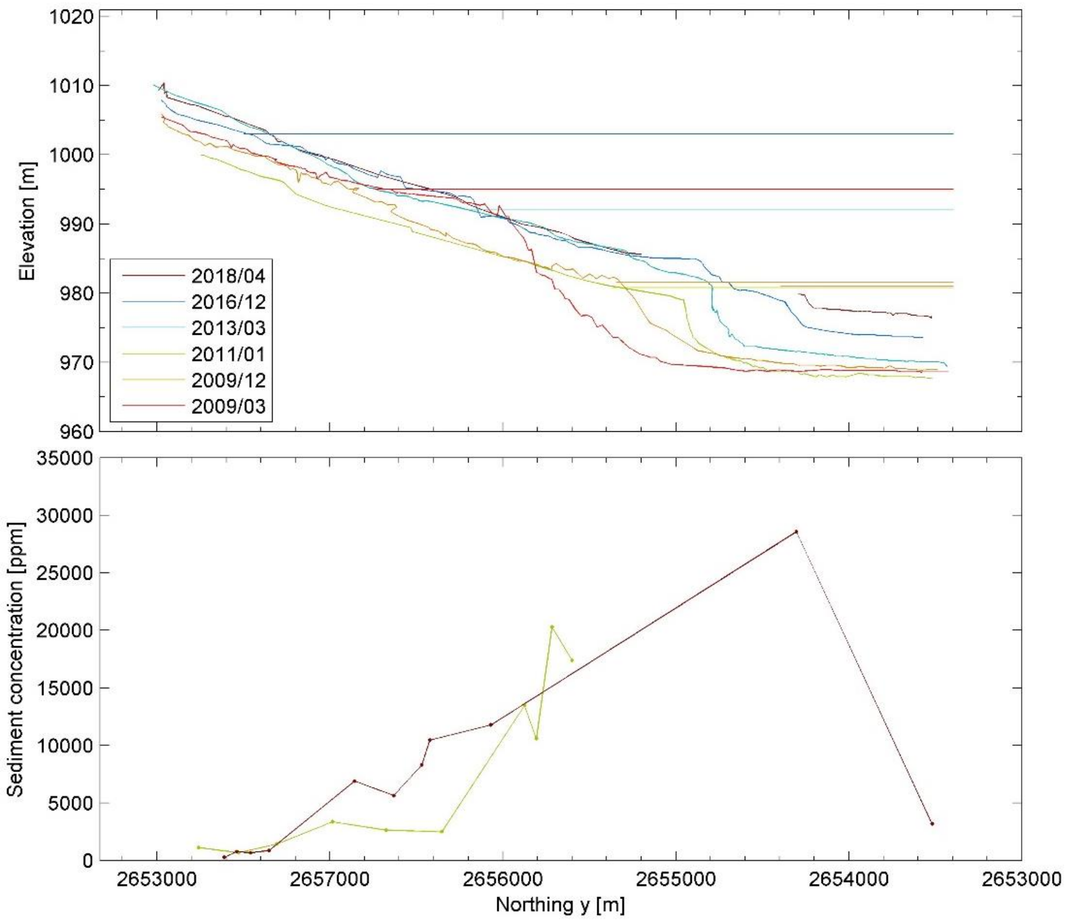

Fig. 8: Repeat surveys of the Wushe Reservoir. Top, delta long profiles from 2009 to 2018. Bottom, suspended sediment concentration profiles in 2011 and 2018.

Fig. 9: Delta river channel in April 2018, upstream (top left) to downstream (bottom right).

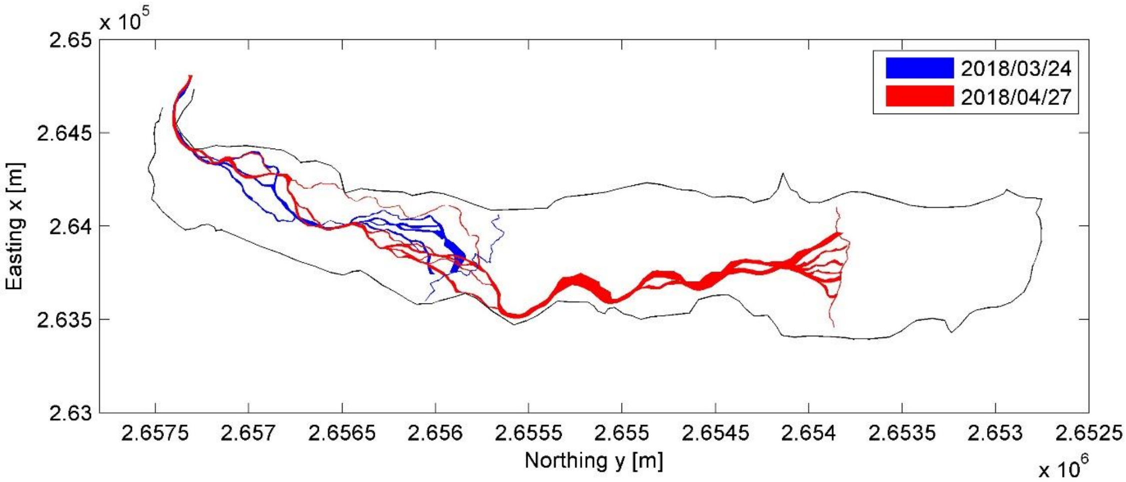

Fig. 10: Evolution of the river channel network from March to April 2018 (from UAV orthophotos).

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