FLOW RESISTANCE AND SEDIMENT TRANSPORT IN SKEWED KINOSHITA MEANDERING RIVERS

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BACKGROUND

Few studies have examined sediment and flow dynamics in skewed meandering rivers (also known as Kinoshita rivers). Research to date has shown that skewness significantly affects flow conditions, sediment transport patterns, and potentially contributes to flow resistance. Understanding these effects will have important implications in river channel design, bank erosion control, computer models, and management of contaminated sediments.

Kinoshita rivers are defined by the sine-generated curve below. The skewness coefficient (J_s) determines the direction and intensity of skewness as illustrated in Figure 1.

$$\theta(s) = \theta_0 \sin(ks) + \theta_0^{\,3}\left[J_s \cos(3ks) - J_f \sin(3ks)\right]$$

In this study, flow conditions and sediment transport were assessed with laboratory measurements and digital elevation models (DEMs), while the Chézy flow equation was used to assess flow resistance:

$$Q = cA\sqrt{gSh}$$

The Chézy flow resistance (c) can be broken down into component effects of friction, bedforms, and meandering intensity. Various methods exist to assess each, and comparing results from differently skewed yet otherwise identical rivers can yield relationships between skewness and flow resistance.

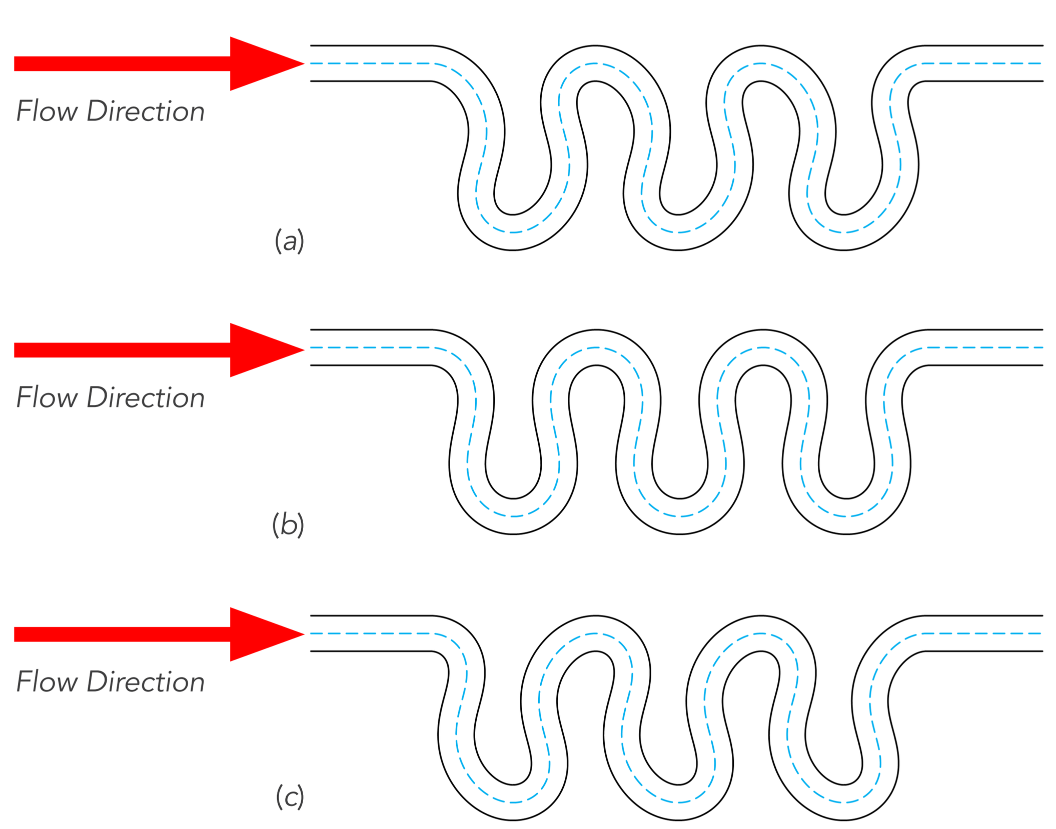

Figure 1: Kinoshita channels with (a) upstream skew ($J_s > 0$), (b) symmetric ($J_s = 0$), and (c) downstream skew ($J_s < 0$)

OBJECTIVES

1. Investigate effects of different skewness intensities and direction on flow depth, sediment transport patterns, and river morphology
2. Quantify the flow resistance component attributable to the skewness intensity
3. Compare observed results to predictions from a computational model

METHODOLOGY

To meet the objectives, a series of laboratory experiments were completed with different skewness intensities and directions using a sand-filled flume. Figure 2 illustrates the conceptual flume setup while Figure 3 shows photographs of the flume during experiments. The sediment distribution for the sand is shown in Figure 4 and can be described as a cohesionless, poorly-sorted sand. The skewness coefficients to be tested included ±1.5/32 and ±0.5/32, to complement existing data for ±1/32 and 0.

To analyze the sediment transport and morphology patterns over time, each experiment was split into time steps and a DEM of the dry channel was developed between each step using photogrammetry. Using a series of photographs taken around the flume and pre-set coordinate markers, a dense point cloud and DEM can be created as seen in Figure 5.

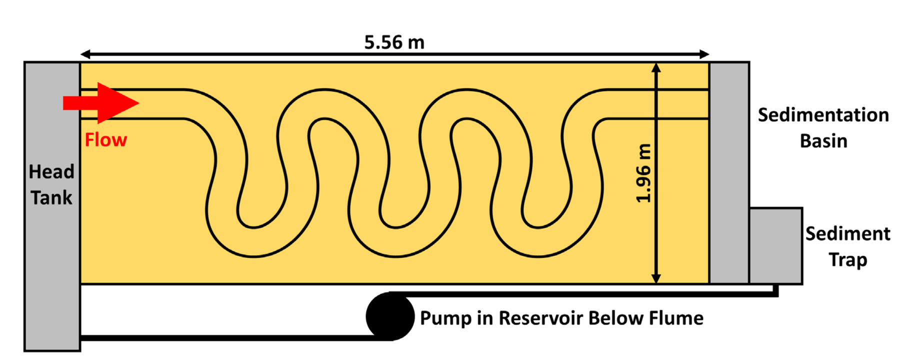

Figure 2: Conceptual diagram of the laboratory flume system

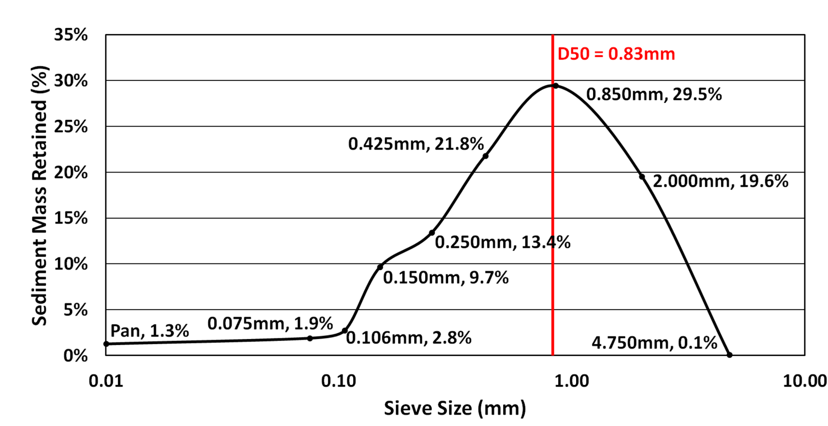

Figure 4: Flume sediment grain size distribution

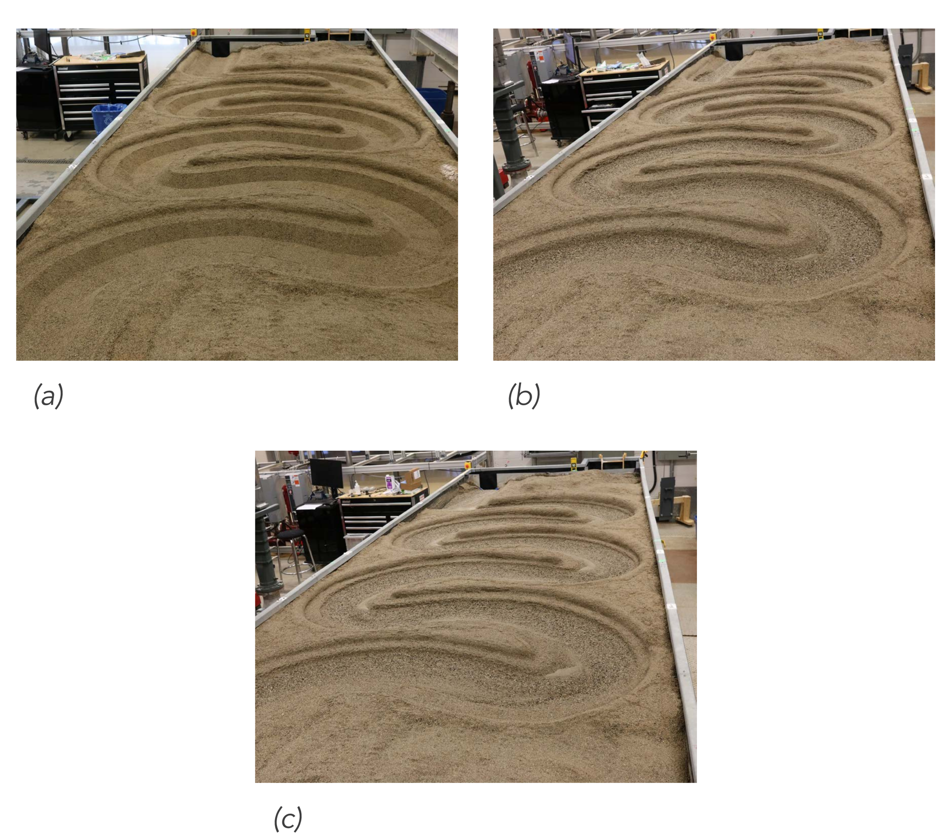

Figure 3: Flume photos for J_s = +1.5/32 at (a) initial conditions (b) end of 0.5 LPS time steps and (c) end of 0.9 LPS time steps

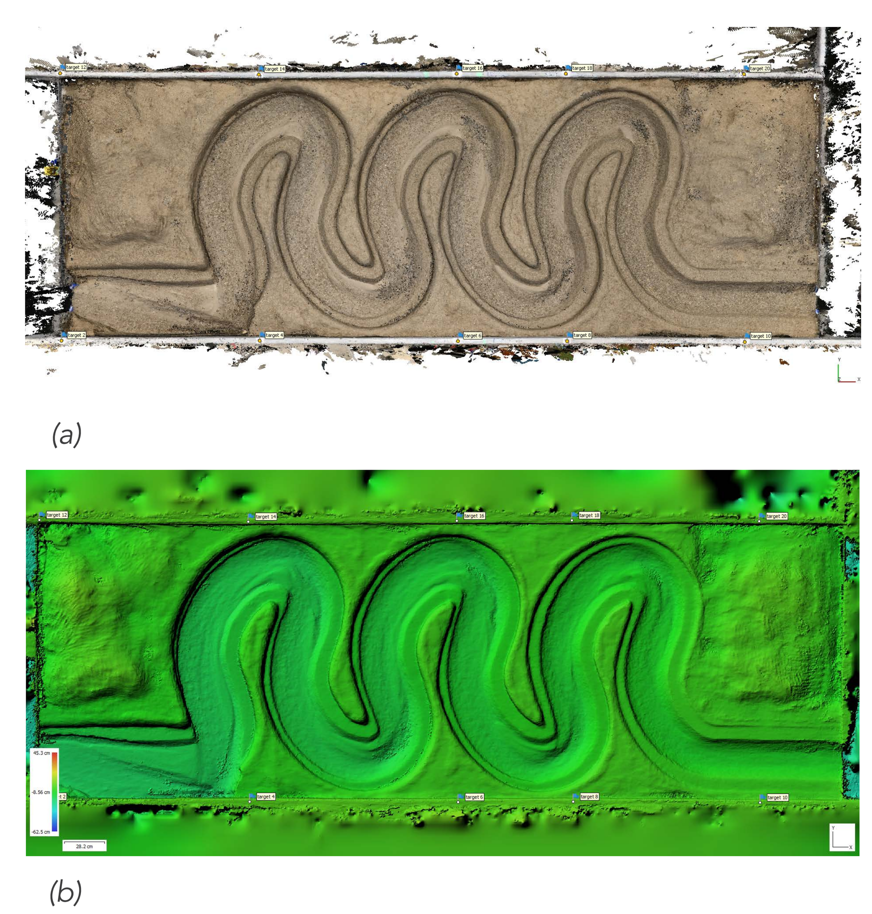

Figure 5: Output for final time step of J_s = +1.5/32 channel for (a) dense point cloud and (b) DEM

RESULTS

Currently, experiments for skewness coefficients of ±1.5/32 have been completed and lab work is on-going for experiments at ±0.5/32. The sediment transport patterns for the upstream skew experiment (+1.5/32) and downstream skew (-1.5/32) are shown in Figures 6 and 7, respectively. Figure 8 shows the manually measured centreline flow depths for the two channels.

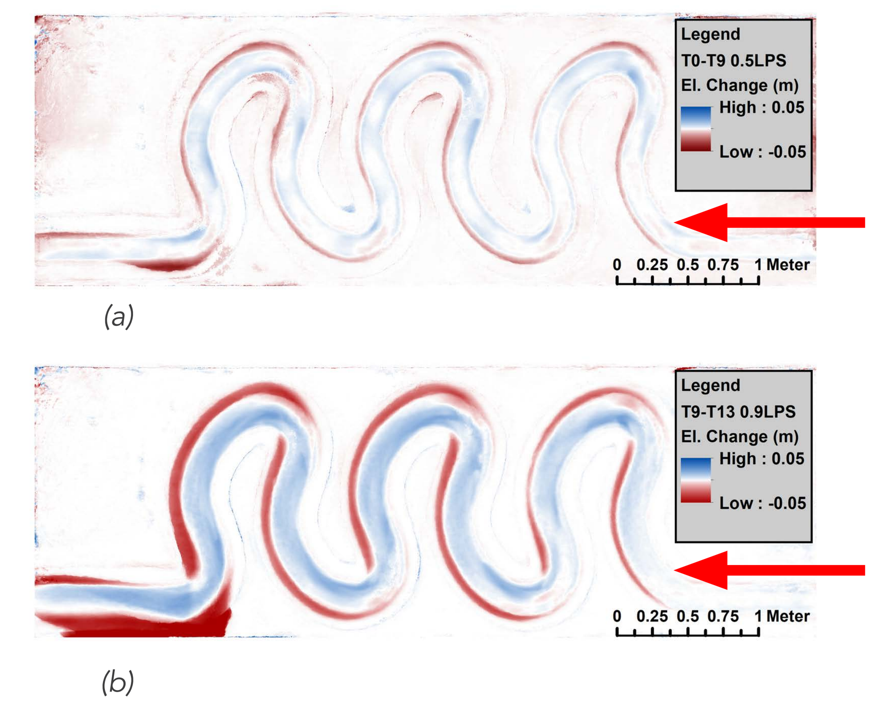

Figure 6: Sediment patterns for Js = +1.5/32 experiment after (a) 120 min total runtime at 0.5LPS and (b) additional 60 min runtime at 0.9 LPS

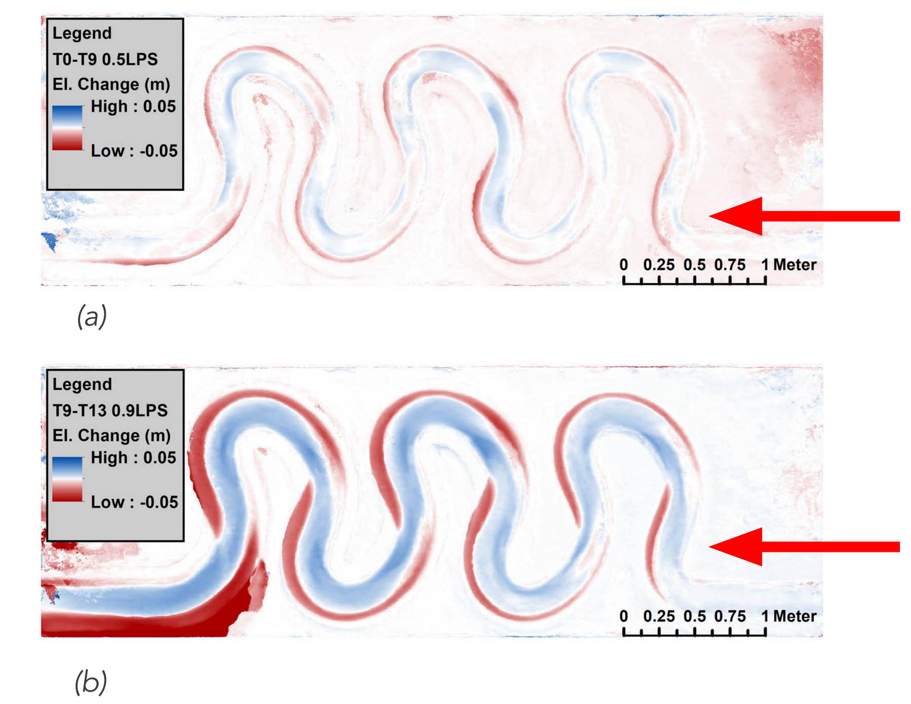

Figure 7: Sediment patterns for Js = -1.5/32 experiment after (a) 120 min total runtime at 0.5 LPS and (b) additional 60 min runtime at 0.9 LPS

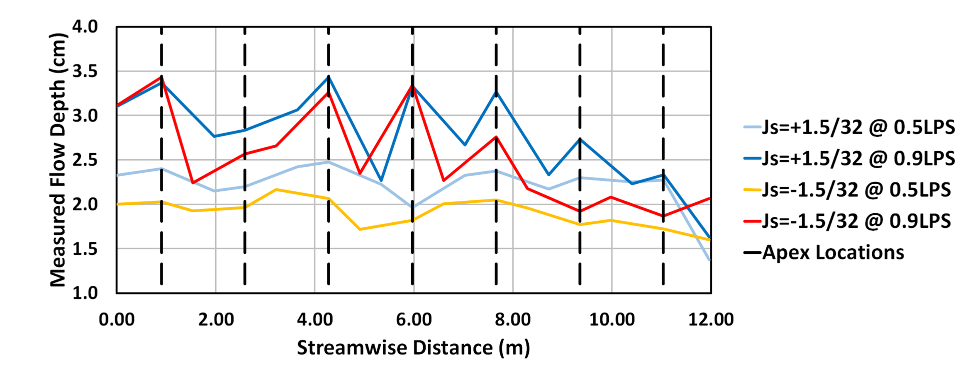

Figure 8: Time-averaged centreline flow depths for each experimental channel at low and high flows

CONCLUSIONS AND NEXT STEPS

Results so far have shown that skewness direction has a significant effect on erosion-deposition patterns, morphological developments, and some effect on flow depths. Data from continuing experiments and previous studies will be used to further analyze relationships of skewness to sediment dynamics, flow conditions, and Chézy resistance. These results may then be compared with sediment transport and flow condition predictions from computational models using the generated photogrammetric DEMs.

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