River Training Structure Design Study for Stabilization at Bonanza Bar

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Extended Abstract

The Huntington District (LRH) currently dredges within the navigation channel on a nearly annual basis at Ohio River Mile (RM) 353, adjacent to a location known as Bonanza Bar. An in-channel bar has developed from the placement of the dredged material along the left-descending bank side of the navigation channel where a bar was historically present according to historical navigation maps. The bar has fluctuated in elevation and extent, but remained present, likely due to historically preferential hydraulics for sediment retention, and in recent years, the need for navigation channel dredging in this segment has decreased. It is hypothesized that the presence of the bar is providing some degree of channel constriction and lessening the need for recurrent dredging in this reach of the navigation channel. LRH approached the ERDC with the desire to model possible river training structures that could be used to provide channel constriction by stabilizing the placement of dredge material at the Bonanza Bar site. A coupled 1D/2D hydraulic model was commissioned using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) to test various structures and estimate the impact the structures would have on the velocities within the main channel, along the length of the bar, and along the mussel habitat within the side channel.

Background

Historically, the bar appeared to be connected to the bank and when dredge material placements first began at the site, the placements were along the bank and out into the channel. With time, LRH altered their placement methods, in accordance with U.S. Fish and Wildlife recommendations, so the current bar is not connected to the left bank; instead, a side channel has developed that supports a mussel bed. No endangered mussels are known to inhabit the bed. There has been an increase in species and density according to recurrent mussel surveys at the site (cite 2020 report), and an additional benefit of the bar being stabilized would be to further encourage the mussel habitat in this side channel and additional side-channel habitat. Optimal velocity ranges for mussel habitat have not been established for this site, but an emphasis is placed on the stability of the substrate and the grain size of sediment that is most conducive to the spawning and establishment of the mussels present in the reach (personal communication Andy Johnson, LRH), which in turn in dictated by the prevalent velocities within the channel.

Overtime, the frequency and amount of dredging needed in the channel has also decreased, which has been possibly attributed to the presence of the bar. The District has interest in furthering the impact Bonanaza Bar has on the channel by providing constriction for self-scour. This would entail either a non-structural method of continuing placement at the bar to ensure its presence within the channel, or a structural option of building one or several river training structures to provide channel constriction in their own right and to encourage bar stability for the hydraulic benefit as well as habitat benefit on the bar and within the side channel.

The goal of this study was to build and utilize a coupled 1D/2D hydraulic model using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) to test various structures and estimate the impact the structures would have on the velocities within the main channel, along the length of the bar, and along the mussel habitat within the side channel. The main objective of the proposed structures is to provide bar stability of the deposited dredge sediment and channel constriction for scour of the main navigation channel, with the secondary concerns of encouraging mussel habitat within the side channel, providing fish habitat around the structure and within the side channel, and providing bird habitat and recreation opportunities on the stabilized bar.

Proposed Structures

The goals of the structures are to provide channel constriction and stabilization of the dredged material and induce bathymetric heterogeneity around the structure for fish habitat. The stabilization of the bar, in turn, would also provide a velocity shed effect for lower velocities in the side channel for mussel habitat. Additionally a stable bar would provide possible bird habitat and recreation opportunities. It should be noted that with any structure, unintentional geomorphic effects such as bank scalloping and erosion could be induced so this should be considered and bank protection may be needed.

The proposed structures to investigate are a rootless dike, bullnose chevron, and timber pile dike. A rootless dike is an impermeable rock structure that is built normal to river flow, but is not attached to the bank thus allowing flow between the structure and bank and provided side channel flow and habitat. The length of the structure, rock size, and distance from the bank much be carefully considered in the design of a rootless dike. Also, pushing flow into the side channel could cause bank erosion so the need for bank protection should also be investigated. Bullnose chevron are rock structures with a rounded head and two legs that extend downstream, parallel to the flow. The structure encourage a concentration of flow in the navigation channel and allow for scour just behind the structure that serves as preferential fish habitat, with sediment deposition further behind the structure, allowing for bar formation and stabilization. This is also a structure that is not attached to the bank, thus allowing for side channel formation, but bank erosion and protection should be considered. A timber pile dike is a permeable structure built of upright timber piles oriented across the flow, with space between the piles. The structure is designed to reduce water velocity as it passed through and encourage sediment deposition such that more flow is concentrated in the main channel and additional sediment transport within the channel is encouraged. The long-term stability of timber as a material and the anticipated sediment load of the river should be considered in its expected efficacy as a structure.

Considerations

It should be noted that upon investigation of the channel, there appears to be a local widening of the channel in the reach of interest. This could be a possible factor allowing for sediment deposition in the navigation channel. With channel constriction as the goal, placement of structures that form a channel alignment with a width consistent to the reaches above and below (those without dredging needs), should be considered. This may not exactly align with the current location of the Bonanza Bar dredged material placements, but would ideally be a more sustainable design.

Modeling

A couple 1D/2D hydraulic model was built using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS). An existing 1D HEC-RAS Ohio River Model was obtained from LRH and the 1D cross sections were used for portions of the new model. A 2D area for the study site was added, connected on either end to the 1D cross sections. The model was calibrated to capture the accurate velocities, and various geometry scenarios were built within the 2D mesh domain to simulate the structure designs at 3 flow conditions.

The study focused on the velocity changes resulting from various structures on the main channel, around the bar, and along the side change. The model is strictly hydraulic and does not contain sediment transport functionality, but the velocities are used as a proxy to infer anticipated sediment movement or deposition relative to the existing conditions. An additional limitation is that the model mesh was created using several bathymetric datasets from various collections (within a year of each other) in order to encompass the largest area with more updated data. This is suited to the needs of the study, however, because the focus is on the comparison of results between the various proposed geometries/structures and the exact bathymetry is expected to change frequently in the system.

References

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