Floodplain reconnection stream restoration in longwall mined watershed increases water and nutrient retention

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Extended Abstract

Extensive floodplain reconnection stream restoration (e.g. Powers et al. 2019) has been completed in rural Western Pennsylvania as a stream and wetland mitigation bank to address subsidence due to longwall coal mining and the effects of long-term land use choices including legacy nutrients in the sediments. The restoration sites serve as a mitigation bank for the shale gas industry's disturbance of streams and wetlands during construction of well pads, access roads, and pipelines. This study evaluated six restored streams and three unrestored streams in a nearby state park. The restoration project as a whole included many more stream reaches than this study could examine. The floodplain reconnection approach has the potential to both overcome the effects of longwall mining, primarily stream loss and streambed alteration due to subsidence, alongside other effects of legacy land use while building stream and wetland function. This study evaluates effects of the floodplain reconnection stream and wetland restoration projects on hydrologic response to precipitation and sediment and nutrient retention within the restored sites.

Prior to restoration, the streams were of moderate quality typical of the region and showed signs of legacy land use impairments. Stream channels were incised and flowed along one lateral edge of the valley as shown in the example in Fig. 1. Prior to restoration, the streams carried high sediment loads and showed evidence of head cutting and erosion. Restoration regraded and re constructed both the channel and the floodplain, creating a broad, wetland floodplain with a shallow, sinuous stream channel flowing (e.g. McMahon et al. 2021) as shown in Fig. 2. The stream channels were intentionally shallow to allow for inundation of the floodplain and their gradient is designed to be low enough to avoid erosion except in large storm events. Restored and unrestored streams were selected in three size classes – primary headwaters, headwaters and wading streams. Unrestored streams represent high quality regional streams and were located in a state park near the restoration sites.

Three years of post-restoration monitoring suggests that the restoration projects improved water retention, sediment retention, and nutrient retention on the sites. Plots of Antecedent Precipitation Index (API) (Fedora and Beschta 1989) which quantifies watershed wetness in lieu of soil moisture measurements versus water level show a decreased response to storms. There was a significant reduction in hydrologic response to precipitation post restoration, substantially higher sediment nutrient concentrations in restored versus reference streams, and substantially lower solids concentrations in restored versus reference streams. Pre-restoration sediment nutrient data are not available. Since restoration affects site soils, carbon was evaluated. TOC varied by season and site, but not by restoration status, large woody debris was not substantially different between sites or restoration status. Further study is being undertaken to examine

organic inputs from both leaves and large woody debris and to determine metrics that are appropriate for this type of restoration.

Variability between restored and unrestored and between restored sites suggests the approaches that would be most effective for future applications of this restoration method. Sites with the most consistent or repeated floodplain inundation retain the most water, nutrients, and sediment. The site with the poorest outcomes has ongoing longwall mining beneath the downstream end of the restoration site, leading to stream loss. At that site, due to water draining downwards from the restored stream-wetland complex, the restored site does not retain water as designed, and is often dry. With low periods of inundation, organic soils are not accumulating in the floodplain at the same rate as sites that do hold more water. This provides anecdotal evidence that period of inundation may be an important variable in performance of these systems.

The data collected to date suggest that the restored sites, beyond the one discussed above, are less responsive to storms, suggesting increased water retention, have higher sediment nutrients, suggesting they are serving as a depositional area for nutrients, and have increased fine sediment, suggesting the hydraulics encourage deposition rather than scouring. The evidence related to carbon inputs does not suggest differences between restored and unrestored sites in terms of carbon inputs from leaves or the presence of large woody debris. In rural mining areas, this stream restoration method can serve to reduce flood response and retain fine grained sediments with the potential to earn mitigation credits on multiple metrics.

Water level sensors have now been deployed for over a year at all sites and will be used in further analysis to define what water levels in the stream channel equate to different amounts and periods of wetland inundation at the restored sites. Further work will characterize period of inundation using aerial surveys by drones and will use geospatial analysis in ArcPro to quantify inundation with the aim of developing performance metrics. Alongside this, we intend to collect additional data about carbon cycling within the restored stream channels.

***Figure 1** Unrestored stream with an incised channel, erosional patterns along valley edge, and channel along valley edge driven by historic land use patterns*

Figure 2 Completed floodplain reconnection stream restoration project with hallmark sinuous, shallow stream channel in wetland floodplain that is readily flooded. Large woody debris has been installed in the floodplain for both carbon and bat habitat

Keywords: Stage zero restoration, mitigation, wetland

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References

Fedora MA, Beschta RL (1989) Storm runoff simulation using an antecedent precipitation index (API) model. J Hydrology 112(1–2):121–33.

McMahon P, Beauchamp VB, Casey RE, Salice CJ, Bucher K, Marsh M, Moore J (2021) Effects of stream restoration by legacy sediment removal and floodplain reconnection on water quality. Environmental Research Letters 16(3):035009.

Powers PD, Helstab M, Niezgoda SL (2019) A process-based approach to restoring depositional river valleys to Stage 0, an anastomosing channel network. River Research and Applications 35(1):3–13