Floodplain Trapping

Nutrient Dynamics in Restored Palustrine and Floodplain Wetlands

The 2014 Expert Panel looked at research that measured the input and output of nutrients from restored and created wetlands located in palustrine and floodplain areas. In this respect, the Panel relied on a previous CBP Expert Panel that comprehensively reviewed nutrient reduction rates associated with wetland restoration projects most of which were located in rural areas (Jordan, 2007). The majority of the research reviewed focused on restored wetlands that received stormflow (and, in some cases, groundwater), as opposed to engineered or created wetlands.

Jordan (2007) noted that restored wetlands had significant potential to remove nutrients and sediments, although the rates were variable. For example, Jordan notes the average TN removal for restored wetlands was 20%, with a standard error of 3.7 % and a range of -12% to 52% (N=29 annual measurements). Similarly, Jordan found that the average TP removal rate for restored wetlands was 30%, with a standard error of 5%, and a range of -54% to 88%.

Jordan (2007) also explored how the removal rates were influenced by the size of the watershed contributing nutrients and sediments to the restored wetlands. He found that removal rates tended to increase as restored wetland area increased (expressed as a percent of watershed area), although the relationship was statistically weak. Most of the low performing wetland restoration projects had wetland areas less than 1% of their contributing watershed area. It should be noted that there were negative removal rates recorded but these data points were not included in the analysis.

More recently, Harrison et al. (2011) measured denitrification rates in alluvial wetlands in Baltimore and found that urban wetlands are potential nitrate sinks. The highest rates of denitrification were observed in wetlands with the highest nitrate concentrations, as long as a carbon source was available. The study supports the notion that stream restoration associated with floodplain reconnection and wetland creation may produce additional N reduction.

The Panel considered the previous research and concluded that the impact of restoration projects in reconnecting streams with their floodplains during baseflow and stormflow conditions could have a strong influence on sediment and nutrient reduction, depending on the characteristics of the floodplain connection project.

Floodplain Trapping and Attenuation

Additional research by the 2019 Protocol 2/3 Work Group looked at stream restoration designs that restore floodplain reconnection and floodplain soils that can achieve additional nutrient and sediment attenuation. Recent research, summarized in Table 6, supports the following takeaways:

- *Sediment and nutrient trapping rates in reconnected floodplains can be similar to "natural" floodplains.* A series of comprehensive monitoring studies, conducted as part of the Chesapeake Floodplain Network, have measured long-term sediment and nutrient trapping rates for floodplains across the Bay watershed (Noe 2013, Noe et al 2019a). The research indicates that both sediment and organic nutrients are effectively trapped by floodplains during larger storms, where they may be stored for many decades. While most of the research has occurred in un-restored floodplains, there is some evidence that FR projects that increase storm flow diverted to floodplains can mimic or replicate trapping function (McMillian and Noe 2017, Noe et al 2019b).

- *Trapping can occur across a wide range of storm events but can be highly variable.* Another finding from recent research is that there is support for refining the treatable floodplain volume cap imposed by the original expert panel. This new research shows that sediment and nutrient retention occurs in the floodplain at a similar rate, regardless of the size of the storm event (Noe et al 2019a). On the other end of the spectrum, deposition can also occur in the frequent, small storm events for highly reconnected systems (McMillan and Noe 2017, Langland et al., 2020). Other studies have shown more mixed results. Filoso et al. (2015) reported that storm events larger than 1 inch resulted in net TSS export from the reach.

- *Restoring the stream and floodplain system will ultimately improve nutrient and sediment retention capacity in well-designed restoration projects.* In addition to trapping, restoration projects that restore floodplain/geomorphic complexity and promote overbank flooding can enhance filtering and microbial uptake removal mechanisms in the floodplain (Noe et al 2013, Hilderbrand et al. 2014, WEP 2016, CBP 2019).

Table 6. Sediment and Organic Trapping in the Floodplain

Summary: Recent literature provides a good understanding of sediment trapping dynamics within un-restored floodplains. Restored streams that promote floodplain reconnection are inferred to provide trapping rates similar to these systems across a wide range of storm events.

Citation	*Region*	*SR Type*	*Duration*	*Key Measurements*
Hupp et al 2013	CB	NRS	2-5 yr	Bank erosion and floodplain deposition rates
Noe et al 2013	CB	NRS	1-2 yr	Soil net ammonification, nitrification, N, and P mineralization
Donovan et al 2015	CB	NRS	N/A	Gross erosion and deposition rates
Gellis et al 2017	CB	NRS	2-5 yr	Erosion and deposition rates in channels and floodplains
McMillian and Noe 2017	OCB	NCD	1-2 yr	Sedimentation and nutrient processing in restored floodplains
Gillespie et al 2018	CB	NRS		Inputs, cycling and losses of nutrients and sediment
Pizzuto et al 2018	CB	NRS		Sediment transport and storage

Noe et al 2019	CB	NRS	5+ yr	Sedimentation rates and nutrient deposition
Noe et al 2019b	CB	NRS	5+ yr	Sedimentation rates and nutrient deposition
Key				
CB: Chesapeake Bay OCB: Outside the Chesapeake Bay Watershed	NCD: Natural Channel Design LSR: Legacy Sediment Removal RSC: Regenerative Stormwater Conveyance NRS: Non-Restored Stream		Duration >1 yr 1-2 yr 2-5 yr 5+ yr	

Upstream vs. Downstream Analysis for Floodplain Diversion

The 2014 EP developed Protocol 3 that was based on estimates of the frequency and volume of annual flows entering the reconnected floodplain using a hydrological model of the upstream watershed and the precipitation distribution from National Airport in Washington D.C. This method was criticized by the design community because of the variation in results from model to model especially for small storms and regional differences in the rainfall record.

Doll et al. (2018) found this method lacked the resolution to estimate the discharge and volume of small storm events for the projects that she studied that had limited floodplain area. An alternative method is to estimate the flows entering the flood plain using local flow duration curves that would rely on more empirical data. This approach is referred to as the “downstream” method while using a hydrologic model to estimate stream discharges is referred to as the “upstream” method.

Altland et al (2019) compared upstream vs. downstream methods for computing the annual volume diverted into the reconnected floodplain for multiple FR-LSR projects of various scales and conditions, including the BSR project that has been extensively monitored.

They concluded that upstream methods tend to under-estimate annual reconnection volumes for low-bank LSR projects, and that downstream methods provide more accurate estimates since they rely on measured baseflow and runoff rates from gage data (and compared well with treatment rates measured at the BSR site). A summary of their modeling results for five projects can be found in Table 13.

Altland et al (2019) suspects the USGS gage approach may be more sensitive to differences in flow distributions due to varying watershed characteristics (e.g., carbonate vs. non-carbonate watersheds, rural, suburban or urban watersheds). Doll et al. (2018) found the downstream method to be more sensitive to smaller flow rates however she did not observe substantive differences between the two methods.

Table 13: Comparison of Floodplain Treatment Volume for 5 Projects Using Different Upstream and Downstream Methods					
Site Factors	FR-LSR Restoration Projects				
	Israel Creek	Bens Branch	Talbot Branch	Furnace Ck	Big Spring Run
Drainage Area (mi^2)	29.1	2.4	0.3	1	1.9
IC (%)	5.0%	5.4%	1.0	45.9	14.0
Length (ft)	3666	4180	3392	4753	2592
Method	Percent of Annual Flow Volume Diverted to Floodplain for Treatment				
Upstream 1	8.6%	11.2	19.9	12.7	14.1
Upstream 2	20.4%	78.6	81.0	78.7	84.4
Downstream 1	48.1%	30.6	19.1	64.6	83.1
Wetland RR	0.2%	2.8	14.3	7.6	2.1
Modeling analysis by Altland et al (2019).					