Date: August 4, 2023

To: Urban Stormwater Workgroup

From: David Wood and Stream Restoration “Group 4”

Re: Protocol 3 Fix to Address Credit Scaling Issue

I. Background on Protocol Process

In its report, “Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects”, the original expert panel recommended ways to define pollutant removal credits for several classes of stream restoration projects using a series of four protocols (USR EP, 2014). Over the last five years, a diverse group of stream restoration stakeholders requested that the original protocols be revisited, and four groups were formed in late 2018 to do so (USWG, 2018). The Urban Stormwater Workgroup (USWG) convened a series of ad hoc teams to review the protocols, update the science and provide additional guidance on their application.

Following two years of review and discussion, the group of experts tasked with revisiting Protocol 3 agreed on improved methods to define the extent of the floodplain treatment zone (FTZ), model flow diversions from the stream to floodplain, and compute sediment and nutrient reductions achieved in the floodplain by individual projects.

The groups concluded that hydraulic modeling that computes critical flow velocities in the floodplain could be used to define the boundaries of the FTZ. While they concluded that the crediting cap that limited nutrient and sediment reductions to the first one foot of water on the floodplain can be relaxed in certain circumstances for projects that otherwise meet the qualifying conditions, an addendum to the report (Appendix K) noted that MDE would conduct an additional literature review to further evaluate this decision.

They also agreed that downstream methods provide superior estimates of the annual volume of storm runoff diverted into the floodplain for treatment, and provided more detail on how to apply them to individual floodplain restoration projects. These include standard baseflow channel definitions, acceptable techniques for separating storm flow from baseflow and methods to select and process appropriate USGS flow gage data.

The groups also endorsed the use of the floodplain pollutant removal rates contained in the recently approved expert panel reports on non-tidal wetland restoration, creation and rehabilitation. The project load reduction is computed by multiplying the nutrient and sediment loads delivered to the floodplain in the FTZ treatment volume by the most appropriate removal rate, given the wetland conditions encountered at individual floodplain restoration/rehabilitation projects.

Lastly, the groups decided to eliminate the upstream watershed to floodplain surface area ratio (>1) requirement. The original expert panel used this watershed ratio as a scaling factor to adjust the load reduction based on the relative size of the watershed to the floodplain trapping zone, but the new groups concluded it was not needed.

Following a lengthy public comment period, these recommendations were approved by the Chesapeake Bay Program's Water Quality Goal Implementation Team in October, 2020.

II. Problem to be Fixed

Since Protocol 3 was approved (CBP, 2020), practitioners have discovered three potential problems when applying it to real world floodplain restoration sites in the Bay watershed.

The first problem is that the new Protocol 3 may not properly "scale-up" the credit to account for more extensive floodplain restoration projects (whether by length or acres of reconnected floodplain). The current protocol credit is based on the change in percentage of flow which is treatable on the floodplain at a cross-section. It doesn't compare the total volume in a floodplain before and after restoration, meaning that it lacks an explicit spatial or time component.

Consequently, projects receive the same amount of credit if they divert the same proportion of new flow onto the floodplain, regardless of whether restored floodplain is 100 or 1000 feet long or 1 to 10 acres in area. This problem can lead to poor project design as it incentivizes small reconnection projects squeezed into constrained floodplains. Table 1 demonstrates this effect on two example restoration sites:

Table 1: Comparison of Floodplain Treatment Volume for Two Hypothetical Project Sites Using Protocol 3*

	Site 1	Site 2
Length of Restoration Site (miles)	1.5	3.0
Restored FTZ Area	14.0	24.0
Upstream Contributing Stream Length (Miles)	4.0	4.0
Bulk Density (lb/cf)	55	55
Proposed increase in treatable flow	39%	39%
% Wetland Restoration	80%	80%
% Wetland Rehabilitation	20%	20%
TSS Removed per year (tons)	**256.5**	**256.5**
TN Removed per year (lbs)	**201.0**	**201.0**
TP Removed per year (lbs)	**56.8**	**56.8**

*See Appendix B for calculation details

The second problem with the protocol is how floodplain sediment and nutrient reduction are calculated. Both the original Protocol 3 and the 2020 update relied on regional pollutant removal rates for non-tidal wetlands in the Bay watershed to represent the effect of floodplain restoration (Jordan, 2007, SR EPR, 2014 and NTW EPR, 2020). The most recent expert panel report established rates for three different categories of non-tidal wetlands: restoration projects, creation projects and rehabilitation projects, as well as floodplain areas that are not classified as wetlands at all. In developing solutions for the spatial scaling issue, it was determined that there are now more applicable datasets to better account for floodplain sediment and nutrient trapping.

The final issue relates to the decision to allow practitioners to relax the crediting cap that limited nutrient and sediment reductions to the first one foot of water on the floodplain in certain circumstances for projects that otherwise meet the qualifying conditions. Since the approval of the report, the Maryland Department of the Environment performed a thorough review of research cited in the expert panel report and found that the basis behind using a critical velocity of 2 feet per second to relax the 1-foot crediting cap is not supported by available documentation.

III. Proposed Solutions

Until recently, there was no systematic data on long-term floodplain sediment accretion in the Chesapeake Bay watershed. While non-tidal wetland rates were the best available removal rates at the time, they do not precisely correspond to how streams and floodplains interact together. To rectify the issues outlined in Section 2, the authors of the 2020 Protocol 3 recommendations gathered for a series of calls to evaluate new data on floodplain sediment storage and accretion. A summary of the newly reviewed data sources is captured in Table 2.

Reference	**Description**
Noe et al., 2020 and Noe et al., 2022	The Chesapeake Delaware Floodplain Network measured long-term (51 years on average) rates of average sediment accretion and bulk density at 68 floodplain sites. Their research encompasses a broad range of physiographic regions across the Bay watershed and provides a direct empirical means of calculating floodplain sediment retention. The 68 sites represent “un-managed” sites. The CDFN data did not include restoration sites, or locations with high frequency or duration of inundation in and along reaches with high sediment load.
McMillan and Noe (2017)	Data are from 5 urban stream restoration sites around Charlotte, North Carolina. Each restoration used a modified natural channel design approach. Average vertical sediment accretion was not published, but the published sedimentation rates were adjusted by Greg Noe’s global average of sediment bulk density from a manuscript in publication (Noe, personal communication), to obtain the average rate of vertical accretion for the sites.
Walter et al. (2017)	Data are from the final report on sediment accretion rates at the Big Spring Run stream restoration site in Lancaster,

	Pennsylvania. The project used a legacy sediment removal design approach. In December 2012 and January 2013, USGS installed 130 tile pads on the restored floodplain surface along 15 cross sections established across the restored wetland area. Soils collected from these pads roughly 4.5 and 5.5 years after restoration, in the late spring of 2016 and 2017, were analyzed for multiple biogeochemical parameters, such as Total P (TP), N (TN), and C (TC). A subset were sampled again in 2022.

Following evaluation of each data source, the Group recommended a proposed fix that would add a Step 6 to Protocol 3 that replaces the Wetland Expert Panel efficiencies with a spatially-adjusted credit based on floodplain sediment storage effectiveness. This step has three main components:

- **Establish the volume of sediment delivered to the site.** Similar to the 2020 Protocol 3 method, the fix would use CAST to establish the sediment load delivered to the project site. The load would then be divided by the average bulk density of floodplain sediments from the CDFN sites, 55 lb/cf.

- **Establish the sediment storage capacity of the floodplain.** The floodplain storage capacity is based on the mean vertical accretion rate from McMillan and Noe (2017) of 0.33 in/year. This depth is multiplied by the restored floodplain acreage to determine the storage capacity.

- **Determine the pollutant removal credit using the floodplain storage efficiency.** The sediment storage efficiency is simply the volume of sediment storage capacity divided by the volume of sediment volume delivered to the site. Therefore, the final credit would be calculated by multiplying the CAST load by the sediment storage efficiency and the percent treatable flow (which is unchanged). Floodplain soil nutrient concentration data is used to determine the TN and TP load reductions.

The complete list of steps in the proposed Protocol 3 revision is included below, along with justification of the selected vertical accretion rate, details on site-specific monitoring, and three design examples to show the impact of the fix. Note that all load reduction calculations should be based on post-restoration conditions and the conditions of the flood treatment zone should be field-verified.

Justification of the vertical accretion rate and floodplain nutrient concentration

After weighing available options for the vertical accretion rate, the Group agreed to recommend the mean vertical accretion rate of 0.33 in/yr from McMillan and Noe (2017). This rate is higher than the accretion rates from the CDFN (0.102 in/yr). The decision reflects that more accretion should be expected in “restored” over “un-managed conditions" because sediment loads are higher, and the floodplains in Protocol 3 projects are more connected due to restoration efforts. The decision was further supported by the Big Spring Run data, which reported a very similar average rate of sediment deposition from tile pads for all cross sections of 0.03 ft/yr, or 0.36 in/yr (Walter et al., 2017), despite a different land use setting and restoration design approach.

The floodplain sediment nutrient concentration is based on unpublished data from Big Spring Run (Walter, personal communication). The data were collected as part of the analysis described in Table 2. The soil nutrient concentrations for accumulated sediments were 2.33 mg/g TN and 0.60 mg/g TP (4.64 lb/ton TN; 1.20 lb/ton TP). These data were consistent with data from the CDFN, which reported floodplain soil nutrient concentrations of 2.67 mg/g TN and 0.72 mg/g TP (5.33 lb/ton TN; 1.43 lb/ton TP). The two datasets were combined, and the median soil nutrient concentrations are recommended for use in Protocol 3 (4.82 lb/ton TN, 1.13 lb/ton TP) in the absence of site-specific monitoring data.

Fixing the floodplain elevation crediting cap

As previously noted, a thorough review of research cited in the expert panel report and found that the basis behind using a critical velocity of 2 feet per second to relax the 1-foot crediting cap is not supported by available documentation. The group unanimously supported the conclusion of this literature review and recommends reverting to the original language from the 2014 Expert Panel Report, which states:

"The maximum ponded volume in the floodplain that receives credit should be 1.0 foot to ensure interaction between runoff and wetland plants." (USR EP, 2014)

Site-Specific Monitoring

In the spirit of collecting more site-specific data to improve the accuracy of pollutant load reductions achieved by stream restoration projects, the Group also recommends that practitioners have the option to update their floodplain storage effectiveness values based on 3-years of post-construction monitoring of floodplain sediment trapping. Pending approval by the states, practitioners will be able to replace the 0.33 in/yr vertical accretion rate from McMillan and Noe (2017) with well-supported, site-monitored data.

For purposes of improving the efficiency factor of stream restoration projects, monitoring is defined as the difference between measurements of pre and post floodplain sediment storage effectiveness. This may include the following methods to measure vertical sediment accretion:

- Artificial marker horizons
- Tiles
- Pins

Post-restoration monitoring should follow the methods outlined in Thomas and Ridd (2014) and be conducted for a minimum of 3 years following completion of the project before re-calculating the floodplain storage efficiency. Monitoring should occur across a range of sites and time periods to produce a representative, unbiased sampling of the project footprint. The number of samples taken along the reach may vary based on best professional judgement. It is recommended that a minimum of one sample be collected every 200-500 linear feet, from both sides of the channel(s), and in areas designed to be highly depositional and those that are not. In addition to measuring vertical sediment accretion, it is also recommended that sediment nutrient concentration data (TN and TP) is collected for accumulated sediments.

Once the new restoration efficiency is calculated, the stream restoration project may be re-reported, replacing the original record. The re-calculated efficiency will be back-dated to ensure the monitored reductions are credited for all years post-installation. Whichever monitoring approach is used for pre-restoration assessment should be used in the post-restoration assessment. For example, if tiles are used to assess pre-restoration sediment accretion rates, tiles must also be used in the post-restoration data collection.

This approach is wholly consistent with the approved recommendations for monitoring prevented streambank erosion under Protocol 1 (Chesapeake Bay Program, 2019). The Group also emphasized the need for more monitoring guidance, including evaluation of new and emerging technologies.

Note on Protocol 3 Verification

While the visual indicators developed to assess the performance of Protocol 3 stream restoration projects are effective in diagnosing major project failure, they may be less precise in defining the long-term impact of floodplain sediment accretion on the intended floodplain/stream flow exchange for the project (i.e.., to what extent does years of sediment deposition in the floodplain, as well as any further channel incision, diminish the desired degree of floodplain reconnection?).

For this reason, it is recommended that initial stream and floodplain elevations be monumented in critical project areas, so that elevation changes in both can be measured from the same baseline over time to assess the degree of floodplain reconnection. While this monitoring approach was suggested in a footnote in the approved table describing the visual indicators developed to assess Protocol 3 restoration projects, it perhaps should be a required element of final project documentation.

Proposed Protocol 3 Steps:

The only proposed change is to Step 6. Steps 1-5 remain the same from the 2020 recommendations.

Step 1: Determine the treatment depth in the Floodplain Trapping Zone (FTZ).

Step 2: Identify channel flow, floodplain flow at the treatment depth and mean baseflow.

Step 3: Develop an appropriate flow duration curve from comparable USGS gauge station.

Step 4: Determine the percent treatable flow.

Treatable flow is the difference from existing to proposed conditions for flow which accesses the floodplain while remaining below the 1 ft elevation cap, with baseflow removed. This should be done for both the existing condition and proposed restoration condition.

Step 5: Determine the annual load delivered to the project

Loads to the site are determined using the CAST modeling for the appropriate land river segment and the length of stream upstream of the project.

Step 6: Spatially adjust the credit based on sediment storage effectiveness

- Convert the annual load of TSS to an annual sediment volume using the average floodplain bulk density from the CBFN (55 lbs/cf).
- Determine the floodplain sediment storage based on .33 in/yr depth.
- Determine sediment storage effectiveness (percent of annual sediment volume that can be stored within the FTZ)
- Multiply by the floodplain soil nutrient concentrations to determine TN and TP reductions (4.82 lb/ton TN; 1.13 lb/ton TP).

Credit = CAST loading x sediment storage efficiency x percent treatable flow x sediment nutrient concentration

Suggested Alteration to Protocol 3 (Example Site 1)

A **3.0-mile-long** restoration site will create **14.0 acres** of restored FTZ area, compared to **2.0 acres** in existing. The upstream contributing stream length was computed as 4 miles delivering 350, 100, and 1,150,000 lb/mi/year of TN, TP, and sediment, respectively from CAST. The bulk density is 55 lb/cf.

Steps 1-4 – Determine the percent treatable flow and floodplain area
Percent treatable flow (using previously approved methods)

- 6% in existing and 45% in proposed.

<u>For both existing and proposed conditions</u>
Determine the floodplain area.

- Suggested approach is to utilize the average cross section utilized in determination of percent treatable flow to determine the depth of water above baseflow on average required to access the floodplain
- Use modeling software to model the area associated with; baseflow, average depth to access floodplain, one foot above average depth to access floodplain
- Floodplain area is the area associated with one foot above average depth to access floodplain minus the average depth to access floodplain.

Step 5 – Determine the yearly loads delivered to the project
1,150,000 lb TSS/mi/year * 4 miles = 4,600,000 lbs/year

Step 6a – Determine the annual sediment volume delivered
4,600,000 lbs/year / 55 lb/cf bulk density = 83,600 cf (1.9 ac-ft)

Step 6b - Determine floodplain sediment storage at 0.33 inches per year
Existing **2.0 acres** * 0.33 in = 0.06 ac-ft sediment storage
Proposed **14.0 acres** * 0.33 in = 0.39 ac-ft sediment storage

Step 6c – Determine sediment storage (trapping) effectiveness
Existing 0.06 ac-ft / 1.9 ac-ft = 3%
Proposed 0.39 ac-ft / 1.9 ac-ft = 21%

Step 6d – Determine the weighted P3 credits as a function of FTZ effectiveness

CAST loading x floodplain sediment storage effectiveness x percent treatable flow

Existing 4,600,000 lbs/yr x 0.03 x 0.06 = 7,906 lbs/yr or 3.9 tons
Proposed 4,600,000 lbs/yr x 0.21 x 0.45 = 415,072 lbs/yr or 207.5 tons

Step 6e -Determine credit as the difference between existing and proposed

207.5 tons -3.9 tons = 203.6 tons

Step 6e – Multiply by soil nutrient concentrations

203.6 tons x 4.82 lb/ton TN = 981 lb/yr TN
203.6 tons x 1.13 lb/ton TP = 230 lb/yr TP

407,166 lb/yr TSS credit (9% reduction)
981 lb/yr TN credit (70% reduction)
244 lb/yr TP credit (58% reduction)

<u>Suggested Alteration to Protocol 3</u>
<u>(Example Site 2)</u>

A **3.0-mile-long** restoration site will create **28.0 acres** of restored FTZ area, compared to **2 acres of existing**. The upstream contributing stream length was computed as 4 miles delivering 350, 100, and 1,150,000 lb/mi/year of TN, TP, and sediment, respectively from CAST. The bulk density is 55 lb/cf.

Steps 1-4 – Determine the percent treatable flow and floodplain area

Percent treatable flow (using previously approved methods)

- 6% in existing and 45% in proposed.

<u>For both existing and proposed conditions</u>
Determine the floodplain area.

- Suggested approach is to utilize the average cross section utilized in determination of percent treatable flow to determine the depth of water above baseflow on average required to access the floodplain
- Use modeling software to model the area associated with; baseflow, average depth to access floodplain, one foot above average depth to access floodplain
- Floodplain area is the area associated with one foot above average depth to access floodplain minus the average depth to access floodplain.

Step 5 – Determine the yearly loads delivered to the project
1,150,000 lb TSS/mi/year * 4 miles = 4,600,000 lbs/year

Step 6a – Determine the annual sediment volume delivered
4,600,000 lbs/year / 55 lb/cf bulk density = 83,600 cf (1.9 ac-ft)

Step 6b - Determine floodplain sediment storage at 0.33 inches per year
Existing **2.0 acres** * 0.33 in = 0.06 ac-ft sediment storage
Proposed **28.0 acres** * 0.33 in = 0.77 ac-ft sediment storage

Step 6c – Determine sediment storage (trapping) effectiveness
Existing 0.06 ac-ft / 1.9 ac-ft = 3%
Proposed 0.77 ac-ft / 1.9 ac-ft = 40.5%

Step 6d – Determine the weighted P3 credits as a function of FTZ effectiveness

CAST loading x floodplain sediment storage effectiveness x percent treatable flow

Existing 4,600,000 lbs/yr x 0.03 x 0.06 = 7,906 lbs/yr or 3.9 tons
Proposed 4,600,000 lbs/yr x 0.405 x 0.45 = 838,350 lbs/yr or 415.2 tons

Step 6e -Determine credit as the difference between existing and proposed

415.2 tons -3.9 tons = 411.3 tons

Step 6e – Multiply by soil nutrient concentrations

> 411.3 tons x 4.82 lb/ton TN = 1,983 lb/yr TN
> 411.3 tons x 1.13 lb/ton TP = 465 lb/yr TP

830,444 lb/yr TSS credit (18% reduction)
1,400 lb/yr TN credit (100% reduction – capped at delivered load)
400 lb/yr TP credit (100% reduction – capped at delivered load)

Suggested Alteration to Protocol 3 (Example Site 3)

A **0.5-mile-long** restoration site will create **2.0 acres** of restored FTZ area, compared to **0.5 acres of existing**. The upstream contributing stream length was computed as 4 miles delivering 350, 100, and 1,150,000 lb/mi/year of TN, TP, and sediment, respectively from CAST. The bulk density is 55 lb/cf.

Steps 1-4 – Determine the percent treatable flow and floodplain area

Percent treatable flow (using previously approved methods)

- 6% in existing and 45% in proposed.

For both existing and proposed conditions
Determine the floodplain area.

- Suggested approach is to utilize the average cross section utilized in determination of percent treatable flow to determine the depth of water above baseflow on average required to access the floodplain
- Use modeling software to model the area associated with; baseflow, average depth to access floodplain, one foot above average depth to access floodplain
- Floodplain area is the area associated with one foot above average depth to access floodplain minus the average depth to access floodplain.

Step 5 – Determine the yearly loads delivered to the project
1,150,000 lb TSS/mi/year * 4 miles = 4,600,000 lbs/year

Step 6a – Determine the annual sediment volume delivered
4,600,000 lbs/year / 55 lb/cf bulk density = 83,600 cf (1.9 ac-ft)

Step 6b - Determine floodplain sediment storage at 0.33 inches per year
Existing **0.5 acres** * 0.33 in = 0.01 ac-ft sediment storage
Proposed **2.0 acres** * 0.33 in = 0.06 ac-ft sediment storage

Step 6c – Determine sediment storage (trapping) effectiveness
Existing 0.01 ac-ft / 1.9 ac-ft = 0.5%
Proposed 0.06 ac-ft / 1.9 ac-ft = 3%

Step 6d – Determine the weighted P3 credits as a function of FTZ effectiveness

CAST loading x floodplain sediment storage effectiveness x percent treatable flow

Existing 4,600,000 lbs/yr x 0.005 x 0.06 = 138 lbs/yr or 0.7 tons
Proposed 4,600,000 lbs/yr x 0.03 x 0.45 = 62,100 lbs/yr or 31.1 tons

Step 6e -Determine credit as the difference between existing and proposed

31.1 tons -0.7 tons = 30.4 tons

Step 6e – Multiply by soil nutrient concentrations

30.4 tons x 4.82 lb/ton TN = 147 lb/yr TN
30.4 tons x 1.13 lb/ton TP = 34 lb/yr TP

61,962 lb/yr TSS credit (1.3% reduction)
147 lb/yr TN credit (10.5% reduction)
34 lb/yr TP credit (8.5% reduction)

References

Chesapeake Bay Program. 2019. Consensus Recommendations for Improving the Application of the Prevented Sediment Protocol for Urban Stream Restoration Projects Built for Pollutant Removal Credit. Approved by Water Quality Goal Implementation Team – Revised February 27, 2020. Annapolis, MD.

Chesapeake Bay Program. 2020. Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits. Approved by Water Quality Goal Implementation Team. Annapolis, MD.

Jordan, T. 2007. Wetland restoration and creation best management practice (agricultural). Definition of nutrient and sediment reduction efficiencies for use in calibration of the phase 5.0 Chesapeake Bay Program Watershed Model. Smithsonian Environmental Research Center. Edgewater, MD.

McMillan, S.K., and G. Noe. 2017. Increasing floodplain connectivity through urban stream restoration increases nutrient and sediment retention. Ecological Engineering 108 (284-295). http://dx.doi.org/10.1016/j.ecoleng.2017.08.006.

Noe, G.B., Hupp, C.R., Schenk, E.R., Doody, T.R., and Hopkins, K.G., 2020, Physico-chemical characteristics and sediment and nutrient fluxes of floodplains, streambanks, and streambeds in the Chesapeake Bay and Delaware River watersheds: U.S. Geological Survey data release, https://doi.org/10.5066/P9QLJYPX

Noe, G., K. Hopkins, P. Claggett, E. Schenk, M. Metes, L. Ahmed, T. Doody, and C. Hupp. 2022. Erosional and depositional streams: Measuring and modeling geomorphic change and watershed material budgets. Environmental Research Letters 17: 064015, doi.org/10.1088/1748-9326/ac6e47

Non-Tidal Wetland Expert Panel (NTW EP). 2019. Nontidal wetland creation, rehabilitation and enhancement: recommendations for nitrogen, phosphorus and sediment effectiveness estimates for nontidal wetland best management practices. Draft for partnership review. CBP/TRS-327-19. Chesapeake Bay Program, Annapolis, MD.

Walter, R., Merritts, D., Potapova, M., Hilgartner, W., Bowne, D., Johnson, R., and J. Moore. 2017. Wetland Program Development in Support of Pennsylvania's Aquatic Resource Protection and Management Action Plan, Program Focus Area 3: Headwater Aquatic Resource Restoration Monitoring. Pennsylvania Department of Environmental Protection.

Thomas, S. and P.V. Ridd. 2014. Review of methods to measure short time scale sediment accumulation. Marine Geology 207 (95-114). doi:10.1016/j.margeo.2004.03.011

USWG. 2018. Formation of technical groups to improve stream restoration protocols. Memo approved September 28, 2018 by USWG and Stream Health Work Group.

Urban Stream Restoration Expert Panel (USR EP, 2014). Recommendations of the expert panel to define removal rates for individual urban stream restoration practices. Test-Drive Revisions Approved by the WQGIT. September 8, 2014.

Appendix A. 2020 Protocol 3 Write-Up

1. Recommendations for Modifying Protocol 3

The group explored options to modify P-3 to improve how it estimates pollutant reduction achieved by FR projects due to increased connection between the stream and its floodplain. The group recommended three key changes to overhaul P-3, summarized in Table 12.

Table 12. Summary of Areas of Consensus for Protocol 3
For All FR Projects: ● Define the vertical and lateral dimensions of the floodplain trapping zone (FTZ) to reflect a project's increased floodplain reconnection. ● Replace the "upstream" method of using rainfall-runoff models to determine the amount of stream flow that is diverted into the floodplain, with a "downstream" method that uses scaled, representative USGS gauge stations to calculate overbank flow. ● Apply updated annual nutrient and sediment removal rates to the pollutant loads in streamflow that accesses the FTZ. The new rates reflect the latest science from recent expert panel reports that investigated pollutant removal by non-tidal wetland restoration projects, and is based on the predominant floodplain wetland conditions (See Tables 14 and 15). ● Floodplain wetlands that are restored, created, or rehabilitated as part of a comprehensive stream and floodplain restoration project (as described in this memo) should be reported using Protocol 3. All other floodplain wetland projects should be reported using the NTW Expert Panel (NTW EP, 2019). They should not be reported twice. ● Remove the upstream watershed to floodplain surface area ratio reduction. ● Nutrient and sediment reductions are only applied to overbank flow. ● Final nitrogen reduction should reflect the difference between pre- and post-restoration conditions.

Defining the Dimensions of the Floodplain Trapping Zones:

The group specified the on-site data needed to establish channel flow and floodplain capacity and define the future boundaries of the floodplain trapping zone. These methods can include spatial data from field-run topographic field surveys, LIDAR data or drone surveys to delineate the above-ground FTZ volume within the project reach.

The group agreed that modeled hydraulic parameters such as critical shear stress velocities could be used to define FTZ boundaries.

The 2014 expert panel implemented a one-foot floodplain elevation cap for crediting purposes. This was based on the assumption that suspended sediments more than one foot above the floodplain surface would not settle out onto the floodplain. Based on new research summarized in Section 4, the team now recommends replacing the one-foot floodplain elevation cap for crediting with a variable cap based on critical floodplain velocities. The group recommends that the upper limit of the floodplain trapping zone be defined by floodplain elevations that remain below critical floodplain velocities, as defined by 1-D HEC-RAS or 2-D hydrodynamic models. [1]

The one-foot maximum floodplain elevation limit would remain as the default but can be relaxed when modeled floodplain flow velocities are below 2 ft/sec (up to 3 feet or the 10-year water surface elevation, whichever is lower). To standardize this assessment, an assumed Manning's n roughness on the floodplain of 0.07 and in the stream channel of 0.035 should be used. A summary of the analysis that led to this recommendation, conducted by Coleman and Altland (2020) is presented in Appendix D.

A Downstream Approach to Diversion Modeling

There are two contrasting approaches to model how stream flow is diverted into the floodplain. The "upstream" approach relies on upstream watershed models to compute flows to the project site using long-term rainfall/runoff statistics, whereas the "downstream" approach relies on scaling USGS flow data measured at long-term gages. The USGS gage(s) may be located in the same watershed or within an adjacent or nearby watershed with similar land use or geology.

The group recommends replacing the upstream approach that is currently embedded in Protocol 3 of the expert panel report (2014), with the downstream approach. In the short term, the team suggests that it is acceptable to use existing upstream rainfall models, but they should be phased out by the end of the "grandfathering" period.

The Group concluded that upstream methods tend to under-estimate annual reconnection volumes for low-bank projects that are highly reconnected to their floodplain, and that downstream methods provide more accurate estimates since they rely on measured baseflow and runoff rates from gage data.

Upstream Approach. The upstream approach is the one currently embedded in P-3 (USR EPR, 2014). Over the last five years, practitioners have created many spreadsheet models to simplify the upstream design approach, which vary greatly in terms of the hydrologic models and technical assumptions employed.

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[1] The floodplain elevation cap is intended as a nutrient and sediment removal crediting construct and does not represent a specific design recommendation. Practitioners should still follow the qualifying conditions described in Section 3, regarding consideration of unintended consequences and duration of floodplain ponding.

The two most common upstream methods include the rainfall to runoff method and the discrete method developed by Medina (Method 1 and 2 in USR EPR, 2014). Uncertainty is created by these methods, however, because they rely on standard hydrologic models to compute runoff that are best suited to predict large infrequent storm events and not the smaller, more common flow events that are important in floodplain reconnection.

Downstream Approach. The downstream approach estimates the floodplain diversion volume using stream flow data derived from USGS 15-minute interval flow gages that have similar watershed characteristics as the project site being evaluated.

The range of flow statistics are then related to the channel capacity of the project reach to compute the estimated overflow frequency and volume to the floodplain, given its new channel/floodplain dimensions. Several methods have been explored by Altland et al (2019), Doll et al (2018) and Lowe (2016).

Each downstream method uses flow duration curves, hydrograph separation and other flow processing techniques to define a range of flow conditions using USGS gage data. The key flow conditions include: baseflow, channel flow, treatable floodplain flows (w/in one foot of floodplain invert) and untreatable floodplain flows (that are more than a foot deep). States and practitioners have the flexibility to adapt one of the existing methods referenced above, or develop their own downstream flow diversion models, but should use the following guidance to ensure consistency:

- USGS gauge data with minimum 15-minute time step
- USGS gauge data with 10+ year flow record
- USGS gauge from watershed in the same physiographic region with similar land cover, slope, and percent karst
- USGS gauge data scaled by comparing the drainage area of gauge site to project site drainage area
- Define the baseflow discharge for the 50% recurrence interval
- Use HEC-RAS or a similar model, to determine the channel flow (the flow that would just fill the existing channel without overtopping its banks) and the floodplain flow at maximum creditable floodplain inundation depth (1 ft is the default unless modeling shows velocities below the threshold described previously).

Altland et al (2019) compared upstream vs. downstream models 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.

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).					

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). Consequently, the group developed more guidance on improved methods to derive regional flow curves from USGS gage data to estimate floodplain flow diversions (see Appendix E). The new methods can be used for all projects in a region to standardize the computation methods and reduce credit variability. At the present time, resources are not available to develop standardized curves, but the group recommends this as a priority moving forward.

Selecting an Annual Floodplain Wetland Removal Rate

The original expert panel report reasoned that floodplain pollutant removal from overbank flow would behave in the same fashion as a restored floodplain wetland and thus relied on wetland removal rates and technical assumptions largely developed by Jordan (2007). In the original formulation of P-3, the pollutant load treated by the floodplain was multiplied by a base wetland removal rate.

Since then, two new panels conducted a comprehensive literature review of the pollutant removal capability of non-tidal wetland restoration practices (WEP 2016; NTW EP 2019). The expanded data analyses contained in these two reports provide new insight into the nutrient and sediment removal capability of floodplain wetlands, and a stronger technical foundation to support base wetland removal rates.
The pollutant removal studies evaluated by the WEP (2016) and NTW EP (2019) were based on surface water input loads from the immediately adjacent land uses, and include trapping, settling and denitrification processes. Because the pollutant removal rates will only be applied to overbank flow in Protocol 3, there will not be double-counting of denitrification with Protocol 2, which only considers denitrification during

baseflow. The removal rates established for three different categories of non-tidal wetland "restoration" are shown in Table 14.

Table 14. Floodplain Wetland Removal Rates in Prior CBP Expert Panel Reports			
Wetland BMP Category	Pollutant Removal Rate (compared to pre-restoration)		
	Total N	Total P	TSS
NTW Restoration	42%	40%	31%
NTW Creation	30%	33%	27%
NTW Rehabilitation	16%	22%	19%

[1] as outlined in expanded lit review and recently approved Expert Panel Report(NTW EP, 2020)

[2] rates are applied to the stream bed and bank load delivered to the project reach (see Table 16 and Appendix H for example). The "upland acres treated" factors from the NTW EP do not apply for Protocol 3.

Group 4 recommends that the pollutant removal rate applied to the floodplain treatment volume should reflect the predominant floodplain wetland category(s) present at the site, as defined in Table 15. Any wetlands that fall within the boundaries of the FTZ and are reported for credit under Protocol 3 should not also be reported using the Non-Tidal Wetlands Expert Panel, as it would double-count nutrient and sediment reductions from these practices.

Wetland delineations are normally required as part of the stream restoration permit approval process. Consequently, designers should have adequate field delineation data to determine how much project floodplain area falls into each restoration category and choose the correct rate to calculate pollutant removal within its FTZ.

Table 15. Definitions of Restoration Categories from NTW EP (2020)
Restoration: Manipulate physical, and biologic characteristics of a site with the goal of returning natural/historic functions to a former wetland: ● No wetland currently exists or has been extensively degraded ● Hydric soils are present ● "prior converted" *Creation:* Manipulate site characteristics to develop a new wetland that did not previously exist at the site: ● No wetland currently exists ● Hydric soils are not present ● Functional gain due to new wetland features *Rehabilitation:* Manipulate site characteristics with the goal of repairing natural/historic functions to a degraded wetland: ● Wetland present ● Wetland condition or function is degraded

Lastly, Group 4 found no evidence in the most recent series of NTW restoration expert panel reports to justify the continued use of Step 4 (from the 2014 Expert Panel Report) for P-3. The original stream restoration panel (USR EPR, 2014) added Step 4 to adjust the FTZ load reduction downward in situations where the upstream watershed to floodplain surface area ratio was less than one. The group noted that sediment and nutrient trapping in the FTZ was governed more by actual flow velocities in the FTZ that occur during storm events which are considered in the new methods to define its boundaries.

Table 16. Simplified design example to show how the revised P3 works for FR projects
Design Example[1] A 4,000 ft FR project is completed. It meets all qualifying criteria outlined in Sections 3.3 and 3.4. The project has the following characteristics: ● Single-threaded meandering channel with perennial baseflow. ● Has a FTZ defined by LiDAR (or other topographic field data) and hydraulic modeling ● The project is located within the Piedmont, with a 2.5 sq mile watershed that is 15% impervious, with little to no karst. ● The floodplain contained hydric soils, demonstrating evidence of historic wetlands that had been buried or degraded by legacy sediment infill.

- The FTZ includes 80% restored wetlands and 20% rehabilitated wetlands.

Step 1. Determine the treatment depth in the FTZ

- Hydraulic modeling showed an average flow velocity of 2.5 fps at one foot of flow depth in the FTZ, so the 1 ft elevation cap is applied.

Step 2. Identify the channel flow, floodplain flow at the treatment depth in the FTZ, and mean baseflow

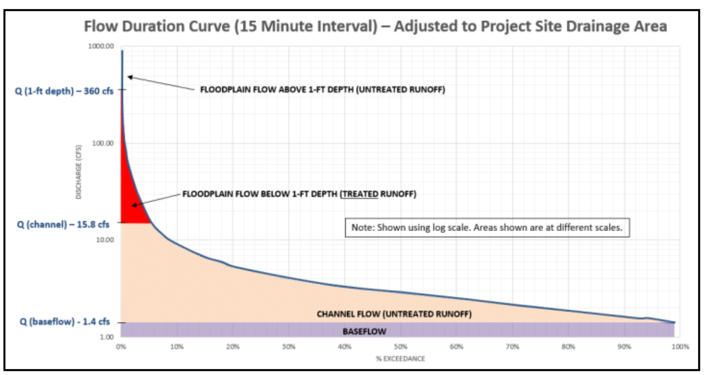
- In this example, the practitioner's hydraulic modeling determined that the top of bank channel capacity is 15.8 cfs.
- Similarly, hydraulic modeling of the flow at 1 ft of depth in the FTZ yielded 360 cfs.
- The 50% exceedance baseflow is 1.4 cfs, as determined by hydrograph separation analysis using USGS HySep computer program, which is incorporated in the Groundwater Toolbox program as outlined in Appendix E.

Step 3: Develop an appropriate flow duration curve from comparable USGS gauge station.

- The practitioner selected a USGS gauge station within the Piedmont with 20% impervious cover in a 5 sq mile drainage area.
- A flow duration curve was developed using methodology presented in Appendix E, adjusting discharges by watershed area.

Step 3. Determine the treatable flow

- Channel flow, floodplain flow at 1' depth and mean baseflow were plotted on the representative flow duration curve below.



- Treatable flow = (Total flow) – (channel flow) – (flow over 1 ft) + (baseflow)
- Convert to % flow treated (area under curve between Q(1-ft depth) and Q(channel) divided by total area under curve above baseflow) = 43.5%
- Using the same flow duration curve, the same process was repeated for existing conditions. Treatable flow in existing conditions = 6.2%
- Difference between existing and proposed conditions is 43.5 – 6.2 = 37.3% treatable flow as a result of the project improvements.

Step 4. Determine the load delivered to the project site

- Using CAST (See Appendix H) determine the total load delivered to the project site
- Load delivered to site (using CAST): 1,570 lbs TN, 329 lbs TP, and 692 tons TSS
- Multiply the percent of treatable flow that is in the FTZ by the pollutant load delivered to the reach
- Treatable Load = Total Load x % treatable flow from Step 3 = 586 lbs TN, 123 lbs TP, and 258 tons TSS

Step 5. Apply the appropriate Wetland Pollutant Removal Efficiencies.

- Using Table 14 determine weighted wetland removal efficiency rate for project (80% wetland restoration and 20% wetland rehabilitation) = 36.8% TN, 36.4% TP, and 28.6% TSS
- TN Removed = Treatable TN Load x 0.368 = 215.6 lbs/yr
- TP Removed = Treatable TP Load x 0.364 = 44.7 lbs/yr
- TSS Removed = Treatable TSS Load x 0.286 = 73.9 tons/yr

[1]Design example represents a simplified hypothetical project site to demonstrate how the nutrient reductions are calculated.

Appendix B. Table 1 Example Calculations

Approved Protocol 3 Modification (Example Site 1)

A **1.5-mile-long** restoration site will create **14.0 acres** of restored FTZ area. The upstream contributing stream length was computed as 4 miles delivering 350, 100, and 1,150,000 lb/mi/year of TN, TP, and sediment, respectively from CAST. The bulk density is 55 lb/cf.

Steps 1-4 – Determine the treatable flow

6% in existing and 45% in proposed. 45% - 6% = 39%.

Step 5 – Determine the yearly loads delivered to the project

1,150,000 lb TSS/mi/year * 4 miles = 4,600,000 lbs/year

Step 6a – Determine the wetland removal efficiencies

80% wetland restoration and 20% wetland rehabilitation = 36.8% TN, 36.4% TP, and 28.6% TSS

Step 6b – Determine the weighted P3 credits as a function of wetland efficiencies

CAST loading x wetland removal efficiencies x percent treatable flow
513,084 lb/yr TSS credit (256.5 tons/yr)
201.0 lb/yr TN credit
56.8 lb/yr TP credit

Approved Protocol 3 Modification (Example Site 2)

A **3.0-mile-long** restoration site will create **24.0 acres** of restored FTZ area. The upstream contributing stream length was computed as 4 miles delivering 350, 100, and 1,150,000 lb/mi/year of TN, TP, and sediment, respectively from CAST. The bulk density is 55 lb/cf.

Steps 1-4 – Determine the treatable flow

6% in existing and 45% in proposed. 45% - 6% = 39%.

Step 5 – Determine the yearly loads delivered to the project

1,150,000 lb TSS/mi/year * 4 miles = 4,600,000 lbs/year

Step 6a – Determine the wetland removal efficiencies

80% wetland restoration and 20% wetland rehabilitation = 36.8% TN, 36.4% TP, and 28.6% TSS

Step 6b – Determine the weighted P3 credits as a function of wetland efficiencies

CAST loading x wetland removal efficiencies x percent treatable flow
513,084 lb/yr TSS credit (256.5 tons/yr)
201.0 lb/yr TN credit
56.8 lb/yr TP credit