WSDOT Scour – Q&A

Questions are organized by each component of total scour, scour countermeasures, streambed construction and SMS/Hydraulic Toolbox

General

1. **What is the expectation for proper coordination between design team, HQ hydraulics and PEO?**
   Key check in points should be coordinated with HQ hydraulics at weekly check in meetings depending on project complexity.

2. **Is it beneficial to use the proposed streambed gradation(s) in the scour analysis rather that make assumptions based on observations of extant surface soils. In many instances, the scour depths may be within the depth of the material proposed. It seemed that this would be an option as long as we clarified what we used in the scour analysis.**
   Most of the scour equations used for the scour analyses do not take into account the size of the sediment. For example, live-bed contraction scour, abutment scour, or pier scour do not use sediment size. With this said, it is important to take a representative sediment sample at an appropriate approach section to determine if your reach/crossing will be in a live-bed or clear-water condition. In addition, most of the water crossings are being designed to restore natural stream processes, including the natural movement of sediment. As these crossings will be in place for over 75 years, careful consideration is needed to determine if sediment that is placed within a crossing will remain in place over the life of the structure. As mentioned in the HD template, designers need to determine the most appropriate types of scour at the crossing and correctly apply equations applicable to the site. Each question will have its own limitations and applicability which the designer needs to understand prior to applying the equation.

3. **We currently have 10-year flow producing deepest scour for Whiskey Creek.**
   This is possible but may be rare for most crossings. Velocity and depth combinations may produce deeper scour depths for more frequent storm events. WSDOT's manuals and templates require delivery teams to evaluate all flows up to the design and check storm events. Keep in mind that the accuracy of the scour equations is no better than the nearest 1 ft or $1/10^{th}$ of a foot. Also, with crossings that may not experience "textbook" contraction, some scour depths may be "computational" and affected by choices in how scour arcs are developed. Finally, keep things in perspective when looking at differences between the various computed scour depths (e.g., For Whiskey Creek if the 100-year scour reads out as 0.73 ft and the 50-year scour reads out as 0.79 ft).

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Long-Term Degradation

1. **Some projects have been estimating deep long-term degradation depths. 10 – 15 feet on some sites with steep channel profile slopes.**
    a. **Can a stream move that much material over the lifespan of the structure?**
    In some situations, it can, this is where geotechnical data, such as bore logs or hand augers, is valuable and establishment of base level control is important. Assess whether the stream has capacity to move that much material over the design life of the structure and if there are observed non-erodible layers or other features during site visits (e.g., downstream structure that will be in place over the life of the proposed structure, bedrock at surface, etc.) that can serve as base level controls. The project geomorphologist needs to assist with determining proper base level control and potential for regrade. Note if geotechnical information is not available and base level control is based on site observations, coordination with the geotechnical should happen as design progresses.

    b. **If we let the stream incise that much will fish habitat even exist?**
    This depends on who you ask, some believe allowing for uncontrolled regrade is the best thing for the system, while others believe establishment of grade control is important. This should be discussed on a project-by-project basis to determine if stream stability should be part of the overall project objective.

    c. **Will we cause downstream problems with that much sediment?**
    Potentially, this is part of the discussion when determining project objectives. Always assess what infrastructure and habitat is downstream and upstream (private property, wetlands, other infrastructure, etc.) and what would be the effects of material being transported downstream or a headcut propagating upstream.

2. **The long-term degradation potential can be the dominate factor in the total scour. In a couple of steeper crossings, we have seen some grade breaks that are close enough (1000- 2000 ft downstream) to the crossing we need to take them into account but far enough away that they are unlikely to have an immediate effect. Projecting back even a minor slope difference this far downstream can lead to some high (10-20 ft) long term degradation values. On some streams, especially smaller ones, this number can seem overly conservative. Should we try to put the long-term degradation potential in context if we feel it is overly conservative and what are some strategies for doing that?**
This is the main reason the watershed long-profile was added to Section 2.7.4 in the HD template. Base level control needs to be determined and may require close coordination with other disciplines or jurisdictions. Risks relating to headcuts or slopes adjusting over time need to be documented in the HD so a risk-based decision can be made for what level of total scour to account for in the design of the water crossing. Depending on stage of design, all information to support base level control or extents of potential regrade may not be known. In these cases, state a range of potential long term degradation values at the crossing and clearly state assumptions used to arrive at values. Also make

recommendations for how the assumptions can be minimized by obtaining additional data as the design progresses, for example coordination with the geotechnical engineer to obtain borings or other information on subsurface information.

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Contraction Scour

1. **The crossings' SFZ for most projects are relatively wide. Most Hydraulic Engineers are going to assume zero contraction.**
   Designers need to perform the appropriate calculation and document that it is zero. Note that when assessing contraction scour, the width being used is the width transporting sediment. If a feature such as a meander bar, LWM, countermeasure, etc. is placed, need to take this feature into account when assessing contraction scour (and other scour components).

2. **What is the difference between NCHRP equation (Abutment scour in Hydraulic toolbox) and contraction scour? In what occasion will we want to use contraction scour equation?**

   The footnote we added to the template:

   Table 16: **Scour analysis summary**

Calculated Scour Components and Total Scour for SR 112 MP 49.48 Whiskey Creek		
	Scour design flood (10-year flow)	**Scour check flood (2080 predicted 100-year flow)**
Long-term degradation (ft)	2.0	2.0
Contraction scour (ft)	0.0	0.0
Local scour (ft)[a]	0.9	0.3
Total depth of scour (ft)[b]	2.9	2.3

   a. *Local scours are estimated using Abutment Scour Tool in Hydraulic Toolbox with method outlined in NCHRP 24-20, which include contraction scour in their estimates.*

   b. *Total scour includes long-term degradation plus contraction or local scour, whichever is greater. Depth of total scour should be applied to the thalweg elevation of the proposed channel to determine the total scour elevation at each infrastructure component (e.g., structure, walls, roadway embankments, scour countermeasure, etc.).*

   The NCHRP local abutment scour equations and the contraction scour equations need to be evaluated separately. It is true that per the NCHRP method, abutment scour is related to general contraction scour, but both situations need to be evaluated by delivery teams for each individual crossing and flow rate. There is a simplifying assumption in the NCHRP abutment live-bed scour equation for the exponent. It should result in small differences in live-bed contraction scour. Contraction scour may be needed when you are out of the crossing or have no abutment scour within the crossing. Please see footnotes in the table in the current template. Below is a good example of a table with appropriate footnotes.

WSDOT Scour – Q&A

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Calculated scour for SR XX XXX Creek		
	Scour design flood	**Scour check flood**
Long-term degradation (ft)[1]	X.X	X.X
Contraction scour (ft)	X.X	X.X
Local scour (ft)	X.X	X.X
Total depth of scour (ft)[2, 3]	X.X	X.X

[1]Reflects the largest end of the range of long-term degradation estimated to be present in the worst-case scour scenario; long-term degradation should be refined in the FHD phase.

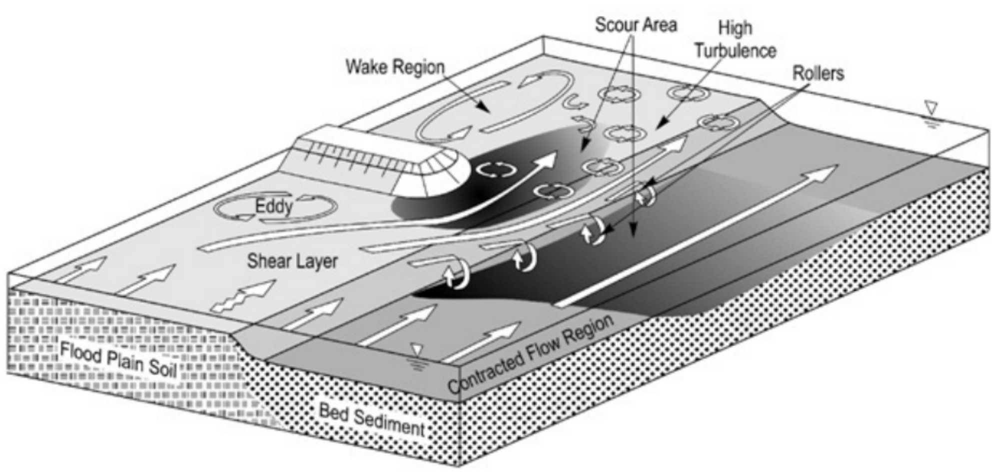
[2]Contraction scour is not included because the local scour method outlined in NCHRP 24-20 includes contraction scour in its estimate, so the two are not additive.

[3]Total depths of scour are assumed to be relative to and extending below the thalweg elevation.

Local Scour

Abutment Scour

1. **Same as contraction scour (large opening, SFZ), majority of Hydraulic Engineers are quickly assuming abutment scour is zero and moving on.**
   Everyone needs to perform the appropriate calculation. Note that abutment scour is when there is a protruding element into the flow. It is not necessarily the location of the structure's abutment foundation. As an example, many fish passage projects due not have wide floodplains and based on the required SFZ, do not have elements that would cause abutment scour. The first step in abutment scour is to assess whether there are the physical features that cause the flow features which drive scour (see HEC 18 figure below).



   a. **Lateral migration. How do designers need to account for a channel moving closer to the wall and triggering abutment scour?**
      Need to use abutment scour Condition A when potential for channel to migrate towards abutments.

   b. **What analysis should be performed for the cluster boulder/meander bar standard designs? Can we use these features provide some sort of quasi protection?**
      No, these features cannot be relied upon to provide protection for bridge structure foundation design, however, they are suggested to maintain channel geometry and retain design flow depths, especially at low flows. See contraction scour guidance above regarding importance of selecting appropriate widths for assessing contraction scour. If features are designed to be stable at the 100-year flow, their width may need to be subtracted from the width that is capable of transporting sediment.

2. **According to HEC-18, abutment scour from NCHRP is not added to contraction scour because it already includes contraction scour, which seems different from the scour summary table in the template (see below). Should [we] report the higher value between contraction scour and abutment scour as total scour? [We] can add a footnote under the**

table to clarify that "the abutment scour includes the contraction scour and the higher one is reported as total scour depth".

Calculated Scour Components and Total Scour for SR 104 Machias Creek		
	Scour design flood (100-year)	Scour check flood (500-year)
Long-term degradation (ft)	0	0
Contraction scour (ft)	0.01	0.05
Local scour (ft)[a]	0.64	0.78
Total depth of scour (ft)[b]	**0.64**	**0.78**

a. Abutment Scour
b. Depth of total scour should be applied to the thalweg elevation of the proposed channel to determine the total scour elevation at each infrastructure component (e.g., structure, walls, roadway embankments, scour countermeasure, etc.).

Teams need to use the most applicable equation(s) given the hydraulic and scour processes occurring at a given infrastructure component, which will likely vary by project and even within a crossing (e.g., abutment, wall, scour countermeasure, etc.). The depth of scour you compute at the abutment location (using the NCHRP 24-20 method) is essentially an amplification of general contraction scour and should not be added/summed again to the general contraction scour depth you may have already computed. So yes, care should be taken when using tables in the reports.

You can also point to the text in the template (Section 7.4.2) that states "The abutment scour calculated using the NCHRP methodology includes contraction scour, therefore contraction scour should not be added to total scour since it is part of abutment scour." That said, this does not mean that general contraction scour by itself is not occurring in other areas of the opening outside of the abutment toes/walls (i.e., the general lowering of the streambed due to the constriction still theoretically occurs inside of the opening).

Also, we should not be reporting scour to the nearest hundredth of a foot, even a tenth of a foot is a stretch.

Bend Scour

1. **What is an appropriate length of bend scour?**
   Bend Scour is in HEC 23, Section 4.3.5. Need to be cautious on using equations that predict scour location, especially in a dynamics system where the location of the bend may change over time. If your channel is anticipated to move over time, bend scour should be applied at all anticipated locations.

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Scour Countermeasures

1. **In 7.1 HD Template '*Scour countermeasures can mitigate all or some components of total scour at walls and roadway embankments through coordination with the region design team and approval by hydraulics, bridge, and the geotechnical offices. Total scour for structure foundations shall not rely on the scour countermeasure'*. Please provide clarification on what is meant by red text.**
   Key check in points should be coordinated with HQ hydraulics at weekly check in meetings depending on project complexity. Ongoing coordination between the Stream team, HQ bridge, HQ geotechnical, HQ hydraulics and the PEO with should be happening throughout the entire HD process. Refer to the Bridge Design Manual for current policy on design structures to account for scour.

   a. **What does WSDOT prefer to see for scour countermeasures?**
      First step is to coordinate with the region PEO/HQ hydraulics to determine if countermeasures are needed. Scour countermeasures need to be designed and constructed per HEC-23 also see WSDOT HM Figures 7-8 and 7-9.

      What will tribes be okay with? The decision to use scour countermeasures needs to be coordinated with the Tribes.

      Can we assume buried revetment is ok for abutment scour countermeasures? Yes, see WSDOT HM Figures 7-8 and 7-9 for example.

   b. **Can we take away abutment scour from the total scour if we recommend scour countermeasures?**
      Coordinate with the region PEO/HQ hydraulics to determine if countermeasures are feasible and appropriate for the site.

   c. **Will WSDOT consider an alternative countermeasure shape other than the 'golf club' shape?**
      Scour countermeasures need to follow HEC 23 (see the shallow foundation tech brief for additional clarification). The "golf club" shape is for when you have potential for abutment scour. The lower portion of the design is an apron which is critical for mitigating the scouring processes when you anticipate abutment scour. Deviations from HEC 23 are not recommended, if there is a need for a deviation, coordinate with HQ hydraulics.

   d. **Are there situations where designers are allowed to put scour countermeasures inside the minimum hydraulic opening?** Yes, see WSDOT HM Figures 7-8 and 7-9. However, coordination with the region PEO/HQ hydraulics and discuss with the Tribes and resource agencies.

e. **Coarsened channels in steep streams: Are designers going to get a lot of push-back from Tribes?**
Yes, some believe allowing for uncontrolled regrade is the best thing for the system, while others believe establishment of grade control is important. This is the discussion the stream team and region PEO should be having and documenting when discussing project objectives.

f. **Can designers account for buried wood as legitimate grade control?**
In general, buried wood should not be counted on for grade control in the design of the bridge foundations.

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Streambed Construction

1. **Will construction/regrading of a stream move a lot of sediment the first year after the site is built? This seems to be problem with steep streams.**
   Imperative that during construction, best practices for streambed construction are followed. As an example, contractor shall wash in fine sediments to fill void spaces and provide a seal to constructed streambed rather than just placing a layer of fine sediment on top of streambed.

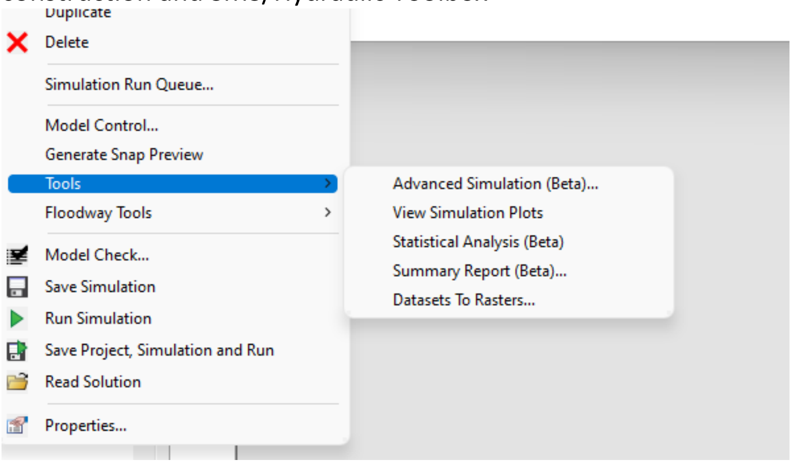
2. **Is the scour caused by meander bar one of the elements for local scour?**
   If meander bars are a significant portion of the channel, they may cause local scour on a culvert wall. Otherwise, the main objective for estimating scour at a meander bar is to make sure it is embedded deep enough within the bed such that as the scour pool forms around it, it does not fail (construct down to anticipated scour).

SMS and Hydraulic Toolbox

1. **It sounded like [we] should draw the abutment arc at the toe of the main channel and have the bank lines at the top of the main channel instead of MHO. This is a little different from my design assumption. I thought the main concern of the scour analysis is for the structure. We are planning to calculate scour caused by habitat features in the crossing, but we've acknowledged there will be localized scour around the features and they are part of the design.**
   SMS abutment arcs are currently intended to be drawn *at* the abutment or abutment toe. SMS only uses the intersection of the abutment arc with the contracted section arc to (1) read a y_o value (i.e., flow depth at abutment toe prior to scour) and (2) to plot the local scour hole in the plot feature of Hydraulic Toolbox, which feature we are not using. When drawing abutment arcs in areas of low flow depth (or zero depth), teams need to pay attention to the y_{max} value and reference it to the thalweg elevation for Section 7 reporting…to aid in this, teams should also get in the habit of manually entering in the flow depth at the thalweg for y_o in Hydraulic Toolbox, which will assure that the scour depth and elevation are correctly referenced to the thalweg.

   Bank arcs, on the other hand, need to be carefully drawn through a variety of items, including an assessment of where live-bed sediment transport occurs (e.g., using the CVI coverage in SMS), the topobathymetry of the "main channel" (top of bank to top of bank, or toe to toe), field information, and vegetation.

2. **A simulation uses a stepped inlet flow boundary condition corresponding to different hydrological scenarios where each step duration is long enough for the model to reach steady state. Scour scenarios were made to pull data from each of these time steps. The issue is that when the .hyd file is exported different results are reached by the hydraulic toolbox depending upon what time step is selected in the model space when the file is exported. Any idea what is happening here? Basically, want to know how SMS is exporting the .hyd file, what it looks for and where it draws the data from the discharges in different scenarios are all extracted from the last timestep.**
   SMS does not appear to have the ability to honor the currently selected time step. We have asked teams to NOT use a stepped inflow boundary condition, but instead, use multiple simulations or the beta feature allowing multiple flows in one simulation (Tools>Advanced Simulation).



3. **Why is the abutment scour from the view value window different with the hydraulic toolbox result?**
   There should not be a difference. SMS passes the parameters directly into the Hydraulic Toolbox.

4. **Misc tips, tricks, and instructions.**
   - Use the SMS packaging tool, but pay careful attention that it contains what you intend.
   - SMS version 13.2.10 was released by Aquaveo on August 10, 2022. Please communicate to QC review teams what version of SMS you are using for your crossing.
   - Please clean up SMS files, map data, and simulations prior to QC reviews.
   - SMS and Hydraulic Toolbox are not connected to each other following the SMS parameter export.
   - Be sure to check and verify that the parameters computed by SMS are correct and that they match what is fed to the Hydraulic Toolbox.
   - All delivery teams are to use the SMS scour tools, including the scour coverage arcs and export to Hydraulic Toolbox.
   - Refer to the PDF “Ten Topics For Successful Scour Analysis” on the HQ Hydraulics webpage