Hydrology report:

- The Drainage Manual, Chapter 6, Appendix E, “Major Flood Events in Connecticut Since 1927”, is not a comprehensive source for flood history. The generalized maps provided may not accurately represent localized flooding, and there are other flood events that have occurred in the state since the maps were developed and included in the manual. Stream gages on or near the subject water course and local rainfall data should be reviewed as well as other sources of local flood history. See “Note” on page 6E-1 of the manual.
- A site-specific rainfall distribution should be developed and used based on the current NOAA Atlas 14 precipitation-frequency data in lieu using the legacy, standard Type III distribution that was based on the 1960-70s era NWS TP-40 rainfall data.
- Recommended design flows should be rounded to the nearest 5 or 10 cfs.
- At least two hydrologic methods, based on their applicability to the subject watershed, should be used to evaluate riverine hydrology. These methods include, but are not limited to, LP3 Gage analysis, USGS StreamStats, NRCS Unit Hydrograph methodology, and Gage Calibration. Flows obtained from FEMA Flood Insurance Studies (FIS) or other previous studies and sources do not count as an independent, project specific form of hydrologic analysis or method; however, the flows from these studies can be used as a comparison to the resulting flow estimates from the aforementioned methods.
- When conducting a Gage Calibration (commonly referred to as “Comparative Gage” by some) as part of the hydrologic analysis, the gage used for calibrating the regression equation (StreamStats) flows should have similar characteristics to the subject watershed. If it does not, then additional explanation and documentation is required to justify its use.
- When developing tidal hydrology for a coastal project, multiple sources of data should be considered. These sources could include, but are not limited to, the CIRCA, NOAA, USACE North Atlantic Coast Study (2015), and FEMA transects and associated Flood Insurance Studies (FIS). If time series data is available from the listed sources, it should be used. If not, then the water surface elevations can be used in conjunction with the equations and spreadsheets from the “Pooled Fund Study” entitled “Development of Hydraulic Computer Models to Analyze Tidal and Coastal Stream Hydraulic conditions at Highway Structures” to develop time series tidal/surge hydrographs. These sources should be compared, and a selection should be made based on the project location and requirements. The documents can be found on the Hydraulics and Drainage webpage via the following link: Tidal Hydraulic Modeling for Bridges (Pooled Fund 2002)

- "Small Structures" conveying streams that have been studied in detail by FEMA shall be designed for the 100-year return frequency per section 9.3.4, "Small Structures", of the Drainage Manual. Additionally, this would necessitate a 500-year check event for the design of the structures.

Hydraulic Report/model:

- When modeling baffles within culverts, follow the guidance provided in "Fish Passage Design for Roadway Crossings Guidance" published by Caltrans. Chapter 7, "Culvert Retrofit Design", provides general guidance on facilitating for fish passage with baffles in culvert retrofits. Please be aware that Table 7-1 is not intended to be used for choosing baffle configurations, it is providing the equivalent roughness for a few specific baffle configurations. Appendix F, "Hydraulics of Baffles", describes the process for modeling and evaluating the hydraulics of baffles in culverts. The engineer designing or analyzing baffles through culverts should be familiar with, at a minimum, these two sections of the Caltrans guidance document. The document can be accessed via the following web site: Fish Passage Design for Roadway Crossings Guidance | Caltrans
- All HEC-RAS models submitted are to be georeferenced. Duplicate effective FEMA models do not need to be georeferenced but corrected effective models and design models created from FEMA models are to be georeferenced.
- SMS-SRH2D models should be developed in accordance with the FHWA Two-Dimensional Hydraulic Modeling for Highways in the River Environment Reference Document and the guidance found here: SMS Learning Center - Aquaveo on the Aquaveo webpage. The model should be reviewed prior to submitting to Hydraulics and Drainage. The review checklist in Appendix C of the reference document should be completed and attached to the Hydraulic Report Appendix.
- The language "hydraulically inadequate or adequate" should not be used in report narratives or to classify structures. Instead, the language should indicate whether the structure meets or does not meet the hydraulic design criteria. This is particularly the case for proposed structures that may not meet one or more of the criteria but are hydraulically and structurally designed to be resilient considering overtopping and/or pressure flow, and the potential scour related to those conditions. Additionally, in many cases, the structure span/size may be optimized and meets or exceeds 1.2 x bankfull width; however, underclearance and/or freeboard criteria can only be met by modifying the roadway design (raising the roadway profile).
- When determining stability of natural streambed material or rounded riprap the archived HEC-11 should not be used. Instead use HEC-23 Design Guide 4 for side slopes and HEC-26 – Culvert Design for Aquatic Organism Passage could be used for the channel bottom or within the structure when specific parameters are met (see guidance within the HEC-26 manual).

- Bankfull width should be field measured. Measurements should be taken in a natural, relatively stable area outside of the influence of any waterway structure crossing or other manmade features. Photos, discussion and other documentation for the bankull width determination should be included in the Hydraulic Report Appendix containing the Data Collection and Field Review Form.
- When replacing an existing structure, an option should be evaluated and presented that meets all the hydraulic design criteria. If meeting one or more of the criteria is found to be impractical or not feasible, than the reasons and justifications must be discussed and documented in the report narrative and the hydraulic model for the option should be included for review.
- Multi-barrel culverts should be avoided, when possible, to minimize maintenance, as they tend to catch debris, and one or more of the barrels typically fill in over time.
- When scour protection/energy dissipation is deemed necessary at the outlet of culverts conveying watercourses, the design should be based on the HEC-14 methodology. The riprap apron and preformed scour hole details in the Drainage Manual are meant for storm drainage outlets and are typically not applicable at these locations.
- The velocities within the bridge or culvert itself should be reviewed in addition to comparing velocities in the sections adjacent to a bridge or culvert. These velocity values can be obtained from the bridge/culvert table outputs. The relevant output printouts should be included in the appendix titled *"Hydraulic Analysis Models – Output."*
- The results of the hydraulic analysis of the check storms must always be thoroughly evaluated and reviewed for the potential impacts or non-impacts of the proposed design and discussed in the report. In accordance with the criteria in the Drainage Manual, where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic is indicated by the analysis of the check storm, increases in waterway or other improvements should be made.
- The report conclusion must provide a definitive recommendation.

Scour Report/model:

- For shallow foundations the top of footing should be placed below the total 500-year scour as measured from the channel thalweg. If this can’t be done, then a deep foundation should be considered. See section 2.6.4.4 of the CTDOT Bridge and Roadway Structures Design Manual and the FHWA Tech Brief, FHWA-HIF-19-007, Hydraulic Considerations for Shallow Abutment Foundations.
- For deep foundation structures the top of footing should be set at least 1’ below the calculated 200-year contraction scour plus long-term degradation as measured at the abutment face or the channel thalweg. If the scour depths are relatively shallow ensure that the bottom of footing is set at least 4’ below the finished grade per the

CTDOT Bridge and Roadway Structures Design Manual, Section 10.7.1.2. If this can't be done the designer should make a recommendation, provide justification, and a multidisciplinary team consisting of Hydraulics & Drainage, Soils & Foundations, and Bridge Design (CLE) can review for acceptability and concurrence. See section 2.6.4.4 of the CTDOT Bridge and Roadway Structures Design Manual and the FHWA Tech Brief, FHWA-HIF-23-048, Hydraulic Considerations for Abutments on Deep Foundations and Bridge Embankment Protection.

- To expedite review of the proposed substructure design in future submissions, we recommend that Rehabilitation Study Reports (RSR's) and preliminary scour reports include more detailed discussion and documentation of the potential for channel migration in the surrounding reaches as well as the potential for shifting of the thalweg in the bridge opening. Because the contraction and expansion of flow at a bridge creates localized hydraulic conditions that are independent from the surrounding reach, the potential for the upstream/downstream channel to migrate is not equivalent to the potential for a thalweg to shift inside of a bridge opening. Evaluation of the potential for the thalweg to shift inside of a bridge is particularly relevant when it is proposed to set the bottom of abutments above the contraction scour elevation.
- The type of abutments being proposed should be identified in the scour report. If integral or semi-integral abutments are proposed, the scour report needs to include verification that the calculated scour depths will not result in the maximum allowable abutment heights being exceeded.
- Riprap will still be required through the bridge and adjacent to the abutments to protect the roadway embankments and abutments even if the proposed bridge is set on deep foundations and is designed to remain stable for the design and check scour events. Horizontal limits of the protection should extend from the abutments into the channel far enough to armor the disturbed areas within the channel adjacent to the abutments, typically keying in the riprap at the toe of slope, and minimizing the extent of the riprap in the streambed. The armoring should wrap around the abutments a distance of either 2*flow depth or to the limits of disturbed area adjacent to the roadway or abutments, whichever is greater. Vertical limits should extend so that the bottom of the key in is at or below the 200-year contraction scour depth and the upper limits of the protection are set at the approximate 200-year water surface elevation (WSE), or one foot above the design WSE, whichever is greater. If the above cannot be done, provide an alternative recommendation, justification, and contact the H&D unit to discuss whether a less conservative design is acceptable.
- When calculating riprap size for embankment protection only HEC-23 DG 4 or 14 should be used, whichever is more applicable to the site conditions. (See also comment - "Riprap Protection at Bridges") At a minimum modified riprap should be used even if the calculated D50 size is smaller than modified riprap.
- Riprap Protection at Bridges:

- Please note that HEC-11 has been superseded by the design guidelines in the current version of HEC-23 and that the HEC-11 document has been "archived" on the FHWA Hydraulic Engineering webpage. The procedures and guidance in HEC-23 should be used for the design of bridge scour and stream instability countermeasures.
- HEC-23 "Design Guideline 4--Riprap Revetment" versus "Design Guideline 14--Rock Riprap at Bridge Abutments" for bridge projects – Unless documentation is provided by the designer justifying the selection of the procedures/equations to be used at a particular project site, the following general guidance should be followed:
  - If the riprap is provided primarily as "stand-alone" protection of the bridge abutments or the ends of the "spill-through" embankment slopes supporting the abutments, Design Guideline 14 may be more appropriate for sizing the riprap. The parameters (flow depth and velocity) in the equations of this guideline are based on the contracted section or bridge opening.
  - If the riprap is being designed as "continuous" revetment that extends upstream and/or downstream of the bridge protecting the stream channel and/or embankment slopes, channelizing the flow through the bridge, Design Guideline 4 may be more appropriate for sizing the riprap. Otherwise, the parameters in the equations of this guideline are based more on channel properties and may not be as easily applied to typical bridge crossings as Design Guideline 14.
  - If the situation does not present a clear choice, evaluate both guidelines and then select the one most appropriate for the project site. In any case, the report should include justification of the procedures used as part of the documentation for the design.
- If pier scour protection is necessary and riprap is proposed, HEC-23 "Design Guideline 11-- Rock Riprap at Bridge Piers" should be used.

- To adequately evaluate scour, a stream/riverbed soil sample is required to determine an appropriate D_{50} grain size. Samples should be obtained early in the design phase. A minimum of two samples should be collected. One at the bridge and one at the approach section. Guidance in Section 6.2.1of HEC-18 states that the D_{50} applied to the critical velocity computation should be based on the upper 1 foot of the streambed material in the upstream reach. The D_{50} applied to the scour depth computations, however, should be based on the material below the armor layer at the bridge location. The armoring layer should be removed, and the samples should be taken from approximately 1' below the bottom of the streambed. Also see section 9.C-2, I. Technical Appendices of the CTDOT drainage manual.

- It is our understanding that a FHWA Tech Brief is currently being developed that addresses abutment scour based on the NCHRP 24-20 methodology with pressure flow. Until it's release, please continue to follow the current practice that when a pressure flow condition prevails (WSE above low chord), the Flow Separation Thickness *t* from Eqs. 6.14 & 6.16 in HEC-18 may simply be added to the NHCRP 24-20 scour to account for the pressure flow condition. To be clear, this means that Eq. 8.3 in HEC-18 can be adjusted to $ymax = aA\ yc + t$ or $ymax = aB\ yc + t$, which provides the contraction and local abutment scour as a single value. Once the Tech Brief is released, it will supersede this direction.
- For NCHRP 24-20 methodology, scour condition A or B is selected based on abutment proximity to the main channel, not whether or not the scour is clear water or live bed.
- The scour report conclusion should provide a definitive recommendation.

Regulatory Report/FMC-MOU Application/FMC General:

- FEMA Floodplain limits should be plotted on the plan sheets in accordance with the May 2016 CTDEEP/DOT guidance floodplainplotsfinalmay2016pdf.pdf
- When an unresolvable water surface elevation increase(s) in the floodplain/floodway analyses is noted, it should be explained thoroughly in the Regulatory Report and FMC-MOU application documents. The explanations should include a discussion on potential impacts to adjacent properties, compliance with NFIP and municipal floodplain zoning requirements, convergence with existing, location of increase(s) relative to the ROW line, and a discussion on the reason for the increase(s).
- The current CTDOT FMC-MOU document is being updated, and the revised version will be available in the near future. One of the changes include a requirement for inundation mapping consistent with CTDEEP requirements. Please include the Inundation mapping showing the existing and proposed inundation area for the 2-, 10-, 25-, 50-, and 100-year discharges, carried to convergence in all subsequent submissions.

Drainage Report/plans:

- When evaluating drainage systems or small culverts using the Rational Method, a frequency factor should be applied to 25-Yr or greater storm events. Please see table 6-2 in section 6.9.3 of the CTDOT Drainage Manual.
- Coordination with the local municipality and CTDOT district maintenance should occur as early as possible in the design phase regarding any known drainage issues or concerns at or in the vicinity of the project site. Record of the coordination should be included in the Drainage Report.
- The contours shown on drainage area maps should extend to limits of the watershed boundary so drainage areas can be verified.

- All drainage structures should be shown on profiles and cross-section plots.
- Catch basins labeled "in-sag" in the drainage calculations and report, must meet the definition listed at the bottom of Table 11-2 in the Drainage Manual.
- Drainage computations should identify structures by station and offset rather than by a numerical identifier. If station and offset is not feasible for the computations, then include an index with the location of the structure corresponding to its numerical identifier. The watershed map should be prepared accordingly.