URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

Digital Flood Hazard Area Delineation (DFHAD) Guidelines

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Prepared by

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REVISE DESCRIPTION

The June 2012 revision of the Digital Flood Hazard Area Delineation (DFHAD) Guidelines has been modified to mainly address clarification of deliverables.

Section 1 emphasizes the inclusion of both Report and Technical Appendix Checklists. Copies of the Checklists and the Agreement Table are provided with the Urban Drainage and Flood Control District (UDFCD) Agreement.

Section 2 clarifies digital file requirements for both the hydrologic and hydraulic analyses.

Section 3 clarifies Flood Map and Flood Profile components, and includes more emphasis on use of the Comment column contained in the Floodplain and Floodway Data Table.

Section4 regarding Submittal Requirements had been extensively revised to address three separate submittal phases for the DFHAD documentation.

Section 5 includes minor clarification to required Quality Control and Error Checking information.

The Appendix now includes the top-width example figures (previously included in the report text).

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1 INTRODUCTION AND PURPOSE

The Digital Flood Hazard Area Delineation (DFHAD) Guidelines were written to offer guidance and direction for consultants developing FHAD studies in a digital PDF format. The guidelines cover the materials to be included in the DFHAD files, the process by which they are to be developed, and specific details for the final product.

1.1 Referenced Documents

The DFHAD guidelines reference several documents. When used in conjunction with these guidelines, these references offer important information for those developing the DFHAD. The following should be consulted routinely throughout the study:

- **Checklists** – The Digital Flood Hazard Area Delineation (DFHAD) Studies Report Checklist, (DFHAD Report Checklist), and the Technical Appendix Checklist for Flood Hazard Area Delineation Studies (Technical Appendix Checklist) identify the information that is required for submittals. The DFHAD checklists are provided in the Agreement with the Urban Drainage and Flood Control District (UDFCD). The DFHAD Report is discussed further in Section 3.
- **Agreement Table** – The Agreement Table is an error-checking tool to be completed by the consultant prior to any DFHAD submittal. It will also be used during submittal review by UDFCD to ensure that there is good correlation between the hydraulic model, Flood Maps, Flood Profiles, and floodplain and floodway data tables. The Agreement Table is also included in the Agreement with UDFCD. Use of the Agreement Table is discussed in more detail in Section 5.2.
- **UDFCD Specifications for Electronic Submittal of FHAD and Master Plan Documents in PDF Format** – Dated August 2006 (revised June 2007), this document was developed as guidance for creating PDFs of the traditional hard copy FHAD and Planning Study reports. These DFHAD Guidelines provide additional criteria specific to DFHAD reports.

1.2 Digital FHAD vs. Traditional FHAD Report

By definition, the DFHAD is a digital format of the FHAD report. Traditionally, the end product of the FHAD report had been a bound 11”x17” printed document. This meant that all of the content was formatted to fit on 11”x17” pages and still effectively illustrate the results of the flood study. Consequently, consultants would prepare plan and profile sheets presenting the Flood Map and Flood Profile. This broke up the floodplain and Flood Profiles into very small sections. This not only was a very time consuming process, but often poorly illustrated the results of the flood study from the big picture.

The DFHAD is essentially the traditional FHAD report, but produced in PDF format. The key difference between traditional printed FHAD reports and the DFHAD is that the final document is not printed and “bound”, thus the Flood Maps and Flood Profiles in the DFHAD can be formatted for sheet sizes larger than 11”x17”. This allows more freedom in the page size resulting in fewer sheets and a less fractured depiction of the floodplains. In addition, some of the content customarily included on the FHAD plan and profile sheets (i.e. representative cross sections and structure sections) is now included in separate sections of the final PDF document.

1.3 **Digital Flood Insurance Rate Map Requirements**

DFHAD hydrology is typically based on existing infrastructure and future land use conditions. If there is a significant difference in 100-year peak discharges between the existing land use condition hydrology and the future land use conditions hydrology (see UDFCD Agreement), technical information will also be required for a Digital Flood Insurance Rate Map (DFIRM). The supporting documentation for a DFIRM will follow the same Technical Appendix Checklist included with the UDFCD Agreement.

2 **DIGITAL FILE FORMATS**

2.1 **Hydrology**

Hydrology for the DFHAD may be baseline hydrology (future land use conditions) from an approved UDFCD parallel study [Major Drainageway Planning Study (MDP), Outfall Systems Plan (OSP), etc.]. The 500-year hydrology will need to be developed for the DFHAD, since it is not required in either the MDP or OSP. If the baseline hydrologic analysis is performed as part of the DFHAD, it must be completed in accordance with UDFCD MDP/OSP requirements for the 10-year, 50-year, 100-year, and 500-year events. All pertinent electronic files and additional calculations used for the hydrologic analysis must be provided as supporting documentation. Files will be consistent with the Technical Appendix Checklist.

The baseline hydrology must have UDFCD approval prior to submittal of any DFHAD hydraulic analysis.

2.2 **Hydraulic Analysis**

The DFHAD hydraulic analysis is based on existing infrastructure and future land use conditions hydrology.

The hydraulic analysis is based on the standard step-backwater method using the most recent version of HEC-RAS, or another method approved in writing by UDFCD. Special conditions, such as major flow splits, may require modeling additional hydraulic reaches based on sponsor consensus. Other conditions may require additional hydraulic calculations to support data used in the hydraulic model.

All pertinent electronic files and additional calculations used in the hydraulic analysis must be provided as supporting documentation for each formal submittal. For HEC-RAS these will typically include the Project (.prj) file with each Plan clearly identified. All files used to analyze pertinent Plans in the project must also be included. Each submittal will include a list of the Project (.prj) file, and individual Plan files (.p0#) with corresponding Geometry (.g0#) and Flow (.f0#) files (complete with file date) to support the analysis (i.e., regulatory multiple-profile run, floodway run, etc.).

A minimum of two submitted HEC-RAS hydraulic models are required for the DFHAD. The HEC-RAS must include (at a minimum) a plan for the multiple-profile analysis (10-, 50-, 100-, and 500-year discharges), and a separate plan for the floodway determination. **A floodway model is required any time there is a designated floodway – even if floodway is equal to floodplain (i.e., confined within a design channel, etc.).**

2.3 Flood Maps and Flood Profile Files

The Flood Map drawing files may be created in either computer-aided design (CAD) format or geographical information system (GIS) format (preferred). Flood Profile files are typically submitted as CAD files. The delivered CAD files must be compatible with AutoCAD 2000 or later and include the .dwg file and pertinent associated files. GIS files must be compatible with ArcView 3.x or ArcGIS 8.x or later and include the .mxd file with relative references.

If the Flood Map files have been created with CAD, they will have to be converted to, and provided as, GIS shapefiles with the final submittal.

2.4 DFHAD Report File

The DFHAD Report is one PDF file containing all elements of the FHAD report including the text, figures, tables, Flood Maps, Flood Profiles, and other supporting material. The PDF file is created from the native software that originally produced the content (i.e. Microsoft Word, AutoCAD, HEC-RAS, etc.). The majority of the report is formatted as 11"x17" similar to traditional FHAD reports except that the Flood Maps and Flood Profiles are formatted for larger sheet sizes as deemed necessary. See Sections 3.1 and 3.2 for additional information about formatting Flood Maps and Flood Profiles.

Consultants should refer to the "UDFCD Specifications for Electronic Submittal of FHAD and Master Plan Documents in PDF Format" written by CH2M Hill dated August 2006 (Revised June 2007). The criteria specified in the DFHAD guidelines take precedence for DFHAD electronic documents. It is important to make sure that the final DFHAD PDF document is well bookmarked and every item listed in the Table of Contents is linked to the appropriate page in the PDF document. This makes the DFHAD document easier to navigate and more user-friendly.

3 DFHAD REPORT

The DFHAD Report has two basic components. The first part is the textual discussion of the study process that provides the reader with background information and supports the hydrology (typically existing infrastructure and future land use conditions) and hydraulic analysis used in the study. The second part consists of the appendices that will contain the majority of the supporting figures, tables and documents for the DFHAD Report.

The engineering information in the DFHAD Report should be presented in an organized fashion for use in development of master drainage plan updates; road and bridge planning and design; design of channel modifications; and design of flood control structures.

The following is a brief outline of the report:

Section 1	Introduction
Section 2	Study Area Description
Section 3	Hydrologic Analysis
Section 4	Hydraulic Analysis
Section 5	References

Appendix A Project Correspondence
Appendix B Hydrologic Analysis Support Documents
Appendix C Hydraulic Analysis Support Documents
Appendix D Floodplain and Floodway Data Tables
Appendix E Flood Maps
Appendix F Flood Profiles

Detailed descriptions of what is to be provided in each of these components, (in addition to required figures and tables) are addressed in the UDFCD Agreement and corresponding DFHAD Report Checklist.

A Technical Appendix will be required for the Final Report Submittal, and will include all final hydrologic and hydraulic models and supporting calculations used for the DFHAD. Please refer to the Technical Appendix Checklist for content.

The following sections provide additional direction for specific portions of the DFHAD Report:

3.1 Flood Maps
3.2 Flood Profiles
3.3 Floodplain and Floodway Data Tables
3.4 Additional Information

3.1 **Flood Maps**

Digital topographic work maps must use either AutoCAD or GIS formats, unless prior authorization is given by the District in advance of the submittal. For AutoCAD formats, the digital submittal must include the .dwg file and pertinent associated files; for GIS formats, the digital submittal must include the .mxd file with relative references. If the Flood Map files have been created with CAD, they will have to be converted to, and provided as, GIS shapefiles with the final submittal.

3.1.1 Map Projection

A major aspect of transportability of mapping or survey files to a geographic information system (GIS) is horizontal and vertical positioning on the earth. Mapping data must be controlled to a grid or geographic projection and referenced to horizontal and vertical datums. These positional references are established prior to the surveying process. Survey control is expressed in the form of horizontal and vertical position plotted on a geographic projection or control grid (State Plane). All planimetric and topographic features must be collected/compiled and referenced to this survey control.

The DFHAD maps shall be delivered in Colorado State Plane, and the appropriate zone projection as specified in the contract, with a NAD83 horizontal datum, adjusted to ground (District-specified elevation) and NAVD88 vertical datum. The mapping source and projections are to be documented in the DFHAD text and included as a note on the Flood Map.

Either the conversion factor from ground coordinates to State Plane, or a table showing XY values for several known points in both grid and ground coordinates shall be included in the

submittal. The amount of X and Y shift is also acceptable. This information is generally available from the organization providing the base data. This will allow the study area to be used with local government base data.

3.1.2 Base Mapping and Topography

Base mapping must show all current features, streets with correct names, railroads, airfields, etc. All streets and roads within or near the floodplain shall be shown and named. There must be adequate planimetrics to distinguish major hydraulic structures, as well as potential buildings impacted by the flood hazard information.

The base mapping and topography must show and label:

- Existing ground contours (differentiating major and minor contours);
- Major contours shall be a minimum of 10-ft intervals;
- Jurisdictional boundaries (City and County limits);
- Hydrographic features such as streams, rivers, canals, and flood control structures;
- Major junctions and confluences;
- Hydraulic structures (culverts, bridges, dams, levees, etc.);
- Streets, roadways, and other transportation features;
- Houses and buildings (especially any insurable structures potentially impacted by the 100-year flood);
- Any other pertinent planimetric features located in, or directly adjacent to, the flood hazard area.

3.1.3 Units

Units for all distances and elevations are in feet.

3.1.4 Map Scale and Size

Flood Maps and Flood Profiles must be at the same horizontal scale. The minimum printed-scale of Flood Maps is 1" = 200'. The horizontal scale should be illustrated by a bar scale and text stating the print scale (e.g. 1" = 200'). The orientation of the printed Flood Map should be horizontal. The north arrow on the Flood Map should always point to the left, top, or right of the sheet and never towards the bottom or bottom corners.

Note that Flood Profiles must be oriented with the downstream end on the left side of the sheet regardless of the Flood Map orientation (see Section 3.2 for more information on Flood Profiles).

The Flood Maps and Flood Profile layouts are to be created to minimize the number of sheets. The printed map size is not to exceed 36" x 120", but no smaller than 11"x17". If multiple sheets are necessary because the maximum map size would be exceeded, clearly indicate match lines between the multiple sheets to indicate breaks and provide a key map on each sheet.

3.1.5 Stream Alignment

Stream alignment (or profile baseline): The stream alignment is the line that determines the Flood Profile. Generally, this follows the channel thalweg or invert. It is important that the length of the channel along the alignment shown on the topographic work map and Flood Profile matches the channel length used in the HEC-RAS hydraulic model. The stream alignment

should depict the flood flow path and generally follow the alignment of the channel stream bed. **Any questions on alignment for the stream centerline/stationing need to be resolved with the District prior to beginning the hydraulic analysis.**

If there are two or more possible flow paths along a drainageway, a consensus will need to be reached on which flow path will be considered dominant (and the basis for the main drainageway stream alignment and stationing). Stream alignments and stationing typically need to follow the surface flow path for floodplain mapping. For example, if there is a minor storm sewer under a development, but the majority of the flood flow will be on the surface, then the stream alignment and stationing need to follow the surface flow path regardless of the minor storm sewer alignment. Significant overtopping of roadway crossings may also warrant alignment consideration.

When a large percentage of the discharge follows a distinctly separate flow path than the main channel, a split floodplain (with a distinctive alignment, modeling reach, cross section locations, Flood Profiles, etc.) may be required. The split flow floodplain delineation will be determined using the split flow discharge. For the majority of situations, the main channel floodplain delineation will still be determined based on the total discharge (i.e., do not reduce the discharge to account for the spill flow). When determining the floodway delineation, if the total discharge cannot be confined to the main channel within the 0.5-foot floodway criteria, a separate, split floodway will likely be required. **It is imperative to discuss split flow areas with the District before analyzing split flows.**

In a few cases for our area, the low-flow channel may be very sinuous with little flow capacity and the overbanks would convey the majority of the flood flows. With this situation, the channel alignment (or profile baseline) may be different from the channel bed and the modeled length of the flood flow path between cross sections may be different (most likely shorter) than the channel bed length between cross sections. Before deciding that the sinuosity of the low-flow channel is considered to be so extreme that separate alignments (both a stream alignment and profile baseline alignment) will be required for the more frequent events (10-yr and 50-yr) versus the major flood events (100-yr and 500-yr), the Engineer must get approval from UDFCD and the local sponsors.

The consequences of using a separate profile baseline for flood flows (i.e., 100-yr and 500-yr events) have a significant impact to the products required for the DFHAD. In addition to the stream alignment that follows the channel bed on the topographic work map and the corresponding HEC-RAS hydraulic model and resulting water surface profiles for the more frequent events (i.e., the 10-yr and 50-yr events), the following items must also be provided:

- The profile baseline must be shown and clearly labeled on the topographic work map <u>in addition to</u> the stream alignment (and include relative stationing);
- Channel distances between cross sections in the HEC-RAS hydraulic model will match those along the profile baseline for the 100-yr and 500-yr events;
- A separate geometry file will be required to reflect the profile baseline distances for the 100-yr and 500-yr events (versus one geometry file for all storm frequencies);

- A separate plan will need to be included in the HEC-RAS model specifically for the 100-yr and 500-yr events (versus one plan for all storm frequencies);
- A separate water surface profile will need to be provided (for the 100-yr and 500-yr events) that reflects the stationing and relative distances between cross sections along the profile baseline (versus one plan for all storm frequencies).

The consequences of using the stream alignment for all storm frequencies in the DFHAD would be the potential to over-estimate the upstream water surface in some reaches with high sinuosity due to additional friction losses accounted for along the stream alignment. The HEC-RAS model, however, already compensates for the differences in channel and overbank reach lengths by using a discharge-weighted reach length between cross sections based on the discharges conveyed in the main channel and left and right overbank segments for a given reach along the drainageway.

All stationing for a given drainageway will use continuous stream stationing from the confluence with the receiving stream regardless of jurisdictional boundaries and increase going upstream. This means that Station 0+00 for the main drainageway will be at the confluence with the receiving stream regardless of the downstream limit of the study area. All drainageways in the study need to have a unique station numbering sequence. For tributaries to the main drainageway, if stationing starts at 0+00 for the tributary at the confluence with the main drainageway, then there must be clear reach identification associated with the cross section stations provided in all models and tables that will result in a unique identifier for each cross section used in the hydraulic model.

3.1.6 Cross Sections

The locations and orientation of all cross sections used in the hydraulic model are shown on the Flood Maps. The lines drawn should correspond to the actual sections studied and should span the largest floodplain studied (i.e. 500-year floodplain). Locations of cross section lines on the Flood Map along the stream alignment (or profile baseline) must correspond to the cross section location on the Flood Profiles.

Cross sections should be placed along the waterway in a manner that reflects the topography of the channel depicting changes in stream cross section geometry and changes in channel slope. In general for hydraulic flood models in urban areas, the distance between cross sections should not exceed 500 feet.

Distances between cross sections measured along the stream centerline, as defined in Section 3.1.5, must agree with corresponding distances shown on the water surface profiles to within the maximum tolerance specified on the Agreement Table.

3.1.7 Floodplain and Floodway Boundaries

The 100-year (and 500-year if required in the scope of work) floodplain boundaries shall be delineated to depict the flood elevations from the HEC-RAS analysis. The 100-year flood boundaries should be continuous through bridges with 100-year capacity, but not continuous through culverts that have 100-year capacity. Identify any overtopping with notes on the map.

Floodway boundaries for the 0.5-foot rise floodway (if required by the scope of work) shall be developed to reflect the results of the floodway analysis. There should be no additional encroachment for a floodway along stream reaches where:

- a 100-year channel has been constructed,
- there has already been fill in the floodplain up to a previously published floodway limit,
- a regional detention pond is located on-stream, or
- floodplain preservation is being implemented.

This is especially the case along Maintenance Eligible stream reaches. In these areas the floodway is equal to the floodplain. Where this occurs, the condition shall be noted in the Floodplain and Floodway Data Table. **It is advisable to consult with District staff before beginning floodway analyses to verify areas of potential encroachment.**

Where there are existing on-site detention ponds adjacent to the channel, the HEC-RAS model top-width ("Top Width" value) reflects the top width of the wetted cross-section including the ineffective flow area within the detention pond. While the ineffective flow area covering the detention ponds is not accounted for in the Floodplain and Floodway Data Table, **the detention pond areas need to be shown as 100-year floodplain** up to the 100-yr WSEL in the adjacent cross-section along the channel.

Existing regional detention ponds that have been accounted for in the DFHAD hydrology must be clearly identified. Include the 100-yr WSEL, 100-yr volume, and peak 100-yr discharges (inflow and outflow) on the topographic work maps. Ensure that the topographic work map delineation of the flood pool for existing detention facilities coincides with the SWMM hydrology model results (i.e., ponding depth, surface area and/or volume, etc). Documentation for all existing regional detention facilities incorporated into the DFHAD hydrology needs to include a sketch/drawing/description of the outlet structure for the existing facility, a corresponding stage versus discharge rating curve for that outlet structure (that is not exceeded in the SWMM model), and a stage versus volume rating curve for the pond (preferably with a grading plan). This information may be included in Appendix B (Hydrologic Analysis Support Documents).

3.1.8 Base Flood Elevations (BFEs)

BFEs represent 100-year flood water surface elevations in feet and are shown by contours drawn normal to the direction of flow of floodwater. BFEs must cross perpendicular to the stream alignment, and extend completely across the 100-year floodplain. BFEs should tie into the intersection of the floodplain boundary with the corresponding topographic contour. BFEs should never crossover a cross section line.

The BFE objects must each be a continuous line/polyline with the minimum number of vertices to correctly represent the feature. BFEs on the Flood Map are to be shown as wavy lines by assigning a line style (see Table 3.1).

Each BFE must be recorded with its elevation above NAVD88 datum, measured to the nearest whole foot and assigned their elevation. In GIS, the BFE features are to be attributed with their elevation. In CAD, the BFE lines/polylines are to be assigned their appropriate elevation.

All BFEs must be labeled with an elevation value that is located above, below, or at the end of the line where it meets the 100-year floodplain. If the BFE label cannot be placed within 0.1 inch of the BFE line, a leader line must be used to connect the BFE label to the BFE line.

The following is an excerpt from FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners* dated April 2003 for help in determining the spacing of BFEs.

> The basic intent of plotting BFEs on the maps is to represent the Flood Profile to within 0.5 foot of elevation tolerance. If BFEs are plotted correctly, the maps can be used to recreate the Flood Profile within 0.5 foot. BFEs are to be plotted at significant profile inflection points, or as close to them as possible. These points are critical to the accuracy of the maps because the Flood Profiles could not be reproduced accurately without them.
>
> Intermediate BFEs are to be plotted between inflection points and required BFEs. Intermediate BFEs are placed at whole-foot elevations whenever possible. The main factor in determining the proper interval at which intermediate BFEs are to be plotted is the Profile slope (gradient). The general guidelines below are to be followed, keeping in mind that the profile slope should be relatively constant between inflection points.
>
> - **Gentle Gradient** – If BFEs rise less than 1 foot per 1 inch of map distance, the BFEs shall be plotted at every whole foot of elevation rise.
> - **Moderate Gradient** – If BFEs rise more than 1 foot per 1 inch of map distance, the BFEs shall be plotted at approximately 1-inch intervals.
> - **Steep Gradient** – If BFEs rise 5 feet or more per 1 inch of map distance, the BFEs shall be plotted at 0.5-inch intervals of map distance or at 5-foot intervals, whichever is greater (i.e. whichever results in a wider BFE spacing).
>
> To determine the proper method for the intermediate BFE interval, the amount of BFE is divided by the map distance over which it rises. For example, in the case where 10 inches of map distance has a 30-foot BFE rise, the gradient equals a 3-foot BFE rise per inch, and the Moderate Gradient method be used to plot the BFEs

3.1.9 Feature Appearance and Layer Conventions

Flood Map features should be formatted in accordance with Table 1 Flood Map Feature Appearance and Layer Conventions. Line styles (patterns, dashes, etc.) should be applied to the feature objects, and not drawn in. Annotation and leader lines must be on separate layers from geographic data.

3.1.10 Additional Flood Map Components

Flood Maps should include the following information:

- DFHAD study name (consistent with the Flood Profile drawings title; typically, "Flood Hazard Area Delineation, [Name of Drainageway]";

- Date of DFHAD (month and year);
- North arrow and scale (See Section 3.1.4 for more information);
- Legend including symbology for cross sections, floodplain and floodway boundaries, BFEs, stream centerline, hydraulic structure symbols, and contours;
- Information about mapping source including the date, horizontal datum, and vertical datum;
- Consultant's information;
- Match lines and key map if more than one Flood Map is produced;
- The following instructions for printing portions of Flood Map PDF to scale:

  Instructions to print an area smaller than the full page to scale:
  1. Using the "Snapshot" tool, select the desired area to print.
  2. Click File>Print...
  3. Select your printer from the printer dropdown menu.
  4. Set the desired paper size using the printer "Properties" menu.
  5. Choose the "Selected graphic" option under "Print Range".
  6. Select "None" from the "Page Scaling" dropdown menu.
  7. Unselect "Choose paper source by PDF page size".
  8. Click "OK" to print selection.

3.2 **Flood Profiles**

Flood Profiles should be developed for the flood frequencies specified in the scope of work. The profiles depict the flood elevation at each cross section. The digital profiles should be one continuous profile. Flood Profiles should be oriented with increasing stationing from left to right so that the most downstream point begins to the left.

Note that Flood Maps must be oriented so that the north arrow points to the left, top, or right of the sheet regardless of the Flood Profile orientation (see Section 3.1 for more information on Flood Maps). There may be instances that the Flood Map and Flood Profile do not flow in the same direction (i.e. left on the Flood Map does not necessarily correspond to left on the Flood Profile).

3.2.1 Units

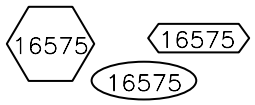
Units for all distances and elevations are in feet.

3.2.2 Map Scale and Size (See Section 3.1.4)

3.2.3 Grid and Scale

The digital profiles shall be plotted on a grid. The horizontal scale of the profile should match the horizontal scale of the Flood Maps. The minimum vertical scale is 1" = 10'. Horizontal grid lines should be spaced every 0.5 inch on the printed Flood Profile. Major vertical grid lines should be spaced every 0.5 inch on the printed Flood Profile with minor vertical grid lines representing every 1-foot of vertical elevation. For exceptionally steep drainageways, consult with UDFCD on reducing the vertical scale.

TABLE 1. FLOOD MAP FEATURE APPEARANCE AND LAYER CONVENTIONS

FEATURE	LAYER NAME	APPEARANCE	OTHER
FLOODING ELEMENTS			
100-Year Floodplain	100-YEAR	Blue, solid outline	Label boundary
500-Year Floodplain* (if specified by contract)	500-YEAR	Green, broken outline	Label boundary
Floodways (if specified by contract)	0.5-FLDWY	Distinct colored, broken outline	Label boundary
Cross Sections	XSECTION	Black, solid line	
Cross Section Text	XSECTXT	Black	
Cross Section Symbol	XSEC-HEX	Black, closed polygon	Example shapes: 
BFE	BFE	Red, zigzag linetype*	
BFE Text	BFETEXT	Red, located on top of or at the end of BFE line	
Study Limits	LIMIT STUDY	Black, solid line	Label study limit
STRUCTURE ELEMENTS			
Stream Centerline**	CHANNEL	Black, solid line	
Centerline Stationing	CHSTATION	Black	
Culverts	CULVERT	Black, solid line	
Bridges	BRIDGE	Black, solid line	
Foot Bridges	FOOTBRIDGE	Black, solid line	
Other Structures	OTHER_STRUCT	Black, solid line	
Structure Text	STRUCTEXT	Black	
BASE MAP ELEMENTS			
Roads	ROAD	Thin gray line	
Road Text	ROADTXT	Same color as Roads	
Railroads	RAILROAD	Thin gray cross hatch line	
Railroad Text	RAILROADTXT	Same color as Railroads	
Buildings	BUILDING	Thin gray line	
Major Contours	MJRCONT	Thin gray solid line	
Minor Contours	MNRCONT	Thin gray solid line, less prominent than Major Contours	
Water Bodies (Lakes, ponds, etc.)	HYDRO	Thin gray outline	
Matchlines	MATCHLINE	Thick black solid line	

*There is a standard FEMA line type available for the BFE lines.
**If a separate profile baseline is also to be used, a distinctive symbol must be used to distinguish it from the stream centerline alignment.

Label the horizontal grid lines with the stations that correspond to the stations along the stream centerline in the Flood Maps at every major horizontal grid line. Label the vertical grid with elevations at 10' intervals. Elevation labels should be repeated at least every 10 inches on the printed Flood Profile.

3.2.4 Profile Lines

Flood Profiles are to include lines for the thalweg (typically stream bed, or profile baseline) and water surface elevations for the flood frequencies specified in the scope of work. Different line types should be used to differentiate the profiles. Flood Profiles should be checked to ensure that the Flood Profile lines do not intersect or cross each other. Drawdowns are typically eliminated from the Flood Profiles. See Table 2 for specific formatting requirements.

3.2.5 Cross Sections

Each cross section should be represented by a symbol (consistent with the symbol on the Flood Map) and the cross section number at the station that matches the cross sections location on stream centerline alignment. Cross section symbols should be a consistent distance from the Flood Profile lines to facilitate capturing pertinent data when printing a select area of the profiles.

3.2.6 Structures

Bridges, culverts, and other hydraulic structures should be illustrated on the profile to depict the open area and length of the structure along the profile. For bridges, the top of road (TOR) and low chord (LC) are to be represented by the conventional symbol (I), where TOR is represented by the upper horizontal bar, LC by the lower bar, and the center of the structure by the vertical bar. For culverts use the overburden culvert symbol typically shown by HEC-RAS.

3.2.7 Feature Appearance and Layer Conventions

Flood Profile features should be formatted in accordance with Table 2 Flood Profile Feature Appearance and Layer Conventions. Line styles (patterns, dashes, etc.) should be applied to the feature objects, and not drawn in. Annotation and leader lines must be on separate layers from geographic data.

3.2.8 Labels

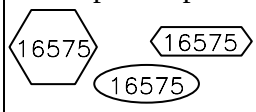
Label the flood elevation lines and the thalweg line on the profile. Label structures with the street name or other identifier with vertical text near the appropriate station. Label jurisdictional boundaries with vertical text near the appropriate station. Vertical labels are typically placed above the Flood Profile, but may be placed below the thalweg if space requires it. Label the peak discharges (10-year and 100-year minimum) at appropriate locations along the profile. Also label the study limits.

3.2.9 Additional Flood Profile Components

Flood Profiles should include the following information:

- DFHAD study name (consistent with the Flood Map drawings title; typically, "Flood Hazard Area Delineation, Name of Drainageway");
- Date of DFHAD (month and year);
- Horizontal and vertical scale (See Section 3.2.3 for more information);

TABLE 2. FLOOD PROFILE FEATURE APPEARANCE AND LAYER CONVENTIONS

FEATURE	LAYER NAME	APPEARANCE	OTHER
100-Year Flood Profile	100-PROFILE	Blue, thick solid line	Label
Other Flood Profiles (if specified by contract)	[Year]-PROFILE	Black, broken line different from 100-year	Label
Thalweg (Stream bed)	THALWEG	Black, solid line, ground hatch below line	Label
Cross Section Text	XSECTXT	Black	
Cross Section Symbol	XSEC-HEX	Black, closed polygon	Example shapes: 
Structures	STRUCTURE	Bridges: conventional I-symbol with upper bar TOR, and lower bar LC, and vertical bar center of structure; Culverts: overburden culvert symbol typical in HEC-RAS	
Grid Lines	GRID	Thin black or gray line	
Text (Stationing, elevations, hydraulic structures; pertinent peak discharges)	TXT-PROFILE	Black	
Match lines	MATCHLINE	Thick black solid line	

- Legend including symbology for Flood Profile lines and cross section symbols;
- Consultant's information;
- Match lines and key map if more than one Flood Profile is produced;
- Also include the same instructions as in Section 3.1.10 for printing smaller portions of the Flood Profile PDF to scale.

3.3 Floodplain and Floodway Data Tables

The Floodplain and Floodway Data Tables list information at each cross section for the floodplains and floodways studied. Floodway data is required even when the design flows are confined within a well-defined channel. Floodway data values reported in the table will be taken from the floodway hydraulic model. A notation in the Comments column of the Floodplain and Floodway Data Table should be added whenever the floodway is equal to the floodplain. Table 3 Floodplain and Floodway Data Table Contents lists the required and optional information that should be included in the table. Please limit values within the Floodplain and Floodway Data Table to reasonable significant digits (i.e., discharges to nearest cubic foot per second, elevations

to nearest .01 foot, distances and top widths to nearest foot, areas to nearest square foot, and velocities to the nearest 0.1 foot per second).

Examples of some typical notations that might appear in the Comments column are provided in Table 4 Example Comments for the Floodplain and Floodway Data Table.

3.3.1 Additional Data Descriptions and Information

Thalweg Elevation (ft) – Defined as the minimum channel elevation. In HEC-RAS 4.0, "Min Ch El" is the minimum channel elevation.

Peak Flow (cfs) – Defined as the peak flood flow (future conditions) for the given storm event. In HEC-RAS 4.0, "Q Total" is the total flow in the cross section.

Water Surface Elevation (ft) – Defined as the flood water surface elevation for the given storm event. In HEC-RAS 4.0, "W.S. Elev" is the calculated water surface from the energy equation.

100-Year Floodplain Width (ft) – Defined as the total width of the floodplain as shown on the Flood Maps, regardless of islands (whether mapped or not) and other obstructions. When this value is different from results in the hydraulic model, note it in the Comments column and state why. In HEC-RAS 4.0, "Top Width" is the top width of the wetted cross section, but does not include islands or obstructions. "Top Width Act" is the top width of the wetted cross section, not including ineffective flow. In most cases, for DFHAD studies, the floodplain and floodway boundaries need to reflect the total top width value for both the floodplain and floodway that includes ineffective flow areas and high ground. Other HEC-RAS top width variables (such as "Top Width Act", or "Top Width") can be the same value as the total top width if no high ground or ineffective flow areas are present

When the cross section indicates islands or obstructions in the floodplain, the top widths reported in HEC-RAS will not produce the proper total top width to list in the Floodplain and Floodway Data Table. The total top width from left to right floodplain lines can be calculated by using HEC-RAS's "Sta W.S. Lft" and "Sta W.S. Rgt" fields which list the left and right station where water intersects the ground. Tables can be defined in HEC-RAS that include a column that will calculate the difference between them. Define the table with "Sta W.S. Rgt", "Sta W.S. Lft", and "Diff" and the total top width will be displayed in the "Diff" column. Since the floodplain and floodway values in the UDFCD DFHAD typically reflect the total width of the floodplain/floodway regardless of ineffective flow, islands, and other obstructions, a note should be added to the Comments column of the table to indicate what is included (i.e., standard Flood Insurance Study (FIS) Floodway Data Tables have historically included only the "Top Width Act" values). These notations will be helpful in explaining discrepancies when the DFHAD data is incorporated into future FIS updates. See the Top Width examples in the Appendix.

For areas where existing on-site detention ponds are located adjacent to the main channel, the floodplain top width shown in the Floodplain and Floodway Data Table adjacent to the detention ponds needs to reflect the top width for actual conveyance without the ineffective flow area (this would typically be the "Top Width Act" value) for these areas.

Note that for DFHAD studies, islands are not typically mapped (shown as high ground) in the floodway. Also note that islands within a floodplain or floodway must be treated on a case-by-case basis and the Engineer should consult with UDFCD when islands occur within the floodplain or floodway limits for further guidance.

Floodway Elev (ft) – Defined as the floodway water surface elevation with encroachments that cause the energy grade line to rise by 0.5-foot.

Floodway Width (ft) – Defined as the total floodway width (irregardless of islands and other obstructions, or ineffective flow area) with encroachments that cause the energy grade line to rise by 0.5-foot. Refer to the definition of 100-Year Floodplain Width for additional information on reporting widths. When the cross section indicates high ground or other obstructions, follow the process in the "100-Year Floodplain Width (ft)" section described above to obtain the total floodway width.

Floodway Area (sq ft) – Defined as the flow area of the entire cross section including ineffective flow. In HEC-RAS 4.0, this is the "Area" variable. When different from results in the hydraulic model, note it in the Comments column and state why. For cross sections with adjacent detention ponds this value may end up being the "Area Channel" or "Flow Area" value.

Floodway Velocity (ft/s) – Defined as the average velocity of the flow in the total cross section. In HEC-RAS 4.0, this is the "Vel Total" variable. For cross sections with adjacent detention ponds this value may end up being the "Vel Chnl" value.

3.3.2 Discrepancies Between Table Values and HEC-RAS Model

The values published in the Floodplain and Floodway Data Table must match the Flood Maps (within acceptable tolerances), but there may be situations where floodplain/floodway does not match the geometry of the HEC-RAS output. For instance, a rapid change in geometry, such as the downstream side of an overtopped roadway, may result in the floodplain delineation differing from the HEC-RAS output. Or a floodplain delineation line around a small island may be omitted to simplify the floodplain limits. In these situations, it is imperative that the discrepancy be well documented. Record the reason for the discrepancy in the Comments column and further describe it in the text of the DFHAD Report.

Table 4 lists several examples of standard comments used to describe or explain discrepancies between the hydraulic model, water surface profile, and topographic work map values in the Agreement Table. In addition, other comments may be more appropriate to describe the situation occurring at a given cross section.

3.3.3 Final HEC-RAS Floodway Model – Method 1

It is important that the floodway encroachments, floodway elevations, and floodway widths agree between the Flood Map, Flood Profile, and the HEC-RAS hydraulic model. The final HEC-

TABLE 3. FLOODPLAIN AND FLOODWAY DATA TABLE CONTENTS

ITEM	LOCATION	CONTENT
Title	Top Center	Table #, FHAD Study Name, Floodplain and Floodway Data Table
Reach	Row Heading	River/Reach
Reference Location	Column 1	Location or other identifier like streets, structures, or other physical features
River Station	Column 2	Station along stream alignment
Cross Section	Column 3	Cross section number/identification from hydraulic model
Thalweg Elevation (ft)	Column 4	Thalweg elevation
Peak Flow (cfs) 10-, 50-, 100- & 500-Year	Columns 5-8	Peak flow data from hydraulic model for 10-, 50-, 100- & 500-year storm events
Water Surface Elevation (ft) 10-, 50-, 100- & 500-Year (specified by contract)	Columns 9-12	Flood water surface elevations from hydraulic model for storm frequencies specified by contract
100-Year Floodplain Width (ft) Energy Grade Line	Columns 13-14	Total floodplain width including high ground and ineffective flow area, and the energy grade line for the 100-year storm event
100-Year Floodway (0.5 ft rise in EGL) Floodway Elev (ft) Width (ft) Area (sq ft) Velocity (ft/s)	Columns 15-18	100-year 0.5 feet floodway water surface elevation, total width of floodway including high ground and ineffective flow area, , flow area of the entire cross section including ineffective flow area (Area), and the average velocity of flow in the total cross section (Vel Total)
Comments	Last Column	Use to note specific details or how the values may differ from hydraulic model and reason for the difference (See Table 4 below)
Footnotes	Below table	Additional notes or a way to note specific details for particular cross sections

TABLE 4. EXAMPLE COMMENTS FOR THE FLOODPLAIN AND FLOODWAY DATA TABLE.

Floodway equal to floodplain.
Floodplain and floodway top width includes high ground or obstruction, and ineffective flow area.
Floodway top width includes high ground or obstruction.
Floodplain top width includes ineffective flow area.
Floodway top width includes ineffective flow area.
Adjacent on-site detention pond.
Island located within 100-yr floodplain not shown because it falls within the floodway.
Roadway overtopping of 'Street Name', top width adjusted for Flood Map delineations.
Floodplain delineation includes ineffective flow area not reflected in the hydraulic model.

RAS model submitted to the District must be saved as a Method 1 floodway, where the exact location of the encroachment stations is specified for each individual cross section.

3.4 **Additional Information**

3.4.1 Drainage Structure Cross-Sections

Cross sections of each of the drainage structures (culverts and bridges) should be included in Appendix C (Hydraulic Analysis Supporting Documents). This information should include the structure's location, station, dimensions, material, and elevations of the invert, low chord, and overtopping weir (road low point elevation).

3.4.2 Cross Sections

Appendix C (Hydraulic Analysis Supporting Documents) includes cross sections from the HEC-RAS model illustrating the 100-year storm event water surface elevations. Create a PDF file from HEC-RAS formatted for multiple cross sections per 11"x17" page at a scale that can be easily read. Cross sections should be in color and include the 100-year water surface elevation, reach name, and river station. It is recommended that each page contain 9-12 cross sections and that the pages are numbered.

4 **SUBMITTAL REQUIREMENTS**

All formal submittals will require evidence of Quality Control and Error Checking (see Section 5), or will be returned without detailed review of the submittal. These rejected submittals may be re-submitted once quality control has been performed by the consultant. All re-submittals and/or new submittals need to include a comment response letter addressing items of concern raised in previous review comments (when applicable).

Three separate submittal phases are required:

- PRELIMINARY SUBMITTAL;
- DRAFT SUBMITTAL; and
- FINAL SUBMITTAL.

Requirements for each separate submittal phase are listed in the following paragraphs.

4.1 **PRELIMINARY SUBMITTAL REQUIREMENTS**

The Preliminary Submittal is provided only to the UDFCD, and is used for an initial technical review of the floodplain analysis methods, and resulting Flood Maps and Flood Profiles.

The following items should be provided with the Preliminary Submittal:

- One set of color hardcopy roll plots of the working Flood Maps and Flood Profiles;
- One hardcopy or electronic copy of the completed Floodplain and Floodway Data Tables (see Section 3.3);
- One hardcopy or electronic copy of the completed Agreement Tables;

- One hardcopy or electronic copy of any other pertinent supporting materials used in the analysis (i.e., specific drainage structure data, etc.);
- One CD containing electronic HEC-RAS input and output files (see Section 2.1), output tables and cross sections; and digital files for Flood Maps and Flood Profiles (see Sections 3.1 and 3.2).

4.2 DRAFT SUBMITTAL REQUIREMENTS

This is the submittal once all items from the Preliminary Submittal have been adequately addressed.

A CD containing electronic PDF file(s) of the report text, appendices, Flood Maps, Flood Profiles, and Floodplain and Floodway Data Tables will be submitted to UDFCD and each of the project sponsors for review. This review set represents the final report product as much as possible and should contain all items required in the completed DFHAD Report Checklist. Clearly mark the PDF pages with "DRAFT" and use the words "Draft" in the PDF file name to distinguish it from the FINAL DFHAD PDF file.

The contract will indicate the number of CDs to be submitted for review. This is typically one set for each reviewing agency.

In addition, this submittal also includes one copy of a CD containing all revised electronic files (previously required with the Preliminary Submittal) to facilitate technical review of the Draft Submittal products.

4.2.1 Draft DFHAD Report

The CD is to contain one PDF file that contains all components of the DFHAD report (in accordance with the DFHAD Report Checklist). For CD production, follow the referenced document in Section 1.1

4.2.2 Technical Data

Submittal of a CD containing all technical supporting documentation must be provided to UDFCD with the DRAFT DFHAD Report. The technical information should be compiled in conformance with the Technical Appendix Checklist, since a formal Technical Appendix will be required for the Final DFHAD Submittal.

4.3 FINAL SUBMITTAL REQUIREMENTS

This is the submittal once all items from the Draft Submittal have been adequately addressed. The submittal will include final versions of all products previously requested for the Draft Submittal, and be accompanied by both completed DFHAD Report and Technical Appendix Checklists.

4.3.1 Final DFHAD Report

See Section 4.2.1. The number of copies of the Final DFHAD Report CD will be in accordance with the UDFCD Agreement.

4.3.2 Technical Appendix

All supporting technical documentation shall be compiled in a Technical Appendix. A completed Technical Appendix Checklist must accompany this submittal. The number of copies provided will be in accordance with the UDFCD Agreement.

5 QUALITY CONTROL AND ERROR CHECKING

5.1 Checklists

The DFHAD Report Checklist identifies the information that is required for DFHAD reports. A copy of the completed DFHAD Report Checklist should accompany both the Draft and Final Submittals to ensure all pertinent materials have been included in the DFHAD report.

The completed Technical Appendix Checklist only needs to be included with the Final Submittal.

5.2 Agreement Tables

The Agreement Tables serve as an error checking device to ensure that data and results for the Flood Maps, Flood Profiles, Floodplain and Floodway Data Tables, and HEC-RAS models agree. If discrepancies exist, the reasons for any valid discrepancies can be noted in the Comments column. Table 5 Agreement Table Contents lists the required and optional information that should be included in the table. Each submission for technical review is to be accompanied by completed Agreement Tables. The Agreement Table will not be included in the Report, but will be included in the Technical Appendix to accompany the final hydraulic model files.

The Agreement Table lists every cross section and compares the distances between cross sections, the cumulative distance, floodplain and floodway top widths, water surface elevations, and an indication of whether the BFE lines have been located correctly relative to the adjacent cross sections and water surface profile (this is typically an ‘ok’ or ‘yes’ once verified by the Consultant). The allowable differences between the map, profile, and table are listed at the bottom of the Agreement Table.

TABLE 5. AGREEMENT TABLE CONTENTS

Column	Contents
1	Reference Location – A location or other identifier like streets, structures or other physical features.
2	Cross Section – The cross section number/identifier used in the hydraulic model (that can sometimes differ from the actual river station). If the cross section identification is consistent with the actual river station along the stream alignment, then this could also be used to reference previous FHAD cross section identifications or FIS cross sections. Start at the downstream cross section and work upstream.
3	River Station – Actual station along the stream alignment that corresponds to the current cross section.
4 through 6	Distance b/a RS, ft – Relative distance from the current cross section to the next downstream cross section in feet.
7 through 9	Cumulative Distance, ft – The total stream distance from the most downstream cross section to the current cross section in feet.
10 and 11	FP Width, ft – The total floodplain top width at the current cross section including high ground and/or ineffective flow areas in feet; however when an on-site detention pond exists adjacent to the main channel, this value will only reflect the top width for actual conveyance without the ineffective flow area (this would typically be the Top Width Act value in HEC-RAS).
12 and 13	FW Width, ft – The total floodway top width at the current cross section in feet. This can include high ground and ineffective flow areas.
14 and 15	BFE, ft – The 100-year water surface elevation for the current cross-section in feet.
16	BFE Loc. – This is a verification that the BFE line plotted on the topographic work map is located correctly based on the corresponding water surface profile near the cross-section.
17	Comments and/or Explanations – A description and/or reasoning for any discrepancies between values from the model/map/profile that occur at the current cross section (see Table 4 Example Comments for the Floodplain and Floodway Data Table, Section 3.3).

The data and results in the Floodplain and Floodway Data Table, Flood Maps, Flood Profiles, and HEC-RAS model must agree within the tolerances specified at the bottom of the Agreement Table. Note that the allowable tolerance for Floodplain and Floodway Widths is within either 25 feet or 5% of the measured width of the floodplain/floodway. In other words, if the measured width is less than 500 feet, then the two values in the Agreement Table must not vary more than 25 feet. If the measured width of the floodplain/floodway on the map is greater than 500 feet, then the values must agree within 5% of the map width.

5.3 Common Sense Check

There are a number of common sense items to check for prior to making a submittal to UDFCD. Several of these items have been listed in Table 6 DFHAD Common Sense Items. Please ensure that a common sense check has been performed prior to submitting products for review.

TABLE 6. DFHAD COMMON SENSE ITEMS

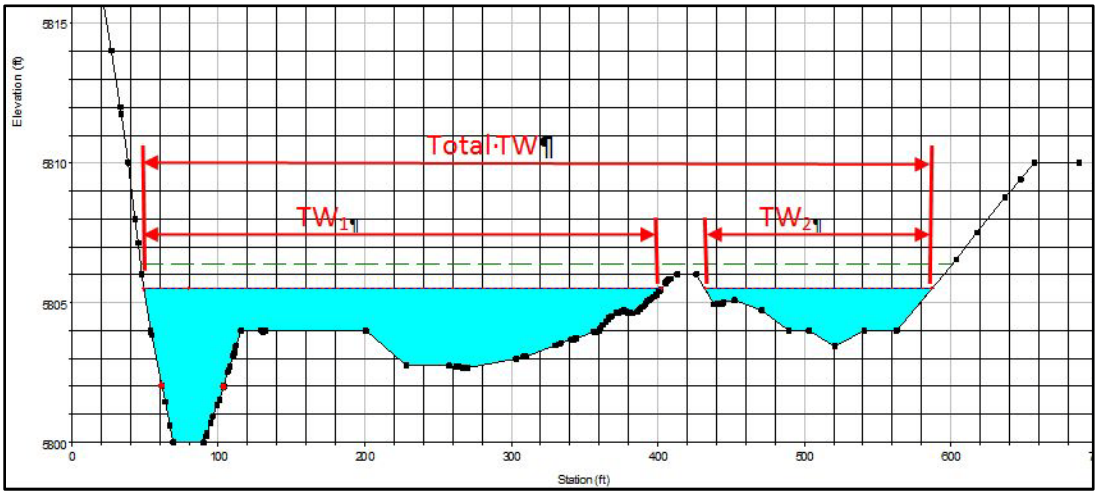
Floodplain delineations are based on subcritical hydraulic analysis results.
Cross section orientation is left to right facing downstream.
Make sure that relative top widths make sense (i.e., the floodway top widths are not greater than the floodplain top width at a given location).
Note differences in floodplain or floodway top widths between the hydraulic model results and the topographic work map delineations in the Floodplain/Floodway Data Table (FP/FWDT).
Existing online detention ponds that were accounted for in the hydrologic analysis are to remain un-encroached to the flood pool elevations.
Make sure the cross section orientations are perpendicular to the flow, stream centerline (or baseline profile), and contours.
Clearly identify both the upstream and downstream study limits on the topographic work map.
Verify for a given cross section that the WSEL is the same on both sides of the plotted floodplain, and that it has been tied-off to the correct contour data based on the topographic work map.
Make sure that the BFE lines: 1. Are oriented perpendicular to the stream centerline, flow and contours; 2. Cross the stream centerline at the same location as shown on the water surface profiles; 3. Are appropriately placed with regard to the BFEs for the adjacent cross sections; 4. Tie-off to the correct contour; 5. Extend across the floodplain width, and do not stop short or extend past the floodplain limits; 6. Do not cross/extend across cross sections; and 7. Are pertinent and are shown adequately to replicate slope changes along the water surface profile.
Make sure that an existing regional detention pond has been accounted for in the hydraulic model to produce consistent results for all storm frequencies modeled (i.e., actual geometry for outlet structure, rating curve, boundary condition, known WSEL, etc.). Verify that the existing detention pond is reflected in the resulting water surface profile from the hydraulic model results.
Verify whether over-topping occurs at roadways or railroad crossings along the drainageway, and make sure the water surface profile and topographic work map clearly indicate if over-topping occurs.
Make sure that floodplain delineations downstream of over-topped crossings are representative of the hydraulic conditions (especially since the hydraulic model will not reflect the impacts of crossing over – topping at downstream cross section).
Make sure that the energy grade lines and/or WSELs between any two split flow segments are within 0.5 ft at the upstream end (breakout point).
Even though the 500-yr floodplain is not the official regulatory floodplain, the delineations for this floodplain need to be mapped to a reasonable accuracy (i.e., the 500-yr delineation on the topographic work map needs to reflect the hydraulic model results).
Verify that the cross section identifications and locations used in the hydraulic model are consistent with those shown on the topographic work map and water surface profile.
Eliminate crossing water surface profiles between the multiple frequencies used along a given drainageway (or provide a logical explanation of what was attempted and why this was not possible, or how it was resolved).
No future detention facilities are to be shown on the topographic work maps for the DFHAD. These proposed facilities are to be shown in the relative master planning documents for the drainageway.

APPENDIX

TOP WIDTH EXAMPLES
Legend

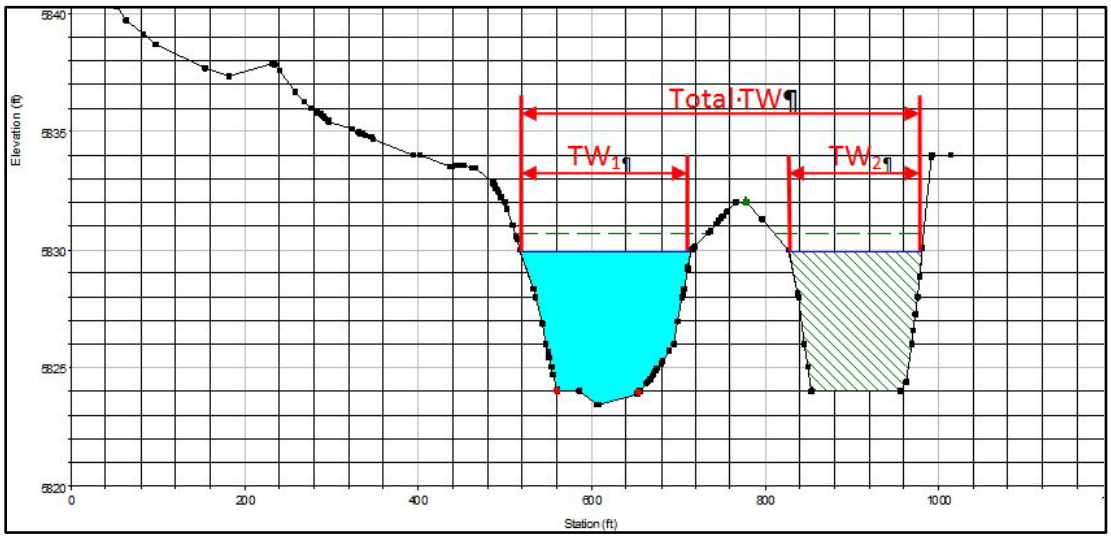
Effective flow area: Ineffective flow area:

Example 1



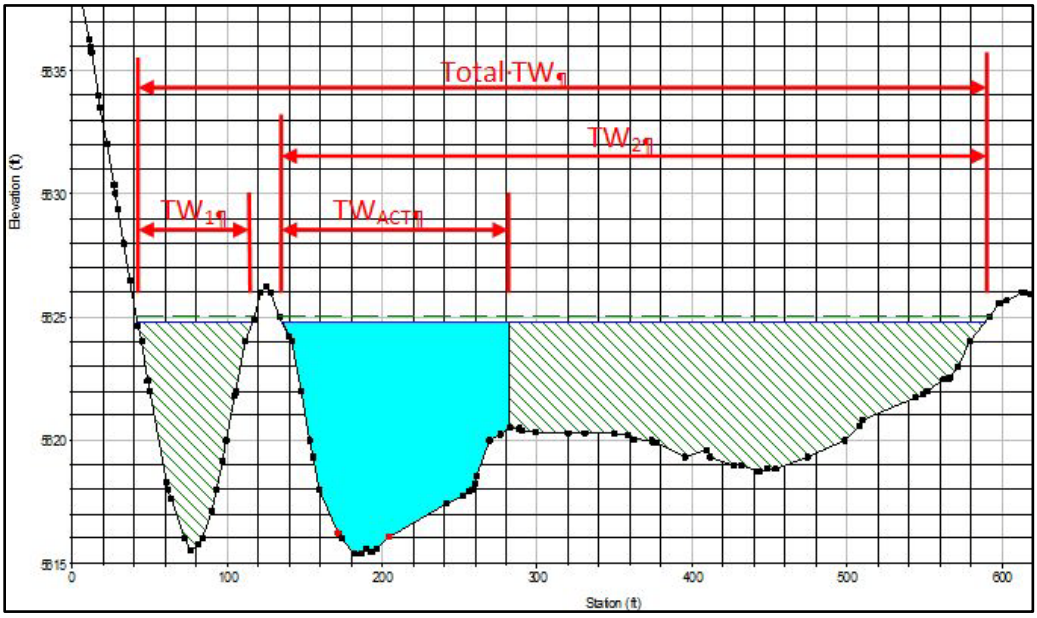
Total Top Width (TW) includes high ground (islands)
Actual Top Width = TW_1 + TW_2

Example 2



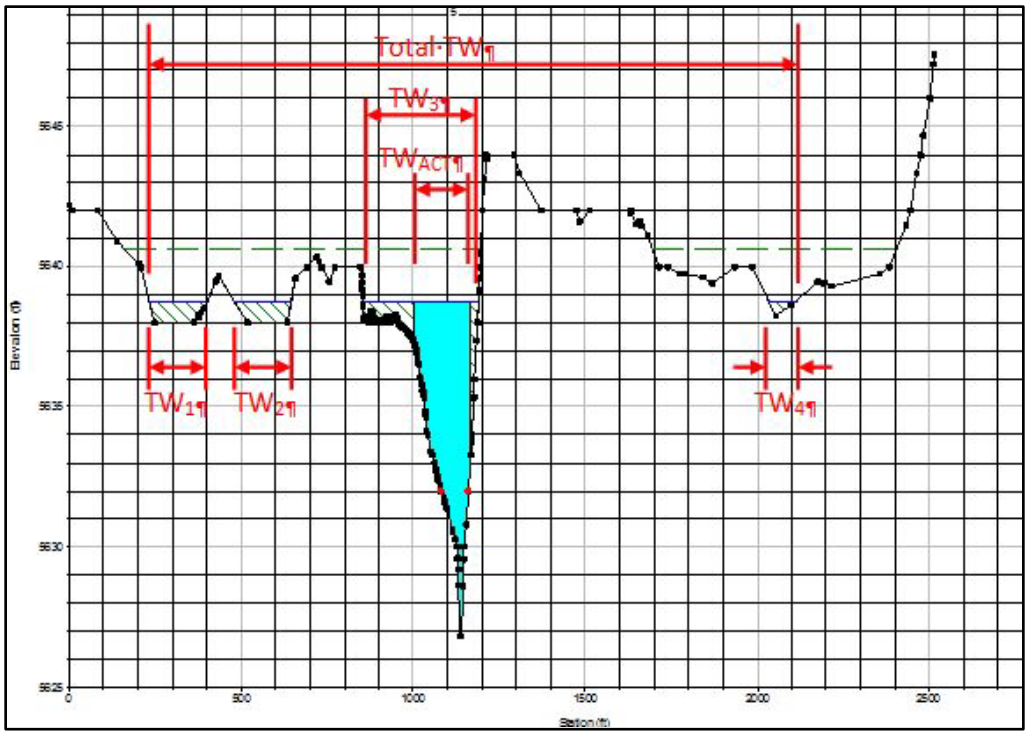
Total Top Width (TW) includes high ground and ineffective flow area (TW_2)
Actual Top Width = TW_1

Example 3



Total Top Width (TW) includes high ground and ineffective flow areas. TW_1 could be an adjacent on-site detention pond. TW_2 includes the Actual Top Width (TW_{ACT}) and an ineffective flow area caused by a downstream embankment.

Example 4



Total Top Width includes ineffective flow areas and high ground.
Top Width = $TW_1 + TW_2 + TW_3 + TW_4$.