Raster QC Checklist Applied Approaches

December 2021

FEMA

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Requirements for the Federal Emergency Management Agency (FEMA) Risk Mapping, Assessment, and Planning (Risk MAP) Program are specified separately by statute, regulation, or FEMA policy (primarily the Standards for Flood Risk Analysis and Mapping). This document provides guidance to support the requirements and recommends approaches for effective and efficient implementation. Alternate approaches that comply with all requirements are acceptable.

For more information, please visit the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage (www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping). Copies of the Standards for Flood Risk Analysis and Mapping policy, related guidance, technical references, and other information about the guidelines and standards development process are all available here. You can also search directly by document title at https://www.fema.gov/library.

Table of Revisions

The following summary of changes details revisions to this document subsequent to its most recent version in December 2021.

Affected Section or Subsection	***Date***	***Description***
	December 2021	Original

Table of Contents

1. Introduction and Background

Flood Risk Products (FRP's) typically include the creation of Water Surface Rasters, Depth Rasters and Analysis Rasters. Checklists exist to ensure that each raster type are being produced with a set of minimum standards. However, this does not preclude the fact that the producer typically needs to refer to multiple documents in order to obtain information on the specification(s) associated with the production standards. This document has been assembled as both a quality assurance tool but also as a valuable production tool. The primary goal of this supplement or addendum to the raster QC Checklist, is to provide visual examples. The visual example is intended to help 1.) Quickly provide examples of how a given item should look or appear and direct both producers and quality assurance reviewers to the resources within the Technical References and/or the Guidance documents.

For most checklist items, each raster quality check item is provided with:

- Reference – a callout that refers the user to Technical References and/or Guidance documents
- Correct example – a representative example of what is reasonably expected of the work product
- Incorrect example – a representative example that illuminates potential incorrect production

Some discussion items are interspersed on an as-needed basis.

2. Water Surface Raster Checks

2.1. WSE_1 and WSE_2

The raster checks for these two items (WSE_1 & WSE_2) are similar in nature and are therefore combined.

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_1	Raster datasets have proper naming conventions.	Flood Risk Database Technical Reference (FEB2018) - Section 4.0 Raster Datasets, Page 74-76; Table 6. Flood Risk Database Rasters (Column FRD Raster Name). Flood Risk Database Guidance (FEB 2018) - Section 6.0 Raster Guidance, Page 8.	FRP QC Tool check 1.1.0.1

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_2	Water Surface Elevation (WSEL) rasters for new riverine studies include the 10%, 4% 2%, 1%, 0.2%, and 1% Plus annual chance flood events	FEMA Policy Standards for Flood Risk Analysis and Mapping FEMA Policy #FP 204-078-1 (Rev 8); Page 55.	FRP QC Tool check 1.1.0.2

Reference Example:

6.0 Raster Guidance

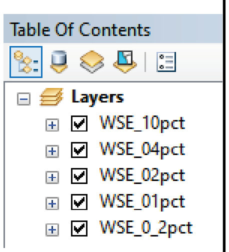
Additional guidance can be found within the Flood Depth & Analysis Grids Guidance document for each of the following raster datasets:

- CstDplhxxxpct (Coastal Flood Depth Grid)
- Depth_xxxxxx (Riverine Flood Depth Grid)
- DVS_xxxxxxx (Depth times Velocity Flood Severity Grid)
- Pct30yrChance (Percent Chance of Flooding over a 30-year Period Grid)
- PctAnnChance (Percent Annual Chance of Flooding Grid)
- Vel_xxxxxxx (Velocity Grid)
- WSE_xxxxxx (Water Surface Elevation Grid)
- WSE_Change (Water Surface Elevation Change Grid)

Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018)

Correct Example 1:

ArcMap Example:



ArcCatalog Example1:

Correct Example 2:

The example below demonstrates the WSE's within a Flood Risk Database (FRD).

Arc Catalog Example 2:

Contents | Preview | Description

Name	Type
FRD_Spatial_Layers	File Geodatabase Feature Dataset
cstdpth01pct	File Geodatabase Raster Dataset
CstWSE01pct	File Geodatabase Raster Dataset
depth_0_2pct	File Geodatabase Raster Dataset
depth_01pct	File Geodatabase Raster Dataset
depth_01plus	File Geodatabase Raster Dataset
depth_02pct	File Geodatabase Raster Dataset
depth_04pct	File Geodatabase Raster Dataset
depth_10pct	File Geodatabase Raster Dataset
pct30yrchance	File Geodatabase Raster Dataset
pctannchance	File Geodatabase Raster Dataset
wse_0_2pct	File Geodatabase Raster Dataset
wse_01pct	File Geodatabase Raster Dataset
wse_01plus	File Geodatabase Raster Dataset
wse_02pct	File Geodatabase Raster Dataset
wse_04pct	File Geodatabase Raster Dataset
wse_10pct	File Geodatabase Raster Dataset

<u>NOTE</u>: Upper Case/Lower Case of raster prefix text “WSE” or “wse” is acceptable.

Incorrect Example:

The example below demonstrates that while the naming includes logic, it does not follow the standard naming convention.

ArcCatalog Example:

Contents | Preview | Description

Name	Type
wtrsrfcelev_0_2prct	Fgdb Raster Dataset
wtrsrfcelev_01plusprcnt	Fgdb Raster Dataset
wtrsrfcelev_01prct	Fgdb Raster Dataset
wtrsrfcelev_02prct	Fgdb Raster Dataset
wtrsrfcelev_04prct	Fgdb Raster Dataset
wtrsrfcelev_10prct	Fgdb Raster Dataset

2.2. WSE_3

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_3	WSEL rasters for new coastal studies include the 1% annual chance flood event	FEMA Policy Standards for Flood Risk Analysis and Mapping FEMA Policy #FP 204-078-1 (Rev 8); Page 55.	manual check

Reference Example:

6.0 Raster Guidance

Additional guidance can be found within the Flood Depth & Analysis Grids Guidance document for each of the following raster datasets:

- CstDpthxxxpct (Coastal Flood Depth Grid)
- Depth_xxxxxx (Riverine Flood Depth Grid)
- DVS_xxxxxxx (Depth times Velocity Flood Severity Grid)
- Pct30yrChance (Percent Chance of Flooding over a 30 year Period Grid)
- PctAnnChance (Percent Annual Chance of Flooding Grid)
- Vel_xxxxxxx (Velocity Grid)
- WSE_xxxxxx (Water Surface Elevation Grid)
- WSE_Change (Water Surface Elevation Change Grid)

Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018)

Correct Example:

Contents | Preview | Description

Name	Type
FRD_Spatial_Layers	File Geodatabase Feature Dataset
cstdpth01pct	File Geodatabase Raster Dataset
CstWSE01pct	File Geodatabase Raster Dataset
depth_0_2pct	File Geodatabase Raster Dataset
depth_01pct	File Geodatabase Raster Dataset
depth_01plus	File Geodatabase Raster Dataset
depth_02pct	File Geodatabase Raster Dataset
depth_04pct	File Geodatabase Raster Dataset
depth_10pct	File Geodatabase Raster Dataset
pct30yrchance	File Geodatabase Raster Dataset
pctannchance	File Geodatabase Raster Dataset
wse_0_2pct	File Geodatabase Raster Dataset
wse_01pct	File Geodatabase Raster Dataset
wse_01plus	File Geodatabase Raster Dataset
wse_02pct	File Geodatabase Raster Dataset
wse_04pct	File Geodatabase Raster Dataset
wse_10pct	File Geodatabase Raster Dataset

CstWSE01pct

<u>NOTE</u>: Existing Guidance for Flood Risk Analysis and Mapping - Flood Risk Database, 6.0 Raster Guidance and also Flood Risk Database Technical Reference (Table 6. Flood Risk Database Rasters) – does NOT include coastal WSE Raster naming convention at this time.

Incorrect Example:

Given that existing Guidance and Technical References do not include coastal WSE Raster naming convention at this time, an Incorrect example is not provided at this time.

2.3. WSE_4

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_4	WSEL rasters are 32-bit Floating Point and shares the same spatial reference, origin, rotation, and cell size resolution with companion depth grids *Check to ensure multi-frequency rasters align with one another.	Flood Risk Database Technical Reference (FEB2018) - Section 4.0 Raster Datasets, Page 74. Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 1.2 Grid Cell Origin; Page 2.	FRP QC Tool check 1.1.0.3 FRP QC Tool check 1.3.0.1

Reference Example:

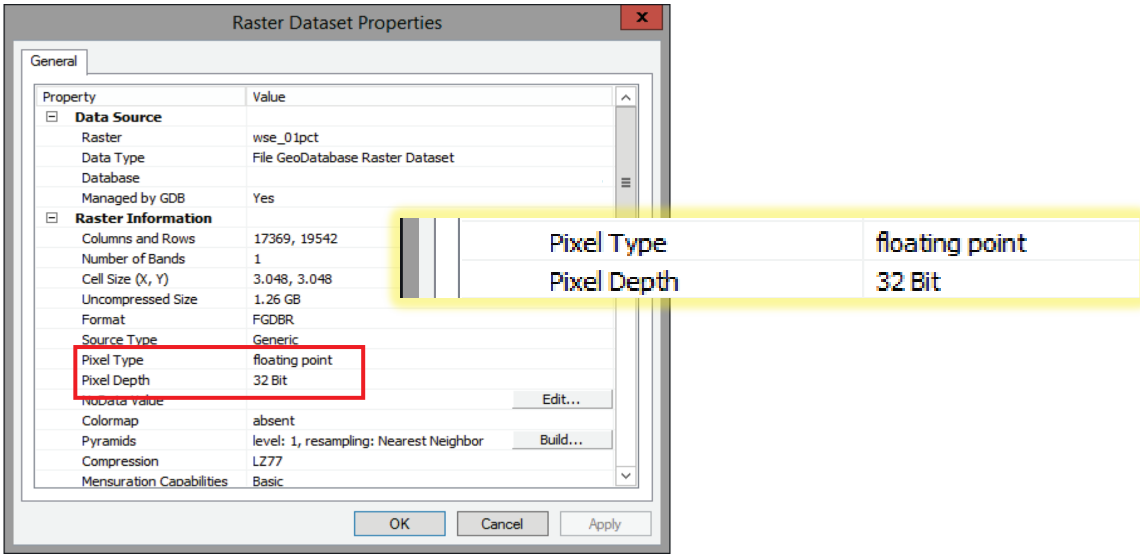
1.2 Grid Cell Origin

In order to be able to properly orient each grid with one another, and to more accurately compare one flood risk data value (such as depth) to another (such as velocity) at a given location, each grid dataset within the FRD should use the same origin, cell size, rotation, and coordinate system. Since many of the grid datasets are derived from other grids (for example, the depth grids are derived from the water surface elevation grids, and the percent-annual-chance grids are derived from those), setting a common origin for all raster datasets within the study area provides for proper alignment of grid cells when comparing one raster dataset to another.

Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018)

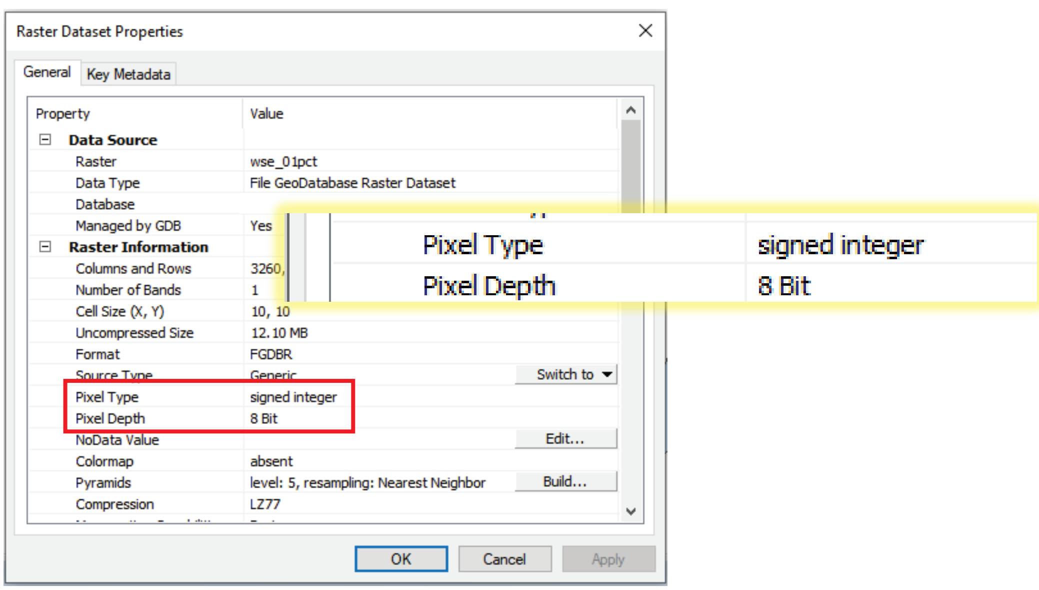
Correct Example (Pixel Type):

The example below demonstrates the proper Raster Information.



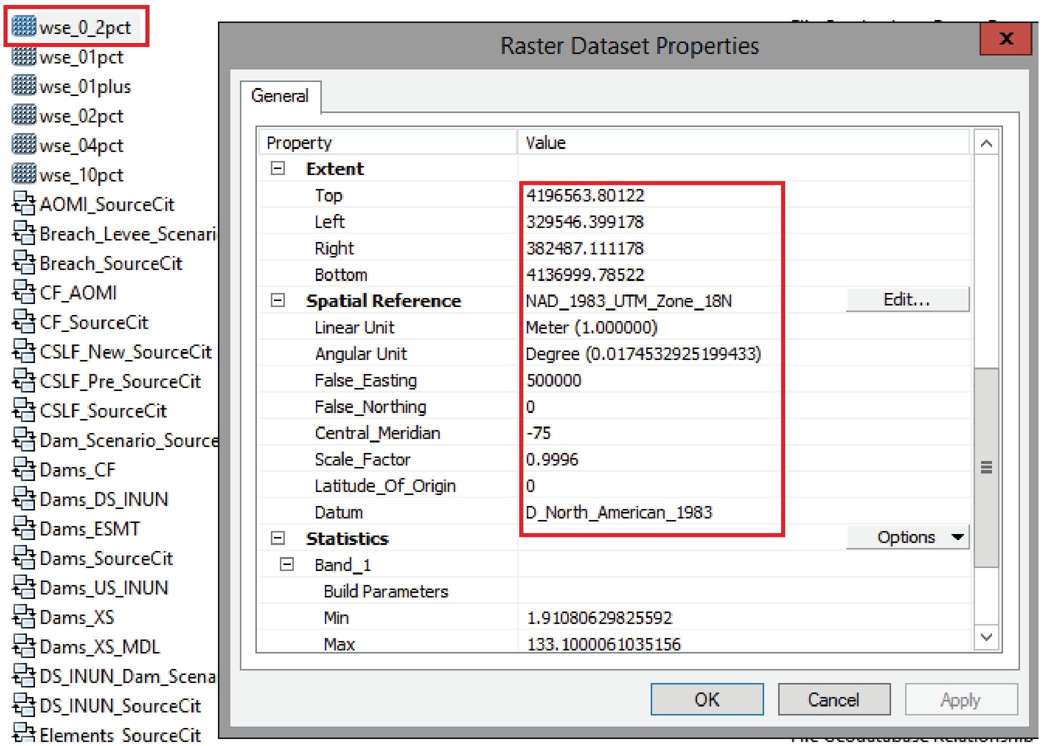
Incorrect Example (Pixel Type):

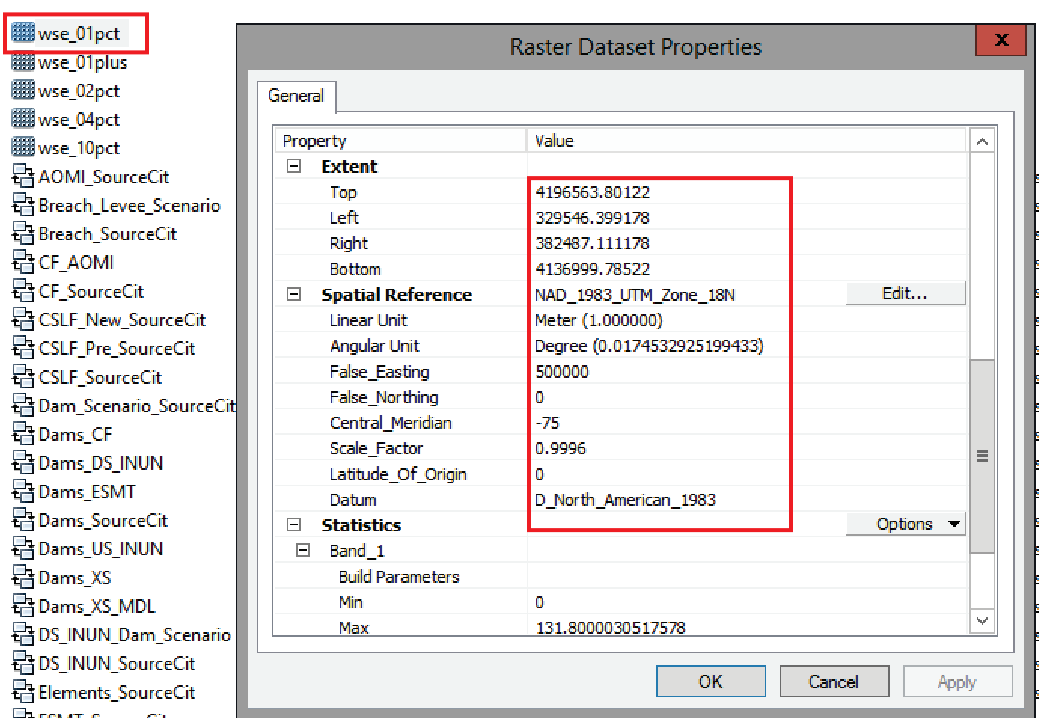
The example below demonstrates improper Raster Information.



Correct Example (Extents & Spatial Reference):

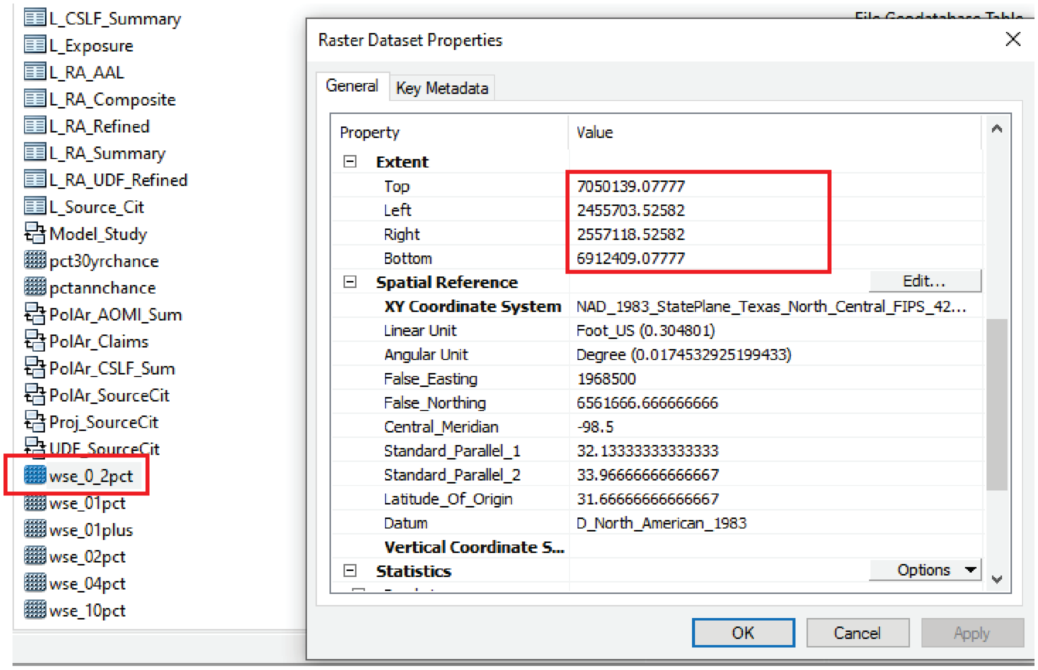
The example below demonstrates the proper Raster Information, where wse_0_2pct has **SAME** information as wse_01pct and so on...

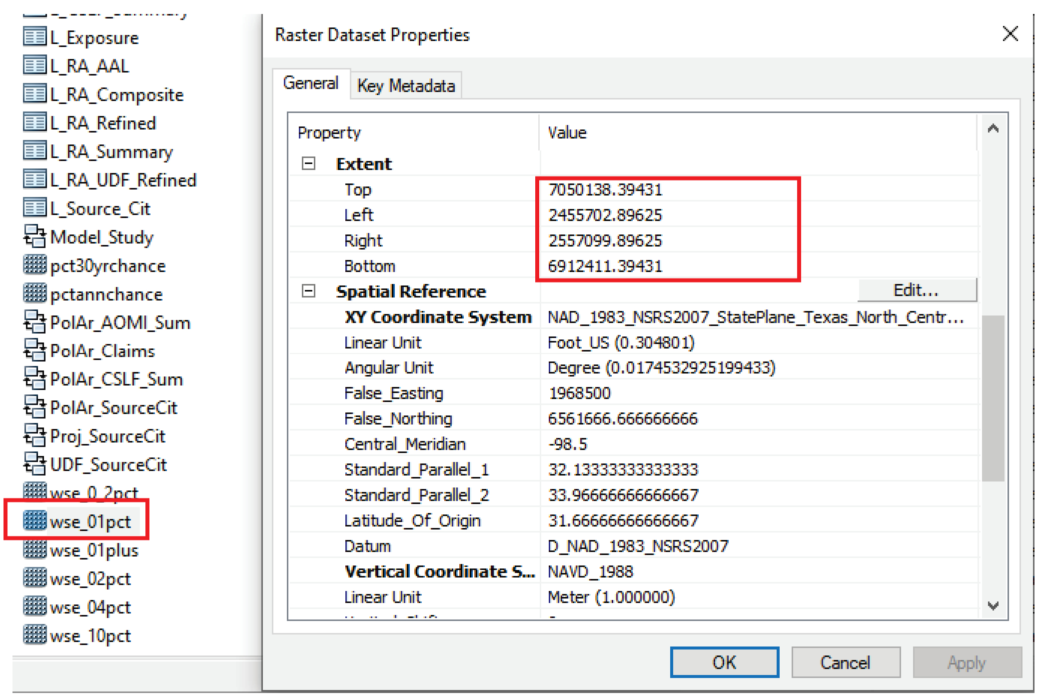




Incorrect Example (Extents & Spatial Reference):

The example below demonstrates improper Raster Information; wse_0_2pct **DOES NOT** have the same information as wse_01pct.





2.4. WSE_5

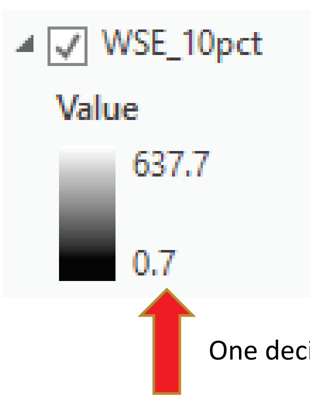
ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_5	WSEL raster values are rounded to the nearest 0.1 feet	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.3 Elevation Accuracy; Page 13.	FRP QC Tool check 1.1.0.4

4.0 Raster Datasets

All depth and analysis rasters within the FRD shall be floating point with data rounded to the nearest tenth of a unit (i.e., 0.1 feet, 0.1 feet/second, or 0.1%) and shall have the same spatial reference, origin, resolution and rotation as one another.

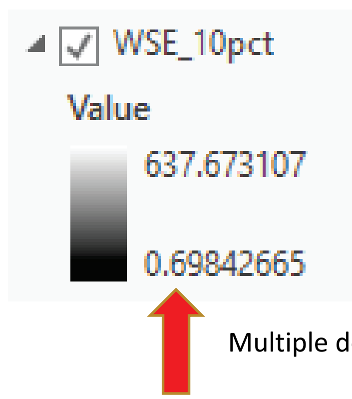
Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018)

Correct Example (Rounding):



One decimal place

Incorrect Example (Rounding):



Multiple decimal places

TYPICAL STEPS TO ROUND PROPERLY

NOTE: prior to performing rounding raster should be in appropriate deliverable coordinate system. If raster is not in appropriate deliverable coordinate system and rounding is performed, and then a re-projection to deliverable coordinates is performed - the result will revert to more than one decimal place because when a raster is projected, by default it is also re-sampled.

- Generate raw depth raster (typically WSE raster minus bare-earth DEM raster)
- Multiply raw depth raster by 100
- Add 0.5
- Convert to Integer raster
- Divide by 100

2.5. WSE_6

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_6	WSEL raster cell size resolution is no larger than 10ft x 10ft	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 1.1 Grid Cell Resolution; Page 1.	FRP QC Tool check 1.1.0.5

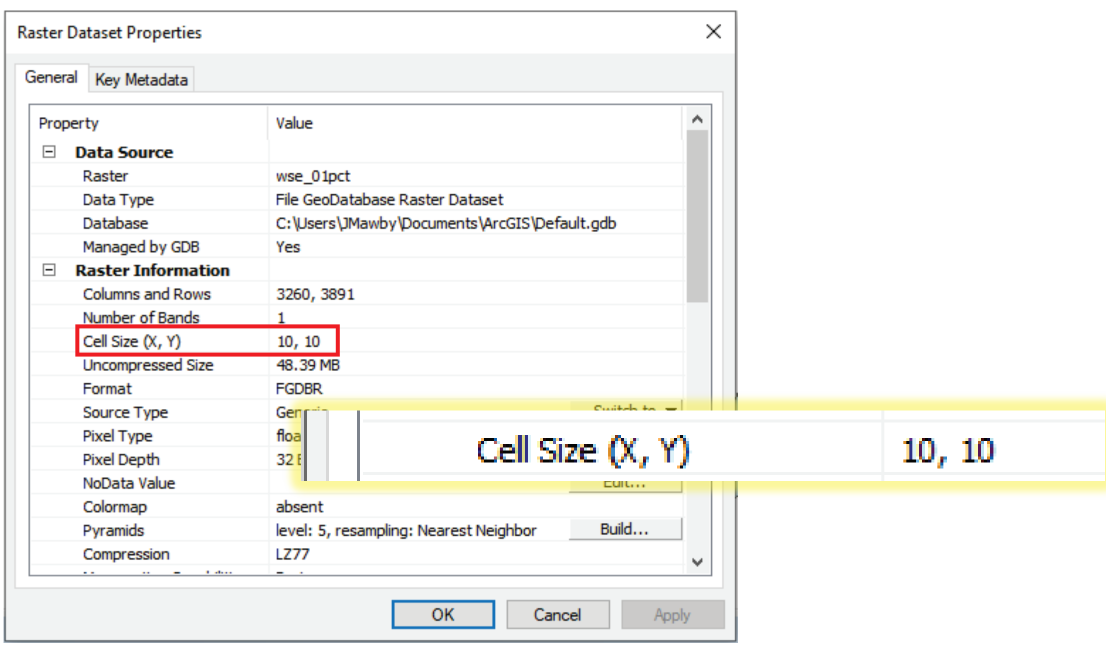
5.0 Spatial Reference Systems

Delivered FRD raster datasets shall have the following spatial reference standards:

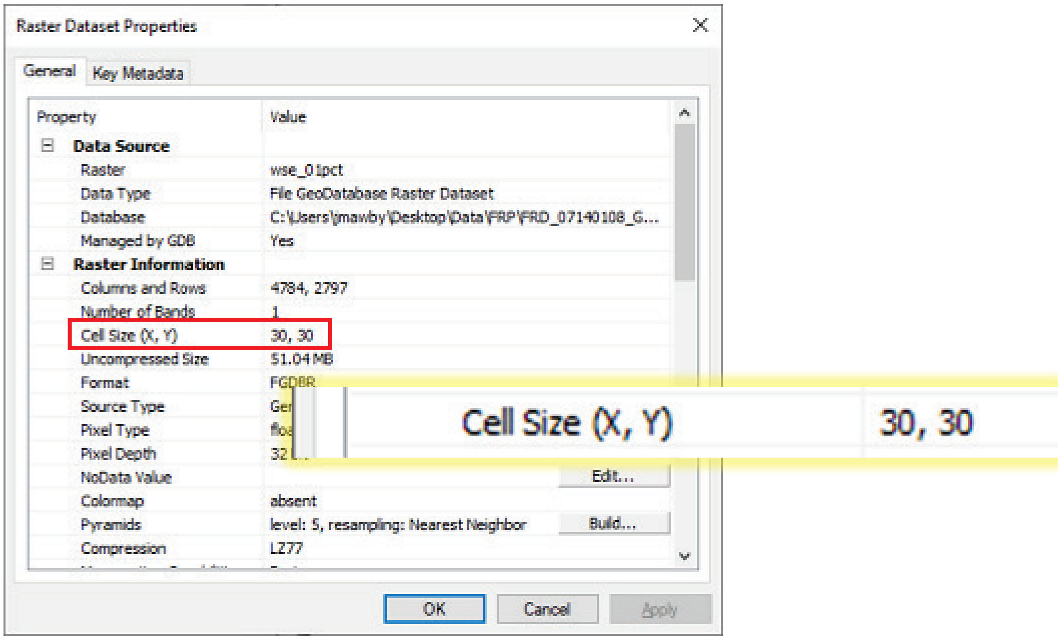
Projection: Universal Transverse Mercator (UTM)
Zone: Single zone which best covers the project area
Horizontal Datum: NAD 83 (1986). This is the original NAD 83 realization.
Horizontal Units: Meters
Cell Size: no larger than 10m
Vertical Datum: NAVD88
Vertical Units: US Survey Feet

Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018)

Correct Example (Cell Size):



Incorrect Example (Cell Size):



2.6. WSE_7

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_7	All rasters in the FRD use the Universal Transverse Mercator (UTM) zone in which the majority of the project area lies.	1. Flood Risk Database Technical Reference (FEB2018) - Section 5.0 Spatial Reference Systems; Page 77. 2. Guidance: Flood Risk Assessments (FEB2018) - Section 3.3 Geographic Information Systems (GIS) Considerations; Page 7.	FRP QC Tool check 1.3.0.6

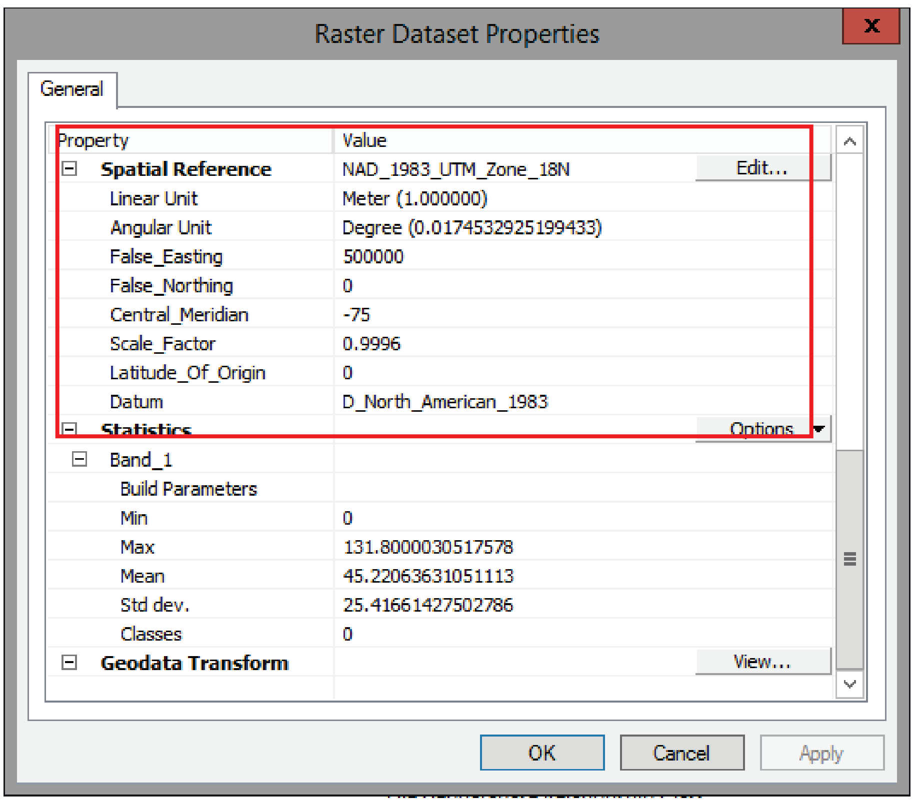
5.0 Spatial Reference Systems

Delivered FRD raster datasets shall have the following spatial reference standards:

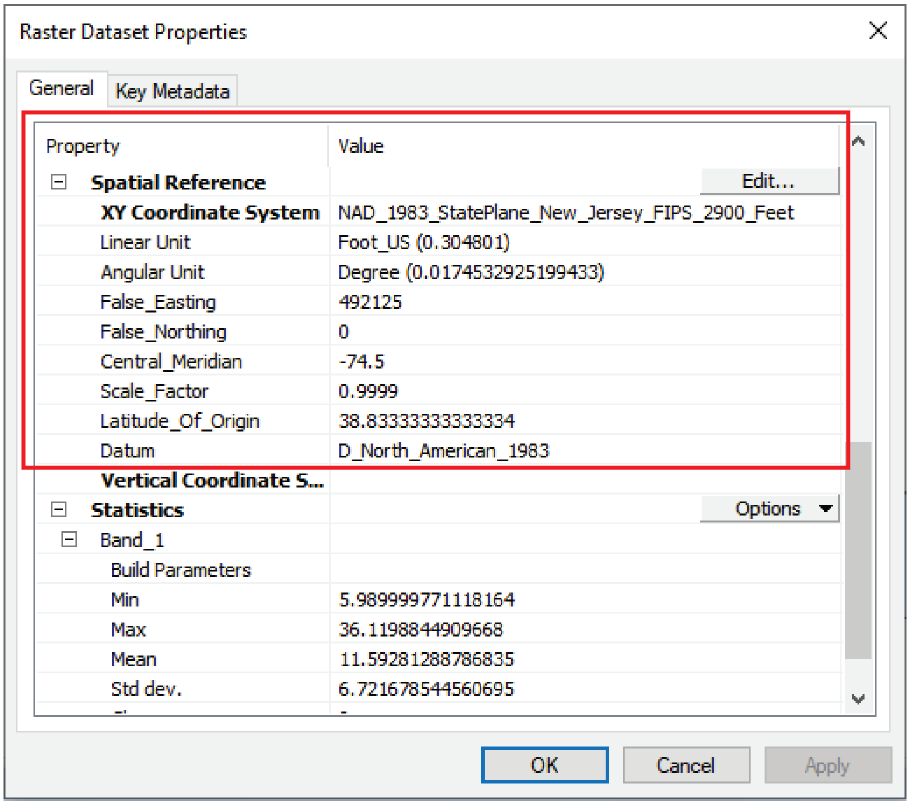
Projection: Universal Transverse Mercator (UTM)
Zone: Single zone which best covers the project area
Horizontal Datum: NAD 83 (1986). This is the original NAD 83 realization.
Horizontal Units: Meters
Cell Size: no larger than 10m
Vertical Datum: NAVD88
Vertical Units: US Survey Feet

Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018)

Correct Example (UTM Spatial Reference):



Incorrect Example (UTM Spatial Reference):

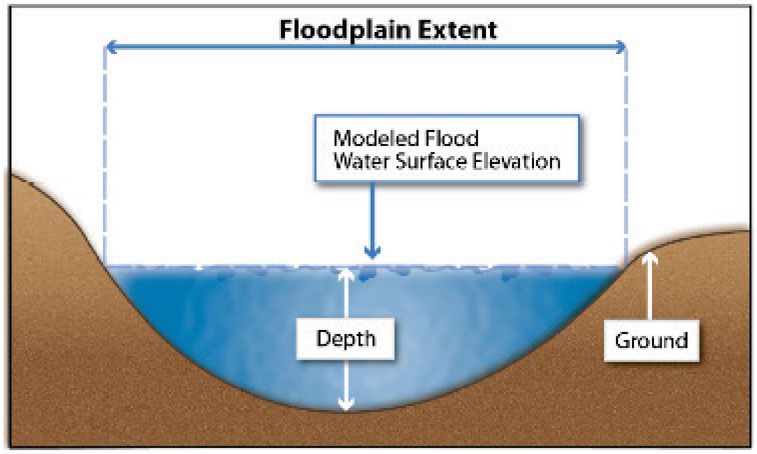


2.7. WSE_8

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_8	WSEL rasters must share the same terrain and bathymetry source datasets as the engineering models.	FEMA Policy Standards for Flood Risk Analysis and Mapping FEMA Policy #FP 204-078-1 (Rev 8); Page 54. Other Consideration: Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 3.2 Depth Grid Considerations for Inland Open Water Areas; Page 23.	manual check

Reference Example:

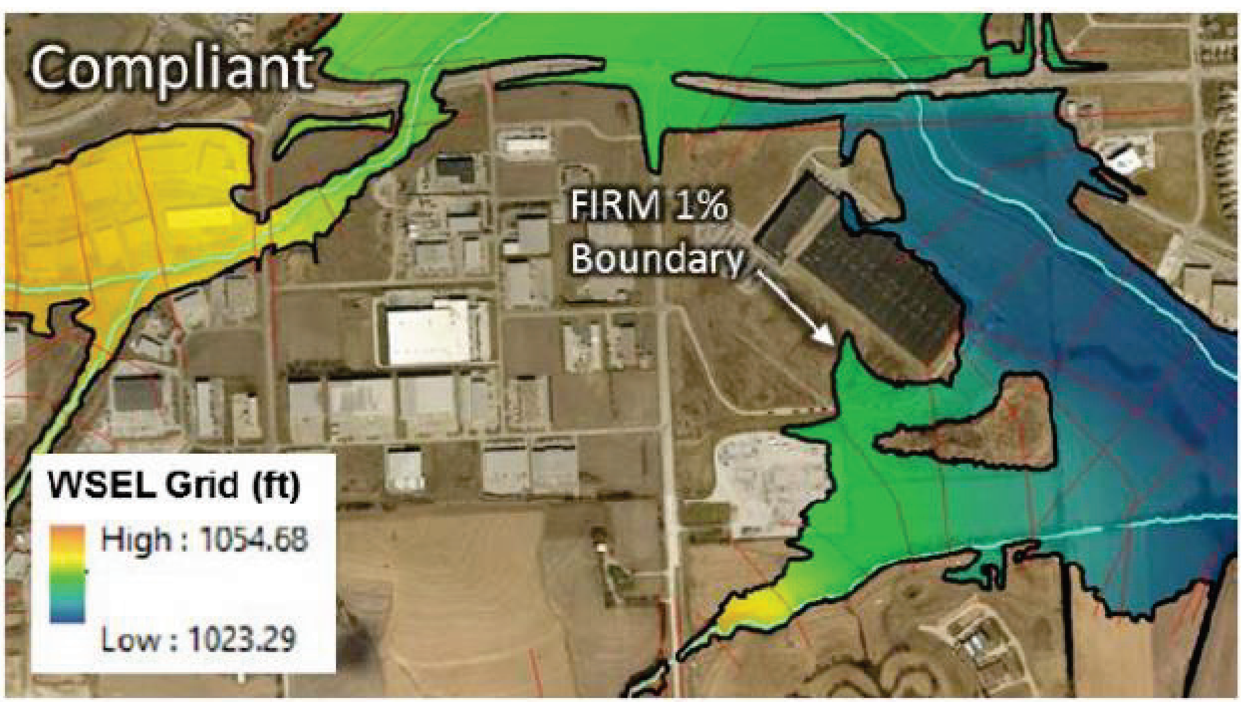
Figure 20: Depth Grid in Cross Section View



Guidance for Flood Risk Analysis and Mapping, Flood Risk Database (Feb 2018); Page 21

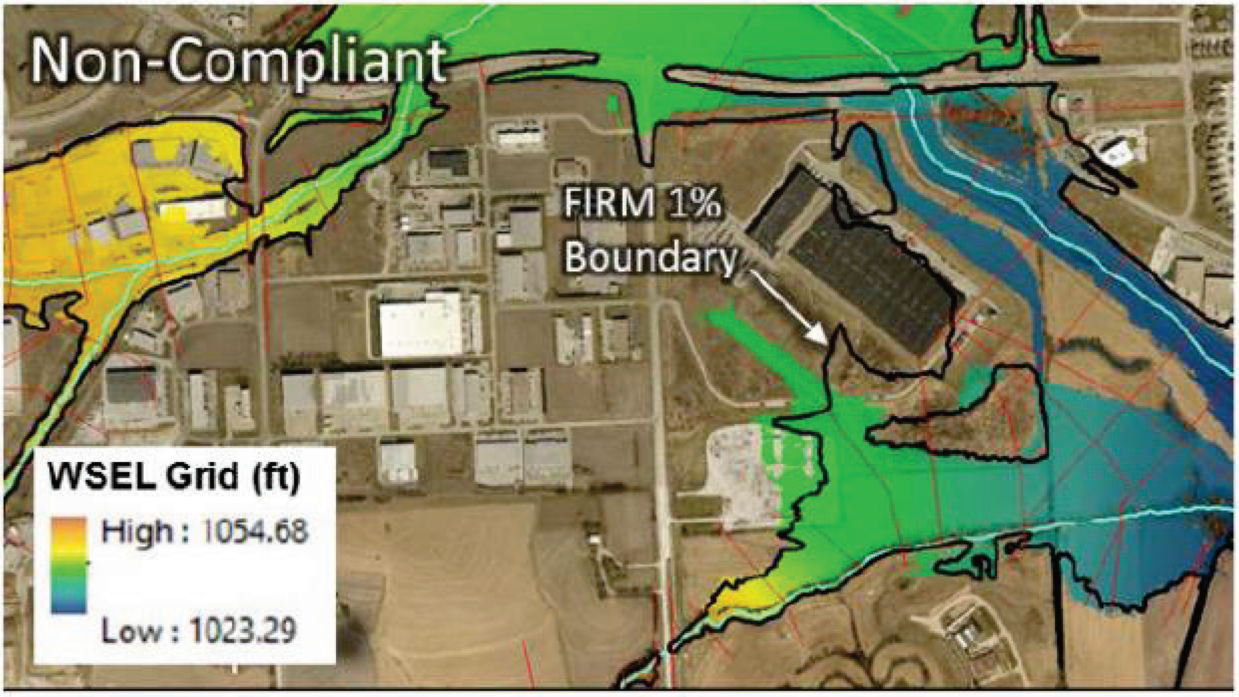
Producers of water surface and depth raster's need to be mindful of the importance to utilize the same ground data utilized to generate associated floodplain modeling. This will ensure that all products (Regulatory & Non-Regulatory) are consistent. The image above offers valuable perspective when considering the following Correct and Incorrect examples. The assumption is that the information in the image above represents use of "the same terrain". In the event that a different ground dataset is utilized, it would essentially change the planimetric shape of the floodplain and subsequent depth raster values – even if the same water surface data is utilized.

Correct Example:



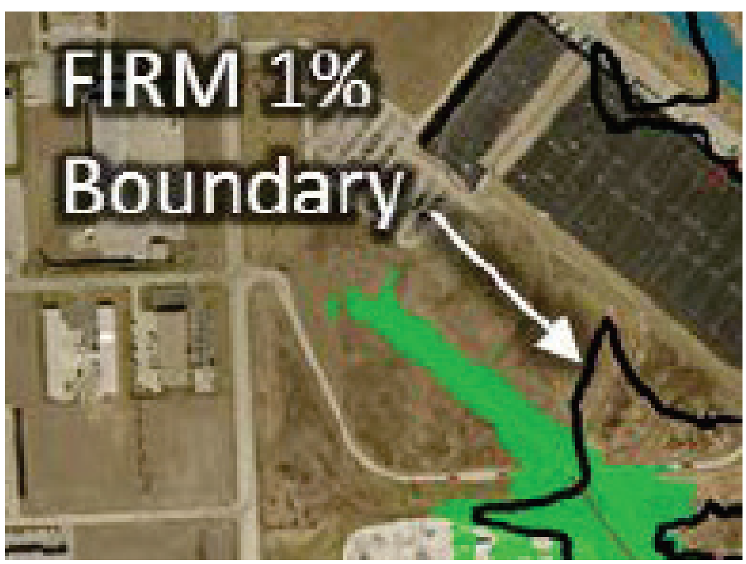
The example above demonstrates that the WSE raster coincides and is consistent with the floodplain boundary.

Incorrect Example:

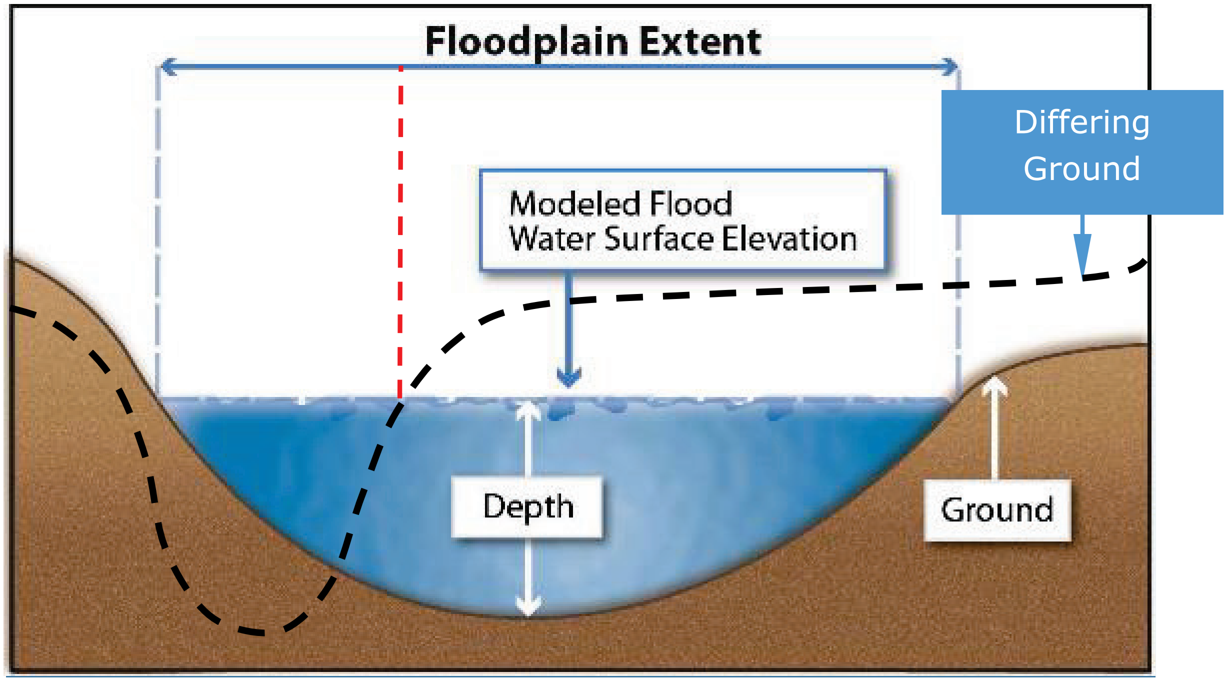


The example above demonstrates that the WSE raster is not consistent with the floodplain boundary.

When considering the following sub-area:



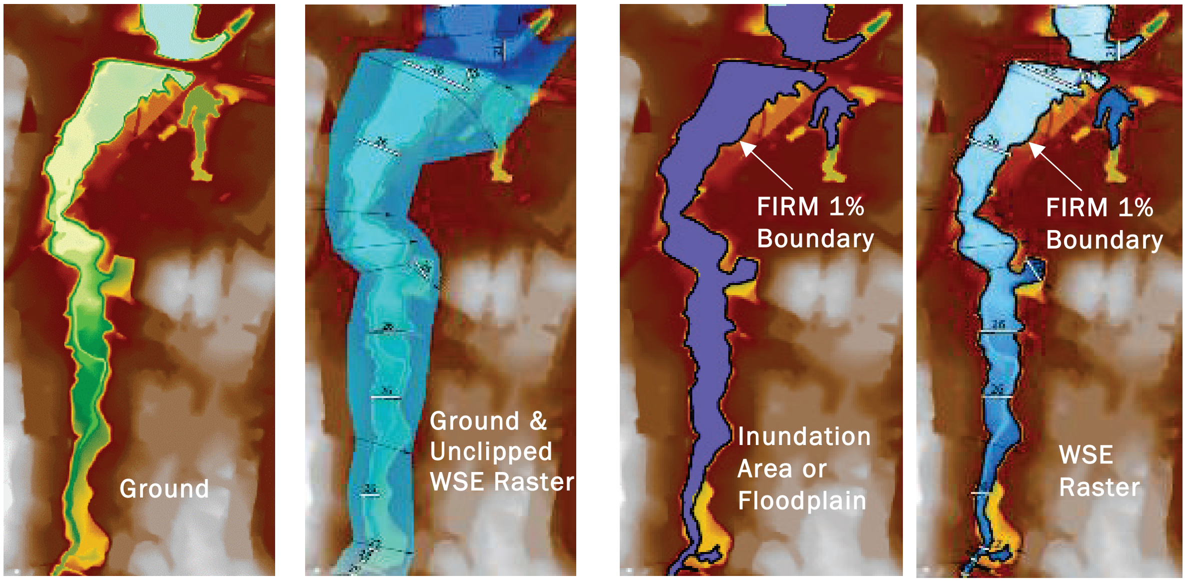
The planimetric shape of the floodplain boundary as compared to the WSE raster indicates that a different ground dataset was likely utilized.



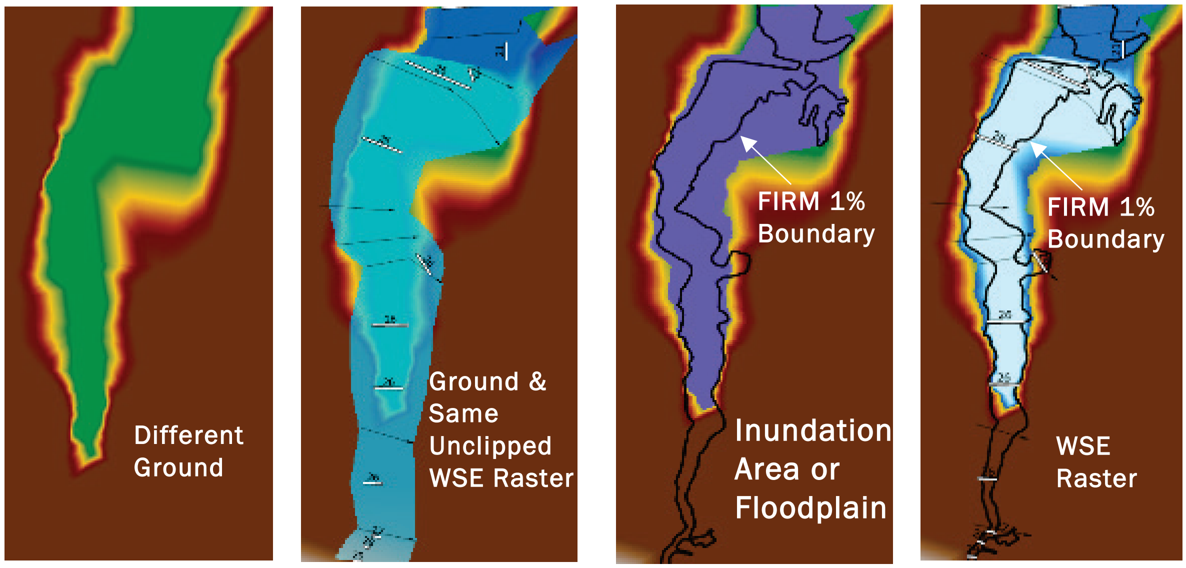
The cross-sectional view above is a generalized sketch that exemplifies the likelihood of the error in this general vicinity, where the shape of the ground is mismatched, and the floodplain is essentially squeezed into a channelized area.

Incorrect Example (Comparison to Exemplify):

In order to properly understand the importance of utilizing the same ground data that was utilized to generate the floodplain mapping, the following comparative example underscores the importance – use of a different ground will result in differing floodplain extents as well as differing depth grids.



The series of images in the set above utilize the same ground that was utilized to generate the FIRM.



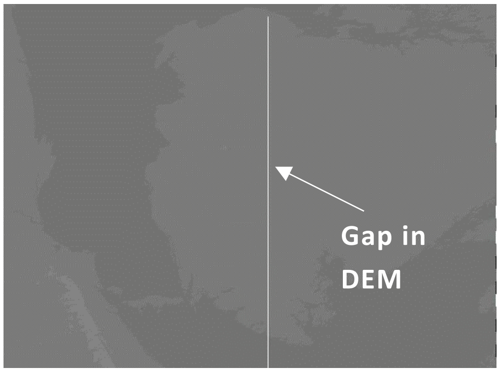
The series of images in the set above utilize differing ground data; while FRP's are able to be produced, they differ greatly from the FIRM floodplain extents. This set of example images exemplify how different ground data will produce incorrect WSE and Depth Rasters; especially use of a less-accurate ground dataset as the example set above.

2.8. WSE_9

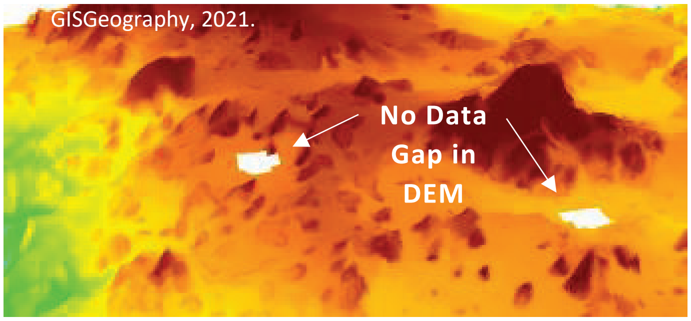
ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_9	Supporting documentation is included for locations where the WSEL raster has large gaps due to issues with the underlying terrain data.	1. Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.4.1 Gaps and Waterfalls; Page 17. 2. Guidance: Flood Risk Assessments (FEB2018) - Section 3.3 Geographic Information Systems (GIS) Considerations; Page 7.	manual check

Example(s) of Terrain Gaps:

The gap represented above may exist between differing surveys and may therefore also cause gaps with WSEL, Depth and Analysis Rasters.



The gap represented above may exist between source DEM tiles. The gap may or may not be valid. If valid, the reasoning should be explained.



The gap represented above, if valid should be explained.

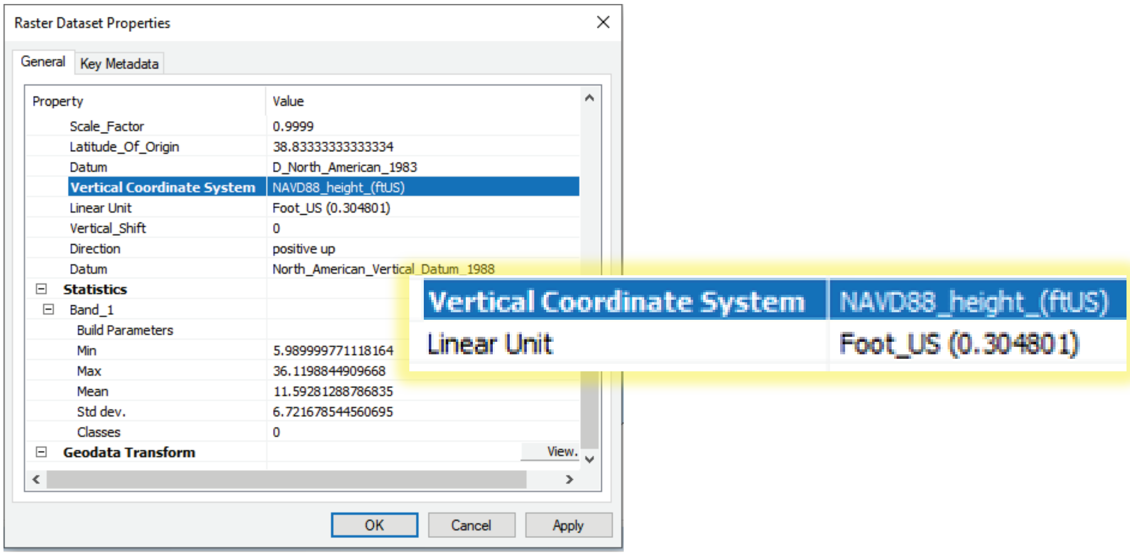
Discussion:

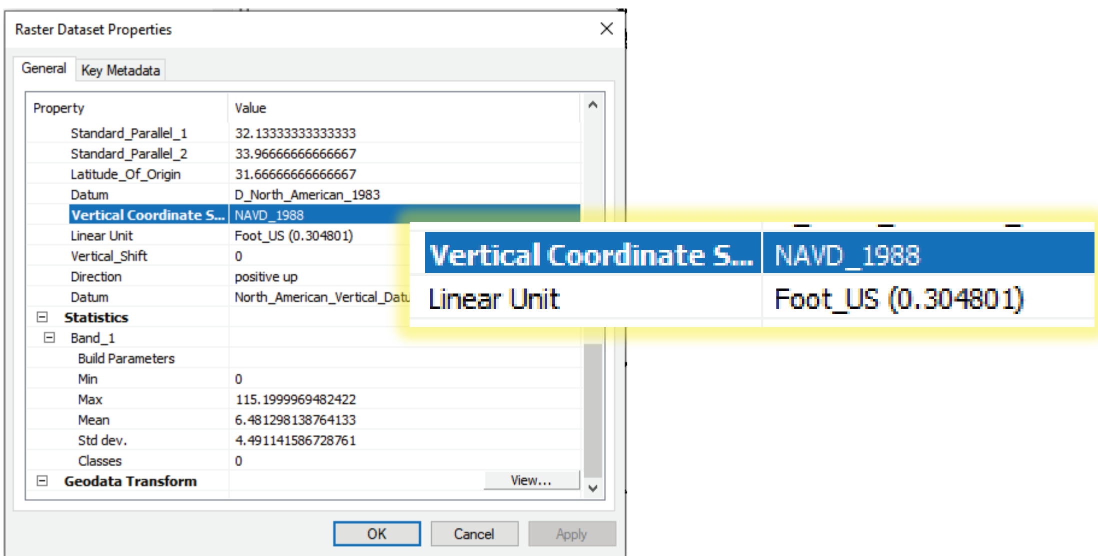
Any gap in the underlying ground data will also result in gaps within subsequent products, floodplains, water surface, depth and analysis rasters. In most instances, data gaps are considered an error – meaning that underlying ground data are not expected to include gaps. If a gap is a known and valid gap, the reasoning should be explained.

2.9. WSE_10

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_10	WSEL rasters reference the North American Vertical Datum of 1988 (NAVD88, Feet).	1. Flood Risk Database Technical Reference (FEB2018) - Section 5.0 Spatial Reference Systems; Page 77.	FRP QC Tool check 1.3.0.7

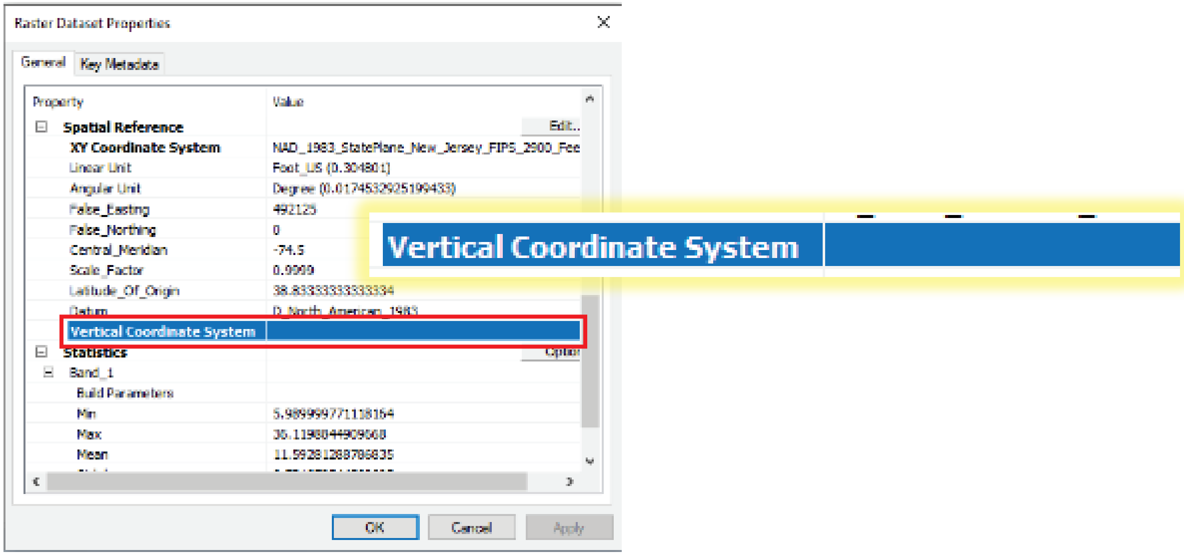
ESRI Raster Dataset Properties Correct Examples:





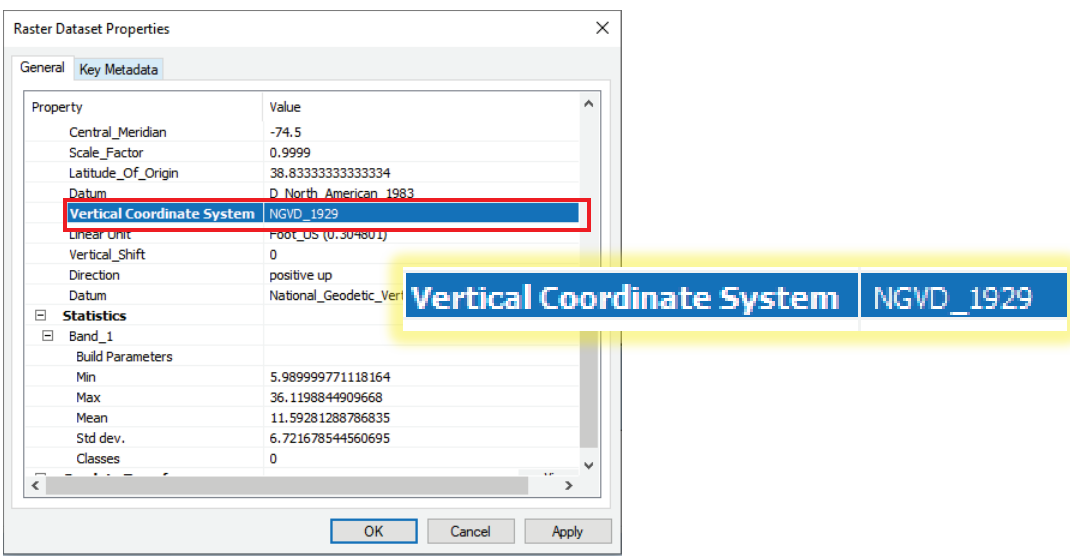
ESRI Raster Dataset Properties Incorrect Example1:

Dataset does not have a Vertical Coordinate System defined.



ESRI Raster Dataset Properties Incorrect Example2:

Dataset <u>has incorrect</u> Vertical Coordinate System defined.



2.10. WSE_11

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_11	WSEL rasters cover the full extent (modeled limit) of the studied flooding source, and are not clipped to the project footprint	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 9.0 Dataset Spatial Extents; Page 35-37 (Figure 33).	FRP QC Tool check 1.3.0.8

Reference Example:

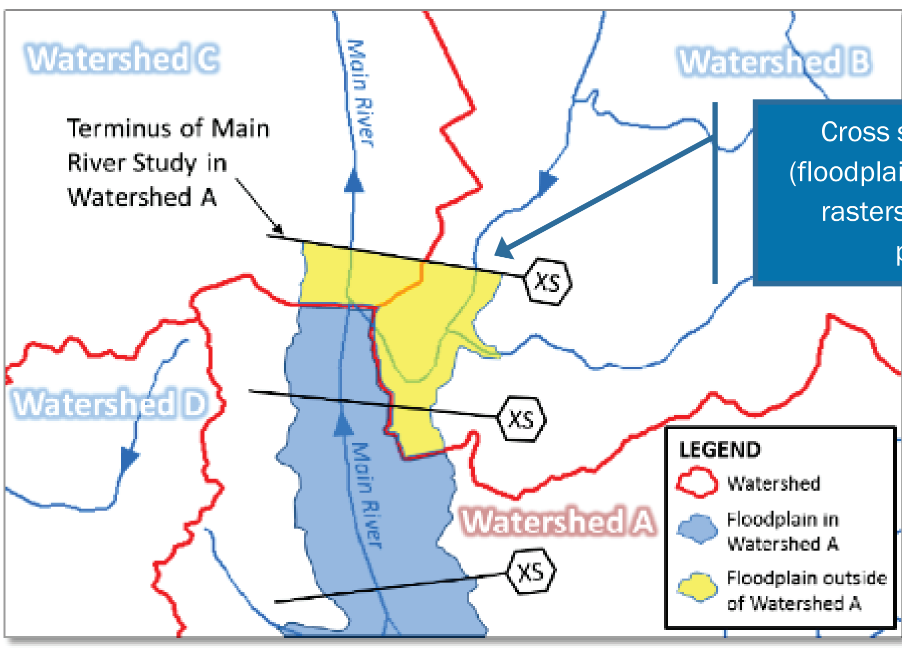
9.0 Dataset Spatial Extents

Certain flood risk datasets will naturally extend beyond the limits of the Flood Risk Project footprint. This additional data may be needed to ensure a complete picture of flood risks within the project area. Figure 33 (Below) provides an example of a typical scenario that will regularly occur at the outlet of watersheds that are being studied. In these cases, the depth and analysis grids should not be clipped to the project footprint but should remain in their entirety to cover the area studied.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 35

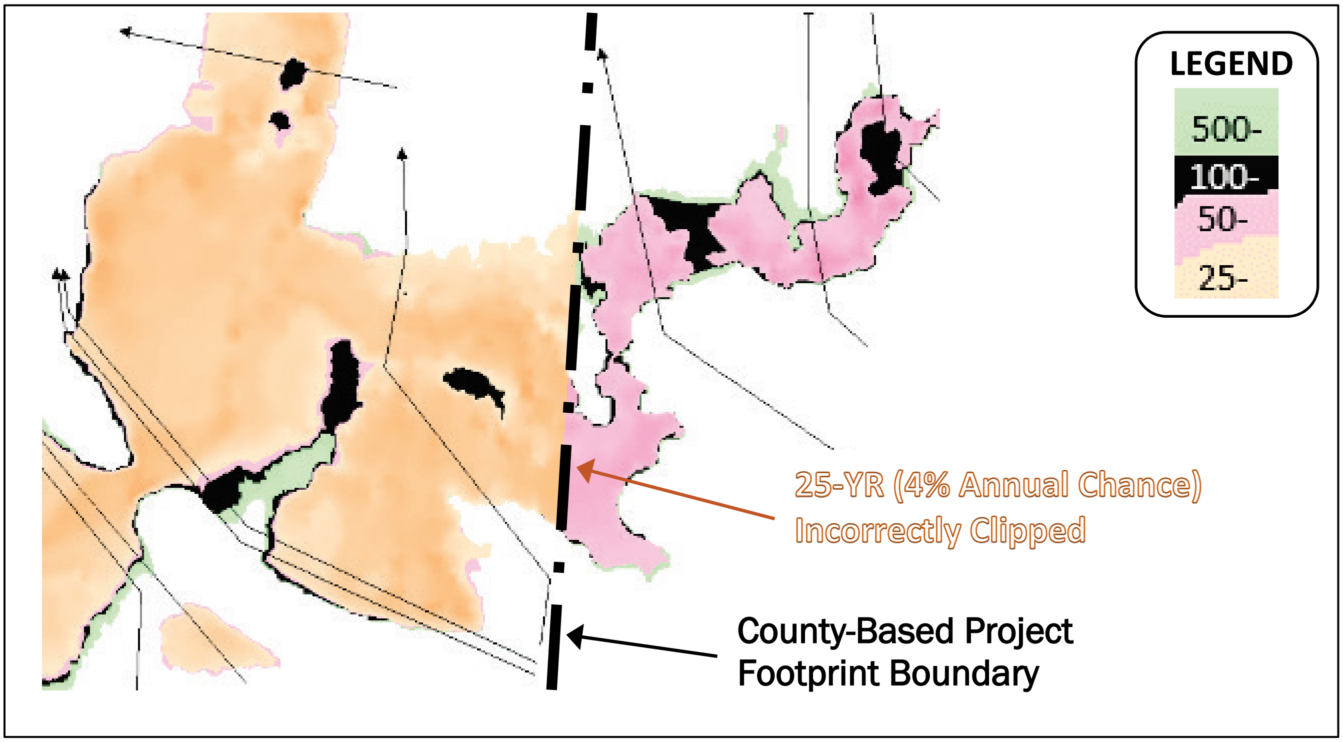
Correct Example

Figure 33: Flood Risk Data Outside of the Project Area



Cross sections (XS) and data (floodplains, WSE/Depth/Analysis rasters are extended beyond project footprint.

Incorrect Example:

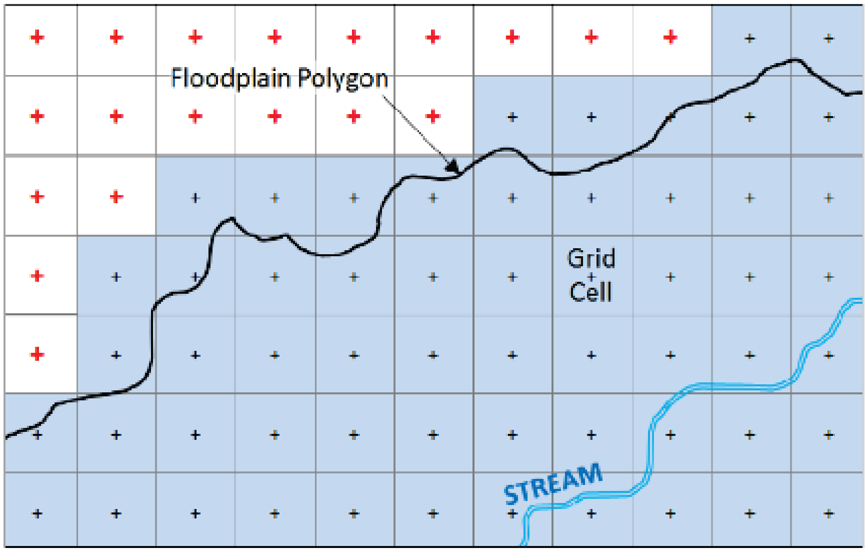


2.11. WSE_12

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_12	Applicable WSEL rasters (1% and 0.2%) are contained by flood hazard area polygons. * Rasterization will not align perfectly to the flood hazard area along the perimeter boundary (due to square pixel format of rasters), but WSEL rasters should show values for cells whose entirety falls within the mapped flood area and may show "NO DATA" for cells whose entirety lie outside of the mapped flood area. * For coastal studies only applies to 1% event	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.2 WSEL Grid Agreement with Applicable Flood Hazard Area Polygon; Page 11-12 (Figure 10 & 11).	GIS software can be used

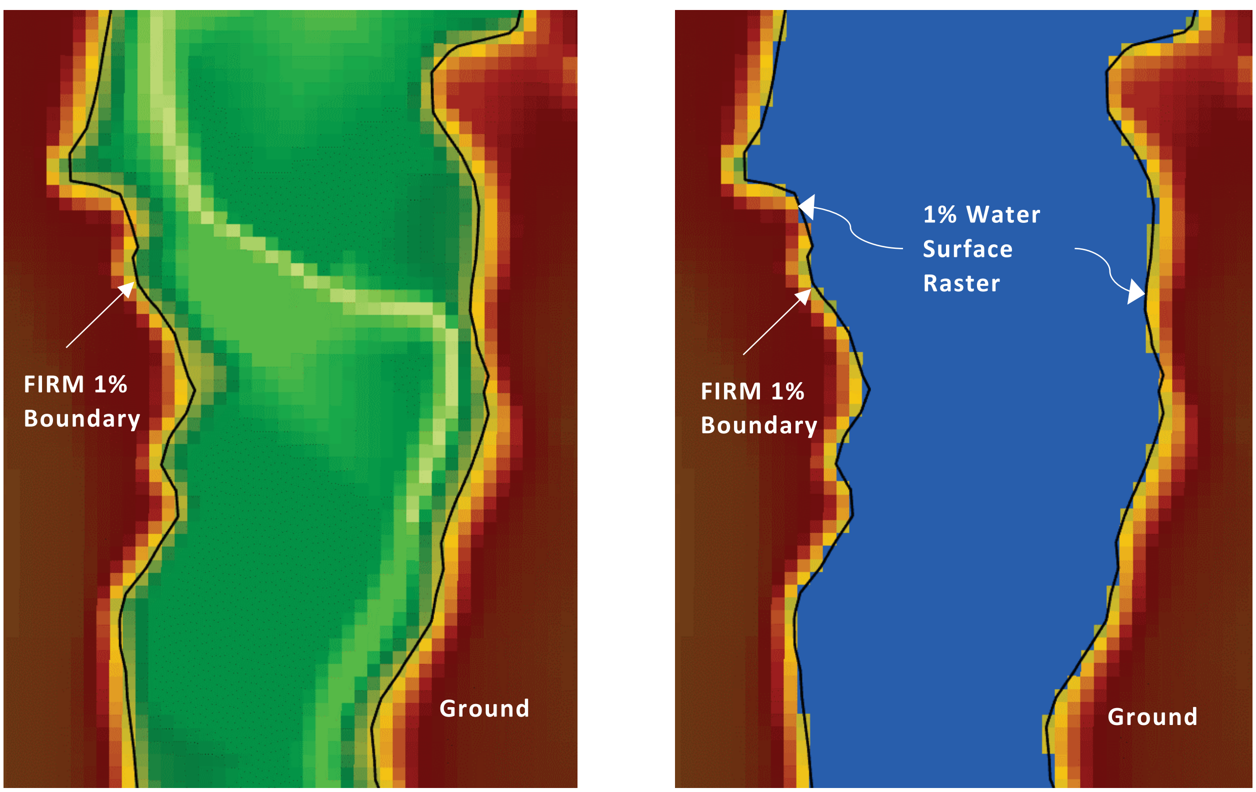
Reference Example:

Figure 10: WSEL Grid Alignment with Floodplain Polygon at Edge of Boundary

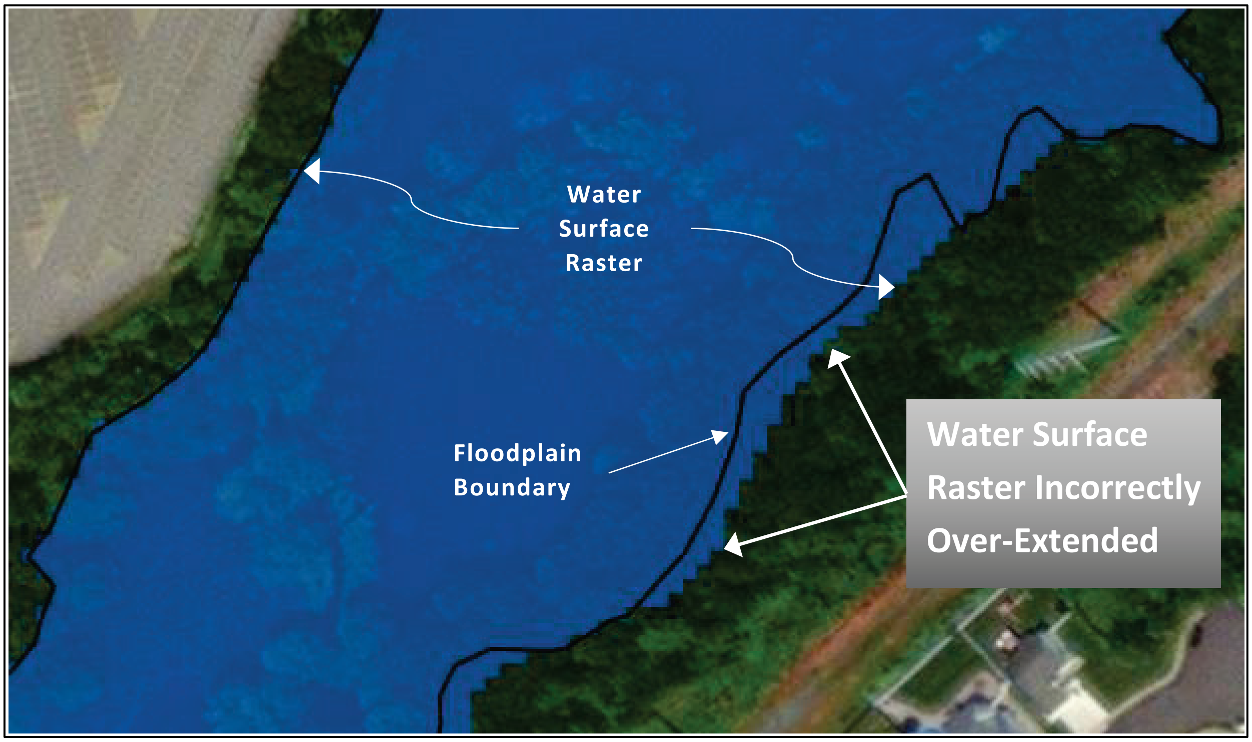


Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 11

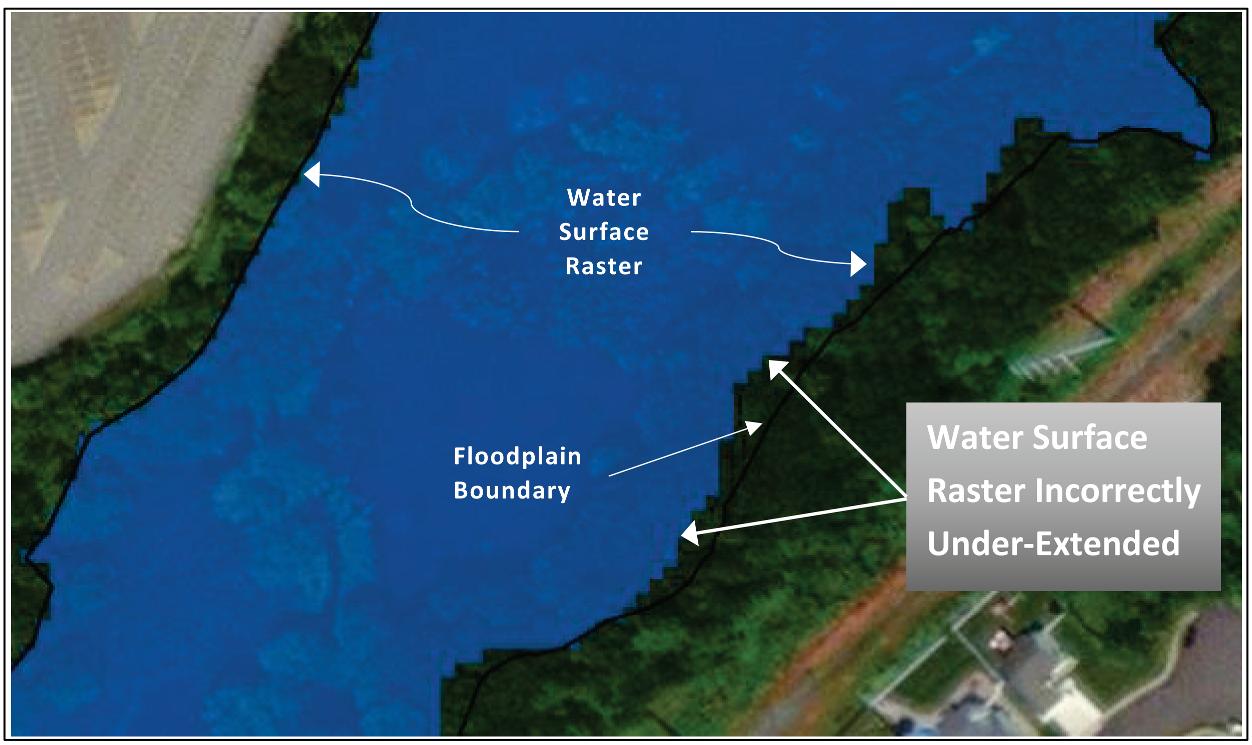
Correct Example:



Incorrect Example (WSE Raster Over-Extended):



Incorrect Example (WSE Raster Under-Extended to Floodplain Boundary):



2.12. WSE_13

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_13	WSEL raster extent for a given recurrence interval is larger than or equal to the extent of the next lower recurrence interval (if data are available for assessment) *For example, in areas where the 1% and 0.2% annual chance floodplains have been mapped, there should be no 1% WSEL raster cells with values where there is also not a corresponding 0.2% WSEL raster cell with values.	Guidance: Flood Depth and Analysis Grids (FEB2018) - A. Section 2.0 Water Surface Elevation (WSEL) Grids provides full discussion; Page 2-20. B. Section 2.6.2 WSEL Grid Agreement with Applicable Flood Hazard Area Polygon provides specifics; Page 11-12 (Figure 10 & 11).	FRP QC Tool check 1.3.0.5

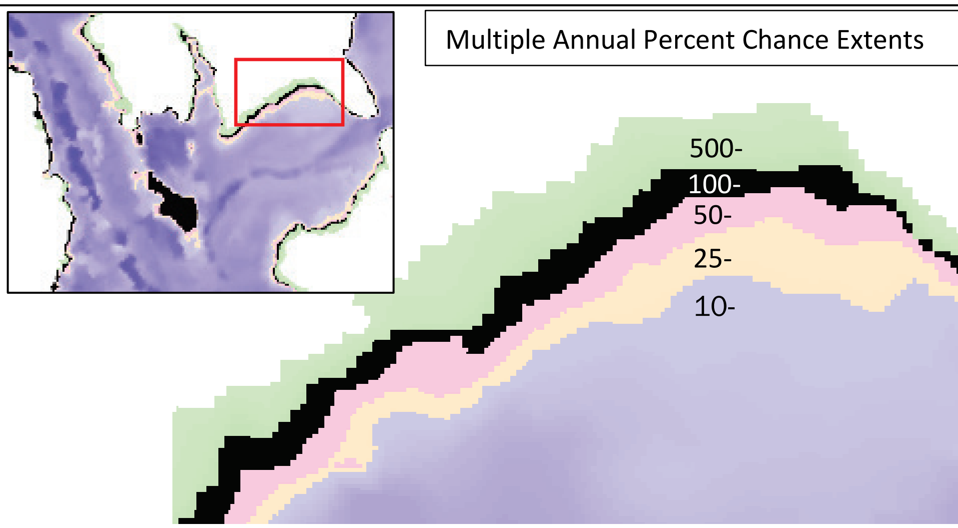
Reference Example:

2.6.2 WSEL Grid Agreement with Applicable Flood Hazard Area

The WSEL grid extent and elevations for a given flood frequency (e.g. the 1-percent-annual-chance) should also be larger than or equal to the extents and elevations of the grid for lower flood magnitudes (e.g. the 2-percent-annual-chance), and should be smaller than or equal to the extents and elevations of the grid for the higher flood magnitudes (e.g. the 0.2-percent-annual-chance). In other words, in areas where the 1-percent and 0.2-percent-annual-chance floodplains have been mapped, there should be no 1-percent-annual-chance WSEL grid cells with values where there is also not a corresponding 0.2-percent-annual-chance WSEL grid with values. Just as it would not be appropriate to show the mapped 1-percent-annual-chance flood hazard polygon wider than the 0.2-percent-annual-chance flood hazard polygon, it is not appropriate to show something similar with the corresponding WSEL grids.

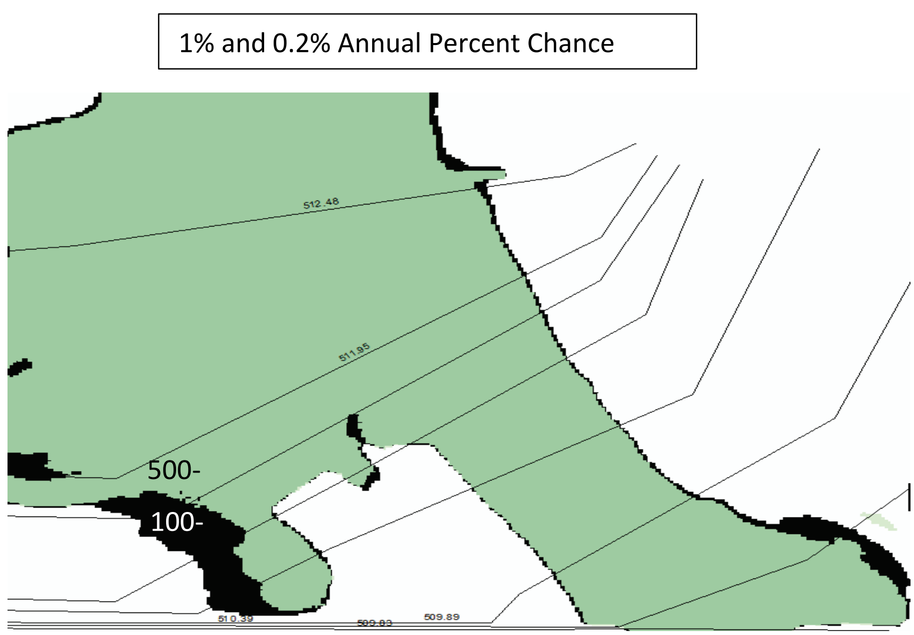
Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 12

Correct Example:



- 10-percent-annual-chance is <u>*contained by*</u> 4-percent
- 4-percent-annual-chance is <u>*contained by*</u> 2-percent
- 2-percent-annual-chance is <u>*contained by*</u> 1-percent
- 1-percent-annual-chance is <u>*contained by*</u> 0.2-percent
- 0.2-percent-annual-chance <u>***contains all lower frequency events***</u>

Incorrect Example:



- 1-percent-annual-chance is **NOT** <u>*contained by*</u> 0.2-percent
- 0.2-percent-annual-chance **DOES NOT** <u>***contain lower frequency event***</u>

2.13. WSE_14

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_14	WSE_1PCT not depicted in AO Zones.	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.3 Depth Grid Considerations for Zone AO Areas; Page 7.	FRP QC Tool check 1.3.0.4

Reference Example:

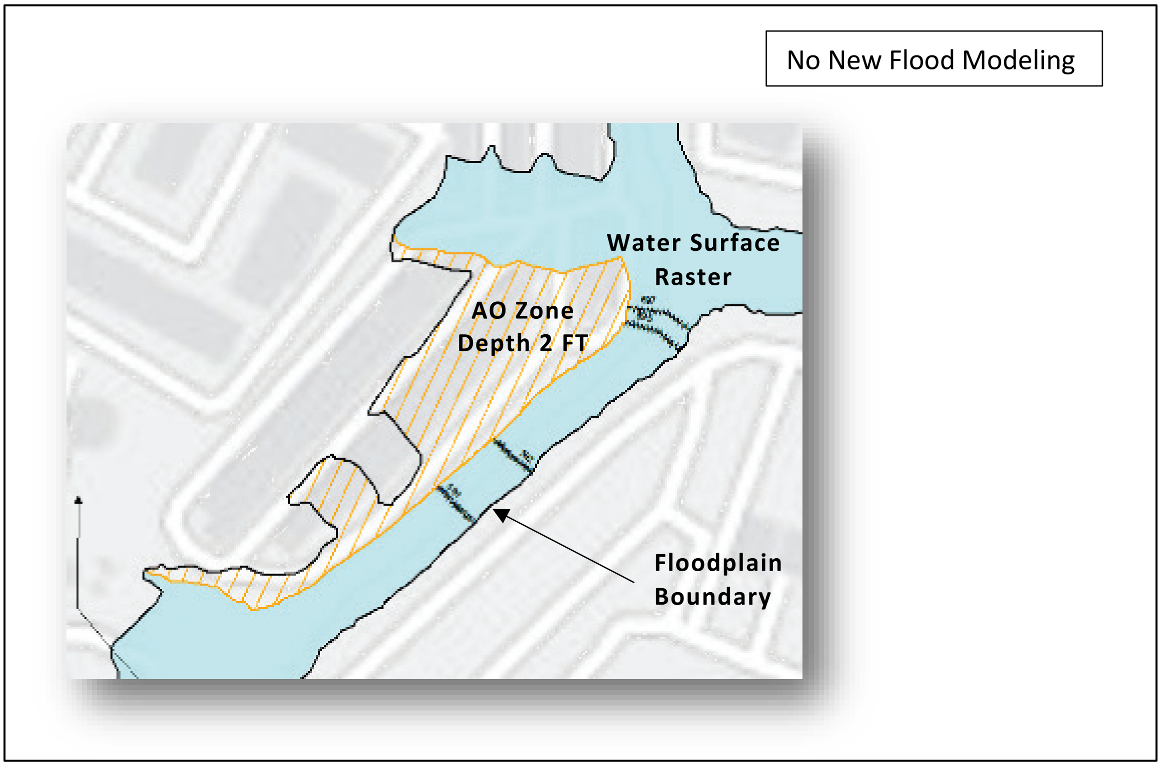
3.3 Depth Grid Considerations for Zone AO Areas

For areas where the new or effective model from which the Zone AO depths were derived is available and the associated WSEL grid has been created, the process for creating the depth grid is the same as described in Section 3. Each depth grid cell can be rounded to the nearest whole-foot value or to the tenth of a foot, provided that the values, when rounded, would equal the whole foot depth reported on the FIRM.

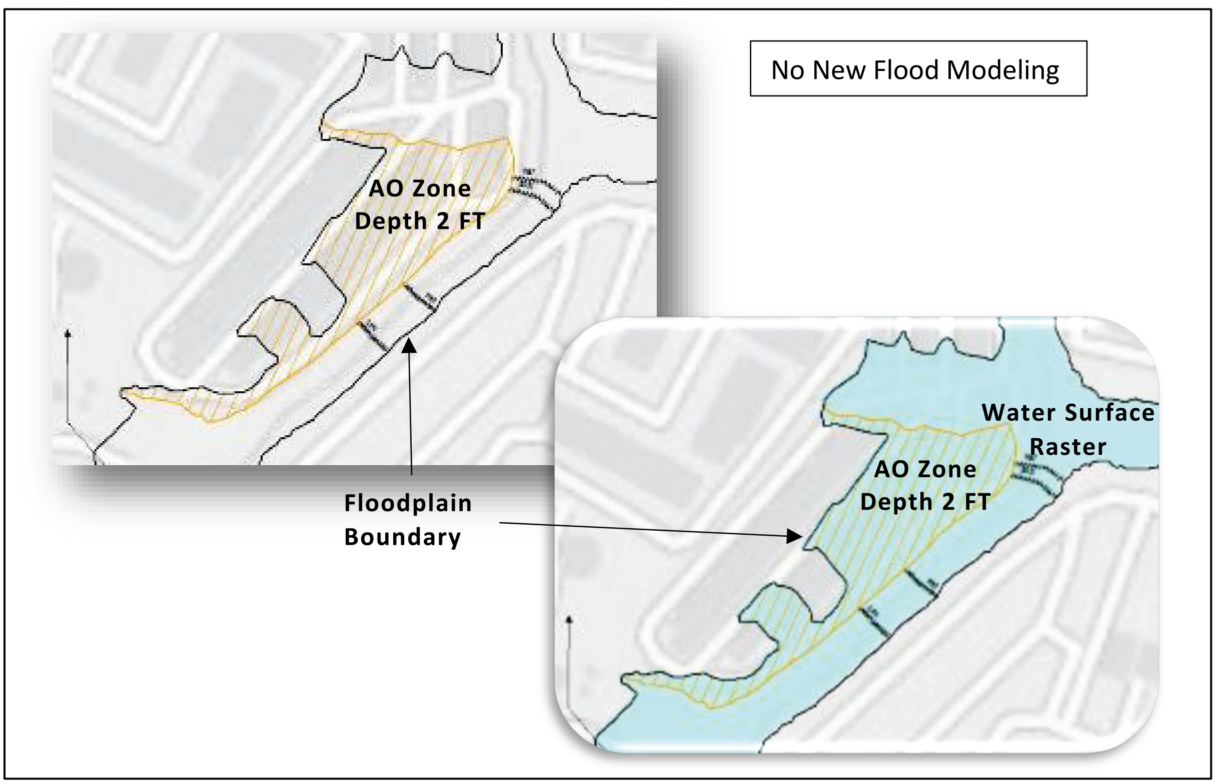
When depth grids are created for areas where the new or effective model is not available, the 1-percent-annual-chance depth grid should be created to match what is shown on the effective FIRMs. The process in these cases is to simply convert the Zone AO polygons to a grid, with the grid values based on the Zone AO depths.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 25

Correct Example:



Incorrect Example:



2.14. WSE_15

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_15	For 1D models, cross-sections (XS) used to perform the QC against the WSEL rasters (referred to as the "QC XS" in the remainder of this checklist) are located at all inflection points shown on the flood profile *All modeled XS should be used to perform the QC check. Unmapped, modeled XS that are not available digitally should be added to the QC XS dataset prior to checking the WSEL rasters.	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.1 Appropriate Input Data; Page 9 (Figure 7).	manual check

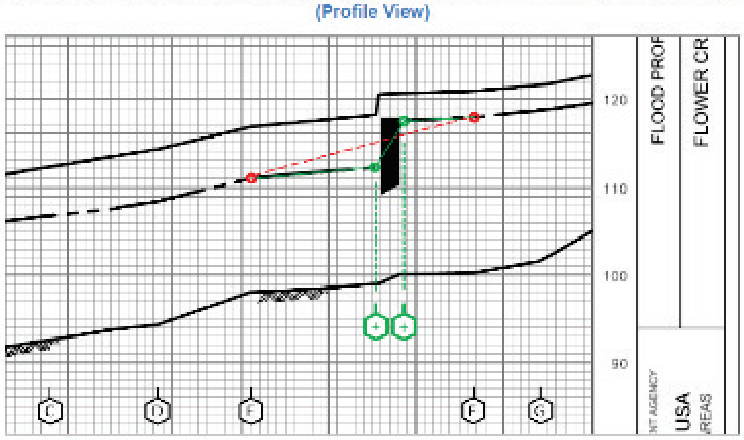
Reference Example:

2.6.1 Appropriate Input Data

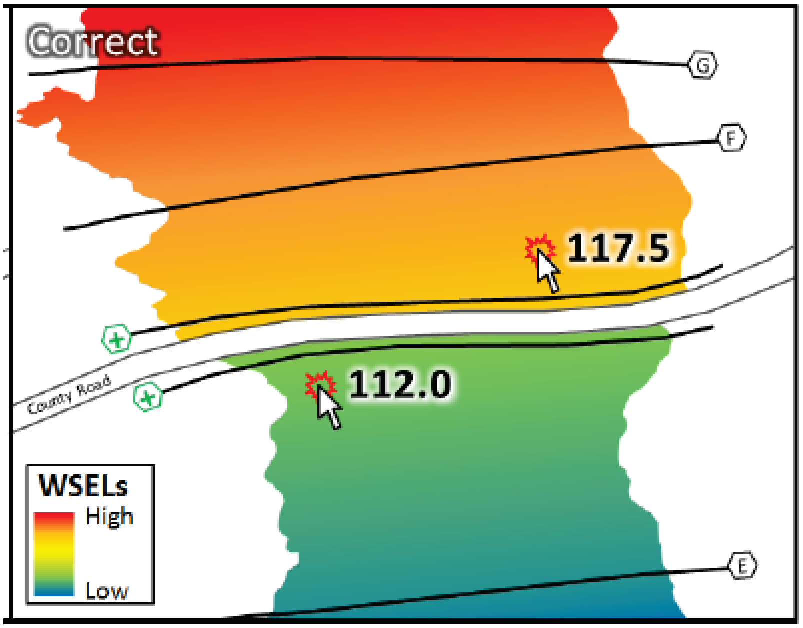
For WSEL grids created from effective studies, especially those that are much older, some modeled cross-sections may not have been mapped and may not be available digitally. In these cases, it is necessary to manually add “mapping” cross-sections to be able to accurately capture the inflections in the effective flood profile. Figure 7 provides an example of an effective study where two manual cross-sections (indicated by the green “+” sign on the profile) should be added upstream and downstream of the road to properly match the model.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 9

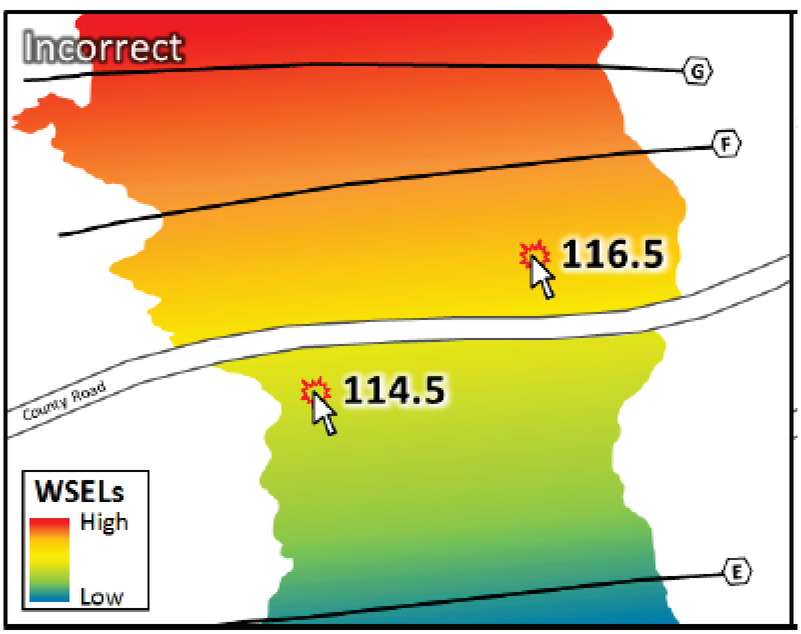
Figure 7: All Modeled Cross-Sections are Necessary for Accurate Grid Representation (Profile View)



Correct Example:



Incorrect Example:



2.15. WSE_16

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_16	Elevations attributed to the QC XS match the elevations shown on the effective flood profile and floodway data table. *QC XS in backwater reflect backwater elevation. Elevations decrease in the downstream direction.	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.4.2 Drawdowns; Page 17-18 (also Figure 7/8).	manual check

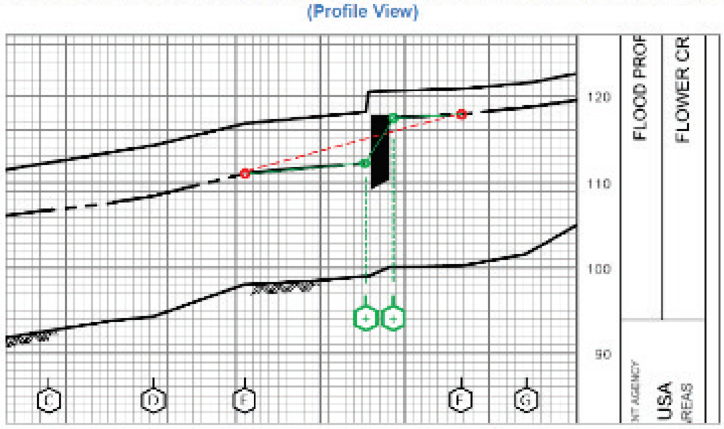
Reference Example:

2.6.1 Appropriate Input Data

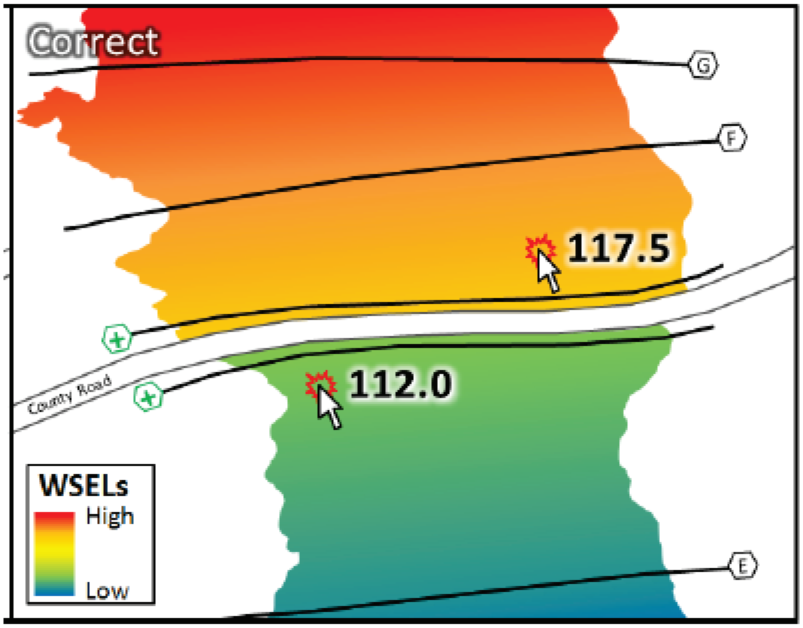
For WSEL grids created from effective studies, especially those that are much older, some modeled cross-sections may not have been mapped and may not be available digitally. In these cases, it is necessary to manually add "mapping" cross-sections to be able to accurately capture the inflections in the effective flood profile. Figure 7 provides an example of an effective study where two manual cross-sections (indicated by the green "+" sign on the profile) should be added upstream and downstream of the road to properly match the model.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 9

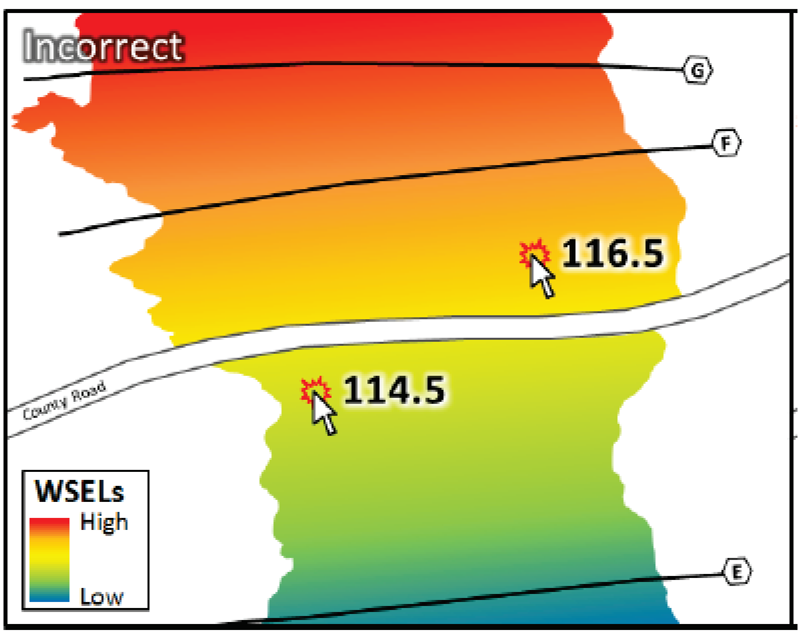
Figure 7: All Modeled Cross-Sections are Necessary for Accurate Grid Representation (Profile View)



Correct Example:



Incorrect Example:



2.16. WSE_17

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_17	WSEL raster values match the QC XS elevations * WSEL raster cells intersecting the QC XS should match within 0.5 ft of one another. Locations where the WSEL grid and QC XS elevations differ greater than 0.5 ft that are justifiable (such as in very steep slopes) must be documented. Originator to provide assurance and justification for such locations.	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.3.1 Elevation check at modeled cross-sections; Page 13-15 (Figure 12 & 13).	GIS software can be used

Reference Example:

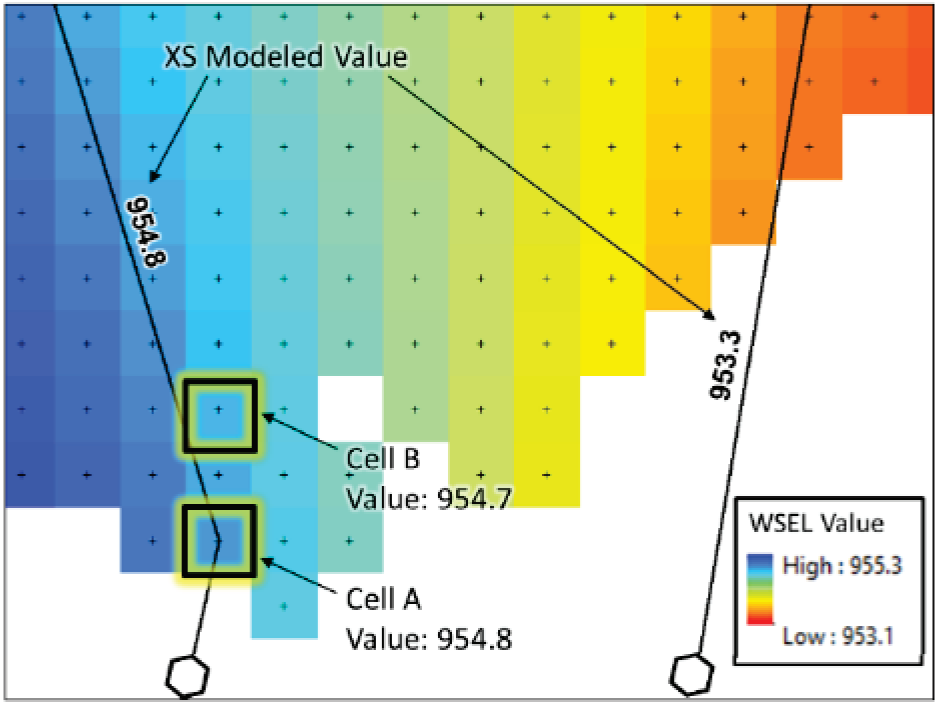
2.6.3.1 Elevation check at modeled cross-sections

For cross-sections not influenced by backwater, the values of WSEL grid cells that intersect the cross-section should match within 0.1 feet of the modeled cross-section elevation for that corresponding flood event. The actual raster values assigned when creating a WSEL grid from cross-sections are generally dependent on where the cross-section intersects the cell, in relation to its centroid. For example, as shown in Figure 12, WSEL grid cells whose centroid is very close to where the cross-section line intersects should have their values nearly identical to the cross-section value (cell A), whereas those that intersect, but whose centroid is farther away will show more of a difference (cell B). This is to be expected. The slope of the water surface profile between cross-sections will influence how rapidly the WSEL transitions from cell to cell the farther you move away from the cross-section.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 13

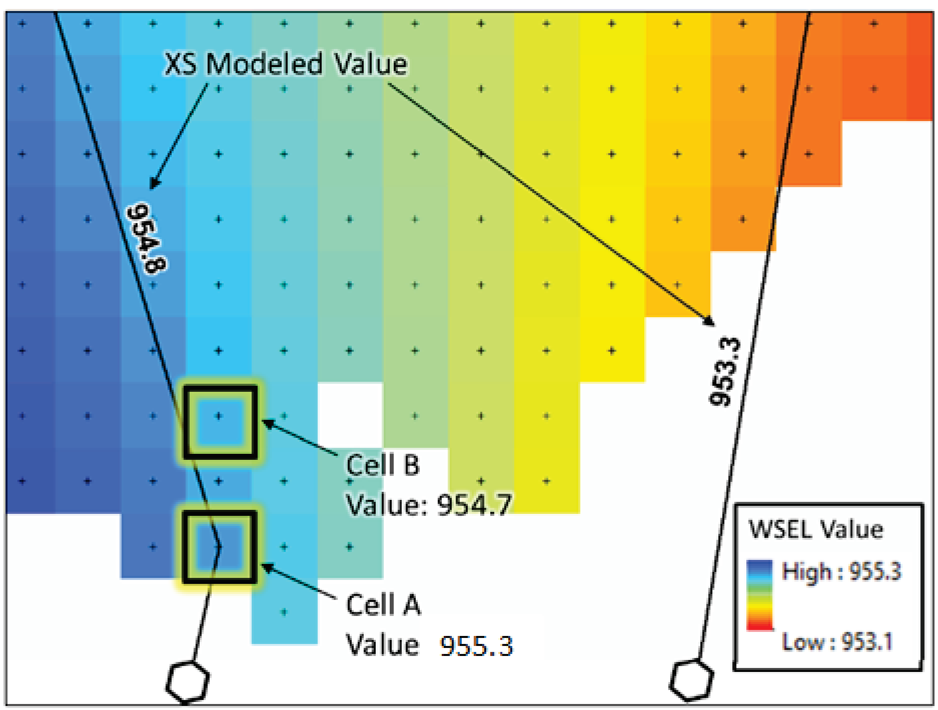
Correct Example:

Figure 12: WSEL Grid Values in Relation to Cross-Section and Cell Centroid Intersection



Incorrect Example:

Figure 12: WSEL Grid Values in Relation to Cross-Section and Cell Centroid Intersection



2.17. WSE_18

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_18	WSEL rasters at studied confluences should match the backwater elevation and upstream extent of the backwater (i.e. where the stream comes out of backwater), as represented along the profile * WSEL raster cells intersecting the QC XS should match within 0.5 ft of one another. Backwater represented as single elevation.	Guidance: Flood Depth and Analysis Grids (FEB2018) - A. Section 2.0 Water Surface Elevation (WSEL) Grids provides full discussion; Page 2-20. B. Section 2.6.4 Confluences and Backwater provides specifics; Page 17.	manual check

Reference Example:

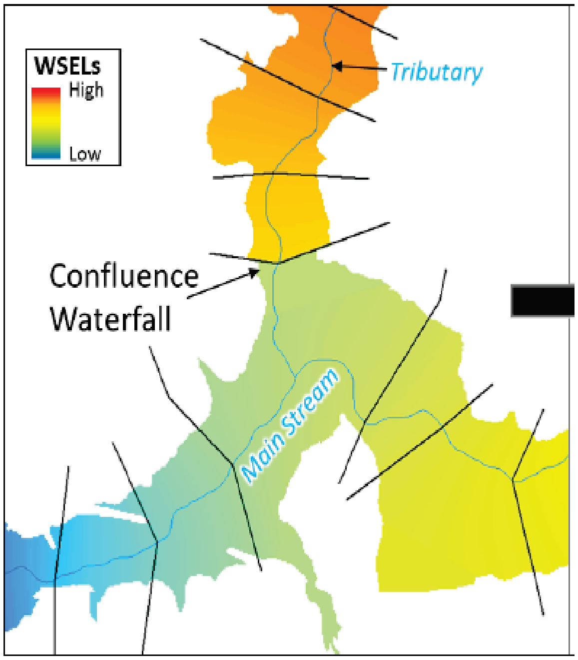
2.6.4 Confluences and Backwater

For 1-D models, confluences require special care and checking to make sure the WSEL grid is produced appropriately and compliant with standards. In a 2-D model that comprises multiple flooding sources, WSEL grids are already generated correctly to reflect backwater effects at confluences, due to the networked nature and hydrodynamics of that type of model. However, many Flood Risk Projects that use 1-D analysis methods do so by modeling individual streams one at a time, and therefore, backwater effects from larger streams are often accounted for as a mapping exercise after the models are run. Although various methodologies exist for accomplishing this, proper backwater must be reflected within the WSEL grids so as to comply with standard ID #415.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 17

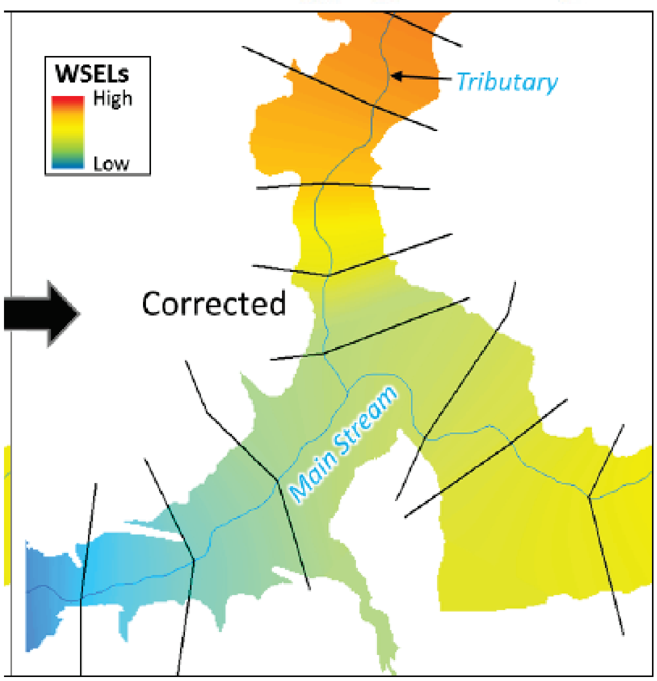
Correct Example:

Figure 16: Confluence Mapping Error – Gaps & Waterfalls



Incorrect Example:

Figure 16: Confluence Mapping Error – Gaps & Waterfalls



2.18. WSE_19

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_19	WSEL raster matches static BFE elevation where applicable (ponding areas, coastal zones, etc.)	Guidance: Flood Depth and Analysis Grids (FEB2018) - A. Section 2.2 Coastal WSEL Grids; Page 5-7. B. Section 2.3 Shallow Flooding and Ponding WSEL Grids; Page 7-8.	FRP QC Tool check 1.3.0.2

Reference Example:

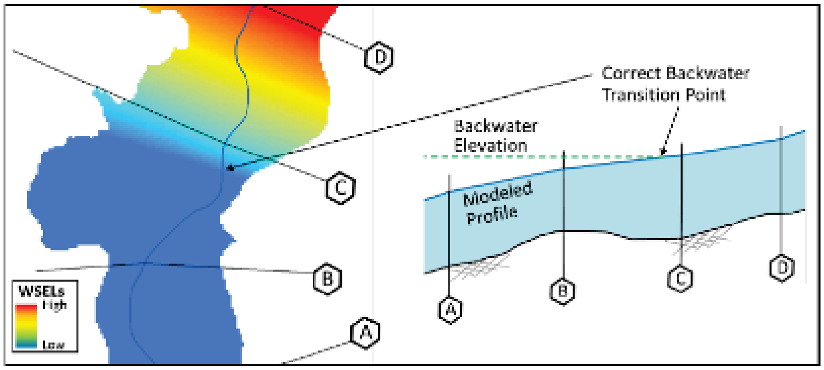
2.6.4.4 Static Backwater vs. Gradient

Care must be taken to avoid introducing inaccuracies into the WSEL grid on account of the methodology used to map backwater areas. Because many out-of-the-box GIS raster mapping approaches will only map a raster within the bounding area created by the cross-sections (see Figure 19), some backwater fingers would incorrectly be excluded from the WSEL grid without additional effort. It is not recommended to simply extend the cross-sections far enough so that these backwater areas will be mapped. Depending on the size of the backwater finger and the slope of the stream, doing so can result in a gradient from one side of the stream to the other, whereas in reality, a static flooding scenario should be depicted. Although there may be scenarios where this gradient is negligible (less than a 0.1 feet difference), it is recommended to apply a static backwater elevation so as to avoid any gradients introduced in backwater areas, where one side of the floodplain would incorrectly be at a higher elevation than the

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 19

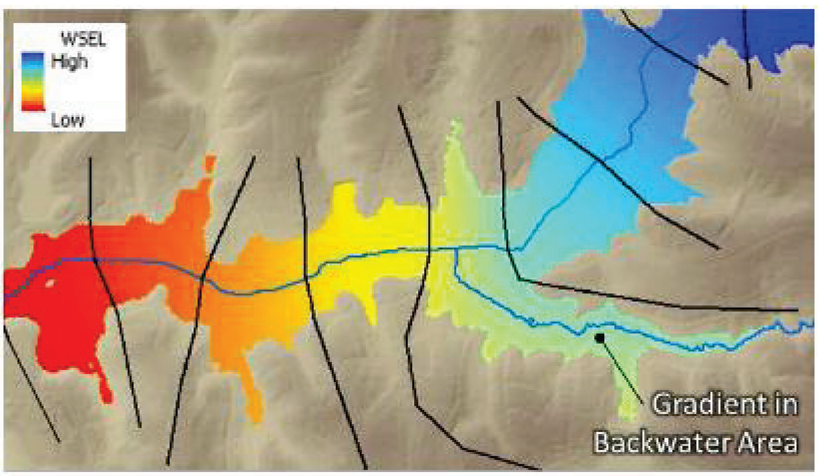
Other valuable discussion is offered associated with Figures 18 and 19 within the Flood Depth and Analysis Grids Guidance.

Figure 18: Backwater Elevation Transition Point at Confluences



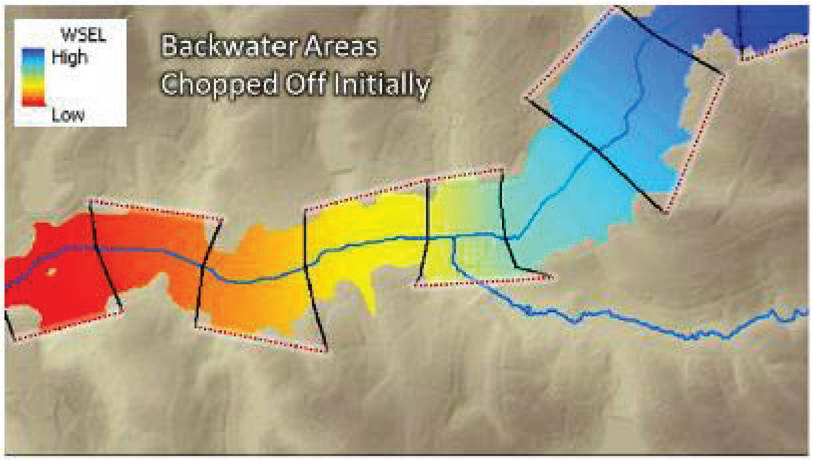
Correct Example (Riverine):

Figure 19: Overextended Cross-Sections can Create False Backwater Gradients

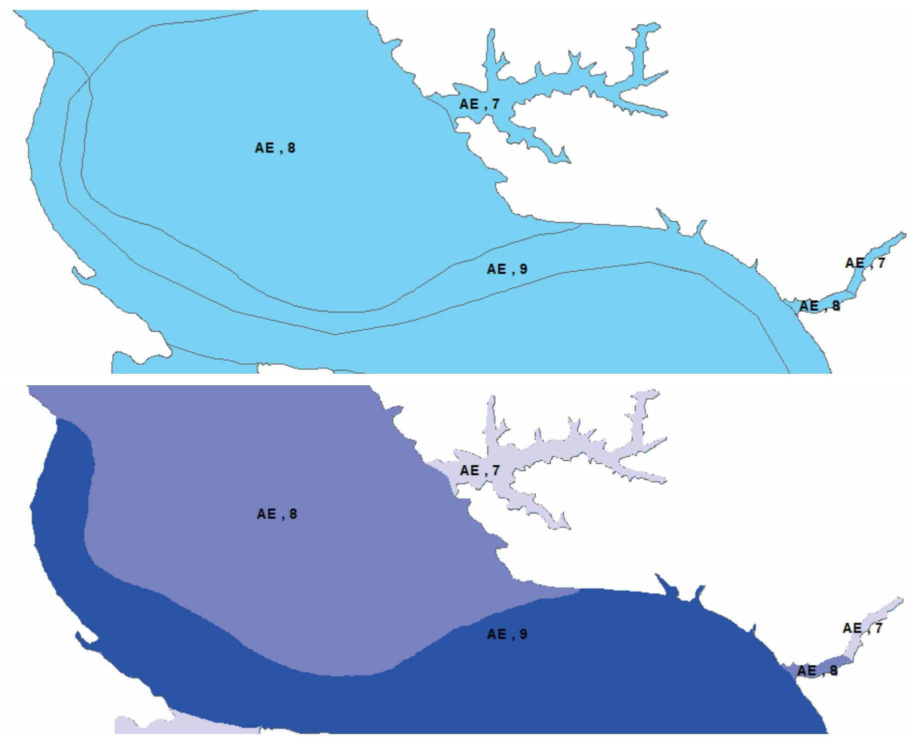


Incorrect Example (Riverine):

Figure 19: Overextended Cross-Sections can Create False Backwater Gradients



Static BFE Example (Coastal):



Static values are utilized without alteration; Direct 1 To 1 value translation. See Sections 2.2 and 2.3 of Flood Depth and Analysis Grids Guidance (Pages 5 to 8).

2.19. WSE_20

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_20	Elevations for WSEL raster cells located in between cross sections are greater than or equal to the elevation at the downstream QC XS and less than or equal to the elevation at the upstream QC XS	Guidance: Flood Depth and Analysis Grids (FEB2018) - Section 2.6.3 Elevation Accuracy; Page 13.	GIS software can be used

Reference Example:

2.6.3.2 Elevation check in between modeled cross-sections

The WSEL change from cell to cell should be gradual and consistent in between consecutive modeled cross-sections along a reach of stream. Abrupt changes should not be present. WSEL grid cell elevations should be less than or equal to the elevation of the upstream cross-section and greater than or equal to the elevation of the downstream cross-section.

Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 15

Discussion:

There are known differences that can result from the Geographic Information System (GIS)-based methods employed to model 1-D water surface elevations. Differing hydrologic and hydaulic (H&H) modeling software packages may utilize differing water surface modeling methods, which could result in data products that are not the same from one method to another just as well as from one software package to another. These differences are entirely precluded by the models that are considered acceptable by FEMA for floodplain mapping. Therefore, while a straight cross section to triangulated irregular network (TIN) interpolation may yield a different result than may be produced by USACE's HEC-RAS Mapper (or any other approved 1-D modeling software that also generates water surface rasters), there is no pure prescriptive method that producers must adhere to when generating water surface rasters - the only exception being that producers are meeting applicable WSE Standards and WSE Quality Control (QC) Checks.

There are however certain distinct guidelines that should be followed in order to avoid introducing erroneous errors that are totally independent of H&H software or GIS-based water surface interpolation methods/tools employed. The following common mistakes are well-captured in the Flood Depth and Analysis Grids Guidance; producers are encouraged to refer to the guidance documentation, but visual examples are reproduced below:

Common Issue Examples:

Figure 14: Importance of WSEL Grid Elevation Checks in Between Cross-Sections

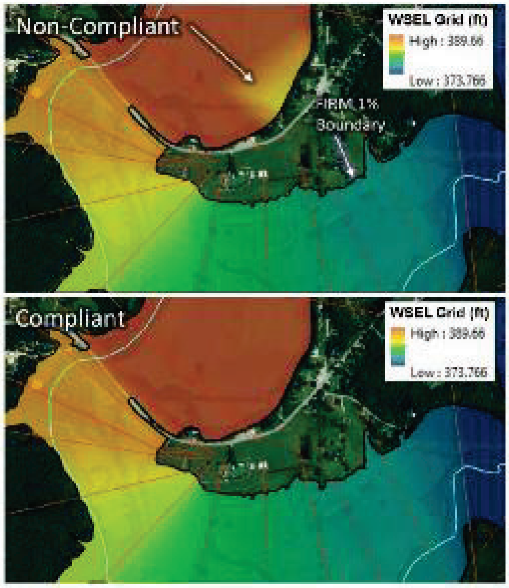


Figure 15: Slope Raster Reveals WSEL Grid Anomalies in Between Cross Sections

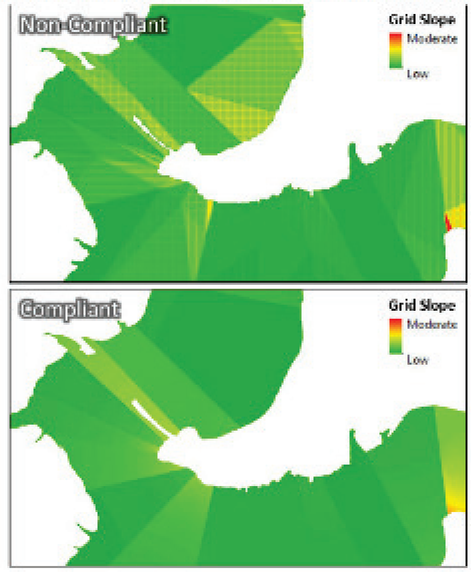
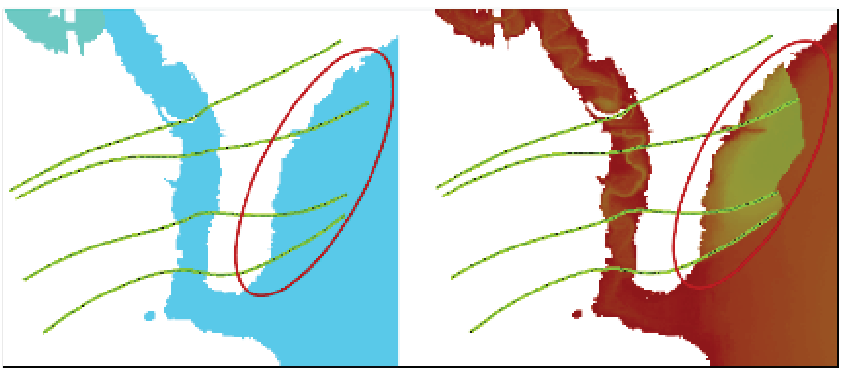


Figure 9: WSEL Grid Errors Resulting from Untrimmed Cross-Sections



2.20. WSE_21

ID	Raster Compliance Check	G&S Reference	Check methodology
WSE_21	WSEL raster values for a given recurrence interval are greater than next lower recurrence interval and lower than next higher recurrence interval (if data are available for assessment) *For example, the 1% WSEL raster value at each cell is greater than the 2% WSEL raster value, but lower than the 0.2% WSEL raster value at that same cell.	Guidance: Flood Depth and Analysis Grids (FEB2018) - 2.6.3.2 Elevation check in between modeled cross-sections; Page 15-16 (Figure 14 & 15).	GIS software can be used

Reference Example:

2.6.3.2 Elevation check in between modeled cross-sections

The WSEL change from cell to cell should be gradual and consistent in between consecutive modeled cross-sections along a reach of stream. Abrupt changes should not be present. WSEL grid cell elevations should be less than or equal to the elevation of the upstream cross-section and greater than or equal to the elevation of the downstream cross-section.

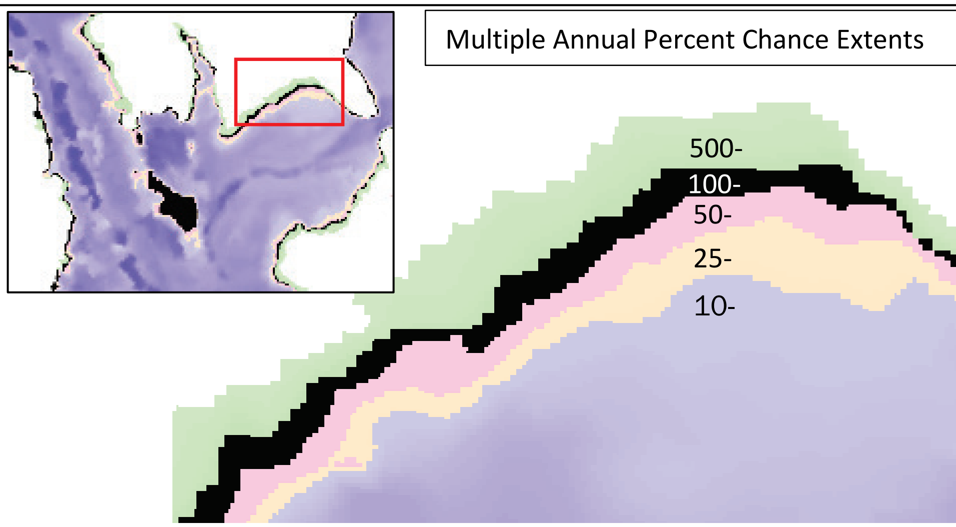
Guidance for Flood Depth and Analysis Grids (Feb 2018); Page 15

Discussion:

Under most modeling circumstances the water surface value from next lower recurrence interval will result in a value that is equal or lesser than next higher recurrence interval for any given cross section. Furthermore, when cross sections and modeling components are then translated into water surfaces, there is an equal expectation that any cell of a lower recurrence interval will result in a value that is equal or lesser than next higher recurrence interval. Therefore, if and when a lower recurrence interval water surface value is higher, an issue exists and must be resolved. The images below depict the expected progression, and the following offers a tabular comparison:

	Example 1		Example 2		Example 3
Recurrence Interval	**WSE Raster Value**		**WSE Raster Value**		**WSE Raster Value**
10-percent-annual-chance	25.6		25.6		25.6
4-percent-annual-chance	26.1		26.1		26.1
2-percent-annual-chance	26.8		26.8		31.1
1-percent-annual-chance	28.2		26.8		26.8
0.2-percent-annual-chance	30.5		30.5		30.5
	This is OK		This is OK		**Error**
	Water Surface Values Ever-Increase		Water Surface Values Ever-Increase; exception two intervals are the same.		Issue with the 2-percent-annual-chance

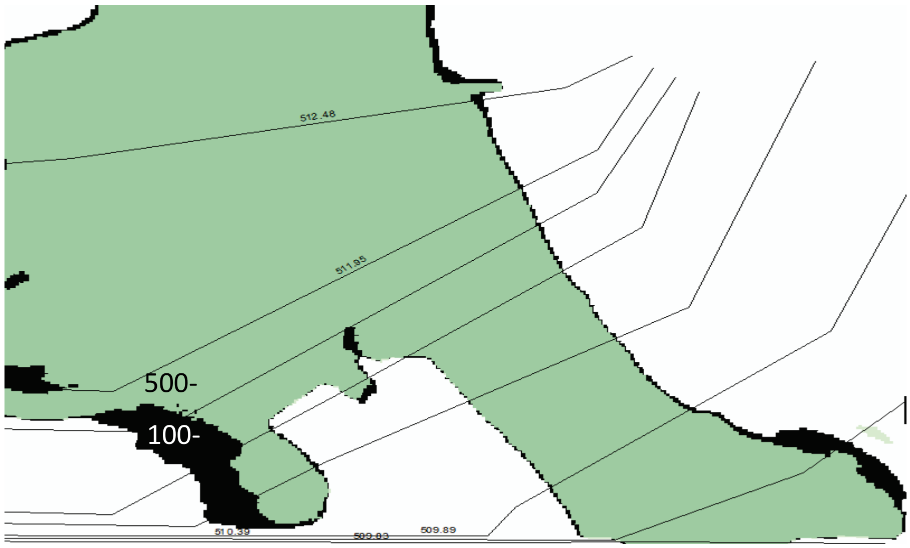
Correct Example:



- 10-percent-annual-chance is *contained by* 4-percent
- 4-percent-annual-chance is *contained by* 2-percent
- 2-percent-annual-chance is *contained by* 1-percent
- 1-percent-annual-chance is *contained by* 0.2-percent
- 0.2-percent-annual-chance ***contains all lower frequency events***

Incorrect Example:

1% and 0.2% Annual Percent Chance



- 1-percent-annual-chance is **NOT** *<u>contained by</u>* 0.2-percent
- 0.2-percent-annual-chance **DOES NOT** ***<u>contain lower frequency event</u>***