Elevation-Derived Hydrography Acquisition Specifications 2023 rev. A2

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Introduction

This document is a copy of the Elevation-Derived Hydrography Acquisition Specifications 2023 revision A2 as found on the USGS National Geospatial Program Standards and Specifications website. For the latest version of the specification, please visit the site: Elevation-Derived Hydrography Specifications.

Schema

Elevation-Derived Hydrography 1.4

Revision History

Version 2023 rev. A2

- Corrected Indefinite Surface Connector channelized segment length special case to include a length for the contiguous United States and Alaska.

Version 2023 rev. A

- The Low Confidence Area features are removed from the elevation-derived hydrography feature types.
- The reservoir feature type is removed from the elevation-derived hydrography feature types.
- Stream/river special condition added for complex interlacing channels.
- Changed or added additional EClass Domain Codes.
- Updated the Feature Type Description, Associated Geometry, and Use Classification Table with new EClass and FClass combinations as needed. This resulted in changes to some feature attribution information in the Elevation-Derived Hydrography Representation, Extraction, Attribution, and Delineation (READ) Rules 2023 rev. A.
- Added FlowClass field to line feature class attributes.
- Add Limitation field to point, line, and polygon feature class attributes.
- Changed name of Sink/rise feature to sink.
- Removed references to the National Hydrography Dataset (NHD) and replaced with elevation-derived hydrography or 3D Hydrography Program (3DHP) where appropriate.
- Ice Mass, Pipeline, and Non-NHD Connector FClass changed from 1 to 2.
- Removed the Feature type description, associated geometry, and use classification table from the Elevation-Derived Hydrography READ Rules 2023 rev. A. and referred the reader to the Elevation-Derived Hydrography Acquisition Specifications 2023 rev. A.
- Reformatted tables and in some case separated information into new tables for easier understanding.
- Changed geoid model to require GEOID18 specifically, instead of most recent.
- Clarified that Sink features may overlap a Playa feature.

Version 2022 rev. A

- Removal of AOCCs from Elevation-Derived Hydrography Specifications and from Task Orders.

Version 2021 rev. A

- Drainageway Definition Updated
    - Old Definition: A drainageway is a watercourse that conveys, or is likely to convey water but lacks a clearly defined channel or banks differentiating it from an ephemeral stream/river. Drainageways typically convey water for limited periods of time and do not carry perennial flow. Drainageways may follow natural topographic flow paths or constructed or human-made flow paths.
    - New Definition: Drainageway features are flowlines delineated where terrain modelling indicates potential headwater drainage but no channel is detectable. The drainageway code must only be applied at the initiation of flowlines or confluence of other drainageway features. The drainageway code must not be applied downstream of other non-drainageway NHD flowlines or waterbody features.

- Four New Elevation-Derived Hydrography Connector FCodes added to Connector Type
    - Culvert (FCode: 33401)—A subsurface feature connecting upstream and downstream hydrography features under a constructed feature (Exception: See READ Rules "Connector" for Dam Features). Typically constructed of formed concrete or corrugated metal and surrounded on all sides; top, and bottom by earth or soil. The hydrographic features defined by this specification are intended to be suitable for elevation surface treatments such as hydro-enforcement. Culvert features are used to maintain connectivity of hydrographic network features, while providing attribution allowing the culverts to be easily identified for elevation surface treatments such as hydro-enforcement.
    - Indefinite Surface (FCode: 33404)—Indefinite Surface Connectors are used where evidence of channelization is not present in the digital elevation model surface but connectivity between an upstream and downstream channel is indicated by terrain modelling. Situations where Indefinite Surface Connectors may be used include low confidence areas in the DEM or heavy vegetative cover in which the channel cannot be resolved. Indefinite Surface Connector features may also be used to connect through areas having conservation treatments such as grassed waterways, which are designed to prevent soil erosion and the formation of channels. This FCode is recommended for use in situations where streams sink into the ground under low or normal flow conditions, but would flow over the surface during high flow or flood conditions and connect to downslope hydrographic features.
    - Terrain Breach (FCode: 33405)—Used to breach terrain (or elevation) features that block the flow in a drainage network, such as a small rise in elevation, landslides, moraines, glacial till, or berms. This connector is used to breach flow blockages on the elevation surface; with no known manmade feature such as a

pipeline or culvert connecting upstream and downstream flow. Do not use the Terrain Breach to represent underground flowpaths in known karst, permafrost or thermokarst terrain (See READ Rules for "Underground conduit").

- Non-NHD Dataset (FCode: 33410)— Used to provide network connectivity to or through a polygon feature that is represented in an external dataset maintained by another agency such as the National Wetlands Inventory, the Randolph Glacier Inventory, or other datasets related to hydrography. This connector will be used to traverse areas with no obvious network connections. Linear and polygon features that represent Stream/river or Canal/ditch flowpaths through the non-NHD dataset areas will be mapped as separate elevation-derived hydrography features. This connector shall be used with a dataset recognized by the USGS for these purposes.

Version 2020 rev. A

- Underground Conduit FCode
  - "Positional Accuracy Indefinite" (FCode 42002) — The underground conduit allows network connectivity through areas where there is some evidence the water flows underground in karst and thermokarst regions.

- UniqueID Field
  - The UniqueID field is meant to be populated by the contractor prior to delivery of data to the USGS. Unique IDs allow communication with contractors by providing a tracking system for individual features.

Collection Area

The collection area refers to the geographic extent where the elevation source exists and from which hydrography will be derived. Hydrographic features can be collected at the same time elevation source data are being processed or taken from an existing 3D Elevation Program (3DEP) collection, when available. Collection areas from multiple sources of elevation data should be inspected and tile and collection area boundaries shall edge-match seamlessly and without gap prior to deriving hydrography.

Collection Concurrent with Elevation

Features shall be collected within the same defined project area (DPA) as the source elevation data (figure 1).

- Hydrography will be delineated for the entire DPA.
- Parts of the DPA within a complete 10-digit hydrologic unit will have complete network connectivity.
- Areas outside a 10-digit hydrologic unit, but within the DPA, will be connected and network connectivity created where possible.
  - Linework will not be snapped to less accurate features outside of the DPA.

- A complete set of features shall be captured up to the boundary, but topology and network connectivity may need to be corrected at a later date.

- If elevation-derived hydrography exists adjacent to the DPA, linework will be snapped and merged to create continuous features that do not stop at the DPA boundary (unless it is also a hydrologic unit boundary).

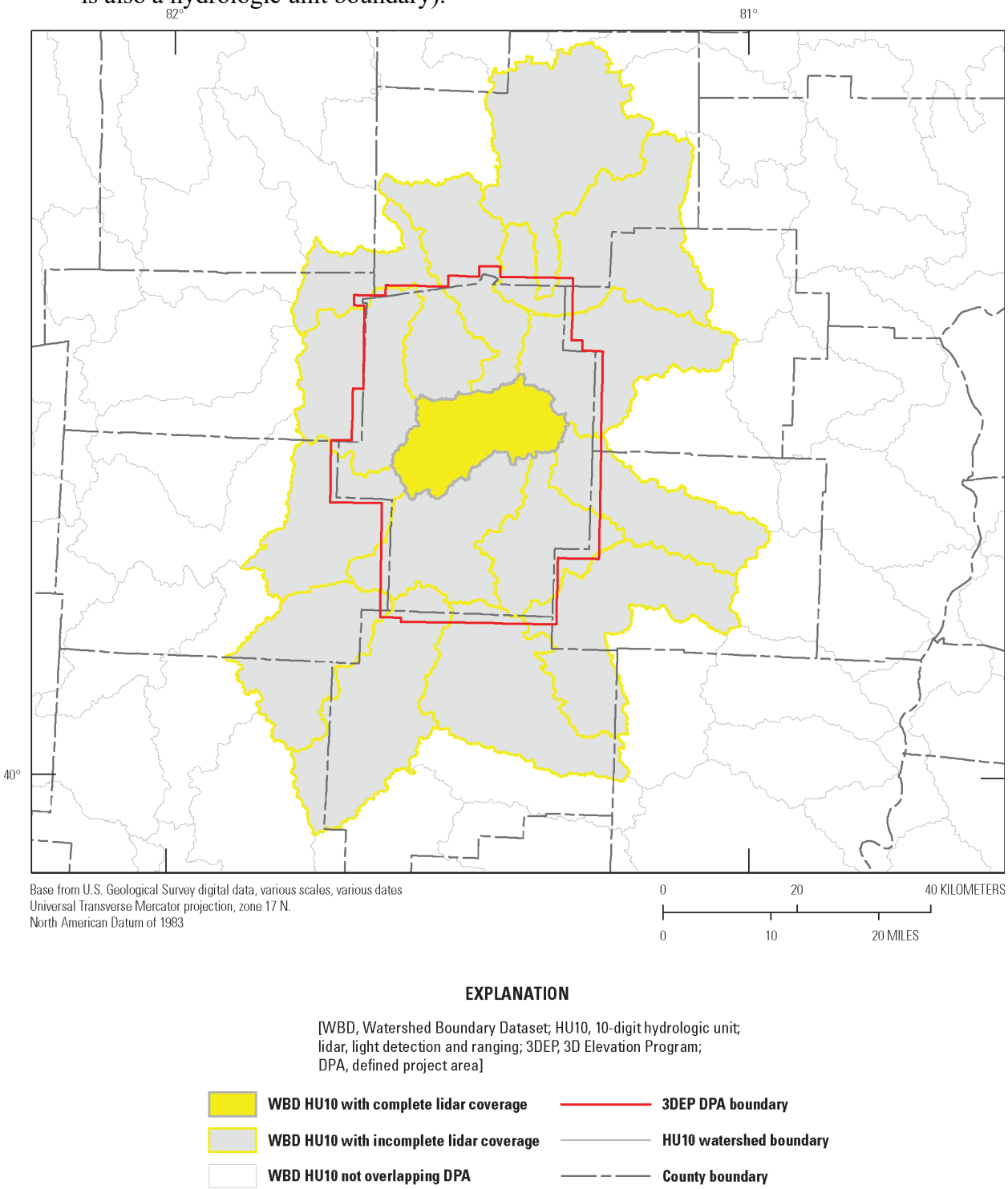

Figure 1. Hydrography collection within a defined project area based on political boundaries.

Collection from Existing Elevation Data

Hydrographic features will be collected within watersheds, as defined by the Watershed Boundary Dataset (WBD). A 10-digit hydrologic unit is the minimum unit size recommended for collection (figure 2).

- Features shall be collected within a minimum 10-digit hydrologic unit area. A buffered area around each 10-digit hydrologic unit will be used to review and delineate features.
- Features that flow from one 10-digit hydrologic unit area to another that contains light detection and ranging (lidar) derived hydrography shall be snapped and topology corrected between hydrologic units.
    - Linear features shall be merged based on the feature code (FCode).
    - Polygons shall be merged with the same FCode.
- If less accurate hydrologic features are the only ones that exist outside of a hydrologic unit, features will not be snapped or adjusted to match those adjacent features.

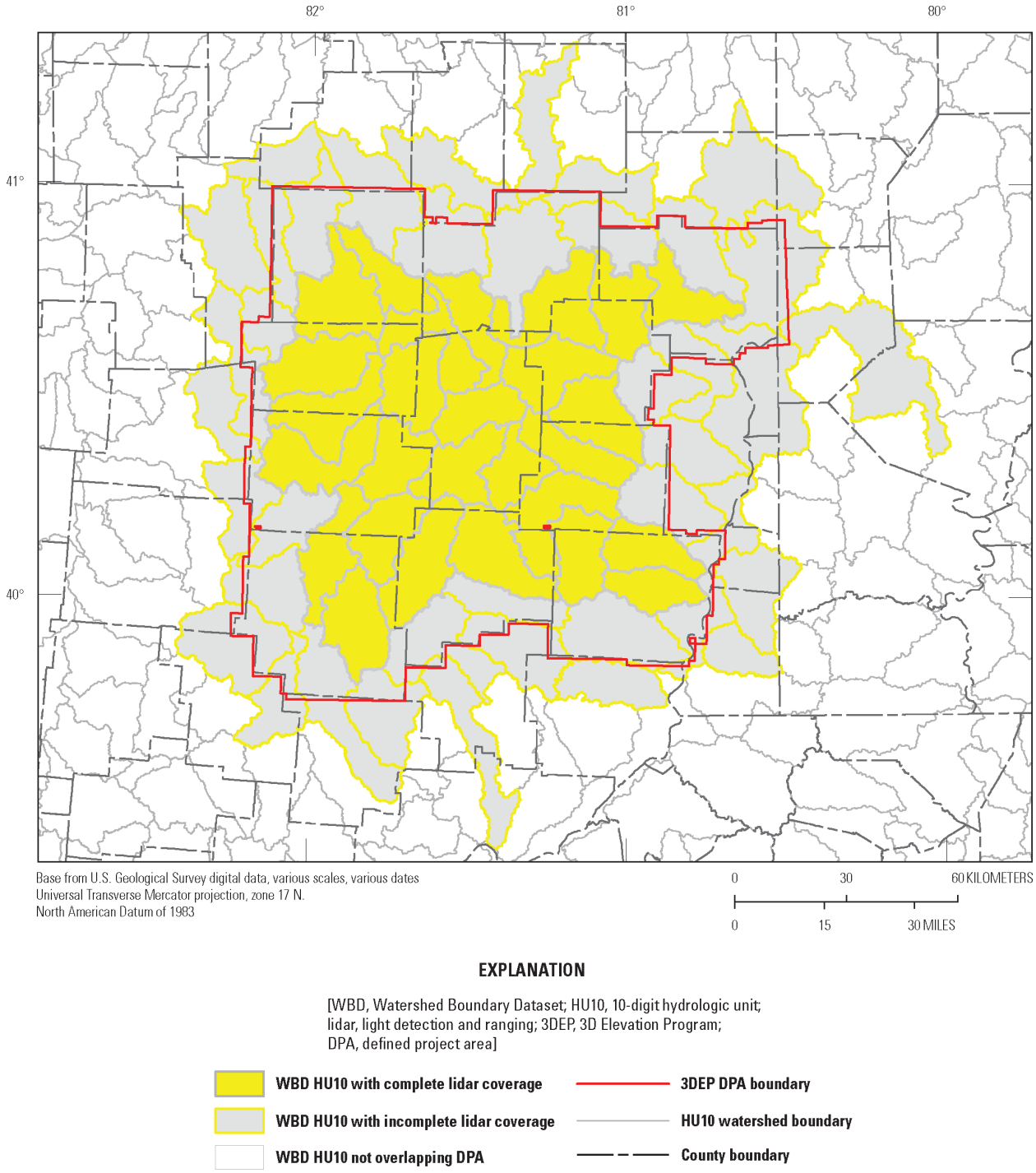

Figure 2. Hydrography collection from existing light detection and ranging source.

Spatial Reference System

Final products shall be in the reference systems defined below. If a collection area is composed of multiple sources of elevation data, all elevation data shall be processed to one common coordinate reference system prior to elevation-derived hydrography compilation.

The digital elevation model used to create the Elevation-derived hydrography shall be:

- Comprised of the best available 3DEP lidar source data or other accepted lidar source data,
- Seamless within the final hydrography defined project area (DPA) boundary,
- Completely encompasses the DPA, plus at least 250 meters outside the DPA, as needed to derive hydrography.

Associated digital elevation model deliverables:

- If 3DEP hydroflattening breaklines are available for the selected elevation datasets, they shall be provided with the elevation derived hydrography delivery as one dataset.
- A spatial metadata layer that describes the source lidar data used.

All geospatial products must meet the following requirements:

- In EPSG:6350 coordinate reference system for CONUS (Contiguous United States).
- In EPSG:3338 coordinate reference system for Alaska.
- For American Samoa, Commonwealth of the Northern Mariana Islands, Guam, Hawaii, Puerto Rico, U.S. Virgin Islands, and other U.S. territories, the following guideline applies:
    - USGS National Geospatial Program and all collection partners shall agree to and specify horizontal and vertical datums, ellipsoids, and geoids in advance of data collection.

Datums

- For the conterminous United States, unless otherwise specified by the user and agreed to in advance by the U.S. Geological Survey (USGS) National Geospatial Program, the following guidelines apply:
    - The horizontal datum for latitude and longitude and ellipsoid heights will be the North American Datum of 1983 (NAD 83) using the most recent National Geodetic Survey published adjustment (currently NAD 83, epoch 2010.00, realization of 2011).
    - The vertical datum for orthometric heights will be the North American Vertical Datum of 1988 (NAVD 88).
    - The geoid model used to convert between ellipsoid heights and orthometric heights will be GEOID18.
- For Alaska, American Samoa, Commonwealth of the Northern Mariana Islands, Guam, Hawaii, Puerto Rico, U.S. Virgin Islands, and other U.S. territories, the following guideline applies:
    - USGS National Geospatial Program and all collection partners shall agree to and specify horizontal and vertical datums, ellipsoids, and geoids in advance of data collection.

Attribute Table Structure

The structure of the attribute tables is described in table 1, table 2, and table 3. An important component of the elevation-derived hydrography features is that they have three-

dimensional (3D) geometry. Each feature type must be z-enabled, with z-values assigned to each point, vertex, and node. The feature classes (pointZ, polylineZ, and polygonZ) are 3D geometry. Each domain is described in table 4, table 5, table 6, table 7, and table 8.

- Feature class (FClass)—A short one-digit integer code describing the hydrographic use of a feature.
    - A 1 is used when a feature is collected to meet the elevation-derived hydrography acquisition specifications. An example of features with an FClass = 1 include a point feature defined as a sink. An example of a line feature with an FClass = 1 is a stream that is too narrow to be represented as a polygon. An example of a polygon feature with an FClass = 1 is a wide river, or a lake/pond.
    - A 2 is used when a feature is outside of the collection criteria. An example is when the features add too much complexity, will not be used for network connectivity, or are outside of the 3D Hydrography Program (3DHP) collection requirements.
    - A 9 is used when a feature is a nonhydrography feature is outside of the 3DHP collection requirements. A line representing a levee, or a dam is an example of a feature that may be useful for elevation processing.
- Feature class for elevation (EClass)—A short integer one-digit code describing the elevation use of a feature.
    - A 0 is used when the feature is not used for elevation derivative.
    - An 11 is used when the polygon derived from the breaklines used for hydroflattening the elevation surface (3D polygon).
    - A 12 is used when the polygon corresponds to a hydroflattened surface, but breakline is either not available, or not horizontally or vertically aligned appropriately with the DEM surface. For use in Alaska or where breaklines do not meet cartographic or horizontal requirements.
    - A 13 is used when the polygon was created without using elevation breakline and the surface of the waterbody is not hydroflattened in the source DEM.
    - A 2 is used for linear hydrographic features that follow the elevation surface. This is the default value.
    - A 3 is used when linear features are below ground level, examples include connectors through dams, culvert connectors, and terrain breach connectors. It is also used for hydro-enforcement.
- FCode—A long integer field containing a coded value. Most of the FCodes are equivalent to the NHD FCode value, which is a five-digit integer code representing various hydrologic feature types. For instance, a lake/pond has an FCode of 39000, and a stream/river has an FCode of 46000. The codes that do not have a corresponding NHD code are included to differentiate features that may be useful in describing limitations in the elevation dataset, potentially affecting hydrography and elevation derivatives.
- Desc—A 250-character free-text field with a text description of FCode, or it can be used for user-defined features not included in the domain list. Not required.
- Source—A 128-character free-text field with a text description of the elevation source data used for deriving the hydrography. Lidar-source data will include collection name, date, and quality level.

- Method—A 250-character free-text field with a text description of the method used for deriving the hydrography. For instance, software or models could be listed, or digitizing techniques, if used. Ancillary datasets could be noted here.
- User-defined code (UserCode)—A 25-character free- text field with a code designated by the acquisition entity to identify features collected outside the scope of features described in this specification document. It is intended to be used as a key to join tables with attributes outside of this specification. Not required.
- Comments—A 250-character free-text field for user comments. Not required.
- UniqueID—A 50-character free-text field that stores a Unique Identifier for each feature in the dataset. The UniqueID is intended to be stable throughout multiple deliveries of a dataset within a project area. The Unique ID field is meant to be populated by the contractor prior to delivery of data to the USGS. Unique IDs allow communication with contractors by providing a tracking system for individual features.
- FlowClass— A short integer one-digit code used in the line feature class that describes whether a feature's flow direction can be determined. In most cases, features will be digitized in the direction of flow and will flow downslope (Flow = 1). In very flat, wetland or tidal areas, it is often impossible to determine the direction of flow (Flow = 0). Water may occasionally flow uphill, such as when a pump is used or, in rare cases, in natural situations. A segment's z-values may flow in an upslope direction in cases where water enters a depression on the landscape and must rise in order to exit the depression. When flow is known to initiate from a lower elevation and discharge to a higher elevation, Flow = 2.
- Limitation— A short integer one-digit code that indicates whether the source elevation contained limitations that create issues meeting vertical or horizontal requirements for the hydrography feature.

Feature Codes and Values

Hydrographic features collected under the scope of this specification document represent a subset of the features included within the NHD. Where appropriate, the FCode values and descriptions match the NHD specifications. Elevation features used as breaklines for hydroflattening, or for other elevation surface treatments, are identified with an elevation class as well as a hydrography FCode. The complete set of domain values required with this specification is provided in table 4, table 5, table 6, table 7, and table 8. The companion document "Elevation-Derived Hydrography—Representation, Extraction, Attribution, and Delineation rules" (READ Rules) further defines the fields, domains, and minimum feature collection requirements for each required feature (Archuleta and Terziotti, 2020).

3D Elevation Program Light Detection and Ranging Base Specification Required Hydroflattening Features

A subset of the features collected for the lidar source projects meeting the Lidar Base Specification (LBS) hydroflattening requirement (U.S. Geological Survey, 2019) can be used directly for waterbody polygon delineations. The elevation-derived hydrography FCodes that correspond to hydroflattening features are cross-referenced in table 11.

Additional User-Defined Features

The primary use for the UserCode field: to identify features that are outside the scope of this specification but are required by the user.

- Additional features (not defined within table 4, table 5, and table 9) may be collected but will be given unique codes in UserCode.
- If the feature is outside the scope of this specification, the following guidelines apply:
    - FClass, EClass, and FCode will be coded as 2, 0 (unless collected to produce an elevation derivative, then 2), and 0, respectively.
    - The Desc field may be used to describe the additional feature.
    - A unique code per feature type will be added to the UserCode field.
    - Codes will not duplicate other defined features or coding used for NHD conflation.

Delineation of Hydrographic Features

Hydrographic features will be captured as either three- dimensional (3D) point, line, or polygon geometry (table 9). Some features may be collected either as 3D lines or 3D polygons, determined by minimum area or length of shortest access (Archuleta and Terziotti, 2020). EClass indicates how the features are used in elevation surface treatments. FClass indicates how the features are used in a hydrography product.

3D Elevation Program Light Detection and Ranging Base Specification Required Hydroflattening Collection

- The features required to meet the hydroflattening requirement may be collected using the specifications outlined within this document (EClass=1).
- The subset of features identified in table 11 can be used to fulfill the hydroflattening requirement.
- Either all EClass=1 features, as defined within this document, can be used to create a hydroflattened surface, or a subset that meets the minimum size for hydroflattening requirements can be used to create a hydroflattened digital elevation model (DEM) to meet the LBS requirements.

Elevation-Derived Hydrography Feature Collection

- The correct geometry shall be used to capture each feature type.
- At a minimum, a hydrographic feature collection shall do the following (see figure 3):
    - capture all features from table 4, table 5, and table 9 that are present in the high-resolution NHD,
    - capture any additional features that meet the capture conditions described in Archuleta and Terziotti (2020), and
    - remove features that are not visible in the lidar data, or appropriate imagery, even if they were in the original NHD.
- Additional features shall be collected for the following reasons (figure 4):
    - if there is clear evidence of the feature in the lidar data source,

- if there is clear evidence of the feature using an appropriate ancillary data source (see table 12 for examples),
- if a method has given good results for delineation of stream channels or other features and it is quality assured using the lidar data and other high-quality ancillary datasets,
- if it is necessary to connect a hydrographic network.

- All criteria described in the following special cases shall be met.

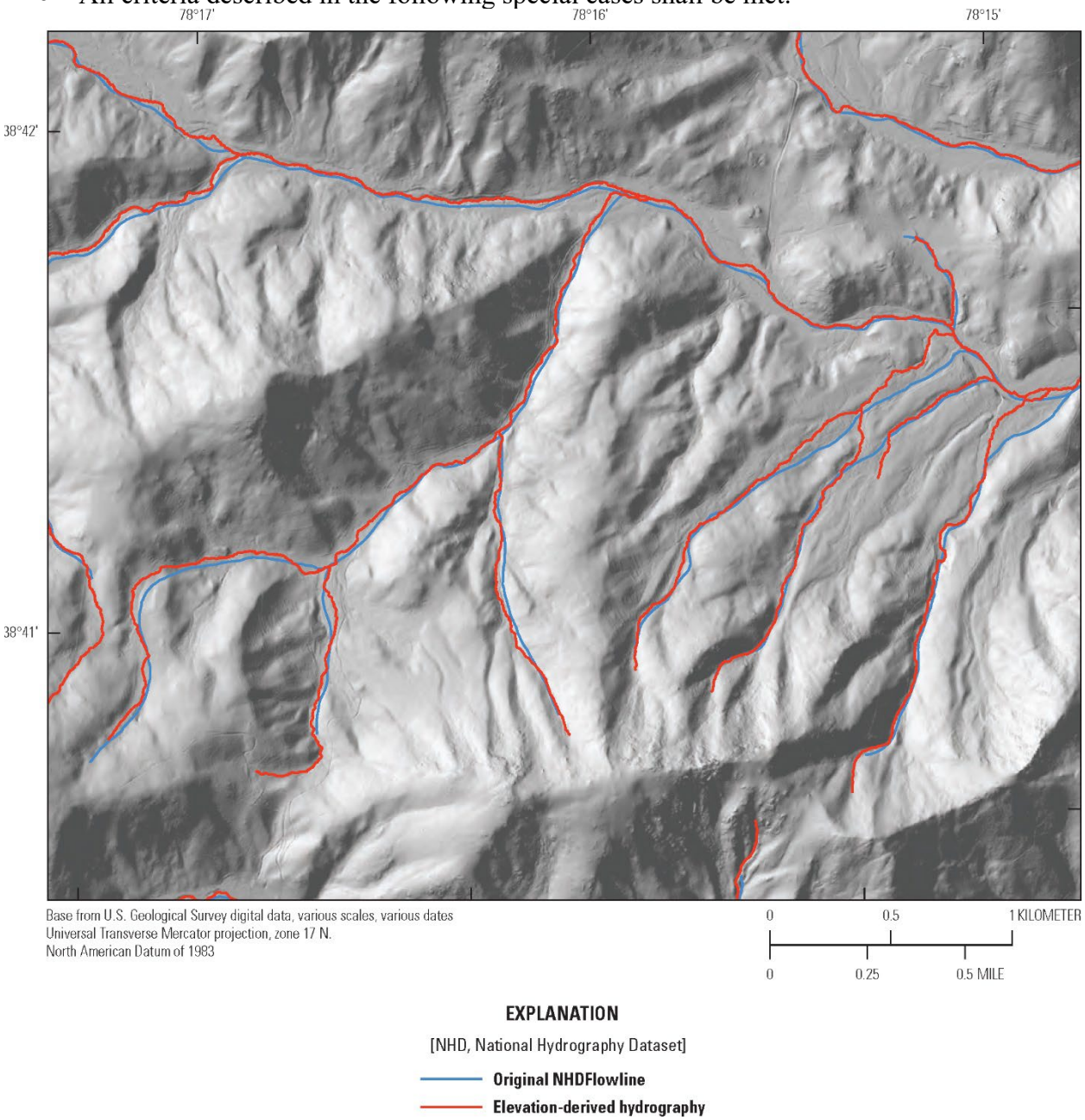

Figure 3. Minimum set of hydrographic features compared to the original National Hydrography Dataset (NHD).

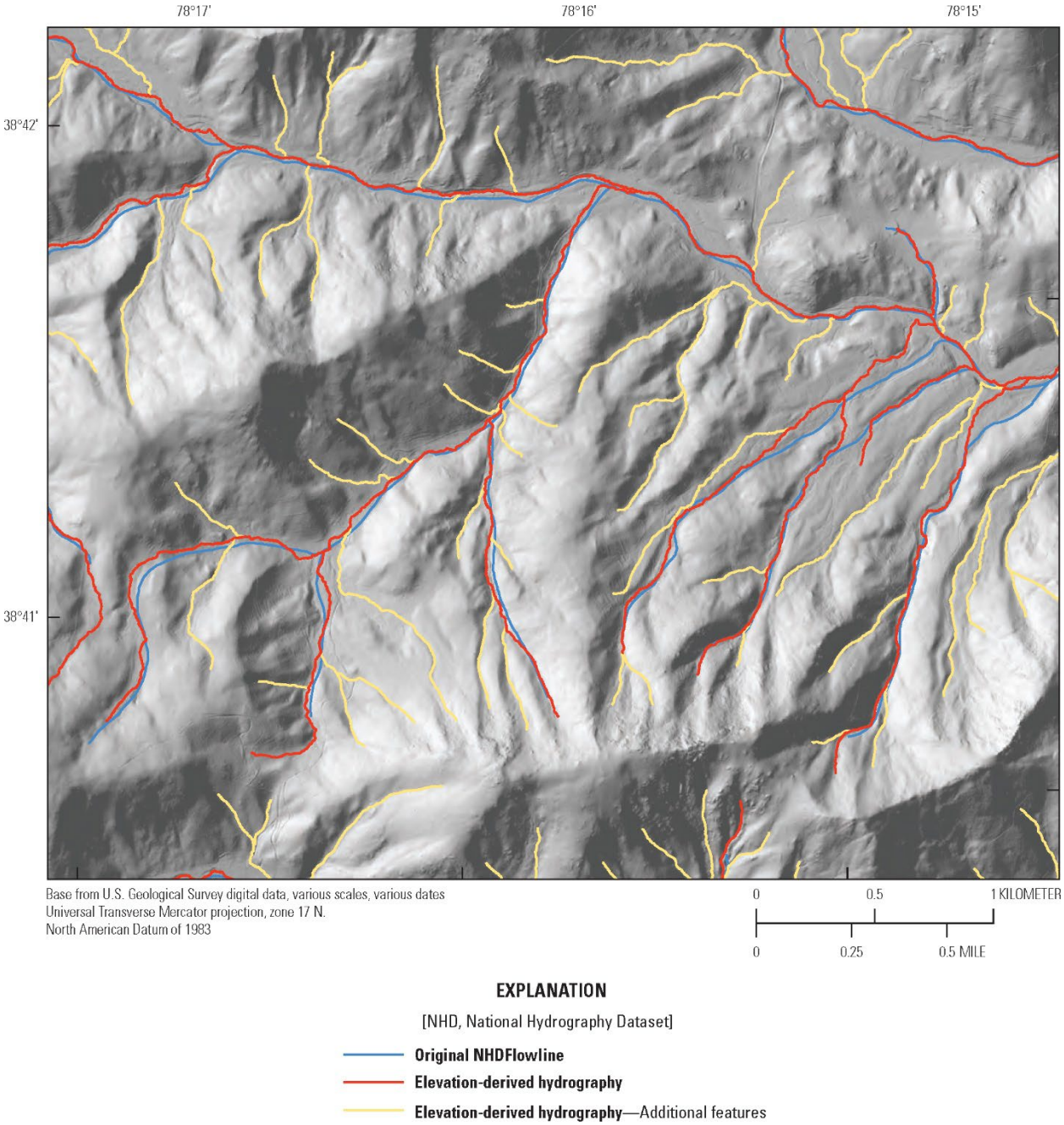

Figure 4. Additional features with visible channels captured from the light detection and ranging-derived elevation surface.

Special Cases

12-Digit Hydrologic Unit Consistency

- New features collected within 12-digit hydrologic unit boundaries will evaluate inconsistencies (figure 5) in line density. New features shall be collected to be consistent with the most densely collected part of the 12-digit hydrologic unit (figure 6).

- Where geomorphology, geology, or other terrain features create actual differences in stream density, the natural representation of features that depicts the disparity in density will be captured.
- If a geographic area has an extremely dense stream network collected to meet local needs, a less detailed depiction of adjacent areas is allowed, but connectivity with major networks shall be maintained (figure 7).

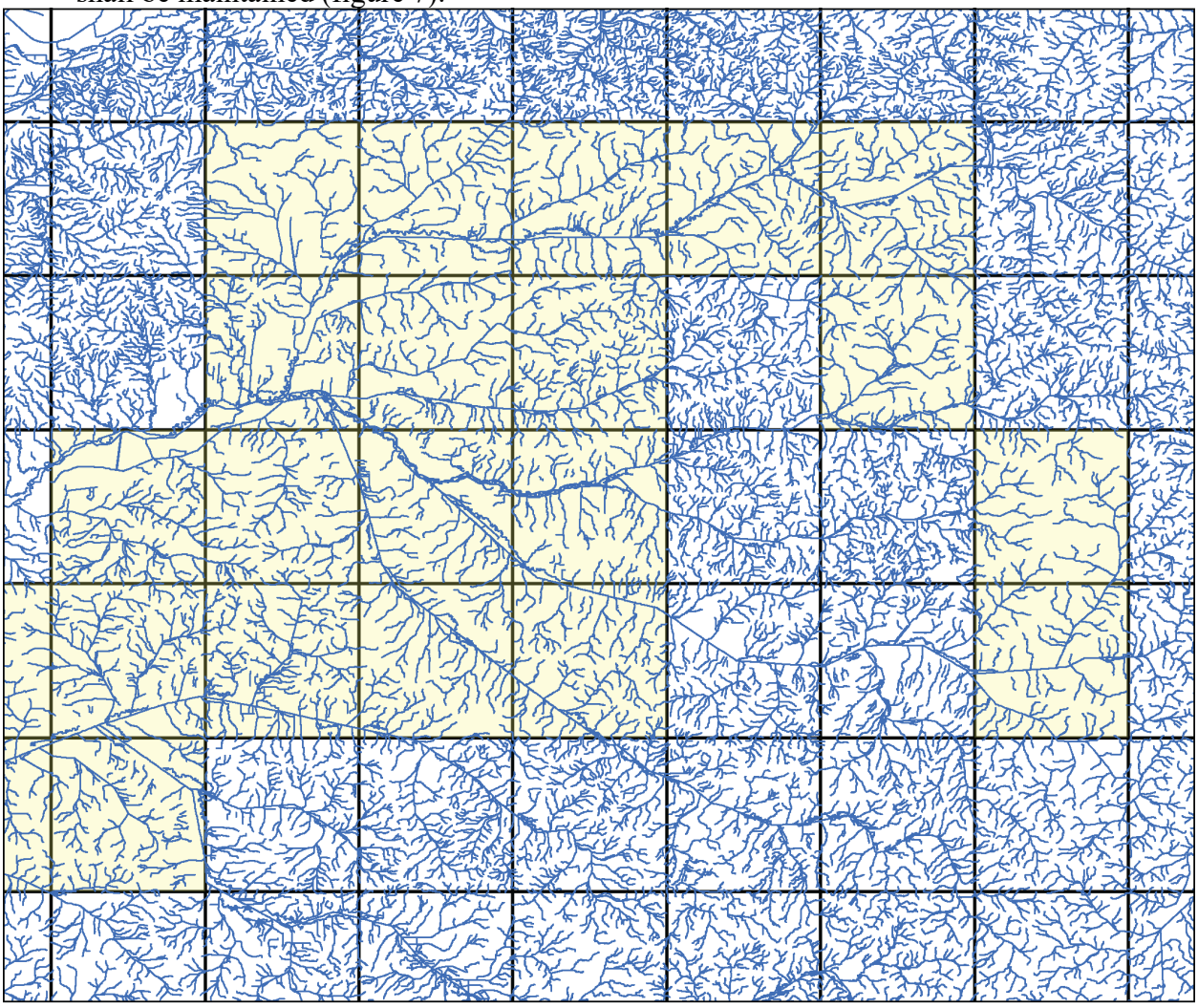

Figure 5. Artifacts within National Hydrography Dataset (NHD) density inherited from original quadrangle map delineation of hydrography.

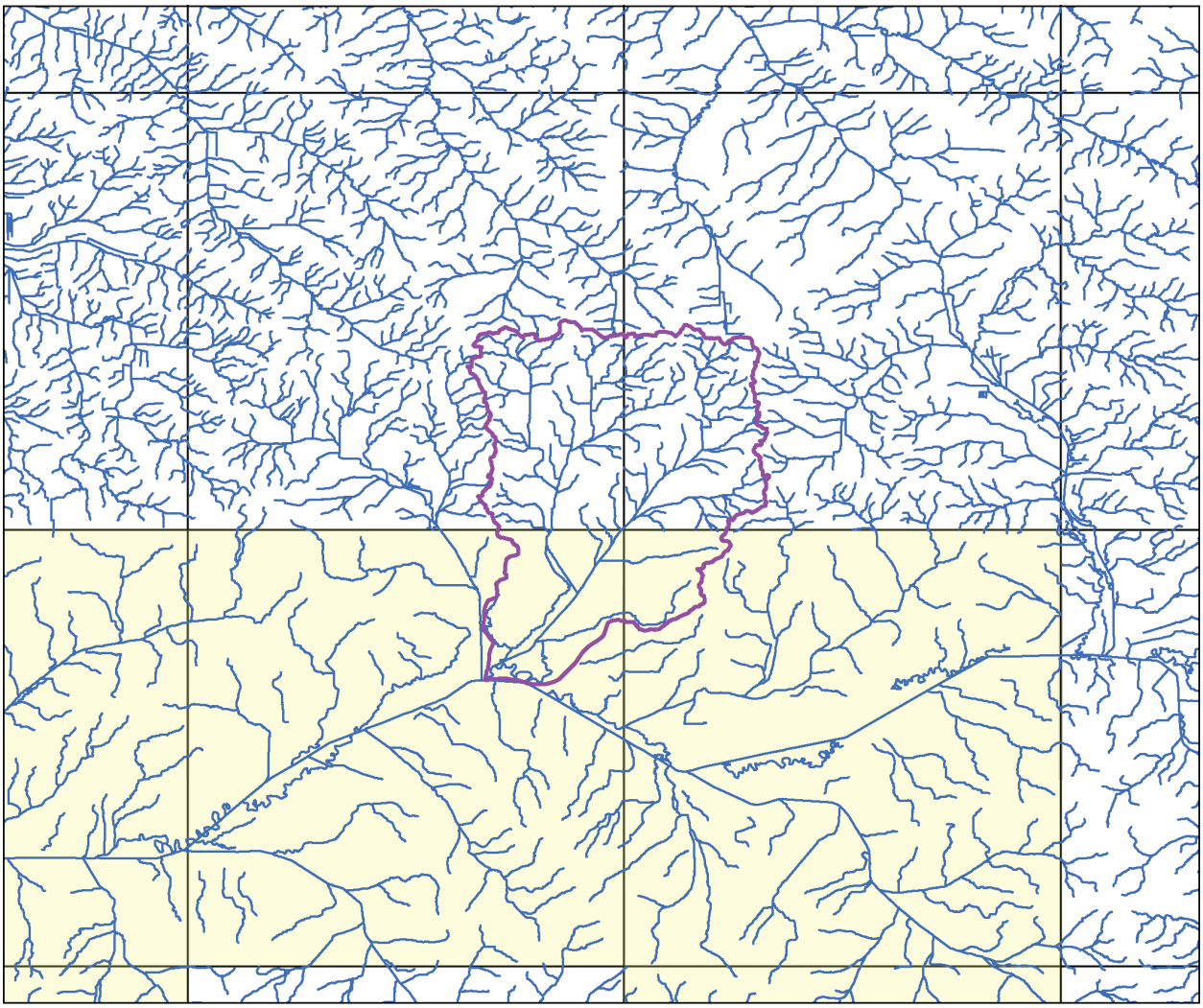

Figure 6. The hydrography within the southern quadrangles of this 12-digit hydrologic unit must be densified to be consistent with the northern quadrangles.

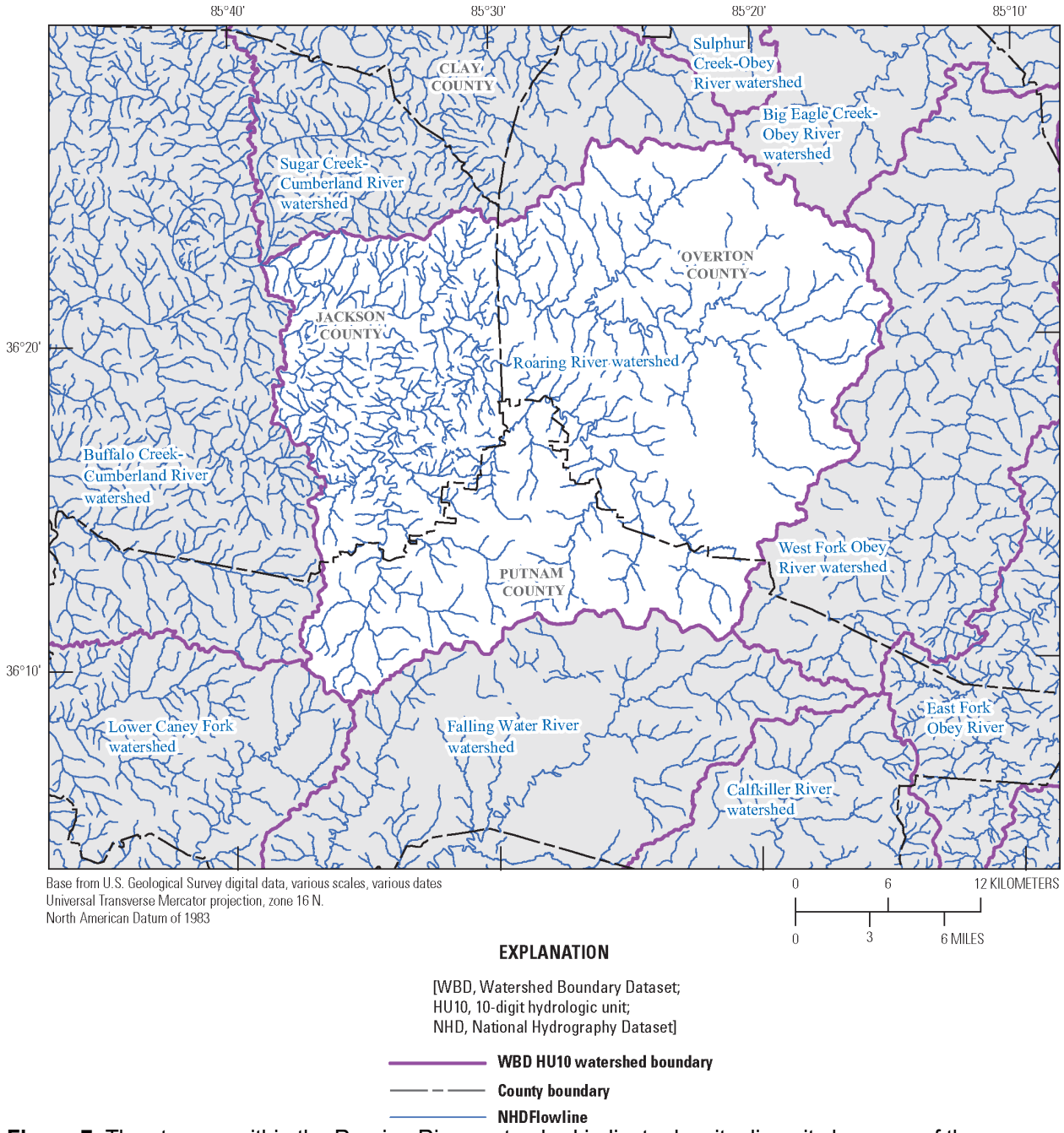

Figure 7. The streams within the Roaring River watershed indicate density disparity because of the collection differences between Jackson, Overton, and Putnam Counties, Tennessee.

Culvert Connector

- The removal of surface points at bridges is done within the bare earth elevation surface to ensure that water features beneath bridges are continuous and shorelines are followed (figure 8). If a bridge was not removed, a hydrography feature below a transportation feature shall be regarded as a culvert.

- A culvert must be a separate feature, nodematched (snapped) at each end to the up and downstream hydrographic features.
- Elevation attribution (EClass=3) will identify the culvert separately (figure 9).
- If a polygon feature contains a culvert within it, the polygon will not be split. The culvert feature shall be delineated on the artificial path of the polygon feature.

Figure 8. Bridge treatment in the bare-earth digital elevation model. The bridge deck is removed, and water surface is interpolated beneath the bridge to maintain a monotonic, continuous water feature.

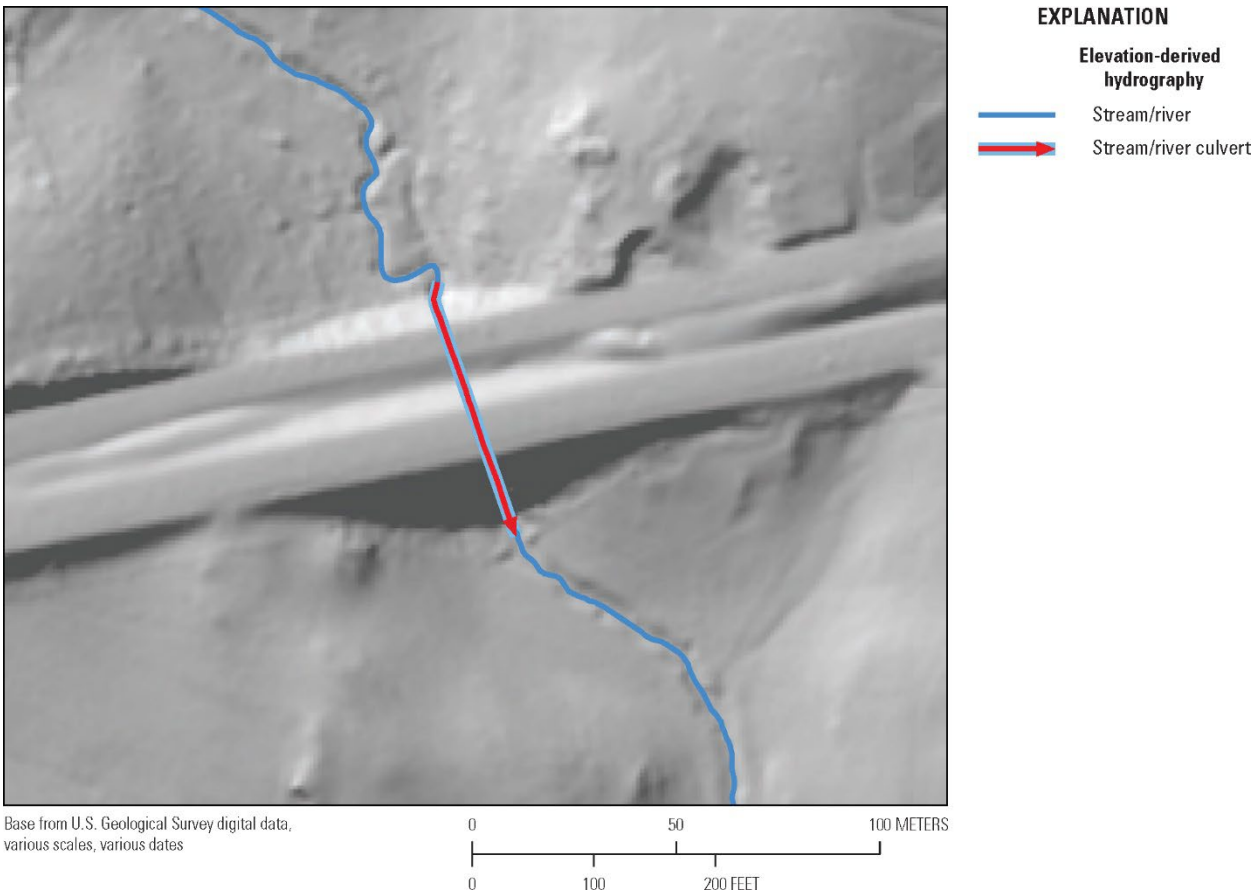

Figure 9. Proper delineation of a culvert feature within a stream segment.

Headwaters at Roads

- Identify any stream whose initiation point (headwater point) is within 100 feet (ft) or 30 m of a road (figure 10).
- If a stream channel is visible (in imagery or a lidar surface) upstream from the road, extend the Stream/river through the road using the rules described for delineation of culverts, and extend the Stream/river at least 100 ft or 30 m upstream from the road intersection.
- If a stream channel is not visible upstream from the road, but there are other indications that a culvert is at the intersection of the road that allows flow to continue into the Stream/river, extend the Stream/river to the road and add a culvert through the road feature. Extending the Stream/river upstream from the culvert is not necessary if a channel is not visible.
- If a stream channel is not visible upstream from the road, and no other indications of a connection between the upstream area and the headwater exist, then no action is required.

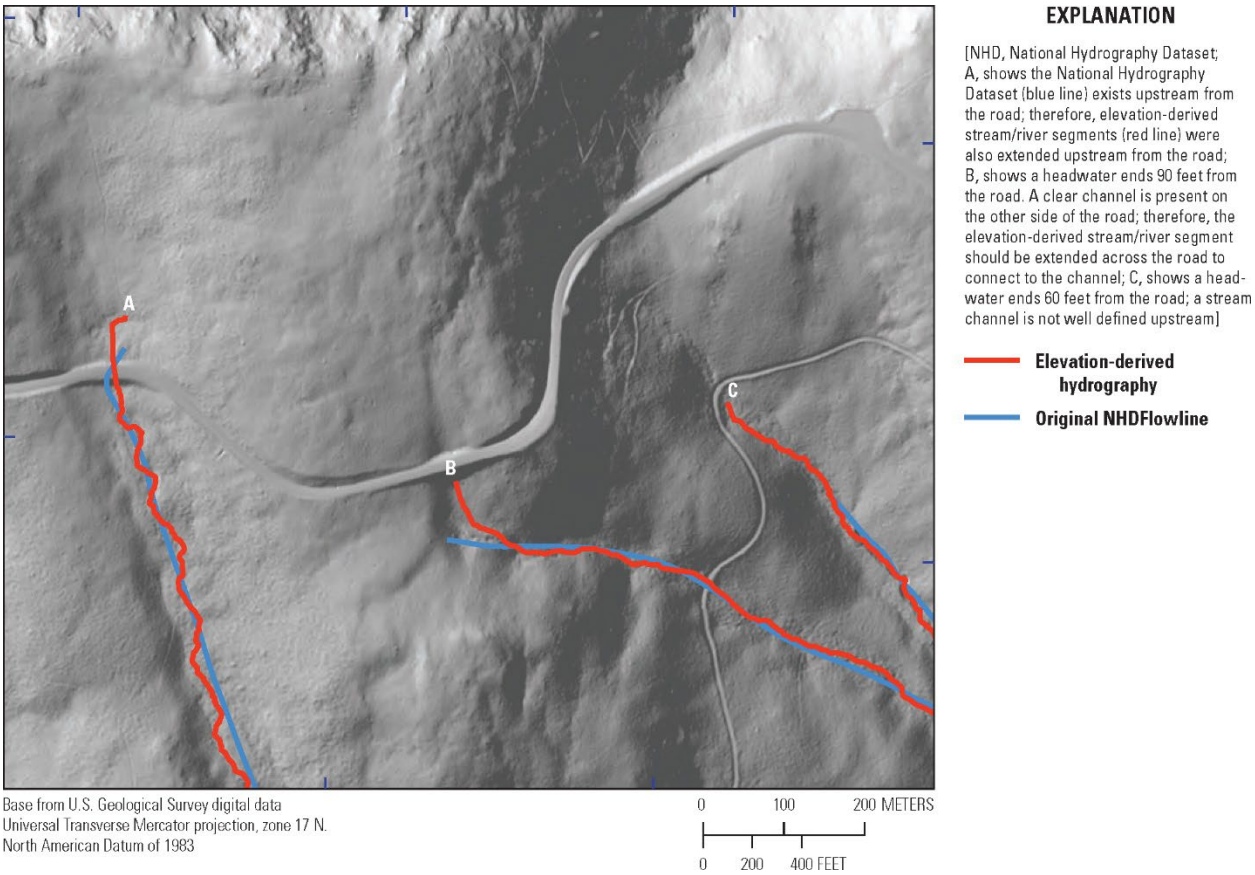

Figure 10. Correcting headwater stream delineation at roads.

Drainageway

- Over mapping features to include some features that are not actual streams may be necessary and cost effective.
- When a high degree of uncertainty exists for headwater features, a feature code (FCode 46800, drainageway) will be used. This code indicates that further investigation is necessary to determine if a hydrographic feature exists on the ground.
- Drainageway features are flowlines delineated where terrain modelling indicates potential headwater drainage, but no channel is detectable (figure 11).
- The drainageway code must only be applied at the initiation of flowlines or confluence of other drainageway features. The drainageway code must not be applied downstream of other non-drainageway flowlines or waterbody features).

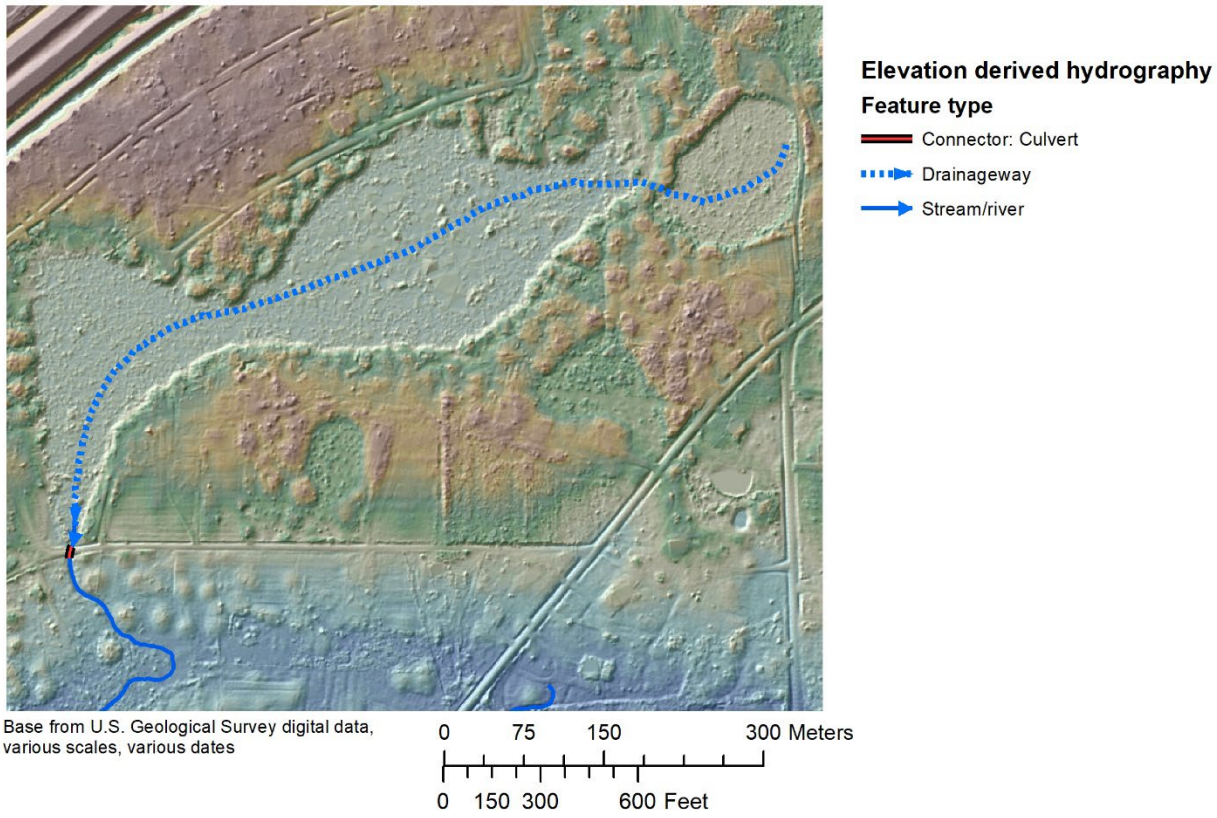

Figure 11. Example map of Drainageway.

Indefinite Surface Connector

- Indefinite Surface Connector features shall be used where evidence of channelization is not present in the digital elevation model surface but connectivity between an upstream and downstream channel is indicated by terrain modelling (figure 12).
    - An Indefinite Surface Connector feature will not have more than 20 percent of the length within a channel.
    - If a section within an Indefinite Surface Connector segment is channelized for more than 100 meters CONUS (200 meters Alaska), it will be split and the section that is channelized will be coded as a Stream/river, Canal/ditch, or other channelized hydrography feature.
- Situations where Indefinite Surface Connector features may be used include low confidence areas in the DEM or heavy vegetative cover in which the channel cannot be resolved.
- Indefinite Surface Connector features may also be used to connect through areas having conservation treatments such as grassed waterways, which are designed to prevent soil erosion and the formation of channels.
- If a feature does not have evidence of channelization, and is a headwater, the Drainageway FCode shall be used.
- The Indefinite Surface Connector FCode is recommended for use in situations where streams sink into the ground under low or normal flow conditions but would flow over the

surface during high flow or flood conditions and connect to downslope hydrographic features.

- Avoid use of the Indefinite Surface Connector FCode if karst terrain indicates underground flow is predominant and year-round (See READ Rules for "Underground Conduit").

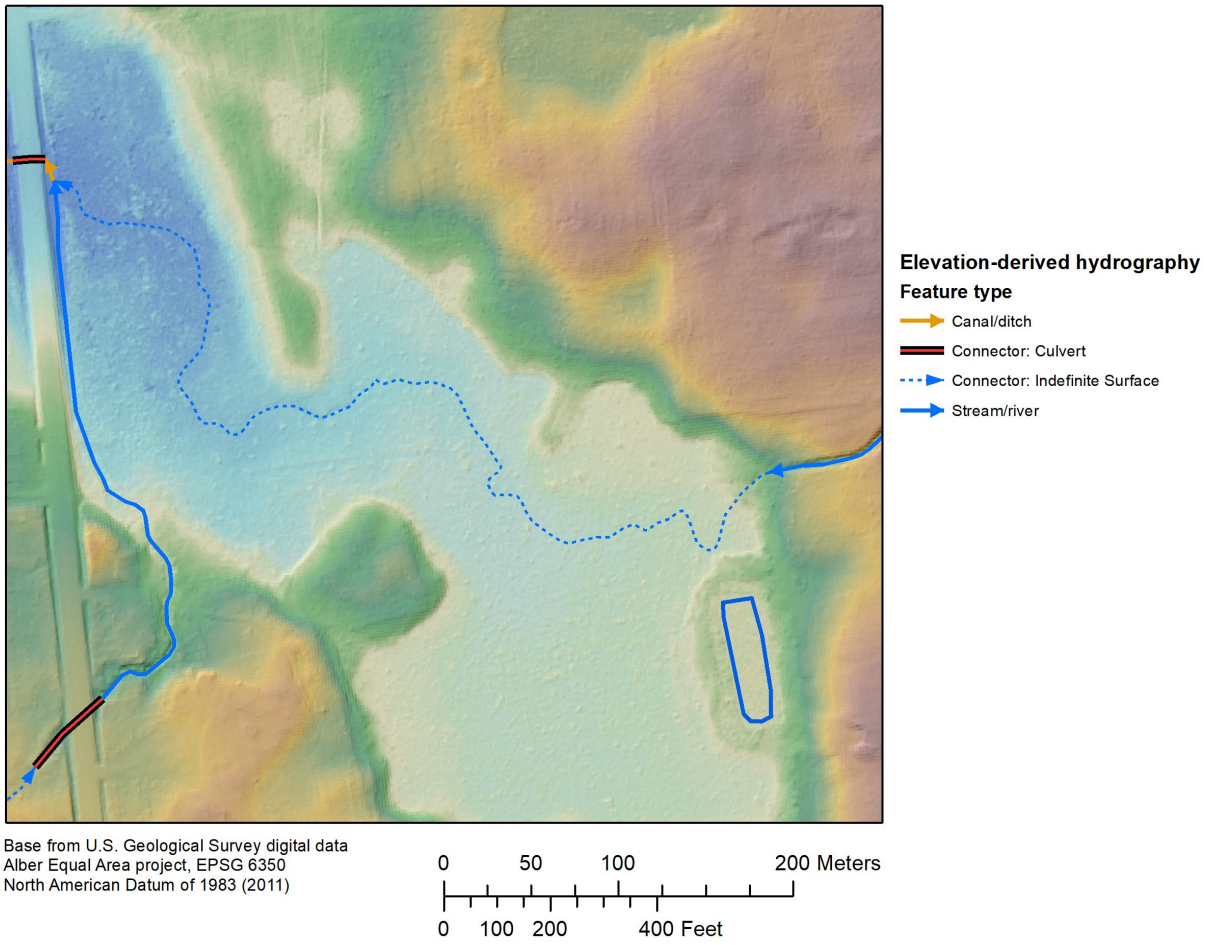

Figure 12. Example map of Indefinite Surface Connector features.

Terrain Breach Connector

- Used to breach terrain (or elevation) features that block the flow in a drainage network, such as a small rise in elevation, landslides, moraines, glacial till, or berms. This connector is used to breach flow blockages on the elevation surface; with no known manmade feature such as a pipeline or culvert connecting upstream and downstream flow (figure 13).
- Do not use the Terrain Breach to represent underground flowpaths in known karst, permafrost or thermokarst terrain (see Underground Conduit in READ Rules).
- A Terrain Breach Connector feature is not necessary:
  - If the rise in elevation requires the z-values along the linear feature to be less than 1 meter below the surface for lidar, or 2 meters below the surface for IfSAR source elevation, or

- if the rise in elevation extends in length for three pixels or less than the source resolution (3 meter for lidar, 15 meters for IfSAR) within the terrain.

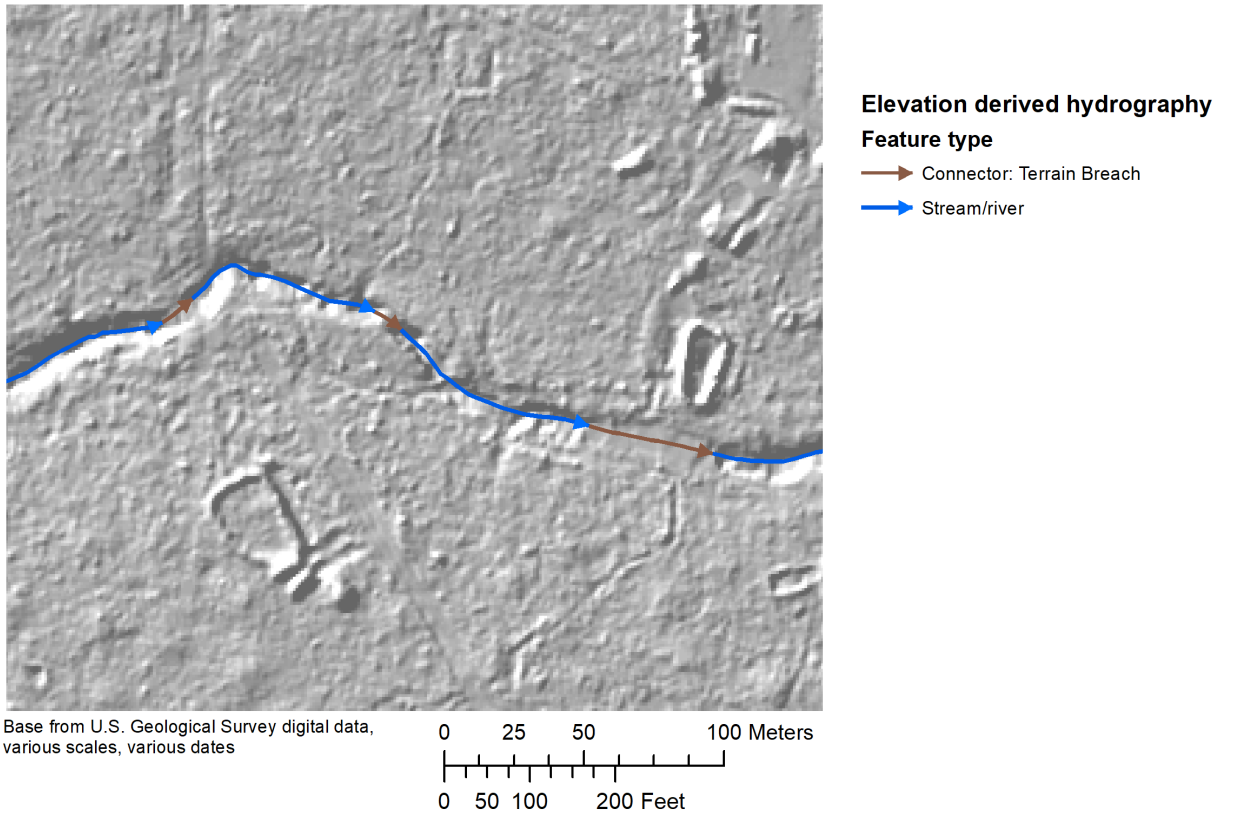

Figure 13. Example map of Terrain Breach Connector.

Non-NHD Feature Connector

- Used to provide network connectivity to or through a polygon feature that is represented in an external dataset maintained by another agency such as the National Wetlands Inventory, the Randolph Glacier Inventory, or other datasets related to hydrography.
- This connector shall be used with a dataset recognized by the USGS for these purposes.
    - Currently there are no Non-NHD datasets approved for use with this connector.

Canals and Ditches

- If a Canal/ditch feature is named, or if a Canal/ditch feature is greater than or equal to 984 ft (300 m) along the longest axis, then it will be captured.
- If a Canal/ditch feature is needed to provide network connectivity, it will be captured.
- If a Canal/ditch feature is within agricultural fields, is less than 300 m, and drains to another Canal/ditch or other hydrologic feature, it will not be captured (figure 14).
- Isolated Canal/ditch features or networks will not be collected unless they are of particular significance to the regional hydrology.

- If a project has a special need for Canal/ditch features not covered by these capture conditions, a separate User- Code attribute should be added to allow those features to be removed from the 3DHP ingestion process.
    - Coding should follow the rules for additional user- defined features:

      FClass, EClass, and FCode should be coded as 2, 0, and 0, respectively. The Desc field may be used to provide a text description. A unique user-defined code should be added to the UserCode field. Codes should not duplicate other defined features or coding needed for 3DHP ingestion.

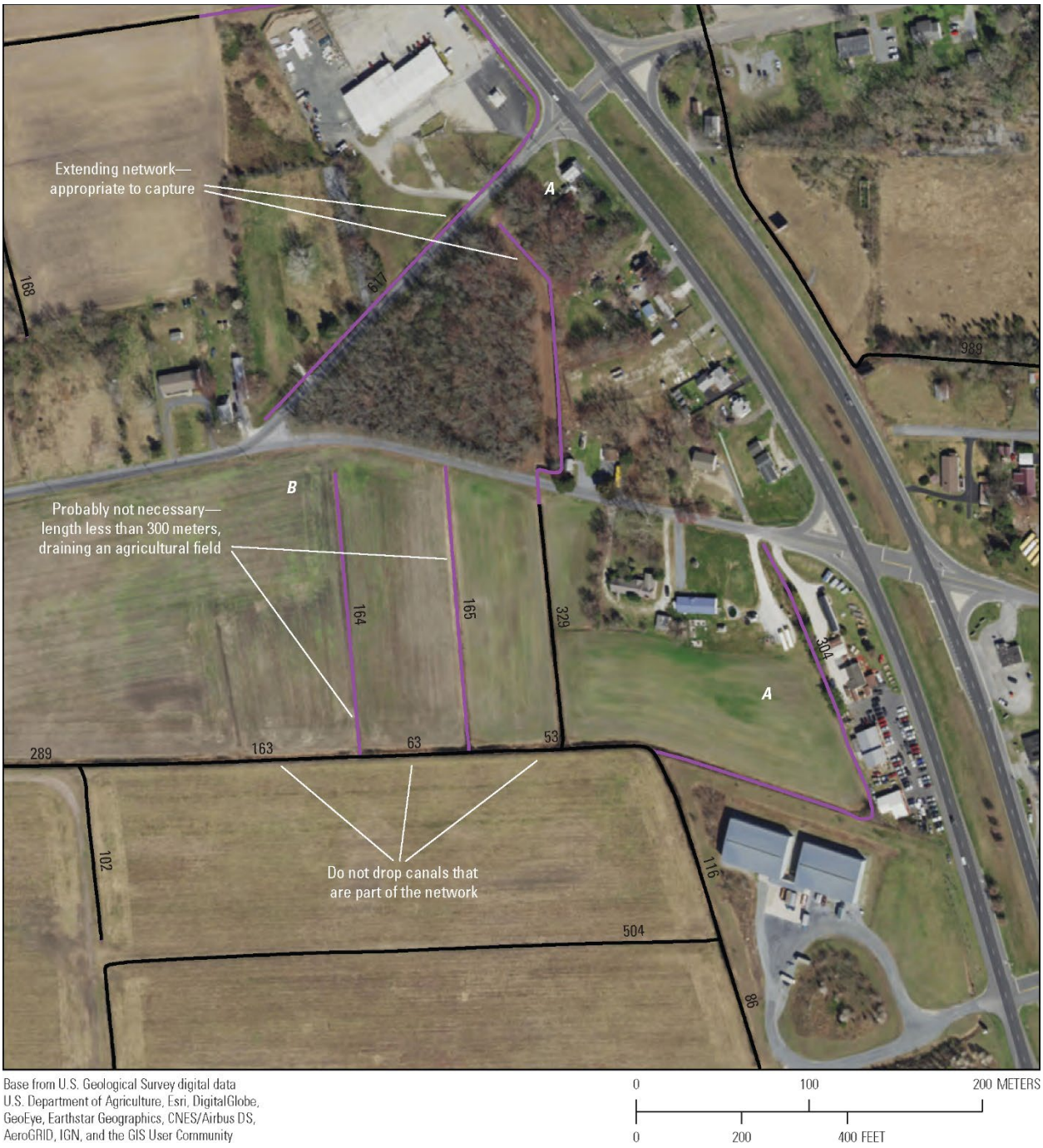

Figure 14. Canal/ditch features as part of a hydrologic network. [A denotes features in purple line color that should be included in the network. B denotes features in purple line color that should be removed from the network].

Stream/river

- Areas of complex interlacing channels will be captured as individual features visible within the elevation surface.

- Areas with dynamic interlaced stream channels will be captured as a minimum set of hydrographic features.
- At least five Stream/river features will be captured to represent a complex set of channels.
- Stream/river features will represent the width of the complex features by adding channels distributed throughout the braid plain area that contains interlaced features.
- Complex flows will be represented if more than five channels are present, regardless of the permanence of the channels within them.
- The resultant braided channel linework should maintain the characteristics of the section of river being depicted.

Figure 15. An area with multiple braided channels visible in the elevation surface.

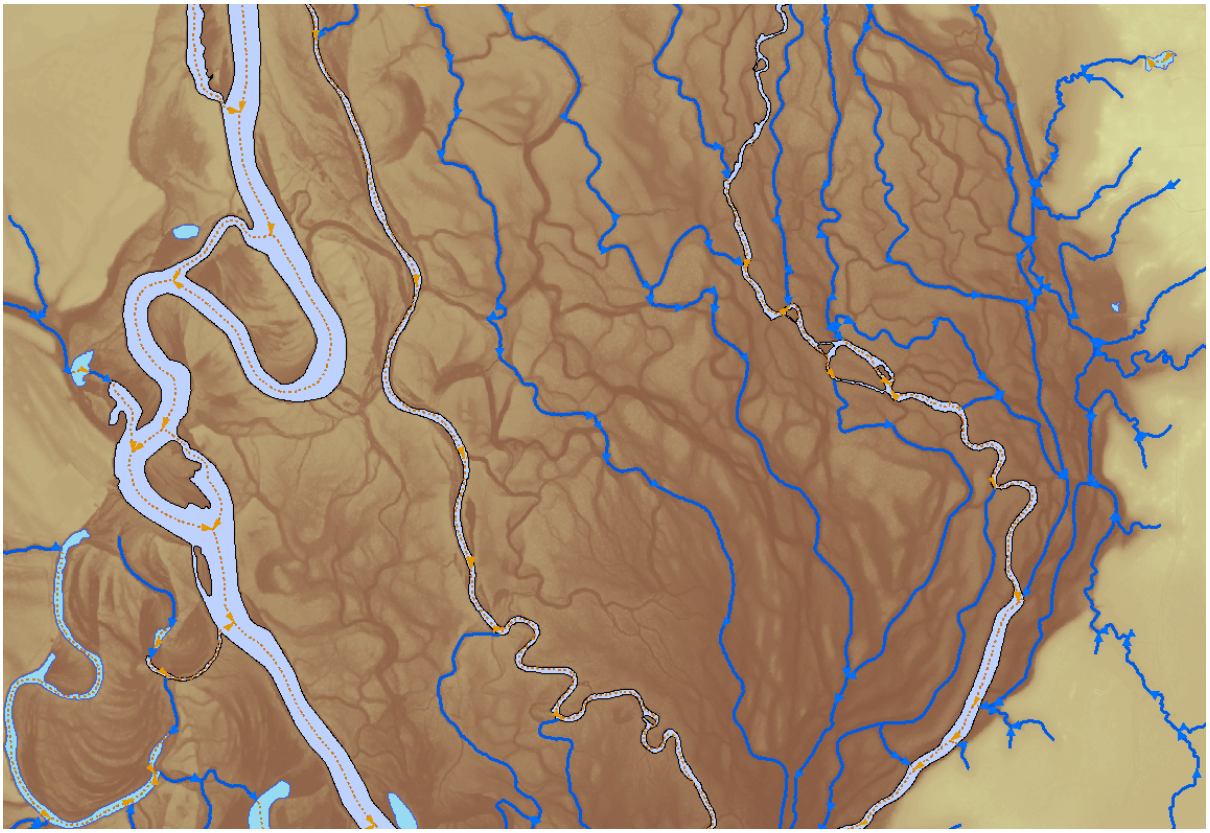

Figure 16. The minimum number of Stream/river features delineated to represent a braided channel system.

Topology

Topology is a set of rules and behaviors that define the spatial relation between the features in the hydrographic network. To prepare for ingestion of hydrographic features into the 3DHP, topology rules must be followed." The 3DHP relies on the topology of the features to maintain a continuous network and to support functions such as network navigation.

Topology Rules

- Remove vertices that are closer than 1.5 m apart.
    - Caution should be exercised to not compromise positional accuracy by removing more vertices than necessary.
    - All features should have a smooth, nonrasterized appearance and maintain horizontal and vertical accuracy.
- Split all line features at polygon boundaries.
    - Code flowlines within a waterbody polygon as “artificial paths.”
    - Any artificial path must be completely within the waterbody polygon, starting and ending at the nodes that are coincident with inflowing features and out- flowing features.
- All line features should be one segment, with no breaks within the feature.

    - The exception to this rule is for "culvert" features. Culverts may split another feature but must use the same FCode as the feature that flows into or out of the culvert. The EClass will be equal to the "Linear features below ground level" code of 3.
- All intersections of features shall have a node (a start/beginning, or end/terminating, vertex) at that intersection.
    - Features that change FCodes within a flowline segment shall be split at that point.
    - Line features that intersect shall be split at that intersection, unless there is evidence that the features do not interact (pipelines, for instance).
    - Lines that meet polygons shall be split at the point where they intersect the polygon. The vertex will exist on the polygon boundary at the connection. Avoid splitting the polygon feature.
    - Artificial paths within a polygon shall have an end or start node that is snapped to incoming linework. The vertex will exist on the polygon boundary at the connection. Avoid splitting the polygon feature.
    - No lines shall have self-intersections or cutbacks.
    - Polygon features shall not overlap, but they may share edges.
- The linear features of the dataset shall create a complete network.
    - Flow shall be from upstream to downstream.
        - Elevation values shall descend from upstream to downstream.
    - Isolated pieces of the network may be present where a DPA does not match a hydrologic unit.
    - Isolated pieces of the network may be present if a sink or other known break in the hydrologic network exists.
        - A sink point shall be used to identify these locations.
- Features smaller than 1.5 m shall be removed or merged in with a longer feature.
- All features shall have a complete set of attributes associated with them.

Z-Values

- Remove Features shall be delivered in shapefile, file geodatabase, or Open Geospatial Consortium GeoPackage formats, as pointZ, polylineZ, or polygonZ feature classes.
- All features shall conform to the defined georeference information defined in the "Spatial Reference System" section of this report.
    - A file with appropriate projection information shall accompany all hydrographic feature deliveries.
- Lakes/ponds waterbody polygons shall be at an elevation at or below the immediately surrounding terrain.
- Lakes/ponds waterbody polygons shall be flat and level with a single elevation value for every shoreline vertex.
- Stream/river polygons or downstream flowing lakes/ ponds shall present a flat and level water surface bank to bank.
- Stream/river polygons or downstream flowing lakes/ ponds shall have a downstream gradient water surface, at or below the immediately surrounding terrain.

    - In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank to bank, the water surface shall be represented as it exists while maintaining an aesthetic carto- graphic appearance.
- Stream/river lines shall have a downstream gradient, at or just below the immediately surrounding terrain.
    - Each vertex in a line shall be at the same or a lower elevation value than the preceding vertex.
- Nontidal boundary waterbodies shall be flat and level for lakes or maintain a downhill gradient for wide rivers and lakes, with the elevation at or just below the immediately surrounding terrain.
- Tidal waterbodies will be flat and level with the elevation at or just below the immediately surrounding terrain.
    - Some vertical discontinuities are acceptable if caused by tidal variations during the collection process.
- At all intersections, regardless of feature type, the geometry of all intersection vertices shall match exactly in x, y, and z, unless there is evidence that there is no interaction between the features (pipelines, for example).
- Features used to traverse surface terrain features (EClass = 3) shall have the elevation values of the connecting features at the end points. The elevation values of the surface above the culvert, connector, or pipeline will not be used.
- Pipelines that are above ground and visible on the elevation surface shall use the elevation of the lidar-derived surface.

Positional Assessment

The goal of the positional assessment is to create a hydrography product that is vertically and horizontally integrated with the 3DEP bare-earth DEM. In general, existing NHD specifications and 3DEP LBS will be followed to ensure completeness and accuracy. Positional assessment of the elevation-derived hydrography is always measured against the bare earth DEM source.

Elevation-Derived Hydrography Positional Evaluation and Reporting

Ideally, all features, or as many features as possible, should be visually inspected to make sure that they meet the accuracy standards described in this specification. If a complete review is impossible, a stratified random sample may be used to select a subset of features to determine the accuracy of the dataset.

To do a holistic review of the dataset, the features reviewed should be:

- Representative of all features in the dataset, so they should contain at least one feature for each EClass and FCode present in the dataset;
- Representative of the complete geographic area of the dataset, so they should have features distributed within each 12-digit hydrologic unit that intersects the DPA;
- Representative of the special cases that make up features, including, but not limited to,
    - Headwaters,

    - Confluences between stream/river reaches,
    - Intersections with polygons and stream features,
    - Canal/ditch features,
    - Isolated networks,
    - Drainageways,
    - Intersections near roads,
    - Culverts,
    - Islands within polygon features;
- Representative of land cover and geologic types or geo- physical regions, including but not limited to,
    - Urban areas,
    - Low slope areas.

Positional Assessment and Reporting

Positional assessment results shall be reported for vertical and horizontal geometry of the hydrographic features relative to the 3DEP bare-earth DEM (see hydroflattening exception below).

- Positional assessment is meant to indicate how accurately the vector hydrographic feature is positioned relative to the feature as represented on the DEM.
- This measure is always represented as (plus or minus) meters.

Hydroflattening Polygon Exception

- An exception to the reporting requirement is for vertices that have been adjusted to maintain monotonicity for hydroflattening.
- Vector features used for hydroflattening must follow the requirements of the LBS.
- Vector features used for hydroflattening purposes shall be integrated into the elevation-derived hydrography dataset and shall follow the Elevation-Derived Hydrography Acquisition Specifications other than the requirement for positional assessment and reporting.

Vertical Positional Assessment of Hydrographic Features Relative to the Digital Elevation Model

- All lines and water surface edges shall be at or just below the elevation value of the immediately surrounding terrain, within 1 m of the location on the bare-earth DEM (figure 17).
    - Exceptions to this requirement are features that are used to traverse surface terrain (culverts, connectors), are underground conduits (culverts, connectors, pipelines), or are overland pipelines (pipelines).

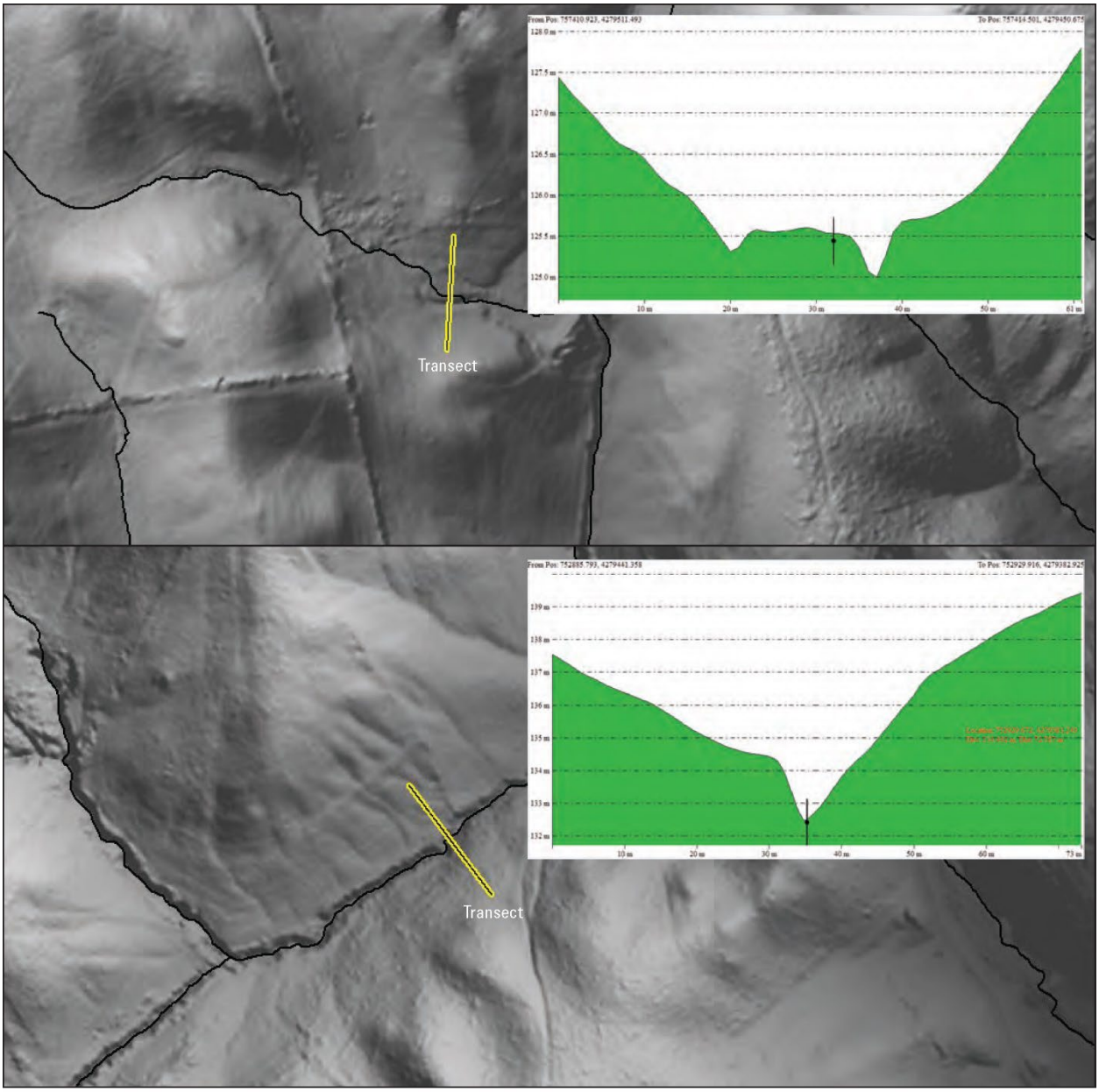

Figure 17. Two cross-sectional views of transects intersecting two stream/river segments. A. This stream/river segment has deviated horizontally from the main channel but is still vertically integrated with the elevation surface. B. This segment is well integrated vertically and horizontally with the lidar-derived surface. Both segments' elevation values are within 0.1 meter of the elevation values of the surface.

Horizontal Positional Assessment of Elevation-Derived Hydrography

The horizontal positional assessment evaluates the placement of vector hydrographic features against the bare-earth DEM from which they were derived. Linear, polygonal and point

features shall be within the visible channels or other hydrographic features visible on the elevation surface.

Linear Features

Stream and other linear channel features shall stay within the apparent channels in the elevation data and shall not leave the channel.

Hydrographic feature positional assessment.—Whereby streams and other linear channel features will stay within the apparent channels in the elevation data and will not leave the channel.

Polygonal Features

Lake/pond and other polygonal features shall match the apparent boundary of the feature in the elevation data and shall not vary from the boundary of the feature.

Hydrographic feature positional assessment.— Whereby lake/ pond and other polygonal features will match the apparent boundary of the feature in the elevation data and will not vary from the boundary of the feature.

Point Features

Point features shall remain within 3 m of the apparent location of the feature in the elevation data.

Hydrographic feature positional assessment.— Whereby point features will remain within 3 m of the apparent location of the feature in the elevation data.

Alignment

Alignment specifications describe the geometry and placement of features. It is important that all features collected shall be logically and spatially consistent with the elevation data horizontally and vertically. Features shall also be spatially consistent with existing NHD features, where appropriate (if an existing feature is spatially correct and will remain unchanged).

Horizontal Alignment

- New features shall align appropriately with existing NHD features outside of the collection area. For instance, if a stream is added to an existing stream channel, it should “snap” to the stream network nodes.
- Features shall be aligned in accordance with topology rules.
- Features shall edge match exactly across tile and project boundaries in the horizontal (x, y) spatial dimensions.

- Delivered data shall be sufficient for the USGS to effectively use for ingestion into the 3DHP or for hydroflattening DEMs as needed.
- Lines shall be oriented from upstream to downstream.
- No lines shall have pseudonodes (other than headwater beginning nodes) or breaks within reaches.
- Polygonal water features shall begin and end at the upstream end of that polygon's centerline (artificial path).
- Where any other features intersect, the intersection shall be coincident with vertices of each feature.
- At all intersections, regardless of feature type, the geometry of all intersection vertices shall match exactly in x, y, and z, unless there is no evidence for interaction between the features (pipelines for instance).
- Features shall align horizontally with the lidar-derived bare-earth DEM they were derived from, within the positional assessment limits described in the "Accuracy" section (figure 18).
- Horizontal discontinuities along the shoreline of a waterbody resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM.

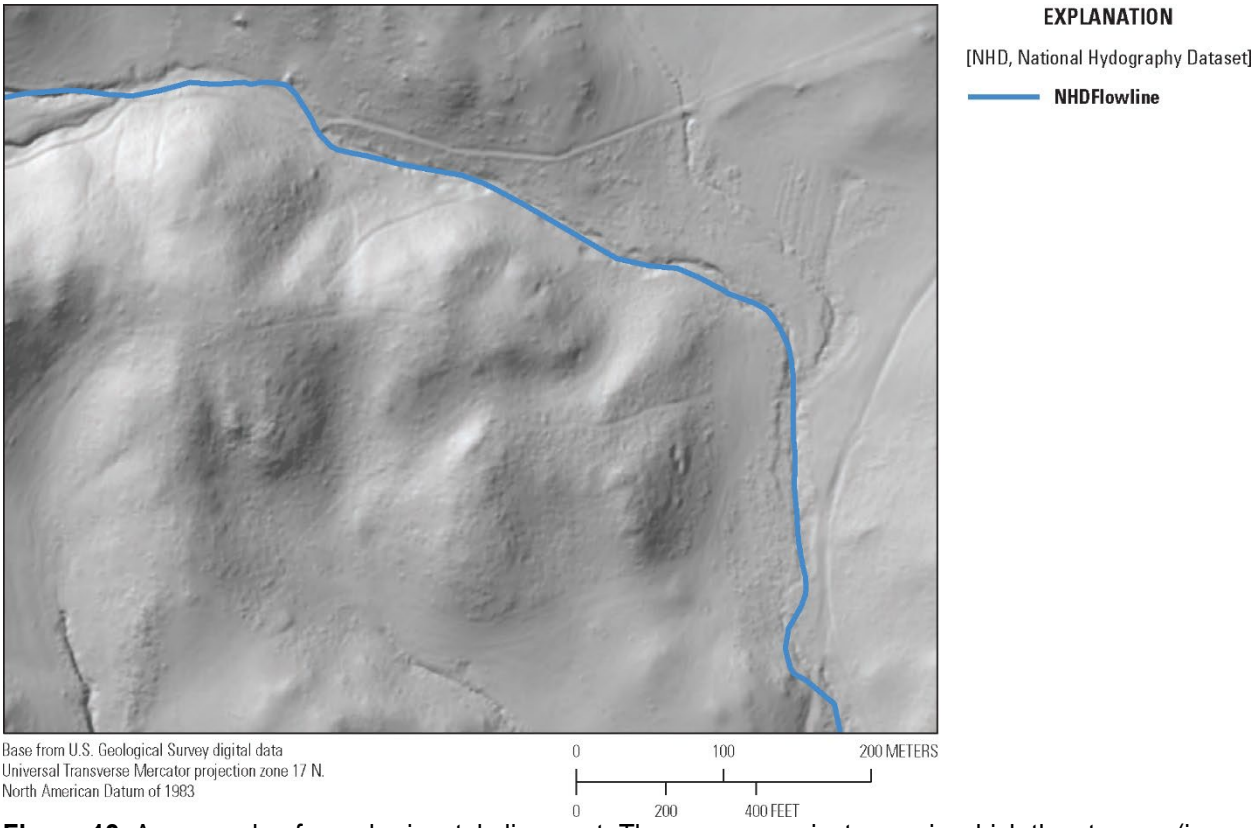

Figure 18. An example of poor horizontal alignment. There are many instances in which the streams (in blue) fall outside the apparent channel of the elevation-derived surface.

Vertical Alignment

- Features shall edge match exactly across tile and project boundaries in the vertical (z) spatial dimensions.
- Delivered data shall be sufficient for the USGS to effectively use for ingestion into the 3DHP or for hydroflattening DEMs as needed.
- Each vertex in a line shall be at the same or a lower elevation value than the preceding vertex in the direction of flow from upstream to downstream.
- At all intersections, regardless of feature type, the geometry of all intersection vertices shall match exactly in x, y, and z, unless there is evidence of no interaction between features (pipelines for instance).
- Features shall align vertically with the lidar-derived bare-earth DEM they were derived from, within the positional assessment limits described in the "Accuracy" section.
- All lines shall be at or just below the elevation of the immediately surrounding terrain, as defined by the lidar points classified as bare earth.
- Flattened waterbodies shall present a flat and level water surface (a single elevation for every bank vertex defining the waterbody's perimeter).
- Long impoundments that are considered lake/pond, whose water surface elevations decrease with downstream travel, shall present a gradient downhill water surface, following the immediately surrounding terrain.
- The entire water surface edge shall be at or below the immediately surrounding terrain (the presence of floating waterbodies will be cause for rejection of the deliverable).
- Flattened streams and rivers shall present a flat and level water surface bank to bank (perpendicular to the apparent flow centerline).
- Flattened streams and rivers shall present a gradient downhill water surface, following the immediately surrounding terrain.
- In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank to bank, the water surface will be represented as it exists while maintaining an aesthetic cartographic appearance.
- The entire water surface edge shall be at or below the immediately surrounding terrain.
- If a polygon is incomplete because it is on the boundary of the collection area, the water surface shall be flat and level, as appropriate for the type of waterbody (level for lakes, gradient for rivers, and so forth).
- All landward water surface edges shall be at or below the immediately surrounding terrain.
- Unusual changes in the water surface elevation that may take place over the course of the collection (for example, different river stages because of increased or decreased discharge from an upstream dam) shall be documented in the project metadata.
- Vertical discontinuities within a waterbody resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM.

Completeness

- All features shall be collected to form a complete stream network without breaks, unless there is evidence a break should occur (for example, isolated waterbodies or subterranean streamflow). All topology rules shall be followed.

- All features shall be coded with the appropriate FClass, EClass, FCode, Desc, source, and method.
- UserCodes shall be used where applicable.
- Domains shall match those specified within the "Elevation-Derived Hydrography—Representation, Extraction, Attribution, and Delineation Rules" (Archuleta and Terziotti, 2020).

Metadata

- Metadata for the breaklines shall be provided in Extensible Markup Language (commonly known as XML; formatted files (Bray and others, 2008) compliant with the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata (Federal Geographic Data Committee, 1998a). The USGS may offer additional or alternative metadata formats in the future.
- Metadata shall document the following:
    - Methods used to delineate features;
    - Minimum feature length;
    - Format of elevation data (lidar derivatives);
    - Source of elevation data (where the data were acquired);
    - Date of source elevation data;
    - Quality level of source elevation data;
    - Ancillary datasets used, including source, date, and resolution;
    - Spatial reference system, including horizontal and vertical units, and horizontal and vertical datum used;
    - Results of relative accuracy assessment of hydro- graphic data;
    - Method for relative accuracy assessment;
    - Field definitions for tables associated with geospatial data (explanation of what type of information the field contains); and
    - Contact information for data collector.

Delivered Products and Formats

Delivered products shall include the following:

- A polygon defining the complete boundary of the DPA,
    - Polygons defining any areas within the DPA that were not included in the hydrography collection.
- A hydrography dataset that adheres to all specifications herein,
    - Data will be delivered as a current version of shapefile, file geodatabase, or Open Geospatial Consortium GeoPackage.
    - Points, lines, and polygons will have 3D geometry.
- A seamless DEM from which the hydrography was derived.
    - The DEM should be in the resolution and spatial reference system defined within this document.
    - A minimum buffer of 250 meters should extend outside of the project area.

    - Have an accompanying spatial metadata layer that identifies the source lidar data used as a source for the seamless DEM.
    - If 3DEP hydroflattening breaklines are available for the source elevation datasets, they shall be provided with the elevation derived hydrography delivery as one dataset.
    - A spatial metadata layer that describes the source lidar data used.
- Metadata describing the final dataset,
- A summary of any accuracy assessments completed on the data. The USGS National Geospatial Program is the maintenance authority for this document.

Tables

Table 1. Geometry of elevation-derived hydrography feature types.

Feature type	Format	Geometry
Point	Vector shape	3D point, pointZ
Line	Vector shape	3D line, polylineZ
Polygon	Vector shape	3D polygon, polygonZ

Table 2. Attribute table structure for line hydrographic features.

Attribute description	Item name	Item	Item type	Domain	Item precision
Feature class (hydrography)	FClass	Integer	Short	FClass	4
Feature class (elevation)	EClass	Integer	Short	EClass	4
Feature code	FCode	Integer	Long	FCode	5
Description	Desc	Text	Text	--	250
Elevation source data	Source	Text	Text	--	128
Hydrography delineation method	Method	Text	Text	--	250
User-defined code	UserCode	Text	Text	--	25
Free-text space for user comments	Comments	Text	Text	--	250
User-defined code	UniqueID	Text	Text	--	50
Digital Elevation Model (DEM) Limitation	Limitation	Integer	Short	Limitation	1
Flow Direction Determination	FlowClass	Integer	Short	FlowClass	1

Table 3. Attribute table structure for area and point hydrographic features.

Attribute description	Item name	Item	Item type	Domain	Item precision
Feature class (hydrography)	FClass	Integer	Short	FClass	4
Feature class (elevation)	EClass	Integer	Short	EClass	4
Feature code	FCode	Integer	Long	FCode	5
Description	Desc	Text	Text	--	250
Elevation source data	Source	Text	Text	--	128
Hydrography delineation method	Method	Text	Text	--	250
User-defined code	UserCode	Text	Text	--	25
Free-text space for user comments	Comments	Text	Text	--	250
User-defined code	UniqueID	Text	Text	--	50
Digital Elevation Model (DEM) Limitation	Limitation	Integer	Short	Limitation	1

Table 4. Domain values for FlowClass feature attributes.

Domain value	Feature attributes
0	Flow direction is unable to be determined from elevation surface. Do not use for hydro-enforcement (EClass = 0)
1*	Flow direction is in digitized direction, and z-values on vertices flow downslope.
2	Flow direction is in digitized direction, and z-values on vertices flow upslope. Do not use for hydro-enforcement (EClass = 0)

*This is the default value.

Table 5. Domain values for Limitation feature attributes.

Domain value	Feature attributes
0*	No elevation dataset limitation.
1	Elevation dataset limitation.

*This is the default value.

Table 6. FCode domain values and descriptions.

FCode	Desc
0	User-defined feature
33400	Connector
33401	Connector: Culvert
33404	Connector: Indefinite Surface

33405	Connector: Terrain Breach
33410	Connector: Non-NHD Dataset
33600	Canal/ditch
34300	Dam/weir
36100	Playa
37800	Ice mass
39000	Lake/pond
42002	Underground Conduit
42800	Pipeline
44500	Sea/ocean
45000	Sink
46000	Stream/river
46800	Drainageway
55800	Artificial path

Table 7. Domain values for FClass feature attributes.

Domain value	Feature attributes
1	Hydrography feature defined within the collection criteria of the elevation-derived hydrography specifications.
2	Hydrography feature captured outside the collection criteria of the elevation-derived hydrography specifications.
9	Nonhydrography feature.

Table 8. Domain values for EClass feature attributes.

Domain value	Feature attributes
0	Not used for elevation derivative.
11	Polygon created from breakline—Polygon derived from the breaklines used for hydroflattening the elevation surface (3D polygon).
12	Polygon created from hydroflattened surface—Polygon corresponding to a hydroflattened surface, but breakline is either not available or not horizontally or vertically aligned appropriately with the DEM surface. For use in Alaska or where breaklines do not meet cartographic or horizontal requirements.
13	Polygon created without using elevation hydroflattening breakline and the surface of the waterbody is not hydroflattened in the source DEM.
2*	Linear hydrographic features that follow the elevation surface.
3	Linear features below ground level—Examples include connectors through dams, culvert connectors, and terrain breach connectors. Used for hydro-enforcement.

*This is the default value.

Table 9. Feature type description, associated geometry, and use classification.

Desc	FCode	Geometry type	FClass Domain value	EClass Domain value
Artificial path	55800	3D line, polylineZ (creates network connectivity)	1	2
Canal/ditch	33600	3D line, polylineZ (does not connect primary network features)	2	0
Canal/ditch	33600	3D line, polylineZ (creates network connectivity)	1	2
Canal/ditch	33600	3D polygon, polygonZ (polygon matches hydroflattening breaklines, breakline used)	1	11
Canal/ditch	33600	3D polygon, polygonZ (polygon based on hydroflattening surface, breakline edits required)	1	12
Canal/ditch	33600	3D polygon, polygonZ (no hydroflattening breakline available, polygon newly captured)	1	13
Connector	33400	3D line, polylineZ	1	3
Connector: Culvert	33401	3D line, polylineZ	1	3
Connector: Indefinite surface	33404	3D line, polylineZ (creates network connectivity)	1	2
Connector: Non-NHD Dataset	33410	3D line, polylineZ (does not connect primary network features)	2	0
Connector: Terrain breach	33405	3D line, polylineZ	1	3
Dam/weir	34300	3D polygon, polygonZ	9	0

Desc	FCode	Geometry type	FClass Domain value	EClass Domain value
Dam/weir	34300	3D line, polylineZ	9	0
Dam/weir	34300	3D point	9	0
Drainageway	46800	3D line, polylineZ (creates network connectivity)	1	2
Ice mass	37800	3D polygon, polygonZ	9	0
Lake/pond	39000	3D polygon, polygonZ (polygon matches hydroflattening breaklines, breakline used)	1	11
Lake/pond	39000	3D polygon, polygonZ (polygon based on hydroflattening surface, breakline edits required)	1	12
Lake/pond	39000	3D polygon, polygonZ (no hydroflattening breakline available, polygon newly captured)	1	13
Pipeline	42800	3D line, polylineZ (does not connect primary network features)	2	0
Pipeline	42800	3D line, polylineZ (creates network connectivity)	1	2
Pipeline	42800	3D line, polylineZ (creates network connectivity)	1	3
Playa	36100	3D polygon, polygonZ	1	0
Sea/Ocean	44500	3D polygon, polygonZ (polygon matches hydroflattening breaklines, breakline used)	1	11
Sea/Ocean	44500	3D polygon, polygonZ (polygon based on hydroflattening surface, breakline edits required)	1	12
Sea/Ocean	44500	3D polygon, polygonZ (no hydroflattening breakline available, polygon newly captured)	1	13
Sink	45000	3D point, pointZ	1	0
Stream/River	46000	3D line, polylineZ (creates network connectivity)	1	2
Stream/River	46000	3D polygon, polygonZ (polygon matches hydroflattening breaklines, breakline used)	1	11
Stream/River	46000	3D polygon, polygonZ (polygon based on hydroflattening surface, breakline edits required)	1	12
Stream/River	46000	3D polygon, polygonZ (no hydroflattening breakline available, polygon newly captured)	1	13
Underground Conduit	42002	3D line, polylineZ (creates network connectivity)	1	0

Table 10. Polygon features used for hydroflattening an elevation surface.

Desc	FCode
Lake/pond	39000
Sea/ocean	44500
Stream/river	46000

Table 11. Hydroflattening feature and updated code.

Hydroflattening feature	Hydroflattening short description (see Lidar Base Specification for all cases)	Elevation-derived hydrographic feature	FCode	Elevation-derived hydrographic feature 2D (polygon) description
Inland ponds and lakes	Waterbodies with a surface area of 0.8 ha (2 acres) or greater (approximately equal to a round pond 100 m in diameter) at the time of collection shall be flattened.	Lake/pond	39000	A standing body of water with a predominantly natural shoreline surrounded by land.
Inland streams and rivers	Streams and rivers of a 30 m or greater nominal width shall be flattened.	Stream/river	46000	A body of flowing water.
Tidal waterbodies	Tidal waterbodies are defined as any waterbody that is affected by tidal variations, including oceans, seas, gulfs, bays, inlets, salt marshes, and large lakes.	Sea/ocean	44500	The great body of saltwater that covers much of the Earth.

Hydroflattening feature	Hydroflattening short description (see Lidar Base Specification for all cases)	Elevation-derived hydrographic feature	FCode	Elevation-derived hydrographic feature 2D (polygon) description
Nontidal boundary waterbodies	Boundary waterbodies are waterbodies that contain some or all of the DPA. • Boundary waterbodies may be any type of waterbody but are virtually always large in area or width. • A boundary waterbody shall be represented as a polygon that follows the shore throughout the project and is then closed using arbitrary line segments as needed across the waterbody. Boundary waterbodies do not include the natural far shoreline.	Any large 2D features at the edge of the DPA. Exceptions are tidal waterbodies: sea/ocean.	39000, 43600, 46000	A 2D feature that is not wholly contained within the DPA and is therefore only partially delineated.

Table 12. Examples of acceptable ancillary datasets.

Required/ recommended	Source	Resolution	Comments	Use
Required	Subset of NHD features required for capture in the elevation-derived hydrography–AS	1:24,000 or better	Download most recent version from The National Map	Use as a guide for minimum features that must be collected.
Required	Elevation surfaces, bare-earth digital elevation model	1 meter	Should be created from bare-earth lidar points.	All features collected must match the surface of the lidar bare-earth surface.
Required	Watershed Boundary Dataset, 12-digit hydrologic units	1:24,000 or better	Download most recent version from The National Map	Use as a guide for minimum density of features that must be collected. Buffer the watershed areas to capture a complete network.
Recommended	Subset of NHD features not required for capture in the elevation-derived hydrography –AS	1:24,000 or better	Download most recent version from The National Map, or use web feature service	Use as a reference for features within the NHD with FCodes not required by elevation-derived hydrography –AS, but potentially useful for understanding the hydrology of the area.
Recommended	Intensity images from same source as lidar surfaces	1 meter	Should be created from bare-earth intensity values	From the same source as the elevation surface. Can be used as imagery. Water and wet areas are often visible.
Recommended	Leaf-off orthoimagery	≤1 meter	Image date should be as close to the lidar collection date as possible	Visible features below tree canopy. Helpful to identify roads and stream intersections.
Recommended	Leaf-on orthoimagery	≤1 meter	Image date should be as close to the lidar collection date as possible	Riparian zones are often obvious in imagery.
Recommended	Near infrared band for vegetation	≤1 meter	Image date should be as close to the lidar collection date as possible	Helpful for vegetation identification.
Recommended	Transportation layer	1:24,000 or better	State or local government data tends to be higher resolution and more current than Federal road and highway datasets	Used for identification of culvert features, and for delineation of headwater streams near roads or railroads (see “Culverts” and “Headwaters at Roads” subsections of “Special Cases” in the “Delineation of Hydrographic Features” section).

Required/ recommended	Source	Resolution	Comments	Use
Recommended	Bridge and culvert datasets from DOT or others	1:24,000 or better	May be difficult to find for many States. Often coarser resolution but useful as a guide. National datasets exist (National Bridge Inventory, Federal Highway Administration, U.S. Department of Transportation) but are coarse	Use as a guide for culvert identification.
Recommended	Dam locations	1:24,000 or better	National dataset coarser than lidar; for example, National Inventory of Dams	Use as a guide for dam identification.
Recommended	Lidar full point cloud	1 meter	Should be from the same lidar collection	Helpful to distinguish features, or buildings that may be in flowpaths.
Recommended	Storm sewer systems and underground systems in urban areas	1:24,000 or better	Source date should be as close to the lidar collection date as possible	Use to identify subsurface connections, pipelines, culverts.
Recommended	Building footprints	1:24,000 or better	Source data should be as close to the lidar collection date as possible. Microsoft building footprints are available nationally but may be several years old. Local or State agencies may have more recently updated building footprints.	Use to route hydrography around buildings. Can be useful in areas where buildings were removed in the bare earth surface, but a pit was created as an artifact of the filtering.

References

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