

NHDPlus Version 2: **User Guide** (Data Model Version 2.1)



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Introduction to NHDPlus

NHDPlus is an integrated suite of application-ready geospatial data products, incorporating many of the best features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), and the National Watershed Boundary Dataset (WBD). NHDPlus, based on the medium resolution NHD (1:100,000-scale), includes the stream network and improved linear networking, feature naming, and “value added attributes” (VAA). NHDPlus also includes elevation-derived catchments.

NHDPlus is built from static copies of the medium resolution (1:100,000-scale or better) NHD¹, 30 meter NED¹, and the WBD. These three datasets are regularly updated. Therefore the snapshots of NHD, NED and WBD that are used to construct NHDPlus are included with the NHDPlus data. Unlike NED and WBD, the NHD is extensively improved by the NHDPlus team during the NHDPlus build process. Because of the demand to release NHDPlus as quickly as possible, incorporating updates in the USGS NHD central repository does not occur prior to distribution. The NHD, NED, and WBD snapshots included with NHDPlus may not be updated by users with the intent of sending updates back to these national databases. EPA is the steward for the medium resolution NHD and updates to this data may be sent to EPA. Updates to NED and WBD should be directed to the respective national stewardship programs sponsored by USGS.

The NHDPlus VAAs provide attributes which greatly improve the capabilities for upstream and downstream navigation, analysis, and modeling. Examples of these enhanced capabilities include using structured queries for rapid retrieval of all NHDFlowline features and catchments upstream of a selected NHDFlowline feature; sub setting the selection of a stream level path (sorted in hydrologic order) for stream profile mapping, analysis, and plotting; and calculating using hydrologic sequence routing attributes to cumulative catchment attributes. VAA-based routing techniques were used to produce additional NHDPlus attributes such as cumulative drainage areas, temperature, and precipitation distributions. These cumulative attributes are used to estimate the NHDPlus mean annual and mean monthly flow estimates and velocities.

The NHDPlus elevation-derived catchments were produced using a drainage enforcement technique first applied in New England, named “The New-England Method.” This technique involves enforcing the 1:100,000-scale NHD drainage network onto the NED elevation data through trenching the network and enforcing the WBD for hydrologic divides via walls. WBD was also used to apply sinks (areas of no external drainage) in non-contributing areas. The resulting modified digital elevation model (DEM) was used to produce hydrologic derivatives that closely agree with the NHD and WBD.

NHDPlus Version 1 (NHDPlusV1) was released in 2006 and planning to incorporate updates and improvements has been ongoing since the first release. NHDPlus Version 2 (NHDPlusV2) is the

¹ NHDPlusV2 for Hawaii, Puerto Rico, U.S. Virgin Islands, Guam, American Samoa, and the Northern Mariana Islands are built from high resolution NHD and 10 meter NED.

result of these modifications and benefits from over six years of NHDPlusV1 user implementation. Feedback and updates provided by a diverse and engaged NHDPlusV1 user community contributed to many of the improvements found in NHDPlusV2. As a result, NHDPlusV2 is a robust and sophisticated suite of geospatial products. Users are encouraged to familiarize themselves with NHDPlusV2 through this guide, other user documentation and training materials, and by consulting with other NHDPlus users. We welcome descriptions of your applications that might be shared with this growing user community through the NHDPlus web site. The NHDPlus team is always available to discuss your application ideas and questions.

Additional information, tools, exercises, training opportunities, news, and the latest NHDPlus data can be found at <http://www.epa.gov/waters>.

NHDPlus Version 1 (NHDPlusV1)

NHDPlusV1 was released in 2006 and has acquired a large and diverse user community. Many applications have been developed around the unique characteristics of NHDPlusV1 and some of these applications are highlighted on the NHDPlus web site. The NHDPlusV1 data, documentation, and training materials are still available in the “NHDPlusV1 Archive” section of the NHDPlus web site.

The remainder of this document is dedicated to NHDPlus Version 2 (NHDPlusV2). For additional information about NHDPlusV1, see the “NHDPlus Version 1 User Guide” located in the “NHDPlusV1 Archive” section of the NHDPlus web site.

Overview of NHDPlus Version 2 (NHDPlusV2)

During 2010 and 2011, the NHDPlus team re-engineered the programs used to generate NHDPlus Build/Refresh Tools in preparation for creating NHDPlusV2 dataset. Four primary goals of the improved NHDPlus Build/Refresh Tools are:

- (1) Enable NHDPlus refresh as the input datasets are improved and refined;
- (2) Provide refresh capabilities that are timely and cost-effective;
- (3) Improve the NHDPlus components by implementing more sophisticated techniques for hydro-enforcement and flow estimation than previously used; and
- (4) Enable the building of NHDPlusV2 from different resolution input datasets, such as high resolution NHD and 10 meter NED.

In conjunction with the development of the NHDPlus Build/Refresh Tools, the NHDPlusV1 data model was enhanced to create the NHDPlusV2 data model. The new data model reflects improvements identified since 2006, from the application of NHDPlusV1 by the user community. The first major modification in the new NHDPlusV2 data model is the division of the NHDPlus data structure into “core” components and “extended” components. The set of “core” data components are the direct results of integrating the three primary source datasets: the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), and the Watershed Boundary Dataset (WBD). All other components of NHDPlusV1 and some new NHDPlusV2 components are the result of extending the primary source dataset integration and are classified as “extended” components in the new data model (e.g. flow estimates, catchment attributes, and accumulated attributes). We envision additional NHDPlusV2 “extended” components will be built in the future by the NHDPlus team and user community.

This document is intended to provide users with an understanding of the format and content of NHDPlusV2, how it was built, and how to use the data.

Highlights of How NHDPlusV2 Differs from NHDPlusV1

Many enhancements have been incorporated into NHDPlusV2 including improved input source data, more robust procedures for building NHDPlusV2 and additional components to enhance the application and utility of NHDPlusV2. Details about the NHDPlusV2 improvements are discussed throughout this guide. For example, Appendix A illustrates the NHDPlusV2 build process and describes the process used to produce NHDPlusV2 catchments which refined and improved the basic process used for NHDPlusV1 catchments¹.

Improved NHD Data – Like NHDPlusV1, NHDPlusV2 uses the medium resolution NHD (1:100,000-scale) data from the USGS NHD database (<http://nhd.usgs.gov/>). Extensive updates were made to the NHD data in preparation for building NHDPlusV1 and those updates were returned to USGS for processing into the NHD database between January 2006 and December 2009. In April 2010, a new one-time extraction or “snapshot” of the NHD data was acquired from the NHD database to begin editing in preparation for building NHDPlusV2. These edits included connecting thousands of isolated networks that existed in the NHDPlusV1. Additional NHD edits included correcting flow routing and coordinate ordering issues and adding spatial detail to the network using high resolution NHD and imagery. Many of these edits required changes and additions to the NHD geometry. The following types of edits were performed to improve the NHD snapshot used for NHDPlusV2:

- Isolated networks connected using geometry from the high resolution NHD data or features digitized from imagery,
- Detail added to the NHD network using geometry from the high resolution NHD data or features digitized from imagery,
- Stream and waterbody names added,
- Name placements corrected,
- Lake features added,
- Lakes split by USGS topographic (quadrangles) map lines merged,
- Real sinks (non-contributing areas and networks that drain into the ground) identified,
- Duplicate geometry removed,
- Small network gaps closed,
- Great Lakes drainage connected, and
- ReachCodes migrated to agree with the February 2012 WBD.

collected. The higher-resolution NED data are used to augment lower resolution NED layers as well. For instance, when new 10-m DEMs are produced, the 10-m NED is updated to include these areas and the 1-arc-second NED (approximately 30-m) is updated by resampling the new 10-m DEM data.

NHDPlusV1 used a NED snapshot from June 2004 (Figure 3).

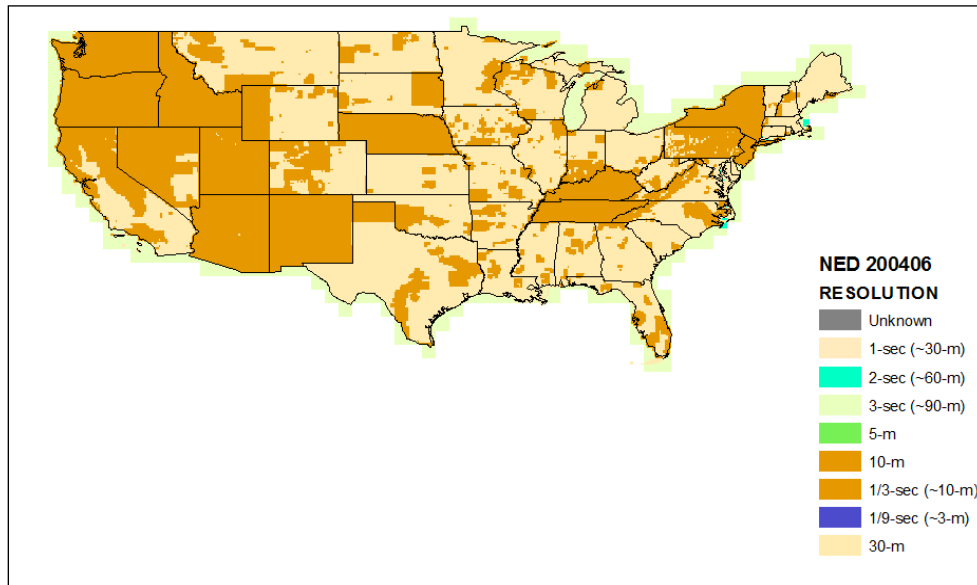


Figure 3: June 2004 NED Resolutions

NHDPlusV2 used the best-available NED snapshots released by USGS during the production period. These NED snapshots were published from August 2010 to December 2011 (Figure 4a)

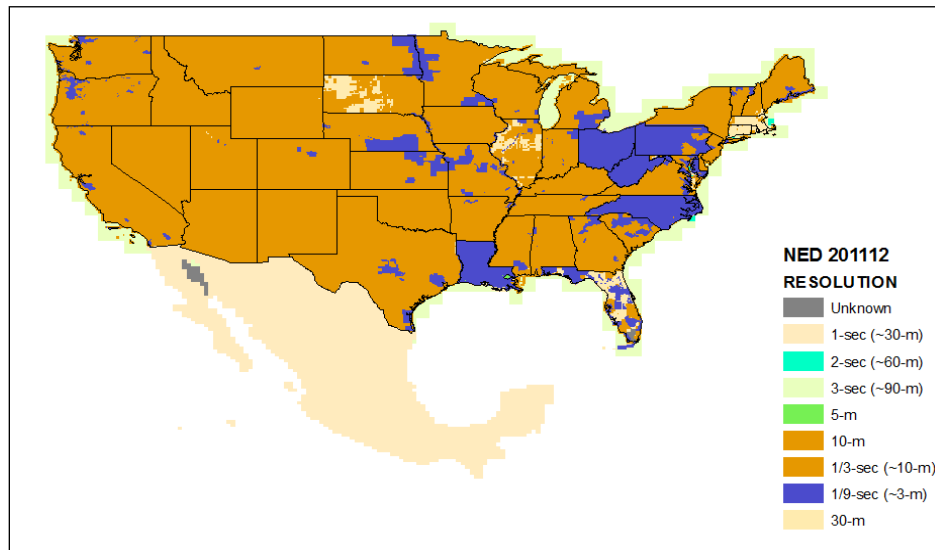


Figure 4a: December 2011 NED Resolutions

Differences between NHDPlusV1 and V2 Processing Units

In NHDPlusV1, the processing units were referred to as “Hydrologic Region” for vector data (even though hydrologic region 10 was split into two pieces) and “Production Unit” for raster data. In NHDPlusV2, the processing units are referred to as “Vector Processing Unit (VPU)” for vector data and “Raster Processing Unit (RPU)” for raster data. The change to VPU and RPU was made to introduce flexibility into the size of units that were processed. This will be especially important when processing higher resolution NHDPlus in the future.

The actual geographic extent of the vector processing units is very similar, though not identical, between NHDPlusV1 and V2. The NHDPlusV2 Vector Processing Units (VPUs) are different from V1 in five areas: (1) the division of hydrologic region 10 into 10U and 10L has changed, (2) hydrologic region 03 was one piece in V1 and is three pieces (03N, 03S, and 03W) in V2, (3) the HUC4 0318 (the Pearl River) is incorporated into VPU 08 in the Mississippi drainage where it belongs hydrologically, (4) VPUs 01, 02, 04, 09, 10U, and 17 extend into Canada and (5) VPUs 13, 15, and 18 extend into Mexico.

While the names of the V2 RPUs are mostly the same as the V1 Production Units, the extents of the RPUs reflect many changes as follows:

- RPUs now extend into more international areas to include contributing drainage areas from Canada or Mexico.
- RPU boundary configurations have changed in V2 as a result of eliminating former Arc Workstation Grid size constraints.
- In V2, RPUs are created by combining whole HUC4 drainages. This was not always the case in V1 Production Units configurations.
- A V2 RPU and a V1 Production Unit of the same name are not always the same extent.

Figure 4b illustrates the V1 and V2 processing units.

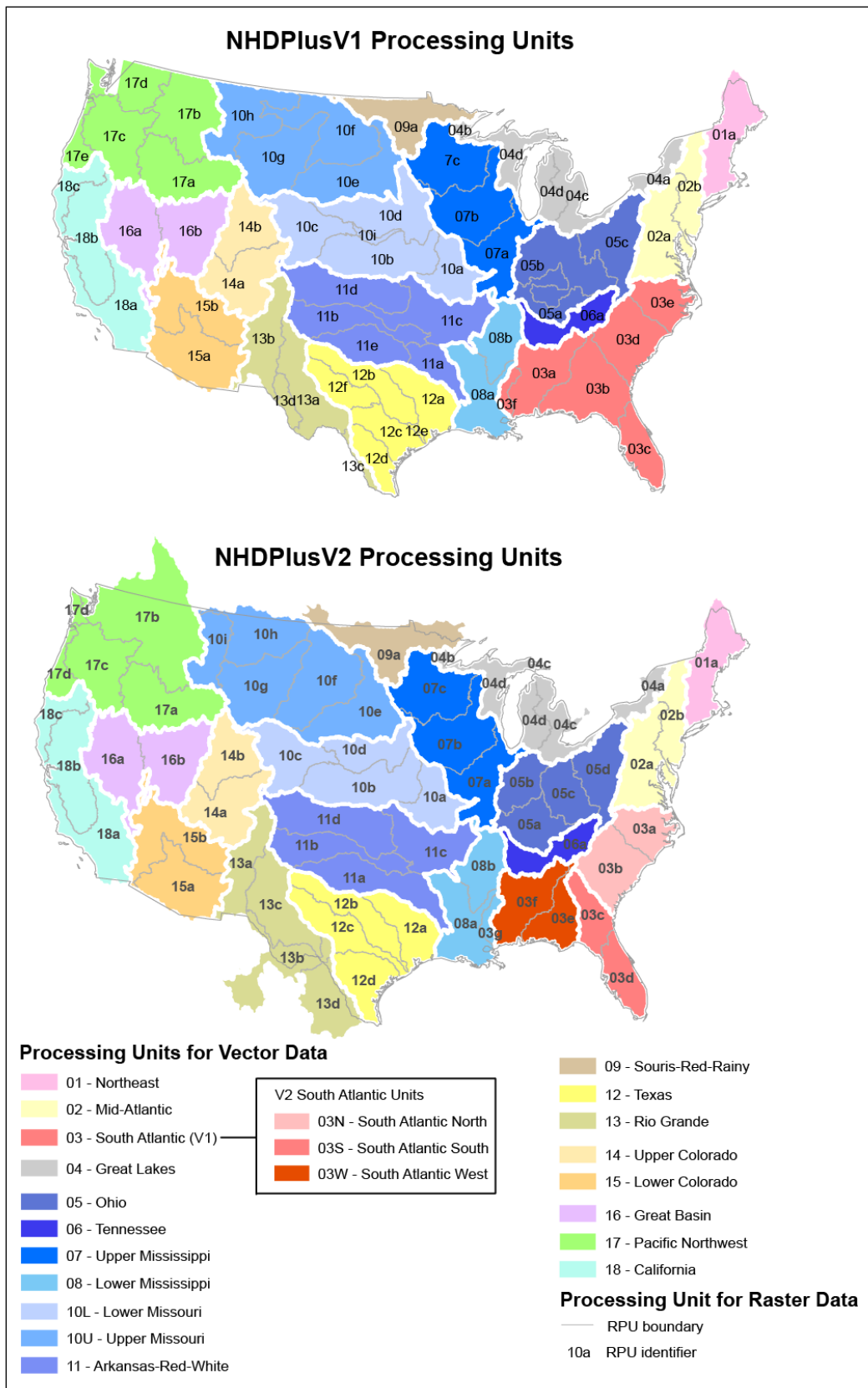


Figure 4b: NHDPlusV1 versus V2 Processing Units

Incorporation of Canadian Data - On the Canadian side of shared international drainages, NHDPlusV2 processing combined the Canadian DEMs with the NED and the Canadian digital drainage divides with the WBD. These additions enhanced the catchment delineations in Canada and thereby the drainage areas that flow into the U.S. These enhancements were not done in NHDPlusV1. In addition, Canadian 1:50,000-scale National Hydrographic Network (NHN) stream data has been incorporated into the high resolution NHD for many hydrologic units that cross the international border. These high resolution NHD features along with additional features from the Canadian NHN were selectively incorporated into the hydro-enforcement processing as "burn lines" to further improve the catchment delineations in Canada. Additionally, precipitation and temperature grids provided by the Canadian Forest Service (McKenney and others, 2006) were used to develop runoff estimates for Canadian drainage areas.

Incorporation of Mexican Data – The 1-arc-second NED data, used for NHDPlusV2 processing, includes elevation data from Mexico. Additionally, hydrography data from Mexico has been incorporated into the high resolution NHD for hydrologic units that cross the international border. These data were used selectively as “burn lines” in the hydro-enforcement processing to improve the accuracy of the catchment delineations in Mexico. In addition, precipitation and temperature grids provided by the Canadian Forest Service (McKenney and others, 2006) were used to develop runoff estimates for Mexican drainage areas.

Improved Flow Estimates – The Enhanced Runoff Method (EROM) provides mean annual stream flow and velocity estimates for all networked flowlines (stream segments) in NHDPlus V2. EROM also has the capability for performing mean monthly (MM) flow and velocity estimates. The MM flows were not included in the initial release because of QA issues. These QA issues have been addressed and now the MM flows are available for distribution. The sections on EROM and EROMQA in Appendix A have also been updated, and users are encouraged to review these updated sections. The input data for EROM (runoff, temperature, precipitation and gage flow) is coordinated to reflect the 1971 to 2000 time period. Therefore, the EROM flow estimates are valid for this 1971 to 2000 time period.

The Enhanced Unit Runoff Method (EROM), used to estimate stream flows in NHDPlusV2, incorporates several improvements to the original Unit Runoff Method (UROM) used in NHDPlusV1. NHDPlusV1 estimated a unit runoff (cfs/km²) for each catchment and conservatively routed and accumulated these incremental flows down the network. Many enhancements have been made in the NHDPlusV2 EROM flow method as reflected in the new 6-step flow estimation process:

1. Unit runoff is computed from a runoff grid produced from a flow balance model. The 900-m runoff grid is at a much finer resolution than the 8-digit Hydrologic Unit (HUC8) runoff values used in NHDPlusV1.
2. A “losing streams” methodology is incorporated estimating stream flow losses that can occur due to excessive evapotranspiration in the stream channels.
3. A log-log regression step using “Reference” gages provides a further adjustment to the flow estimates. Reference gages (Falcone, et. al.) are those gages determined to be

largely unaffected by human activities. The regression-adjusted flows should be considered the “best” NHDPlusV2 estimates of “natural” flow.

4. A new table in NHDPlusV2, PlusFlowAR, provides a method to account for flow transfers, withdrawals, and augmentation.
5. A gage adjustment component adjusts flows upstream of gages based on the flow measurements at the gage locations. This step performs the flow adjustments for all gages that meet criteria as explained in the details in the next step (6). The gage adjustment causes the flow estimates to match the gaged flow at the gage locations. Prorated adjustments are also made to the incremental catchments flow estimates upstream of the gages. After the upstream adjustments have been made, catchment incremental flows are accumulated down the network thereby making necessary adjustments to the flows below gages. The gage-adjusted flow estimates should be considered the “best” NHDPlusV2 flow estimates for use in models and analyses.
6. The gage adjustment, performed in step 5, forces the NHDPlusV2 flow estimates to match the gaged-flows at the gage locations. Gaged-flow cannot be used to perform quality assurance (QA) on the results of step 5. This sixth step, called “gage-sequestration”, is designed to measure how well the step 5 gage adjustment has performed in estimating flows throughout the network. First, a proportion of the gages (typically 20%) are randomly selected and set aside (sequestered). The remaining gages are used to perform a gage adjustment identical to step 5. Finally, the sequestered gages are used to QA the results of the gage adjustment. These QA results can be viewed as the QA of the flow estimates produced in step 5.

Unlike NHDPlusV1, NHDPlusV2 contains statistical QA measures of the flow estimates. These QA statistics are included with the NHDPlusV2 data and provide a comprehensive assessment of the quality of the flow estimates.

Improved Off-network Waterbody Enforcement – In NHDPlusV1, no enforcement of off-network waterbodies occurred. Consequently, the NHDPlusV1 catchment delineation could erroneously delineate a catchment boundary through a waterbody (see Figure 4c). In NHDPlusV2, the off-network lake/ponds were imposed into the DEM using the minimum elevation cell within each feature. Then the elevation values inside each feature were dropped below the surrounding land surface. Figure 4d shows the improved catchment delineation in NHDPlusV2.

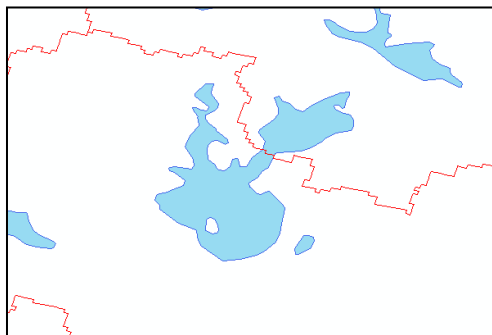


Figure 4c: NHDPlusV1

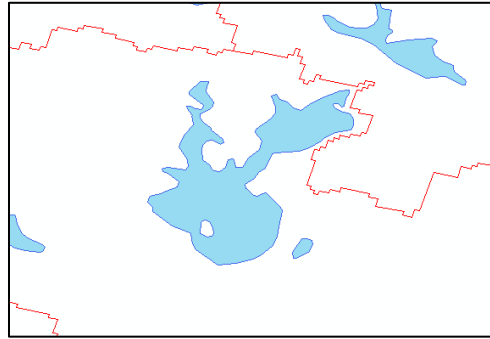


Figure 4d: NHDPlusV2

Improved Sinks - NHDPlusV2 has a new point feature class, Sinks, which allows the user to represent non-contributing areas that cannot be represented by the NHDFlowline features. Sinks are used to insert a NoData cell into the hydro-enforced DEM. Areas around the sink points drain into the sinks. During the hydro-enforcement fill process, areas draining to sinks do not fill nor spill into down-gradient areas.

Sinks are also used to represent terminal ends of NHDFlowline isolated stream networks, waterbody features (lake/pond and playa) identified as "closed" (i.e. with no NHDFlowline outlet), and WBD HUC12 units that are attributed as "closed basins" For sinks representing waterbodies, a bathymetric gradient is applied during hydro-enforcement which forces cells within the waterbody to slope toward the sink. Sinks within a WBD closed basin can represent one or a combination of sink sources.

In NHDPlusV1, the ends of isolated networks were assigned sinks only if the network was in a HUC8 classified as a closed basin and as an arid area (mean annual precipitation less than 14 inches). In NHDPlusV1, the ends of isolated networks not given sinks would "fill and spill" in the hydro-enforced DEM, thus draining to down-gradient areas. This created a disagreement between the NHDPlusV1 vector and raster data: the vector data contained isolated networks, while the raster data (flow direction and flow accumulation grids) connected the drainage areas of the isolated networks to down-gradient drainage areas.

In NHDPlusV2, the additional sinks improve the flow direction and flow accumulation grids, which now drain into the sink at the end of each isolated network, resulting in the raster representation of flow being isolated, as shown in the vector network.

As a result of these additional representations, many more sinks exist in NHDPlusV2 than are included in NHDPlusV1.

Improved Trimming of Streams - In NHDPlusV1, headwater streams were trimmed by a small distance to account for the buffer around flowlines that was burned in the DEM. In NHDPlusV2, headwater flowlines were trimmed to reduce the possibility that WBD drainage boundaries would be breached by headwater catchments. If trimmed headwater flowlines were touching or within one grid cell width of WBD divides, the flowlines received additional trimming. As a result, hydro-enforcement in NHDPlusV2 uses a stream network that conforms closely to the WBD drainage boundaries.

In NHDPlusV2, the upstream ends of flowlines representing minor paths at stream network divergences were also trimmed. This was done to direct the flow direction and flow accumulation grids down the main flow path identified by the NHDPlusV2 stream network.

In the NHDPlusBurnComponents folder, BurnLineEvent contains the trimmed stream network used to hydro-enforce the DEM. In some cases, headwater and minor divergent path flowlines were so short that sufficient trimming was not possible and these flowlines were removed from BurnLineEvent. Catchments are only created for flowlines in BurnLineEvent.

Nationally Consistent WBD Drainage Divide Enforcement – In both NHDPlusV1 and NHDPlusV2, drainage divides represented by the WBD HUC12 boundary lines were incorporated as “walls” during the hydro-enforcement of the DEM. In NHDPlusV2, additional techniques were used to refine the walls and the resultant drainage grids. Non-closed HUC12s with no NHDFlowline features were identified. Portions of the walls for these HUCs were removed to enable these areas to drain to an appropriate down-gradient area, thus correcting flow direction issues found in NHDPlusV1

Use of NHDPlusV2 VAA Attribute HydroSeq for Elevation "stepping" - This enhancement utilizes the hydro-sequence number from the NHDPlusV2 Value Added Attributes (VAA) to ensure flow paths in the hydro-enforced DEM follow the NHDPlusV2 flow path directions as defined in the NHDPlusV2 flow table (PlusFlow). Implementing this process minimizes problems discovered during the hydro-enforcement fill process by replacing the NHD stream cells with a gradual downstream “stepping” of elevations within the stream “canyon” (burned into the DEM). This “stepping” improves NHDPlusV2 over NHDPlusV1 data where the previous hydro-enforcement filling process occasionally created reverse flow situations.

Enforcement of Stepped Values in the Ocean and Estuaries – In NHDPlusV1, ocean and estuary areas were set to NoData. In NHDPlusV2, the NHD ocean coastlines were hydro-enforced into the DEM by setting the elevation values below the minimum “burned” elevation value of the BurnLineEvent features. Then selected estuaries were given elevation values 1cm higher than the ocean coastline elevation values. This stepping of coastal water elevation values enables watershed delineations within the selected estuaries.

Catchment/Burn Attributes - In NHDPlusV2, greater controls over the hydro-enforcement process were introduced through attributes in the BurnLineEvent table. Using these attributes, individual flowlines could be logically removed from the burning process and/or logically removed from the catchment delineation process.

Controlling which features are burned provides flexibility in representing the network in the flow direction and flow accumulation grids. For example, pipeline features, certain elevated sections of canals, or flowlines that would create problems near WBD walls, were removed from the burning process.

Controlling which features receive catchments prevents features not receiving overland flow from having a catchment. Examples of flowlines that should not receive a catchment include pipelines and elevated sections of canals.

Rasterization of Burn Line Features using StreamLevel - In both versions of NHDPlus, catchments are delineated with the ArcGIS Watershed Tool using the NHDPlus flow direction grid and a raster grid representation of the flowlines (used as the "seed" source). In NHDPlusV1, the grid representations of these burn lines were problematic at node intersections, where when multiple burn lines existed within a grid cell, the DEM cell value was assigned to the feature with the greatest length within the cell. This created an issue when the confluence node was assigned to a tributary stream rather than the main path stream- leading to undesirable results in catchment delineation. In NHDPlusV2, this problem was eliminated by using the VAA "StreamLevel" attribute to control the rasterization of streams. Now at a confluence in the burn lines, the stream with the lowest StreamLevel receives the confluence node in its catchment.

BurnAddLine and BurnAddWaterbodies - In NHDPlusV2 new capabilities include non-NHD features for hydro-enforcement of the DEM. Additional linear features are stored in the BurnAddLine feature class, while additional waterbody polygons are stored in the BurnAddWaterbody feature class.

Features placed in BurnAddLine were derived from multiple sources and are used for a variety of purposes. For example, BurnAddLine features were added to ensure proper drainage of WBD HUC12 units where NHD is not present. Another use of BurnAddLine features was to improve catchment delineation in international areas. BurnAddLine features were also added to provide a flow channel within estuaries.

Features in BurnAddWaterbody were commonly added to ensure sink placement for closed lakes not found in the medium resolution NHD. BurnAddWaterbody also holds waterbodies from international areas to enhance catchment delineations across international borders. Waterbody polygons placed in BurnAddWaterbody were derived from high resolution NHD or the Canadian National Hydrography Network dataset, or were digitized from imagery.

Flow Direction Grid with NoData Values for Burn Line Stream cells - FdrNull is a new grid in NHDPlusV2, and is a variant of the NHDPlusV2 flow direction grid in which the cells of BurnLineEvent features are set to NoData. FdrNull and can be used to compute flow path length grids. Flow path length grids are useful for a variety of purposes including determining the mean flow path length within a catchment or deriving stream riparian buffer areas.

Improved and Expanded Value Added Attributes (VAAs) – The NHDPlusV2 processing tools perform extensive automated quality assurance/quality control (QA/QC) on the VAAs to ensure the accuracy and consistency of attributes. New VAAs have been added, such as RTNDIV (returning divergence) which identifies flowlines where an upstream divergence returns to the network. The VAAs FromMeas and ToMeas, expose the measures (m-values) assigned to the "bottom" and "top" endpoints of NHDFlowline features. In NHDPlusV2, assigning HydroSeq (hydrologic sequence number) is performed across an entire drainage area rather than for each HUC8 (as was done for NHDPlusV1). Assigning the HydroSeq this way adds power to queries using HydroSeq. Additionally, unlike NHDPlusV1, NHDPlusV2 has VAAs calculated for Coastline features.

Introduction of Flow Split Controls – NHDPlusV2 contains a divergence fraction/main path table (DivFracMP) that permits control over network splits. The NHDPlusV2 processing tools used this table to determine which path in a divergence is the main path and the stream flow fraction assigned to each path of the divergence.

Points of Addition and Removal – NHDPlusV2 gives users the ability to specify points along the NHDFlowline network where flow is removed or added and to specify the quantity of water removed or added. These points are stored in the PlusARPointEvent and the PlusFlowAR tables. Irrigation withdrawals and returns, drinking water withdrawals, and permitted discharges may be specified using this new capability. In addition, a withdrawal point and an addition point may be linked to represent an inter-basin flow transfer.

Great Lakes Supercatchments – NHDPlusV2 includes polygons known as “Supercatchments” representing the drainage areas above the outlets of four of the Great Lakes: Lake Superior, Lake Huron, Lake Erie, and Lake Ontario. These Supercatchments include the areas on the Canadian side of the Great Lakes and are used to provide accurate cumulative drainage areas for the rivers flowing from the lakes.

Flow Accumulation Grid Extent and Content – In NHDPlusV1 and V2, the hydro-enforcement process is run for a Raster Processing Unit (RPU) and a buffer area surrounding the RPU. In NHDPlusV1 and V2, the distributed grids do not contain values outside the RPU boundaries (i.e. in the buffer area). In NHDPlusV1 and V2, if one RPU drains into another RPU, the flow accumulation values in the upstream RPU do not carry into the downstream RPU. In other words, cell counts of an upstream RPU drainage are not reflected in the cell counts of a downstream RPU.

In NHDPlusV1, while the distributed grid does not contain the processed buffer area, if all or part of the buffer area drains into the RPU, then the RPU’s flow accumulation grid cell values include the upstream cells from the buffer area.

In NHDPlusV2, the distributed grid does not contain the processed buffer area and, if all or part of the buffer area drains into the RPU, then the RPU’s flow accumulation grid cell values DO NOT include the surrounding buffer area. Only cells within the RPU are counted in the NHDPlusV2 flow accumulation grids.

The list above briefly describes the primary improvements incorporated into NHDPlusV2. All improvements are described in more detail in this guide.

NHDPlusV2 Data Structure

In NHDPlusV1, the geographic units were (1) “Production Units” for the raster components (elevation, flow direction and flow accumulation grids) and (2) “Hydrologic Regions” (2-digit Hydrologic Units) for catchment grids, all vector feature classes and all tables. In the future, as the source datasets for NHDPlus become higher resolution, these geographic units will need to change and, in general, become smaller. Thus NHDPlusV2 introduces new and flexible geographic divisions. NHDPlusV1 “Production Unit” is replaced by the NHDPlusV2 “Raster Processing Unit” (RPU). The NHDPlusV1 “Hydrologic Region” is replaced with the NHDPlusV2 “Vector Processing Unit” (VPU).

Because NHDPlusV2 is constructed from the same resolution inputs as NHDPlusV1, the VPUs in NHDPlusV2 are similar to the “Hydrologic Regions” defined in NHDPlusV1. In NHDPlusV1 and NHDPlusV2, Hydrologic Region 10, the Missouri River Basin, was divided into 2 VPUs. Also Hydrologic Region 3, Southeastern United States (“South Atlantic”), was processed as one VPU in NHDPlusV1, but processed as three VPUs in NHDPlusV2. The NHDPlusV2 RPUs are similar, but not identical to the NHDPlusV1 “Production Units”. RPUs represent some hydrologic improvements over the “Production Units”.

NHDPlusV2 data is distributed by the major drainage areas of the United States. Within a Drainage Area, the NHDPlusV2 data components are packaged into compressed files either by Vector Processing Unit (VPU) or Raster Processing Unit (RPU). A Drainage Area is composed of one or more VPUs and a VPU is composed of one or more RPUs. The valid NHDPlusV2 Drainage Areas, VPUs and RPUs are shown in Figures 5a and 5b.

Drainage Area Name	Drainage Id	VPUs	RPUs
Northeast	NE	01	01a
Mid-Atlantic	MA	02	02a, 02b
South Atlantic	SA	03N, 03S, 03W (less 0318) ²	03a, 03b, 03c, 03d, 03e, 03f
Great Lakes	GL	04	04a, 04b, 04c, 04d
Mississippi	MS	06, 05, 07, 08, 10U, 10L, 11 and 0318 ²	06a, 05a, 05b, 05c, 05d, 07a, 07b, 07c, 08a, 08b, 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10h, 10i, 11a, 11b, 11c, 11d, 03g
Souris-Red-Rainy	SR	09	09a
Texas	TX	12	12a, 12b, 12c, 12d
Rio Grande	RG	13	13a, 13b, 13c, 13d
Colorado	CO	14, 15	14a, 14b, 15a, 15b
Great Basin	GB	16	16a, 16b
Pacific Northwest	PN	17	17a, 17b, 17c, 17d
California	CA	18	18a, 18b, 18c

Figure 5a: NHDPlusV2 Drainage Areas, VPUs, and RPUs

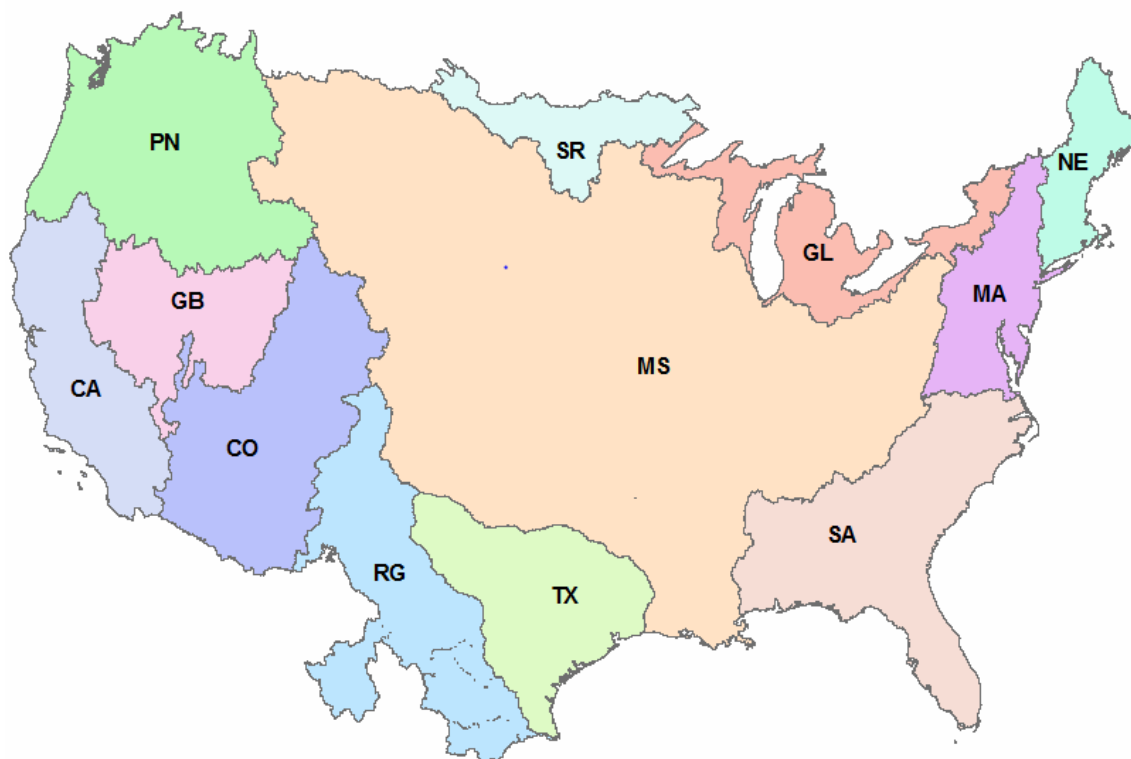


Figure 5b: NHDPlusV2 Drainage Area Map

² The HUC4 0318 contains the Pearl River drainage which has both inflows and outflows with Hydro Region 08, while being completely disconnected from the rest of Hydro Region 03. Because of the connections with Hydro Region 08, NHDPlusV2 includes 0318 with the Mississippi drainage area.

Note that some large areas of WBD have been recoded with Hydrologic Unit Codes (HUC codes) that differ significantly from previous HUC codes. For example: HUC4s 0111 and 0201 were renumbered to 0415; and 1001 was renumbered to 0904. Numerous smaller changes have also occurred. The NHDPlusV2 processing for the re-coded areas was already underway when the changes were detected and, given the timing, it was not feasible to re-process those areas or to physically move data from one NHDPlusV2 workspace to another. However, the NHD snapshot ReachCodes on both NHDFlowline and NHDWaterbody features were adjusted to reflect the HUC8s in the February 1, 2012 version of WBD. Therefore, in some NHDPlusV2 workspaces, some NHDFlowline and NHDWaterbody features will have ReachCodes that reflect a different hydrologic region than the VPU in which the features are stored. When NHDPlusV2 is reprocessed for these areas, these issues will be addressed.

Like NHDPlusV1, NHDPlusV2 data is distributed as shapefiles, grids, and .dbf tables. The NHDPlusV2 data structure is shown below. An asterisk (*) is used to indicate new or changed components relative to the NHDPlusV1 data structure.

The overall data structure is:

\NHDPlusGlobalData

BoundaryUnit (polygon feature class) *

BoundaryValue (table) *

\NHDPlusV21Metadata

This folder contains a collection of metadata for NHDPlusV2 and for the source datasets used to produce NHDPlusV2.

\NHDPlusNationalData

GageLoc (point feature class) *

GageInfo (table) *

Gage_Smooth (table) *

nationalcat (grid) *

\SuperCatchments*

SuperCatchments (polygon feature class)*

\supercatgrids*

\info

\sc<featureid> (grid)

.

.

Where featureid is an NHDFlowline ComID

NationalWBDSnapshot (polygon feature class)

National_Seamless_GeoDatabase (file geodatabase)

The content of the \NHDPlusDD folder is referred to as a Drainage Area workspace.

Each Drainage Area workspace has the following structure:

- \NHDPlusDD (drainage area folder)
 - \DAAttributeExtension (NHDPlus data extensions for the Drainage Area)
 - \NHDPlusVVVVVVVV (VPU folder)
 - [VPU feature classes, grids and tables]
 - \NHDPlusRRRRRRRR (RPU folder)
 - [RPU feature classes, grids and tables]
 - [Additional RPUs]
 - [Additional VPUs]
 - [Additional Drainage Areas]

Where

- DD = Drainage Area Id of 1-2 characters
- VVVVVVVV = VPUIDs of 1-8 characters
- RRRRRRRR = RPUIDs of 1-8 characters

The content of a \NHDPlusVVVVVVVV folder is referred to as a VPU workspace.

Each VPU workspace will contain:

- \NHDPlusVVVVVVVV
 - \NHDPlusAttributes
 - CumulativeArea (table) *
 - DivFracMP (table) *
 - ElevSlope (table) *
 - HeadwaterNodeArea (table) *
 - PlusARPointEvent (table) *
 - PlusFlowlineVAA (table) *
 - PlusFlow (table) *
 - PlusFlowAR (table) *
 - MegaDiv (table)*
 - PlusFlowlineLakeMorphology (table)*
 - PlusWaterbodyLakeMorphology (table)*
 - \NHDPlusCatchment
 - cat (grid)
 - \info (info tables for cat grid)
 - Catchment (polygon feature class)
 - FeatureIDGridCode (table) *
 - \NHDPlusBurnComponents
 - BurnAddLine (line feature class) *
 - BurnAddWaterbody (polygon feature class) *
 - BurnLineEvent (table) *
 - BurnWaterbody (polygon feature class) *
 - LandSea (polygon feature class) *

- Sink (point feature class) *
- Wall (line feature class) *
- \NHDSnapshot
 - NHDFcode (table)
 - NHDSReachCode_ComID (table)
 - NHDSReachCrossReference (table)
 - \hydrography
 - NHDSFlowline (line feature class)
 - NHDSWaterbody (polygon feature class)
 - NHSDPoint (point feature class)
 - NHSDLine (line feature class)
 - NHSDArea (polygon feature class)
 - NHSDHydroAreaEventFC (empty polygon feature class)
 - NHSDHydroLineEventFC (empty line feature class)
 - NHSDHydroPointEventFC (empty point feature class)
- \NEDSnapShot
 - \NEDRRRRRRRR
 - \elev_cm
 - \shdrelief*
 - \info
- \WBDSnapShot
 - \WBD
 - WBD_Subwatershed (polygon feature class)*

RPU folders reside under the VPU workspace folder and will contain NHDPlusV2 RPU components. Each RPU folder name ends in RRRRRRRR which is replaced with the RPUid.

- \NHDPlusCatSeedRRRRRRRR
 - \catseed (grid)*
 - \info
- \NHDPlusFdrFacRRRRRRRR
 - \fac (grid)
 - \fdr (grid)
 - \info
- \NHDPlusFdrNullRRRRRRRR
 - \fdnull (grid)*
 - \info
- \NHDPlusFilledAreasRRRRRRRR
 - \filledareas (grid)*
 - \info
- \NHDPlusHydrodemRRRRRRRR
 - \hydrodem (grid)*
 - \info

The NHDPlusV2 extended components will be stored in separate folders under the NHDPlusV2 Drainage Area or VPU folders, as appropriate. The structures of the, currently defined, extended components are:

\DAAttributeExtension

No drainage area attribute extensions have been defined as yet.

\NHDPlusVVVVVVVV (VPU folder)

\EROMExtension

EROM_MAnnnn (table)*

EROMQA_nnnn (pdf)*

EROMQA_MAnnnn (table)*

\VOGELEExtension

VogelFlow (table)*

\VPUAttributeExtension

IncrLat.txt*

IncrPrecipMA.txt*

IncrPrecipMM01.txt*

IncrPrecipMM02.txt*

IncrPrecipMM03.txt*

IncrPrecipMM04.txt*

IncrPrecipMM05.txt*

IncrPrecipMM06.txt*

IncrPrecipMM07.txt*

IncrPrecipMM08.txt*

IncrPrecipMM09.txt*

IncrPrecipMM10.txt*

IncrPrecipMM11.txt*

IncrPrecipMM12.txt*

IncrTempMA.txt*

IncrTempMM01.txt*

IncrTempMM02.txt*

IncrTempMM03.txt*

IncrTempMM04.txt*

IncrTempMM05.txt*

IncrTempMM06.txt*

IncrTempMM07.txt*

IncrTempMM08.txt*

IncrTempMM09.txt*

IncrTempMM10.txt*

IncrTempMM11.txt*

IncrTempMM12.txt*

IncrROMA.txt*

IncrROMM01.txt*

IncrROMM02.txt*

IncrROMM03.txt*

IncrROMM04.txt*
IncrROMM05.txt*
IncrROMM06.txt*
IncrROMM07.txt*
IncrROMM08.txt*
IncrROMM09.txt*
IncrROMM10.txt*
IncrROMM11.txt*
IncrROMM12.txt*
CumDivPrecipMA.txt*
CumTotPrecipMA.txt*
CumDivTempMA.txt*
CumTotTempMA.txt*

Projection Information

All vector data in feature class format uses the following projection/coordinate system:

Projection	GEOGRAPHIC
Datum	NAD83
Zunits	NO
Units	DD
Spheroid	GRS1980
Xshift	0.0000000000
Yshift	0.0000000000

All grid datasets (cat, fac, fdr, elev_cm, ext_fac, ext_fdr) for the conterminous U.S. are stored in an Albers Equal-Area projection:

Projection	ALBERS
Datum	NAD83
Zunits	100 for elev_cm, otherwise "NO"
Units	METERS
Spheroid	GRS1980
Xshift	0.0000000000
Yshift	0.0000000000
Parameters	
29 30 0.000	/* 1st standard parallel
45 30 0.000	/* 2nd standard parallel
-96 0 0.000	/* central meridian
23 0 0.000	/* latitude of projection's origin
0.00000	/* false easting (meters)
0.00000	/* false northing (meters)

A Guide for Installing NHDPlusV2 Data

NHDPlusV2 data is distributed in compressed files created by 7-Zip (compression software) with a “.7z” extension. While 7-Zip can create files in standard Zip format, the NHDPlusV2 data is stored in a special 7-Zip format which creates even smaller compressed files. This helps preserve disk space and shorten the time required for data download,

Along with other zipping utilities that support “.7z” files, 7-Zip may be used to uncompress the NHDPlusV2 data. 7-Zip is a free utility available at: <http://www.7-zip.org/download.html>.

NHDPlusV2 data is distributed by Drainage Area. Within a Drainage Area, the NHDPlusV2 data components are packaged into .7z files either by Vector Processing Unit (VPU) or Raster Processing Unit (RPU). A Drainage Area is composed of one or more VPUs and a VPU is composed of one or more RPUs.

After installing 7-Zip (or other zipping utility that supports “.7z” files) and downloading the NHDPlusV2 data, please follow these steps to install the data:

1. Make a folder for the NHDPlusV2 data (e.g. \NHDPlusV2Data). For the best performance, install the data on a local drive.
2. The compressed data files are named:

NHDPlusV2nn_<dd>_<VPUid>_componentname_<vv>

Or

NHDPlusV2nn_<dd>_<VPUid>_<RPUid>_componentname_<vv>

Where:

V2nn is version (2) and subversion (nn) of the NHDPlusV2 data model,
dd is the Drainage Area identifier,
VPUid is the VPU identifier,
RPUid is the RPU identifier,
Componentname is the name of the NHDPlusV2 component contained in the file,
and
vv is the data content version, 01, 02, ... for the component.

The valid values for NHDPlusV2 Drainage Areas, VPUs and RPUs are provided in section “NHDPlusV2 Data Structure”.

Each NHDPlusV2 “.7z” file should be uncompressed into the folder created in step 1. **When using 7-Zip, allow it to automatically preserve/create the folder structure that is included in the “.7z” files.** To accomplish this using 7-zip installed on Windows, use the “Extract Here” option. First, save all “.7z” files to the folder created in step 1. Second, select all “.7z” files using Windows Explorer. Third, right-click on the selected

files and use the “Extract Here” option. This will ensure all folders and files are extracted into their appropriate locations.

3. Using Drainage Area GL (i.e. Great Lakes) and a VPU 04 (i.e. Hydrologic Region 04) as an example, when completely installed, the uncompressed data should look like this:

```
\NHDPlusV2Data
  \NHDPlusGL
    \DAAtributeExtension
    \NHDPlus04
      \<NHDPlusV2 component folders>
```

4. NHDPlusV2nn_Global Data_vv.7z should be uncompressed into the same upper level folder as the drainage area data. The decompression will create the \NHDPlusGlobalData folder.

```
\NHDPlusV2Data
  \NHDPlusGlobalData
```

5. NHDPlusV2nn_NationalData_vv.7z, it should be uncompressed into the same upper level folder as the drainage area data. The decompression will create the \NHDPlusNationalData folder.

```
\NHDPlusV2Data
  \NHDPlusNationalData
```

6. NHDPlusV2nn_Metadata_vv.7z should be uncompressed into the same upper level folder as the drainage area data. The decompression will create the \NHDPlusV2nn_Metadata folder.

```
\NHDPlusV2Data
  \NHDPlusV2nn_Metadata
```

NHDPlusV2 Distribution Files and NHDPlusV2 Components

The correspondence between the NHDPlusV2 .7z distribution files and the NHDPlusV2 data components that are contained in the .7z file is shown in the table below.

Distribution Zip Files	Zip File Contents
NHDPlusV2nn_Metadata_dd.7z	\NHDPlusV2nn_Metadata
NHDPlusV2nn_GlobalData_dd.7z	\NHDPlusGlobalData
	BoundaryUnit.shp
	BoundaryValue.dbf
	\SuperCatchments
	SuperCatchments.shp
	\supercatgrids
	\sc<ComID> (grid)
NHDPlusV2nn_NationalData_dd.7z	\NHDPlusNationalData
	GageLoc.shp
	GageInfo.dbf
	RefGages.txt
	GageSmooth.dbf
	\nationalcat (grid)
	NationalWBDSnapshot.shp
	WBDCatch_XWalk.dbf
NHDPlusV2nn_NationalData_National_Seamless_GeoDatabase_dd.7z	National_Seamless_Geodatabase.gdb
The zip files below contain higher level folders as needed and as described previously.	\NHDPlusV2dd \NHDPlusVVVVVVVVV \NHDPlusRRRRRRRR
NHDPlusV2nn_DD_<VPUid>_EROMExtension_dd.7z	\EROMExtension
	EROM_MA0001.dbf
	EROM_mm0001.dbf, where mm is 01 thru 12
	EROMQA_MA0001.dbf
	EROMQA_mm0001.dbf, where mm is 01 thru 12
	EROMQA_0001.pdf
NHDPlusV2nn_DD_<VPUid>_<RPUid>_NEDSnapshot_dd.7z	\NEDSnapshot
	\ned<rpuid>
	\elev_cm (grid)
	\shdrelief (grid)
NHDPlusV2nn_DD_<VPUid>_NHDPlusAttributes_dd.7z	\NHDPlusAttributes
	CumulativeArea.dbf
	HeadwaterNodeArea.dbf
	DivFracMP.dbf
	PlusFlowlineVAA.dbf
	PlusFlow.dbf
	PlusARPointEvent.dbf
	PlusFlowAR.dbf
	MegaDiv.dbf
	ElevSlope.dbf
	PlusFlowlineLakeMorphology
	PlusWaterbodyLakeMorphology
NHDPlusV2nn_DD_<VPUid>_NHDPlusBurnComponents_dd.7z	\NHDPlusBurnComponents
	BurnlineEvent.dbf

	BurnWaterbody.shp
	Sink.shp
	Wall.shp
	BurnAddLine.shp
	BurnAddWaterbody.shp
	LandSea.shp
NHDPlusV2nn_DD_<VPUID>_NHDPlusCatchments_dd.7z	\NHDPlusCatchment
	\cat (grid)
	Catchment.shp
	FeatureIDGridCode.dbf
NHDPlusV2nn_DD_<VPUID>_<RPUID>_CatSeed_dd.7z	\NHDPlusCatSeed<rpuid>
	\catseed
NHDPlusV2nn_DD_<VPUID>_<RPUID>_FdrFac_dd.7z	\NHDPlusFdrFac<rpuid>
	\fdr (grid)
	\fac (grid)
NHDPlusV2nn_DD_<VPUID>_<RPUID>_FdrNull_dd.7z	\NHDPlusFdrNull<rpuid>
	\fdrnull
NHDPlusV2nn_DD_<VPUID>_<RPUID>_FilledAreas_dd.7z	\NHDPlusFilledAreas<rpuid>
	\filledareas
NHDPlusV2nn_DD_<VPUID>_<RPUID>_Hydrodem_dd.7z	\NHDPlusHydrodem<rpuid>
	\hydrodem
NHDPlusV2nn_DD_<VPUID>_NHDSnapshot_dd.7z	\NHDSnapshot
	\hydrography
	NHDFlowline.shp
	NHDWaterbody.shp
	NHDArea.shp
	NHDPoint.shp
	NHDFcode.dbf
NHDPlusV2nn_DD_<VPUID>_VogelExtension_dd.7z	\VogelExtension
	VogelFlow.dbf
NHDPlusV2nn_DD_<VPUID>_VPUAttributeExtension_dd.7z	\VPUAttributeExtension
	IncrLat.txt
	IncrPrecipMA.txt
	IncrPrecipMmm.txt
	CumDivPrecipMA.txt
	CumTotPrecipMA.txt
	IncrTempMA.txt
	IncrTempMmm.txt
	CumDivTempMA.txt
	CumTotTempMA.txt
	ROMA.txt
	ROMmm.txt
NHDPlusV2nn_DD_<VPUID>_WBDSnapshot_dd.7z	\WBDSnapshot
	\WBD
	Sub_Watershed.shp

Figure 6: NHDPlusV2 Distribution Files and Their Contents

NHDPlusV2 Versioning System

NHDPlusV2 has a dual versioning system; both the data model and the data content are versioned. The NHDPlusV2 .7z download files each contain the version information in the filename. The filenames have two formats:

NHDPlusV2nn_<dd>_<VPUid>_componentname_<vv>

Or

NHDPlusV2nn_<dd>_<VPUid>_<RPUid>_componentname_<vv>

Where:

V2nn is version (2) and subversion (nn) of the NHDPlusV2 data model

vv is the data content version, 01, 02, ... for the component.

Additionally, each component can be versioned and distributed without the need to re-release all components in the VPU. For example, at any given time, both NHDPlusV21_MS_10L_Catchment_01.7z and NHDPlusV21_MS_10L_NHD_03.7z might be available for download. In this example, the Catchment shape file has data model version 2.1 and data content version 01, while the NHDSnapshot component has schema version 2.1 and data content version 03.

The NHDPlus download site contains the most recent version for each component. When a change in NHDPlusV2 affects more than one component, the new version of all affected components will be made available at the same time. Therefore, users can be assured that all components on the download site, regardless of their indicated versions, are compatible with each other.

Users can determine which versions they have downloaded and uncompressed by examining the version text files that reside within the uncompressed NHDPlusV2 data. Each .7z files contain a .TXT file with the same name as the .7z file. For example, NHDPlusV21_MS_08_NHDSnapshot_02.7z will contain a file called NHDPlusV21_MS_08_NHDSnapshot_02.txt.

When NHDPlusV2 .7z files are uncompressed, the version text files are stored in the appropriate Drainage Area folder. These empty text files are used solely to denote, by their file name, the version of NHDPlusV2 data component that has been installed. The existence of these .TXT files means that the user, at one time, installed the indicated versions of the specified NHDPlusV2 components.

To serve as a history of the NHDPlusV2 component version, the .TXT files will not be overwritten when a component update is uncompressed. In general, when a new version of an NHDPlusV2 component is released, a note about the component is added to the release notes for that VPU.

When an updated component is available, users must first delete the existing version of the component. This may be accomplished using ArcCatalog or Windows Explorer. The superseded NHDPlusV2 components that must be deleted are listed in the section above entitled “NHDPlusV2 Distribution Files and NHDPlusV2 Components”. Once the superseded version of the component is deleted, the updated component should be installed as instructed (see section titled “A Guide for Installing NHDPlusV2”).

NHDPlusV2 documentation is versioned by the data model version only (see first page of guide). When you download a component containing a new data model version, you should also download new documentation.

The first public version of NHDPlusV2 has a data model designation of V2.1 with the components having different data content versions. Draft NHDPlusV2 data was distributed to a limited number of evaluation users. The draft data contains a data model designation of “V2” and was not accompanied by version .TXT files.

NHDPlusV2 Global Data Feature Class and Table Descriptions

NHDPlusV2 Global Data tables BoundaryUnit and BoundaryValue contain information compiled during the NHDPlus Build/Refresh process and include spatial and continuity information (such as the connection information between multiple VPUs in a Drainage Area and the geographic boundaries of VPUs and RPUs).

The NHDPlusV2 Global Data tables PlusMetadata, PlusSourceCitation, and PlusSourceUsed are metadata tables for NHDPlus. Metadata is created during the NHDPlusV2 Build/Refresh process and includes information about the source datasets used to build NHDPlusV2 and about the processing steps performed.

The NHDPlusV2 Global Data feature classes, conus_ned_metadata_<yymm> contain the metadata for each of the NED snapshots used to build NHDPlusV2.

The following conventions are used when describing NHDPlusV2 component attributes:

- Field formats are intended to be technology-neutral. Primary and foreign keys are all long integer format to facilitate relates and joins. Other formats show the maximum size and precision of the field.
- A particular database technology may dictate the format for a given field. As an example, a number with 6 total digits with 3 to the right of the decimal point is specified in this volume as (6,3), however it would be (7,3) in a .dbf file.
- All redundancy (un-normalized fields) in the database has been introduced to increase performance in the build/refresh tools and end-user tools.
- All field names are verbose to enhance readability, however, in some implementation formats, the field names may be truncated. For example, field names will be truncated to 10 characters in .dbf files.
- A field value of -9998 signifies that a value is applicable, but unknown.
- A field value of -9999 signifies that a value is not applicable

WHDPlusGlobalData\BoundaryUnit (feature class)

Description: Contains a polygon boundary for each geographic unit used to build NHDPlus. The unit types with boundaries are VPU and RPU. The boundaries are constructed from NHDPlusV2 Catchments.

Field Name	Description	Format
DrainageID	Drainage Area identifier	Character (2)
UnitID	Boundary Unit unique identifier	Character (8)
UnitName	Boundary Unit Name (populated for VPUs)	Character (100)
UnitType	Boundary Unit Type - "VPU", "RPU"	Character (5)
Hydroseq	Hydrologic order of Boundary Unit (populated for VPUs)	Num(11)
AreaSqKM	Area in square kilometers of the unit	Num(13,4)
Shape_Area	Feature area in square decimal degrees	See ESRI documentation

WHDPlusGlobalData\SuperCatchments (feature class)

Description: Contains Supercatchment polygons. Supercatchments are drainage polygons for the NHDFlowline associated with Supercatchments.FeatureID. The Supercatchment is the entire drainage area upstream of the associated NHDFlowline designated by FeatureID. Supercatchments were created only for Hydrologic Region 04 (Great Lakes) to represent the entire drainage, both Canadian and US, into each of the lakes.

Field Name	Description	Format
GridCode	Catchment gridcode for the NHDFlowline catchment	Num(10,0)
FeatureID	ComID of the associated NHDFlowline	Long Integer
SourceFC	“NHDFlowline”	Char(20)
AreaSqKM	Area of the supercatchment in square kilometers	Num(18,6)
VPUID	Vector Processing Unit Identifier	Char(8)

WHDPlusGlobalData\SC<featureid> (grid)

Description: These are Supercatchment grids. There is a grid for each Supercatchment polygon in SuperCatchments. The featureid in the grid name links to SuperCatchments.FeatureID.

Field Name	Description	Format
Value	The value stored in the grid cell; a unique, compact identification number for a NHDFlowline Super catchment; also referred to as GridCode – See FeatureIDGridCode	Long Integer
Count	Number of grid cells with a particular value in the Value field.	Long Integer

NHDPlusV2 Metadata Collection

WHDPlusMetadata\WHDPlusV2_Metadata.htm (and .xml)

Description: This file contains overall metadata for NHDPlusV2. Metadata for individual VPUs is located in the \NHDPlus\VVVVVVVV folders.

WHDPlusMetadata\WHD_MedRes_metadata.xml

Description: In April 2010, the medium resolution NHD data was extracted from the USGS NHD database in preparation for building NHDPlusV2. The data was extensively edited prior to NHDPlusV2 production (see section entitled “Highlights of How NHDPlusV2 Differs from NHDPlusV1”). The following links provide documentation about NHD:

<http://nhd.usgs.gov/index.html>

http://nhd.usgs.gov/userguide.html?url=NHD_User_Guide/Feature_Catalog/NHD_Feature_Catalog.htm

WHDPlusMetadata\WHD_HiRes_metadata.xml

Description: In 2014, the high resolution NHD data was extracted from the USGS NHD database in preparation for building NHDPlusV2 for Hawaii, Puerto Rico, the U.S. Virgin Islands, American Samoa, Guam and the Northern Mariana Islands. The following link provides documentation about high resolution NHD:

<http://nhd.usgs.gov>

WHDPlusMetadata\Conus_NED_Metadata<yymm> (feature class)

WHDPlusMetadata\NED_DataDictionary20100601 (pdf)

WHDPlusMetadata\NED_Metadata_Hawaii (feature class)

WHDPlusMetadata\NED_Metadata_PuertoRico (feature class)

WHDPlusMetadata\NED_Metadata_Guam (feature class)

WHDPlusMetadata\NED_Metadata_NorthernMariana (feature class)

WHDPlusMetadata\NED_Metadata_AmericanSamoa (feature class)

Description: These files contain metadata for the NED snapshots that were used to build NHDPlusV2. NHDPlusV21.met contains the NED snapshot date used for each VPU. Each NED snapshot has a separate metadata shapefile contained in the \NHDPlusGlobalData folder. The NED_DataDictionary20100601.pdf contains the field descriptions for the Conus_NED_Metadata_<yymm> feature attributes.

WHDPlusMetadata\CDED_Metadata\CDED_Index_Polygons (polygon feature class) and cded_<tile>_fgdc_en.xml

Description: This folder contains metadata for the portions of the Canadian Digital Elevation Data (CDED) used to build NHDPlusV2. The CDED data were downloaded from the <http://www.geobase.ca> website. The CDED_Index_Polygons feature class contains an index to the individual data files that were used for NHDPlusV2. The CDED data tiles were accompanied by FGDC metadata xml files. The metadata files are provided in the metadata folder, and the first part of the filenames may be matched with the filenames shown in the Path field of the CDED_Index_Polygons feature class.

WHDPlusMetadata\WBD_Poly_Seamless.Met (text)

Description: This file contains the metadata for the WBD snapshots that were used to build NHDPlusV2. NHDPlusV21.met contains the WBD snapshot date used for each VPU. The WBD metadata is cumulative, with process descriptions listed in chronological order. The metadata for each WBD snapshot is described by all the process descriptions with dates equal to or earlier than the snapshot date.

NHDPlusV2 National Data Feature Class and Table Descriptions

The following conventions are used when describing NHDPlusV2 component attributes:

- Field formats are intended to be technology-neutral. Primary and foreign keys are all long integer format to facilitate relates and joins. Other formats show the maximum size and precision of the field.
- A particular database technology may dictate the format for a given field. As an example, a number with 6 total digits with 3 to the right of the decimal point is specified in this volume as (6,3), however it would be (7,3) in a .dbf file.
- All redundancy (un-normalized fields) in the database has been introduced to increase performance in the build/refresh tools and end-user tools.
- All field names are verbose to enhance readability, however, in some implementation formats, the field names may be truncated. For example, field names will be truncated to 10 characters in .dbf files.
- A field value of -9998 signifies that a value is applicable, but unknown.
- A field value of -9999 signifies that a value is not applicable

NHDPlusNationalData\GageLoc (feature class)

GageLoc contains the locations of stream flow gages on the NHDFlowline features. This table is used in the EROM gage adjustment step (See Appendix A).

Field Name	Description
ComID	Not populated, a unique id for each NHD event assigned during the central NHD update process.
EventDate	Date event was created
ReachCode	ReachCode on which Stream Gage is located
ReachSMDat	Reach Version Date (Not populated)
Reachresol	Reach Resolution, always "Medium" (i.e. 1:100K scale)
FeatureCom	Reserved for future use
FeatureCla	Reserved for future use
Source_Ori	Originator of Event
Source_Dat	Description of point entity
Source_Fea	Gage ID/USGS Site Number
Featuredet	URL where detailed gage data can be found (NWISWEB)
Measure	Measure along reach where Stream Gage is located in percent from downstream end of the one or more NHDFlowline features that are assigned to the ReachCode
Offset	Always zero
EventType	"StreamGage"
FLComID	ComID of the NHDFlowline feature on which the gage is located.

WHDPlusNationalData\GageInfo (table)

GageInfo contains information about each gage extracted from the National Water Information System (NWIS). This table is used in the EROM gage adjustment step.

Field Name	Description
GageID	NWIS Gage ID
Agency_CD	Agency Code
Station_NM	Station Name
State_CD	State Code
State	State name
DASqMi	NWIS Drainage Area (Sq. Miles)
DASqKm	NWIS Drainage Area (Sq. Kilometers)
LatSite	NWIS Latitude
LonSite	NWIS Longitude
Active	NWIS Status: 0 = Not Active, 1 = Active, 9 = Status Unknown
ActiveDate	Date active status was determined
GagesII	Blank = not in GagesII dataset, "Ref" = Reference Gage in GagesII dataset, "Non-ref" = in GagesII dataset but not a reference gage

WHDPlusNationalData\Gage_Smooth (table)

Gage_Smooth provides data for the mean annual and mean monthly gage flows. This table is used in the EROM reference gage regression and the gage adjustment steps (See Appendix A). To coordinate the gage flows with the other EROM inputs, this table is used to compute mean annual and mean monthly gage flows for the 1971 to 2000 time period.

Variable	Format	Description
Site_No	Char(16)	The NWIS Gage ID
Year	Char(4)	The year
Month	Char(2)	The Month. "MA" = Mean Annual, "01" = January, "02" = February, etc.
Ave	Double	The mean flow for the year/month at the gage (cfs)
CompleteRe	Integer	<p>0 = There is not a complete record for the time period.</p> <p>1 = There is a complete record for the time period.</p> <p>A complete record is daily flow values for every day in the time period.</p> <p>The time period is the Year/Mo for a monthly mean and the Year for an annual mean. The gage adjustments are only done using records that have a complete record.</p>

WHDPlusNationalData\nationalcat (grid)

Description: An ESRI integer grid containing a national version of the VPU catchment (cat) grids (see “\NHDPlusCatchment\cat (grid)”). The cat grids contained in the individual VPUs are combined to build the nationalcat grid. NHDPlus catchments are created for NHDFlowline features and for Sink features.

The national cat grid is provided for display purposes by users interested in the overall distribution of catchments. Due to the large size of the national dataset, data analysis requiring linking NHDPlus data and attributes to the catchments probably should be done at the VPU level rather than at the national level. The catchment grid (cat) at the VPU level has a raster attribute table, with the attribute “FeatureID” that can be used to link other NHDPlus data and attributes to the catchments.

Field Name	Description	Format
Value	The value stored in the grid cell; a unique, compact identification number for each catchment; also referred to as GridCode – See FeatureIDGridCode	Long Integer

WHDPlusNationalData\National_Seamless_Geodatabase (file geodatabase)

Description: See separate User Guide available at file download site.

NHDPlusV2 Core Feature Class, Grid, and Table Descriptions

The following conventions are used when describing NHDPlusV2 component attributes:

- Field formats are intended to be technology-neutral. Primary and foreign keys are all long integer format to facilitate relates and joins. Other formats show the maximum size and precision of the field.
- A particular database technology may dictate the format for a given field. As an example, a number with 6 total digits with 3 to the right of the decimal point is specified in this volume as (6,3), however it would be (7,3) in a .dbf file.
- All redundancy (un-normalized fields) in the database has been introduced to increase performance in the build/refresh tools and end-user tools.
- All field names are verbose to enhance readability, however, in some implementation formats, the field names may be truncated. For example, field names will be truncated to 10 characters in .dbf files.
- A field value of -9998 signifies that a value is applicable, but unknown.
- A field value of -9999 signifies that a value is not applicable

NHDPlusCatchment\FeatureIDGridcode (table)

Description: Tables containing crosswalk between Catchment FeatureIDs and gridcodes.

Field Name	Description	Format
FeatureID	FeatureID of the Catchment which equals the ComID of an NHDFlowline feature or the SinkID of a Sink feature	Long Integer
GridCode	Unique, compact identification number for a Catchment	Long Integer
RPUID	RPU identifier for the Catchment	Char(8)
SourceFC	Source Feature Class (“NHDFlowline” or “Sink”)	Char(20)

NHDPlusCatchment\cat (grid)

Description: An integer grid dataset that associates each cell with a catchment. NHDPlus catchments are created for NHDFlowline features and for Sink features.

Field Name	Description	Format
Value	The value stored in the grid cell; a unique, compact identification number for each catchment; also referred to as GridCode – See FeatureIDGridCode	Long Integer
Count	Number of grid cells with a particular value in the Value field.	Long Integer
FeatureID	FeatureID of the Catchment which equals the ComID of an NHDFlowline feature or the SinkID of a Sink feature	Long Integer
SourceFC	Source Feature Class (“NHDFlowline” or “Sink”)	Char(20)

WHDPlusCatchment\Catchment (polygon feature class)

Description: Contains a catchment polygon for either an NHDFlowline feature or a Sink feature.

Note: Some polygons may be multipart polygons.

Field Name	Description	Format
FeatureID	FeatureID of a Catchment which is equal to the ComID of an NHDFlowline feature or the SinkID of a Sink feature	Long Integer
GridCode	See FeatureIDGridCode	
AreaSqKm	Catchment area in square kilometers	Num(13,4)
SourceFC	Source Feature Class (“NHDFlowline” or “Sink”)	Char(20)

WHDPlusAttributes\CumulativeArea (table)

Description: Tables containing cumulative area upstream of the downstream end of an NHDFlowline feature.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
TotDASqKm	Total Upstream Cumulative Drainage Area, in square kilometers, at the downstream end of the NHDFlowline feature	Num(14,6)
DivDASqKm	Divergence-routed Cumulative Drainage Area, in square kilometers, at the downstream end of the NHDFlowline feature	Num(14,6)

WHDPlusAttributes\DivFracMP (table)

Description: Contains specifications about the fraction of a cumulative attribute to be routed through each path in a divergence. The ComIDs in this table represent NHDFlowline surface water features, found in the PlusFlow table, that form a network divergence (i.e. a flow split). All the paths in a given divergence are identified in this table by a unique NodeNumber.

PlusFlowlineVAA.Divergence always follows the named stream path. When stream name is used to determine the main path in a divergence, the entries in the DivFracMP table do not override the main path designation in the Divergence flag in PlusFlowlineVAA. When stream name does not determine the main path, then values in DivFracMP will establish the value in PlusFlowlineVAA.Divergence.

All divergences are represented in this table. If DivFracMP values are specified, they are used in the divergence routing method of all NHDPlus accumulated attributes, such as drainage area. Divergences where no information is known about the fractional split have DivFracMP.DivFrac = -9998 for all paths in the divergence. In this case, the Divergence Routing method uses the PlusFlowlineVAA.Divergence field and routes a fraction of 1 to the main path (i.e. Divergence = 1) and a fraction of 0 to all other paths (i.e. Divergence = 2). The impact of using DivFracMP in the Divergence Routing method is discussed in section “Understanding and Using NHDPlusV2”.

When not set to -9998, the sum of the DivFrac values for all paths in a divergence (i.e. all records with the same NodeNumber) must equal 1.

Field Name	Description	Format
NodeNumber	See PlusFlowlineVAA.FromNode	Num(11)
ComID	ComID of an NHDFlowline feature which is a path in a divergence	Long Integer
DivFrac	Fraction used for routing cumulative attributes down the flowlines paths in a divergence. Values between 0 and 1	Num(5,4)
StatusFlag	Reserved for use during NHDPlusV2 Build/Refresh Tools Processing	Char(1)

WHDPlusAttributes\ElevSlope (table)

Description: Elevation and slope derived for NHDFlowline features.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
FDate	See NHDFlowline	
MaxElevRaw	Maximum elevation (unsmoothed) in centimeters	Num(10,3)
MinElevRaw	Minimum elevation (unsmoothed) in centimeters	Num(10,3)
MaxElevSmo	Maximum elevation (smoothed) in centimeters	Num(10,3)
MinElevSmo	Minimum elevation (smoothed) in centimeters	Num(10,3)
Slope	Slope of flowline (meters/meters) based on smoothed elevations; a value of -9998 means that no slope value is available. See Appendix A, step 22 for information about slope computation.	Num(12,8)
ElevFixed	Flag indicating that the downstream elevation is fixed (i.e. not smoothed)	Char(1)
HWType	“H” – real headwater, “A” – Artificial Head water (i.e. all inflows have Gapdist > 43m)	Char(1)
StatusFlag	Reserved for use during WHDPlusV2 Build/Refresh Tools Processing	Char(1)
SlopeLenKm	NHDFlowline feature length (kilometers) used to compute slope. Will be less than NHDFlowline.LengthKM when the NHDFlowline feature was trimmed during the hydro-enforcement process. See Appendix A, step 14 and 15 for information about trimming of NHDFlowlines.	Num(11,3)

WHDPlusAttributes\HeadwaterNodeArea (table)

Description: For each headwater node in the surface water network, the HeadWaterNodeArea table contains the size of the land area that drains to the node at the upstream end of the flowline.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
FDate	See NHDFlowline	
HwNodeSqKm	Catchment area in square kilometers that drains to the headwater node of the NHDFlowline feature	Num(13,4)

WHDPlusAttributesMegaDiv (table)

Description: Table containing the PlusFlow records for divergences that have more than two outflow paths.

Field Name	Description	Format
FromComID	Common identifier of the upstream NHDFlowline feature	Long Integer
ToComID	Common identifier of the downstream NHDFlowline feature	Long Integer

WHDPlusAttributes\PlusWaterbodyLakeMorphology (table)

Waterbody data used for computing time of travel (PlusFlowlineVAA.TOTMA) in NHDWaterbody LakePond and Reservoir features. For additional information, see Appendix A “Time of Travel”.

Field Name	Description	Format
ComID	Common identifier of NHDWaterbody feature	Long Integer
MeanDepth	Mean Lake Depth in meters from Jeff Hollister (2015, https://edg.epa.gov/clipship/)	Long Integer
LakeVolume	Lake Volume in cubic meters from Jeff Hollister (2015, https://edg.epa.gov/clipship/)	Num
MaxDepth	Max Lake Depth in meters from Jeff Hollister (2015, https://edg.epa.gov/clipship/)	Num
MeanDUsed	Mean lake depth used in computations (includes estimated values where MeanDepth is missing)	Num
MeanDCode	Mean Depth Code – source of MeanDUsed (see values below)	Short Integer
LakeArea	Lake area in square meters	Num

1	Based on nearby waterbody
2	Hollister - Modified - if predicted depth < 0.02 m then set = 0.02 m
3	Hollister - NHDPlus V1 to V2 match by waterbody reach code
4	Hollister.Jeff@epa.gov - https://edg.epa.gov/clipship/ - National Lake Morphometry
5	http://onlinelibrary.wiley.com/doi/10.1111/eff.12040/pdf
6	http://www.lake-link.com/Wisconsin-Lake-Finder/lake.cfm/5651/793/Lac-La-Belle-Waukesha-County-Wisco*
7	https://en.wikipedia.org/wiki/Lake_Macatawa
8	https://en.wikipedia.org/wiki/Lake_Oahe
9	Mean for region and lake area 0.5-1 sqkm
10	Mean for region and lake area 1-2 sqkm
11	Mean for waterbody area < 0.1 sqkm
12	Mean for waterbody area 0.1 - 0.5 sqkm
13	Modified Hollister - Lake Areas < 0.01 sqkm set depth to mean value with data 0.45m
14	setting similar to Muskegon

WHDPlusAttributes\PlusFlowlineLakeMorphology (table)

Flowline data used for computing time of travel (PlusFlowlineVAA.TOTMA). For additional information, see Appendix A “Time of Travel”.

Field Name	Description	Format
ComID	Common identifier of NHDFlowline feature	Long Integer
LakeFract	Fraction of waterbody allocated to NHDFlowline feature	Num
SurfArea	Waterbody surface area assigned to NHDFlowline feature in square meters	Num
RAreaHLoad	Reciprocal area hydraulic loads assigned to NHDFlowline feature in days/meter. This is a useful parameter in water quality modeling. It is, for example, used to determine if	Num

Field Name	Description	Format
	estimated nutrient loss in reservoirs is statistically significant.	

WHDPlusAttributes\PlusFlowlineVAA (table)

Description: Value Added Attributes (VAAs) for each NHDFlowline feature that appears in the PlusFlow table (i.e. every NHDFlowline with NHDFlowline.FlowDir = “With Digitized”). The NHDPlusV2 Build/Refresh process populates the PlusFlowlineVAA table. The PlusFlowlineVAA table differs from the NHDFlowlineVAA table. NHDFlowlineVAA is an official table in the NHD schema, contains any VAA values that are stored in the NHD central database and is not populated by the NHDPlusV2 Build/Refresh process.

Additional documentation on VAAs can be found in Appendix A under “Step 6”, “Step 10” and “Time of Travel”.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
FDate	See NHDFlowline	
StreamLeve	Stream level	Num(2)
StreamOrde	Modified Strahler Stream Order ³	Num(2)
StreamCalc	Stream Calculator	Num(2)
FromNode	Unique identifier for the point at the top of the NHDFlowline feature	Num(11)
ToNode	Unique identifier for the point at the end of the NHDFlowline feature	Num(11)
HydroSeq	Hydrologic sequence number; places flowlines in hydrologic order; processing NHDFlowline features in ascending order, encounters the features from downstream to upstream; processing the NHDFlowline features in descending order, encounters the features from upstream to downstream	Num(11)
LevelPathI	Level Path Identifier - Hydrologic sequence number of most downstream NHDFlowline feature in the level path	Num(11)
PathLength	Distance to the terminal NHDFlowline feature downstream along the main path	Num(13,4)
TerminalPat	Terminal Path Identifier - Hydrologic sequence number of terminal NHDFlowline feature	Num(11)
ArbolateSu	Arbolate Sum - Kilometers of stream upstream of the bottom of the NHDFlowline feature	Num(13,4)
Divergence	0 – feature is not part of a divergence 1 – feature is the main path of a divergence	Num(1)

³ http://en.wikipedia.org/wiki/Strahler_number

	2 – feature is a minor path of a divergence	
StartFlag	0 – feature is not a headwater flowline 1 – feature is a headwater flowline	Num(1)
TerminalFl	0 – not a terminal NHDflowline feature 1 – a terminal NHDFlowline feature	Num(1)
DnLevel	Streamlevel of main stem downstream NHDflowline feature	Num(2)
ThinnerCod	Not valued; Reserved for future use	
UpLevelPat	Upstream mainstem level path identifier	Num(11)
UpHydroSeq	Upstream mainstem hydrologic sequence number	Num(11)
DnLevelPat	Downstream mainstem level path identifier	Num(11)
DnMinorHyd	Downstream minor hydrologic sequence number	Num(11)
DnDrainCou	Count of NHDFlowline features immediately downstream	Num(2)
DnHydroSeq	Downstream mainstem hydrologic sequence number	Num(11)
FromMeas	ReachCode route measure (m-value) at bottom of NHDFlowline feature	Num(8,5)
ToMeas	ReachCode route measure (m-value) at top of NHDFlowline feature	Num(8,5)
ReachCode	See NHDFlowline	
LengthKm	See NHDFlowline	
FCode	See NHDFlowline	
RtnDiv	Returning Divergence Flag; 0 = no upstream divergences return at the top of this NHDFlowline feature 1 = one or more upstream divergences returned to the network at the top of this NHDFlowline feature	Num(1)
OutDiv	Not valued; Reserved for future use	Num(1)
DivEffect	Not valued; Reserved for future use	Num(1)
VPUIn	Are there VPU inflows? 0(no) or 1(yes)	Num(1)
VPUOut	Are there VPU Outflows? 0(no) or 1(yes)	Num(1)
AreaSqKm	See Catchment	
TotDASqKm	See CumulativeArea	
DivDASqKm	See CumulativeArea	
Tidal	Is NHDFlowline feature considered Tidal? 0(no) or 1(yes)	Num(1)
TOTMA	Time of Travel (populated for non-tidal NHDFlowline Features) in days Note: Note: TOTMA should not be used on minor paths at divergences (PlusFlowlineVAA.Divergence = 2), because these are treated as “start” reaches, with a corresponding lower flow and smaller velocity estimate.	Num(10,5)
WBAreaType	For FType = Artificial Path, the NHDWaterbody.FType or NHDArea.FType for feature identified in NHDFlowline.WBAreaComID	Char(24)

WHDPlusAttributesPlusFlow (table)

Description: A table that describes flowing and non-flowing connections between NHDFlowline features. The table contains entries for: (1) pairs of NHDFlowline features that exchange water, (2) headwater NHDFlowline features, (3) terminal NHDFlowline features, (4) surface water NHDFlowline features that connect to coastline NHDFlowline features, and (5) coastline NHDFlowline features that connect to each other.

Note: Native NHD contains a flow table called NHDFlow. NHDFlow contains only geometric connections between NHDFlowline features. PlusFlow, on the other hand, includes non-geometric and geometric connections. Non-geometric connections are used to represent situations such as return flows along an international border and underground connections in karst topography.

Field Name	Description	Format
FromComID	Common identifier for the upstream NHDFlowline feature	Long Integer
FromHydSeq	HydroSeq of FromComID	Num(11)
FromLvlPat	LevelPathID of FromComID	Num(11)
ToComID	Common identifier for the downstream NHDFlowline feature	Long Integer
ToHydSeq	Hydroseq of ToComID	Num(11)
ToLvlPat	LevelPathID of ToComID	Num(11)
NodeNumber	Node number at the bottom of FromComID and the top of ToComID	Num(11)
DeltaLevel	Numerical difference between StreamLevel for FromComID and StreamLevel for ToComID	Num(3)
Direction	714 – coastal connection (FromComID may be a coastline and ToComID is always a coastline) 709 – flowing connection 712 – network start (ToComID is a headwater) 713 – network end (FromComID is a network end)	Num(3)
GapDistKm	Distance between the downstream end of FromComID and the upstream end of ToComID	Num(13,4)
HasGeo	“Y”es FromComID touches ToComID, “N”o, there is a geometry gap between FromComID and ToComID	Char(1)
TotDASqKm	See CumulativeArea	
DivDASqKm	See CumulativeArea	

WHDPlusAttributes\PlusARPointEvent (table)

Description: A table containing point events which represent the locations of flow additions to and flow removals from the stream network. The network location is provided by the ReachCode and measure based on the linear referencing system of the NHDFlowline feature class. The geometry of the point events may be derived using the ArcGIS Linear Referencing Tool called Make Route Event Layer.

Field Name	Description	Format
ComID	A nationally unique negative ComID assigned to the point of addition or removal	Long Integer
EventDate	Data event was created	Date
ReachCode	See NHDFlowline	Char(14)
ReachSMDat	See NHDReachCode_ComID table	Date
ReachResol	“Medium”	Char(7)
FeatureCom	Not valued	Long Integer
FeatureCla	Not valued	Char(15)
Source_Ori	Not valued	Char(130)
Source_Dat	Not valued	Char(100)
Source_Fea	External identifier of the event point, generally a key in an external database	Char(40)
FeatureDet	URL link to information about the event point	Char(254)
Measure	m-value (0 to 100) of the point location along the NHDFlowline route defined by ReachCode	Num(8,5)
Offset	Not valued	Num
EventType	“Addition” or “Removal”	Char(100)

WHDPlusAttributes\PlusFlowAR (table)

Description: A table that describes the connections between NHDFlowline features, flow addition points and flow removal points. See PlusARPointEvent

Type of Table Entry	FromComID	ToComID
Flow addition	Addition point	NHDFlowline feature
Flow removal	NHDFlowline feature	Removal point
Flow Transfer	Removal point	Addition point
Flow use/consumption	Removal point	none

Field Name	Description	Format
FromComID	ComID of NHDFlowline feature, Addition point, or Removal point	Long Integer
FromFC	“NHDFlowline” or “PlusARPointEvent”	Char(20)
ToComID	ComID of NHDFlowline feature, Addition point, or Removal point	Long Integer
ToFC	“NHDFlowline” or “PlusARPointEvent”	Char(20)
Quantity	Quantity of Flow through this connection	Num(14,7)
Units	Units of measurement for Quantity, “CFS” = cubic feet per second	Num(3)

WHDPlusFdrFacrrrrrrrVfac (grid)

Description: An integer flow accumulation grid which contains the number of cells within the RPU draining to each cell within the RPU based on the HydroDEM.

Field Name	Description	Format
Value	Number of cells that drain to each cell.	Long Integer

WHDPlusFdrFacrrrrrrrVdr (grid)

Description: An integer flow direction grid which contains the codes that show the direction water would flow from each grid cell within the RPU based on the HydroDEM.

Field Name	Description	Format
Value	The value for the grid cell. Can be assigned one of eight possible values: 0 _ Flow ends (sink) 1 – Flow is to the East 2 – Flow is to the Southeast 4 – Flow is to the South 8 – Flow is to the Southwest 16 – Flow is to the West 32 – Flow is to the Northwest 64 – Flow is to the North 128 – Flow is to the Northeast	Long Integer
Count	Number of cells with a particular value in the Value field	Long Integer

WHDPlusFilledAreas\filledareas (grid)

Description: An integer grid which identifies cells raised by the Fill process.

Field Name	Description	Format
Value	The value for the grid cell. Can be assigned one of two possible values: 0 – Cell was not changed by the Fill process 1 – Cell was raised by the Fill process	Long Integer
Count	Number of cells with a particular value in the Value field	Long Integer

WHDPlusCatSeed\catseed (grid)

Description: An integer grid which contains the codes showing the locations of the seed cells used to produce the NHDPlusV2 catchments.

Field Name	Description	Format
Value	Gridcode of the catchment. See FeaturnIDGridCode	Long Integer

WHDPlusFdrNullrrrrrrr\fdnull (grid)

Description: An integer grid which contains the codes showing the direction water would flow from each grid cell based on the HydroDEM. Identical to the fdr grid except that the stream network cells are set to “no data”.

Field Name	Description	Format
Value	For Stream Network cells, No Data For cells not on the stream network, the value for the grid cell is: 0 _ Flow ends (sink) 1 – Flow is to the East 2 – Flow is to the Southeast 4 – Flow is to the South 8 – Flow is to the Southwest 16 – Flow is to the West 32 – Flow is to the Northwest 64 – Flow is to the North 128 – Flow is to the Northeast NoData – a stream network cell	Long Integer
Count	Number of cells with a particular value in the Value field	Long Integer

WHDPlusHydroDemrrrrrrr\hydrodem (grid)

Description: An integer grid of the hydro-conditioned digital elevation model, with all aspects of the NHDPlus burn components integrated and filled. This grid is used to generate the flow direction grid from which the flow accumulation and catchment grids are generated. The elevations are in centimeters.

Field Name	Description	Format
Value	Elevation value in centimeters	Long Integer

NHDPlusBurnComponents\BurnLineEvent (table)

Description: Events describing the parts of NHDFlowline features used for hydro-enforcement.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
Hydroseq	See PlusFlowlineVAA	
FCode	See NHDFlowline	
FType	See NHDFlowline	
Fdate	See NHDFlowline	
ReachCode	See NHDFlowline	
ReachSMDat	See NHDReachCodeComID	
FromMeas	Downstream BurnLineEvent Measure (m-value)	Num(8,5)
ToMeas	Upstream BurnLineEvent Measure (m-value)	Num(8,5)
StartFlag	See PlusFlowlineVAA	
LengthKm	See PlusFlowlineVAA	
BurnLenKm	Length of BurnLineEvent feature	Num(7,3)
Divergence	See PlusFlowlineVAA	
StreamLevel	See PlusFlowlineVAA	
StreamCalc	See PlusFlowlineVAA	
StatusFlag	Reserved for use during NHDPlusV2 Build/Refresh Tools Processing	Char(1)
InRPU	RPU that contains the BurnLineEvent feature	Text(8)
GridCode	GridCode assigned to the NHDFlowline feature	Long Integer
Catchment	“Y” – line will receive a catchment, “N” - will not receive a catchment	Text(1)
Burn	“Y” – line will be used for hydro-enforcement, “N” - will not be used for hydro-enforcement	Text(1)

WHDPlusBurnComponents\BurnWaterbody (polygon feature class)

Description: NHDWaterbody and NHDArea features used for hydro-enforcement.

Field Name	Description	Format
ComID	Common identifier of the NHDWaterbody feature or NHDArea feature	Long Integer
SourceFC	NHD Feature Class – “NHDWaterbody”, “NHDArea”	Character(20)
FCode	See NHDWaterbody or NHDArea	
ReachCode	See NHDWaterbody	
ReachSMDate	See NHDReachCodeComID	
OnOffNet	Hydro Enforcement Flag - 1 = Hydro Enforced (i.e. On network or contains a sink), 0 = not Hydro Enforced	Num(1)
PurpCode	Purpose Code	Char(2)
PurpDesc	Purpose Description	Char(254)

WHDPlusBurnComponents\Sink (point feature class)

Description: Point locations of sinks used for hydro-enforcement.

Field Name	Description	Format
SinkID	Unique identifier for Sink point	Long Integer
PurpCode	Purpose of Sink, See Appendix E	Char(2)
PurpDesc	Description of Sink	Char(254)
StatusFlag	Reserved for use during NHDPlusV2 Build/Refresh Tools Processing	Char(1)
FeatureID	The id of a feature in another feature class. This is a ComID, if the feature is in NHDFLowline or NHDWaterbody Gaz_ID, if the feature is in WBD_Subwatershed PolyID, if the feature is in BurnAddWaterbody	Long Integer
SourceFC	The feature class of the feature referenced in FeatureID. Values are “NHDFlowline”, “NHDWaterbody”, “WBD_Subwatershed”, and “BurnAddWaterbody”.	Char(20)
FDate	If SourceFC = “NHDFlowline”, this is the NHDFlowline.Fdate value.	Date
GridCode	GridCode assigned to the Sink point	Long Integer
InRPU	RPU ID that holds the Sink.	Char(8)
Catchment	“Y” – line will receive a catchment, “N” or Null - will not receive a catchment	Text(1)
Burn	“Y” – line will be used for hydro-enforcement, “N” or Null - will not be used for hydro-enforcement	Text(1)

WHDPlusBurnComponents\Wall (line feature class)

Description: Lines used as walls in hydro-enforcement.

Field Name	Description	Format
WallID	Unique identifier for wall line	Long Integer
Source_Id	Place holder for WBD unique identifier (not part of the WBD data model used for NHDPlus)	Long Integer

WHDPlusBurnComponents\LandSea (polygon feature class)

Description: Polygons used for hydro-enforcement along the NHD coastline.

Field Name	Description	Format
LandSeaID	Unique identifier for land/sea polygon	Long Integer
Land	A numeric code to identify land/sea/estuary areas. 1 = Land, -2 = Sea, -1 = Estuary	Short Integer

WHDPlusBurnComponents\BurnAddLine (line feature class)

Description: Additional lines not in BurnLineEvent that are needed for hydro-enforcement.

Field Name	Description	Format
LineID	Unique identifier for wall line	Long Integer
PurpCode	Purpose of added line. See Appendix E.	Text(2)
PurpDesc	Description of added line.	Text(254)
GridCode	Manually assigned gridcodes. See Appendix A, Step 15.	Long Integer
StreamLeve	Manually assigned stream level value. See Appendix A.	Short Integer
HydroSeq	See PlusFlowLineVAA; a manually assigned number that puts the additional line in the proper hydrologic sequence with BurnLineEvent.	Long Integer

WHDPlusBurnComponents\BurnAddWaterbody (polygon feature class)

Description: Additional waterbodies not in BurnWaterbody that are needed for hydro-enforcement.

Field Name	Description	Format
PolyID	Unique identifier for wall line	Long Integer
PurpCode	Purpose of added waterbody (see Appendix E)	Text(2)
PurpDesc	Description of added waterbody	Text(254)
OnOffNet	Hydro Enforcement Flag - 1 = Hydro Enforced (i.e. On network or contains a sink), 0 = not Hydro Enforced	Short Integer
FCode	See NHDFCode	

NHDPlusV2 Extended Feature Class and Table Descriptions

The following conventions are used when describing NHDPlusV2 component attributes:

- Field formats are intended to be technology-neutral. Primary and foreign keys are all long integer format to facilitate relates and joins. Other formats show the maximum size and precision of the field.
- A particular database technology may dictate the format for a given field. As an example, a number with 6 total digits with 3 to the right of the decimal point is specified in this volume as (6,3), however it would be (7,3) in a .dbf file.
- All redundancy (un-normalized fields) in the database has been introduced to increase performance in the build/refresh tools and end-user tools.
- All field names are verbose to enhance readability, however, in some implementation formats, the field names may be truncated. For example, field names will be truncated to 10 characters in .dbf files.
- A field value of -9998 signifies that a value is applicable, but unknown.
- A field value of -9999 signifies that a value is not applicable (e.g. velocities for Coastline features or flowlines identified as Tidal).

VEROMExtension\EROM_MA0001 and EROM_mm0001 (tables)

Description: Enhanced Unit Runoff Method (EROM) mean annual flow estimates and mean monthly flow estimates for NHDFlowline features in the NHDPlus network. These flow estimates reflect the 1971 to 2000 time period. The best EROM flow and velocity estimates are the gage adjusted values. These values are Q0001E and V0001E, respectively, in the tables. Table 2 of the EROM QA report provides an estimate of how good these flow estimates are as compared to gage flows. For “natural” flows and velocities, the best estimates are the Reference Gage Regression values. These values are Q0001C and V0001C, respectively, in the tables. The “RefGage Reg” column in Table 3 of the EROM QA Report provides an estimate of how good these flow estimates are as compared to gage flows.

For additional information on the EROM tables, see Appendix A, “EROM Extension”.

Note: In EROM_mm0001, mm is 01 through 12 for January through December.

All Flow estimates are in cubic feet per second (cfs) and represent the flow at the bottom (downstream end) of the NHDFlowline feature.

All Velocity computations are in feet per second (fps) using the Jobson Method (1996) and represent the velocity at the bottom of the NHDFlowline feature.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
Q0001A	Flow from runoff (cfs)	Num(14,3)
V0001A	Velocity for Q0001A (fps)	Num(14,5)
QIncr0001A	Incremental Flow from runoff (cfs)	Num(13,5)
Q0001B	Flow with Excess ET (cfs)	Num(14,3)
V0001B	Velocity for Q0001B (fps)	Num(13,5)

QIncr0001B	Incremental Flow With Excess ET (cfs)	Num(13,5)
Q0001C	Flow with Reference Gage Regression applied to Q0001B (cfs)	Num(14,3)
V0001C	Velocity for Q0001C (fps)	Num(13,5)
QIncr0001C	Incremental Flow by subtracting the sum of upstream Q<eeee>C flows from the sum of the upstream Q0001C (cfs)	Num(13,5)
Q0001D	Flow with PlusFlowAR (cfs)	Num(14,3)
V0001D	Velocity for Q0001D (fps)	Num(13,5)
QIncr0001D	Incremental flow with PlusFlowAR (cfs)	Num(13,5)
Q0001E	Flow from gage adjustment (cfs)	Num(14,3)
V0001E	Velocity from gage adjustment (fps)	Num(13,5)
QIncr0001E	Incremental flow from gage adjustment (cfs)	Num(13,5)
Q0001F	Flow from gage sequestration step (cfs)	Num(14,3)
QIncr0001F	Incremental flow from gage sequestration step (cfs)	Num(13,5)
ARQ0001Nav	PlusflowAR flow not available on flowline (cfs)	Num(14,3)
Temp0001	Catchment temperature (Deg. C)	Num(14,5)
PPT0001	Catchment precipitation (mm)	Num(14,5)
PET0001	Catchment PET (mm)	Num(14,5)
QLoss0001	Catchment flow loss from Excess ET (cfs)	Num(14,3)
QG0001Adj	Gage adjustment flow (cfs)	Num(14,3)
QG0001Nav	Gage adjustment flow not available (cfs)	Num(14,3)
DivDASqKm	Divergence-routed cumulative area	Num(14,6)
AreaSqKm	See Catchment	Num(14,6)
Lat	Average Latitude of catchment in decimal degrees	Num(9,5)
GageAdj	Flag indicating that Q<eeee>E and QIncr0001E have been adjusted by gage flow. “0” = not adjusted, “2” = adjusted, including the NHDFlowline feature at the gage and the NHDFlowline features upstream.	Text(1)
AvgQAdj	Gage Q adjusted for bottom of an NHDflowline feature (cfs)	Num(14,3)
SMGageID	The ID of the gage located on NHDFlowline feature	Text(16)
SMGageq	Gaged flow measured by the gage on NHDFlowline feature (cfs)	Num(14,3)
ETFract1	Excess ET Fraction 1	Num(5,3)
ETFract2	Excess ET Fraction 2	Num(5,3)
A	Reference gage regression coefficient “a”	Num(11,5)
B	Reference gage regression coefficient “b”	Num(11,5)
BCF	Reference gage regression Bias Correction Factor	Num(11,5)
r2	Reference gage regression Log-Log r^2	Num(11,4)
SER	Reference gage regression log-log Standard Error of the Regression	Num(11,5)
NRef	Number of Reference gages used in the regression	Num(5,4)
GageSeqP	Proportion of gages to sequester in the gage sequestration step. Values 0 to 1.	Num(5,3)

GageSeq	0 = gage not sequestered, 1= gage sequestered	Num(5,3)
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\\EROMExtension\EROMQA_0001 (pdf)

Description: QA statistics, in report form, for the EROM mean annual and mean monthly flow estimates contained in \\EROMExtension\EROM_MA0001 and EROM_mm0001 tables.

VEROMExtension\EROMQA_MA0001 and EROMQA_mm0001 (tables)

Description: QA statistics in table form for the EROM mean annual flow estimates in the EROMMA_0001 and for the mean monthly flow estimates in EROM_mm0001. The file layout is designed to facilitate graphical and statistical analyses. All data values are adjusted for the bottom of the flowline. The files are sorted by GageRef so that all of the reference gages are at the top of the file; this is useful for users who want to look at graphs or additional statistics for only the reference gages.

For additional information on the EROM tables, see Appendix A, “EROM Extension”.

Note: In EROMQA_mm0001, mm is 01 through 12 for January thru December.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
GageID	The NWIS gageid	Text(16)
GageRef	Text field: “Ref” = Falcone Reference Gage. Blank = not Reference gage.	Char(3)
DivDASqKm	The NHDPlusV2 divergence-routed drainage area at the bottom of the flowline. (sqkm)	Num(14,3)
Q_E	The Gage Flow (cfs)	Num(14,3)
Q_A	Cumulative runoff (cfs)	Num(14,3)
Q_B	Q_A – Excess ET (EET) (cfs)	Num(14,3)
Q_C	Q_A - EET +/- Refgage Regression Adjustment (cfs)	Num(14,3)
Q_D	Q_A – EET +/- Refgage Regression Adjustment +/- PlusFlowAR (cfs)	Num(14,3)
Q_EUnitRo	Q_E / DivDASqKm (cfs/sqkm)	Num(14,3)
Q_AUnitRo	Q_A / DivDASqKm (cfs/sqkm)	Num(14,3)
Q_BUnitRo	Q_B / DivDASqKm (cfs/sqkm)	Num(14,3)
Q_CUnitRo	Q_C / DivDASqKm (cfs/sqkm)	Num(14,3)
Q_DUnitRo	Q_D / DivDASqKm (cfs/sqkm)	Num(14,3)
Q_ADelta	Q_E – Q_A (cfs)	Num(14,3)
Q_BDelta	Q_E – Q_B (cfs)	Num(14,3)
Q_CDelta	Q_E – Q_C (cfs)	Num(14,3)
Q_DDelta	Q_E – Q_D (cfs)	Num(14,3)
Q_AURoDelt	Q_Eunitro – Q_Aunitro (cfs/sqkm)	Num(14,3)
Q_BURoDelt	Q_Eunitro – Q_Bunitro (cfs/sqkm)	Num(14,3)
Q_CURoDelt	Q_Eunitro – Q_Cunitro (cfs/sqkm)	Num(14,3)
Q_DURoDelt	Q_Eunitro – Q_Dunitro (cfs/sqkm)	Num(14,3)

VogelExtension\VogelFlow (table)

Description: Vogel Method flow volume and velocity estimates for NHD flowlines. The Vogel Method is not applicable for total drainage area ranges that fall outside of the AreaMax and AreaMin values in the Vogel_Coefficients Table (see Appendix A, Vogel). These drainage area ranges vary by hydrologic region.

Field Name	Description	Format
ComID	Common identifier of an NHDFlowline feature	Long Integer
MAFlowV	Mean Annual Flow (cfs) at bottom of flowline using Vogel Method.	Num(14,7)
MAVelV	Mean Annual Velocity (fps) at bottom of flowline using Jobson Method (1996) with MAFlowV.	Num(8,5)

\\VPUAttributeExtension\ncrLat (comma delimited table)

Description: Mean latitude of each NHDPlusV2 catchment. The mean latitude is needed in EROM as part of the potential evapotranspiration calculation.

Field Name	Description	Format
FeatureID	FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Catchment with no data	Num(13,4)
LatVT	Value Type, "V" meaning average	Char(1)
LatV	Mean latitude in degrees	Num(5,2)
HydroSeq	When FeatureID represents an NHDFlowline feature, the Hydrologic Sequence Number of the feature; When FeatureID represents a Sink, set to -9998	Num(11)

VPUAttributeExtension\ROMA and ROMMmm (comma delimited tables)

Description: Mean annual and mean monthly runoff in the area of each NHDPlusV2 catchment. There is a mean monthly table for each month (mm = 01 through 12). Mean annual runoff values were used in computing EROM mean annual flow estimates. The mean monthly runoff values will be used to compute EROM mean monthly flow estimates in the future (see Appendix A: EROM). As with all other EROM inputs, the runoff values are computed for the 1971 to 2000 time period for CONUS (See Appendix A: EROM).

Note: If a catchment extends beyond the extent of the runoff data, the value will be the runoff over the portion of the catchment which does have data. MissDataA will contain the area in the catchment where data was not available.

Field Name	Description	Format
FeatureID	FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Catchment with no data	Num(13,4)
RunOffVT	Value Type, “V” meaning average	Char(1)
RunOffV	Mean runoff (mm)	Num(5,2)
HydroSeq	When FeatureID represents an NHDFlowline feature, the Hydrologic Sequence Number of the feature; When FeatureID represents a Sink, set to -9998	Num(11)

WHDPlusAttributeExtension\CumTotROMA, CumDivROMA, CumTotROMMmm, CumDivROMMmm (comma delimited tables)

Description: Mean annual and mean monthly runoff accumulated down the NHDFlowline network. Two tables are created for mean annual and each mean monthly: (1) Total upstream accumulation and (2) Accumulation based on the Divergence Routed method.

Field Name	Description	Format
FeatureID	ComID of an NHDFlowline feature and, where applicable, FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Drainage Area with no data	Num(13,4)
RunOffCT	Value Type, “V” meaning average	Char(1)
RunOffCV	Mean Runoff in area upstream of the bottom of flowline (mm)	Num(5,2)
Hydroseq	Hydrologic Sequence Number of an NHDFlowline feature	Num(11)

WHDPlusAttributeExtension\IncrPrecipMA and IncrPrecipMMmm (comma delimited tables)

Description: Mean annual and mean monthly precipitation averaged over the area of each NHDPlusV2 catchment. IncrPrecipMA contains the mean annual precipitation and the 12 IncrPrecipMMmm tables contain the mean monthly values where mm = 01 through 12). The precipitation values have been computed using a grid which combined the Parameter-elevation Regressions on Independent Slopes Model data (PRISM) (<http://www.prismclimate.org>) for the conterminous U.S. and a set of 1-km grids from the Canadian Forest Service, Natural Resources Canada, for areas in Canada and Mexico. Mean annual precipitation values were used in computing EROM mean annual flow estimates. The mean monthly precipitation values are used for estimating excess evapotranspiration in EROM. As with all other EROM inputs, the precipitation data is for the 1971 to 2000 time period (See Appendix A: EROM).

Note: If a catchment extends beyond the extent of the precipitation data, the value will be the average over the portion of the catchment which does have data. MissDataA will contain the area in the catchment where data were not available.

Field Name	Description	Format
FeatureID	FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Catchment with no data	Num(13,4)
PrecipVT	Value Type, “V” meaning average	Char(1)
PrecipV	Mean precipitation in millimeters * 100	Num(5,2)
HydroSeq	When FeatureID represents an NHDFlowline feature, the Hydrologic Sequence Number of the feature; When FeatureID represents a Sink, set to -9998	Num(11)

WHDPlusAttributeExtension\CumTotPrecipMA, CumDivPrecipMA, CumTotPrecipMMmm, and CumDivPrecipMMmm (comma delimited tables)

Description: Mean annual and mean monthly precipitation accumulated down the NHDFlowline network. Two tables are created for mean annual and each mean monthly: (1) Total upstream accumulation and (2) Accumulation based on the Divergence Routed method.

Field Name	Description	Format
FeatureID	ComID of an NHDFlowline feature and, where applicable, FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Drainage Area with no data	Num(13,4)
PrecipCT	Value Type, “V” meaning average	Char(1)
PrecipCV	Mean annual precipitation in area upstream of the bottom of flowline in millimeters * 100	Num(5,2)
Hydroseq	Hydrologic Sequence Number of an NHDFlowline feature	Num(11)

***WHDPlusAttributeExtension\IncrTempMA and IncrTempMMmm
(comma delimited tables)***

Description: Mean annual and mean monthly temperature averaged over the area of each catchment. IncrTempMA contains the mean annual precipitation and the 12 IncrTempMMmm tables contain the mean monthly values where mm = 01 through 12). The temperature values have been computed using a grid which combined the Parameter-elevation Regressions on Independent Slopes Model data (PRISM) (<http://www.prismclimate.org>) for the conterminous U.S. and a set of 1-km grids provided by the Canadian Forest Service, Natural Resources Canada, for areas in Canada and Mexico. Mean annual temperature values were used in computing EROM mean annual flow estimates. The mean monthly temperature values are used for estimating potential evapotranspiration in EROM. As with all other EROM inputs, the temperature data is for the 1971 to 2000 time period (see Appendix A: EROM).

Note: If a catchment extends beyond the extent of the temperature data, the value will be the average over the portion of the catchment which does have data. MissDataA will contain the area in the catchment where data was not available.

Field Name	Description	Format
FeatureID	FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Catchments with no data	Num(13,4)
TempVT	Value Type, "V" meaning average	Char(1)
TempV	Mean annual temperature in degrees centigrade * 100	Num(5,2)
HydroSeq	When FeatureID represents an NHDFlowline feature, the Hydrologic Sequence Number of the feature; When FeatureID represents a Sink, set to -9998	Num(11)

***WHDPlusAttributeExtension\CumTotTempMA, CumDivTempMA,
CumTotTempMMmm, and CumDivTempMMmm (comma delimited
tables)***

Description: Mean annual and mean monthly temperature accumulated down the flowline network. Two types of tables are created for mean annual and each mean monthly: (1) Total upstream accumulation and (2) Accumulation based on the Divergence Routed method.

Field Name	Description	Format
FeatureID	ComID of an NHDFlowline feature and, where applicable, FeatureID of an NHDPlusV2 Catchment	Long Integer
MissDataA	Area of Drainage Areas with no data	Num(13,4)
TempVCT	Value Type, "V" meaning average	Char(1)
TempVC	Mean annual temperature in area upstream of the bottom of flowline in degrees centigrade * 100	Num(5,2)
Hydroseq	Hydrologic Sequence Number of an NHDFlowline feature	Num(11)

Understanding and Using NHDPlusV2

Note: User-written scripts illustrating the use of NHDPlusV2 will be posted on the NHDPlusV2 web site.

NHDPlus and Divergences

The NHDPlusV2 network includes complex hydrography (network components), including convergent, divergent and complex flow paths (Figure 7). A convergent junction is the simplest type of junction for downstream routing and accumulating attributes, such as drainage area. Divergent and other types of complex junctions, however, complicate computing cumulative values. These issues and how the cumulative values are computed in NHDPlusV2 are described below.

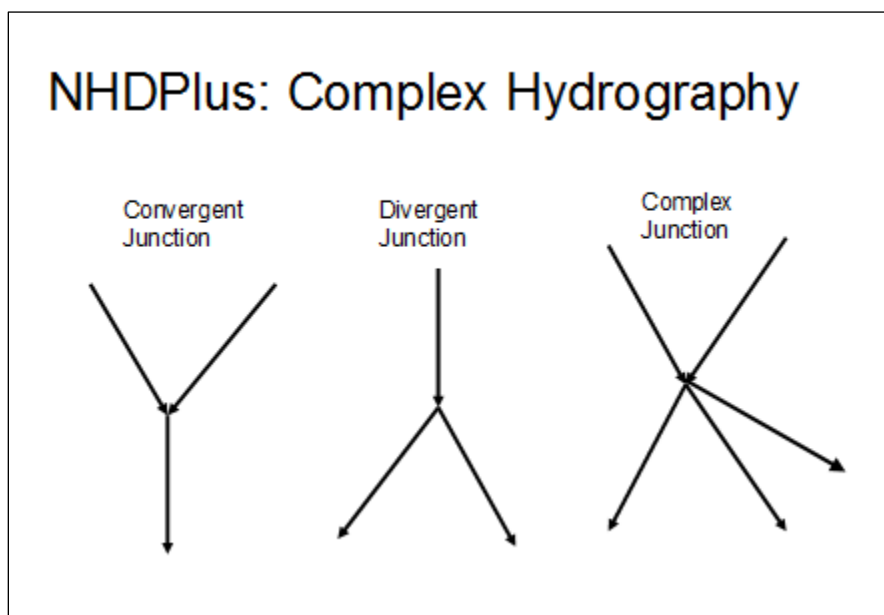


Figure 7: NHDPlusV2 Complex Hydrography

The DIVERGENCE field in the `\NHDPlusAttributes\PlusFlowlineVAA` table defines “main” and “minor” paths at divergences. One path is designated as the main path and is given a DIVERGENCE field value of “1”. All other paths in the divergence are designated as minor paths and are given a DIVERGENCE field value of “2”, as illustrated in Figure 8.

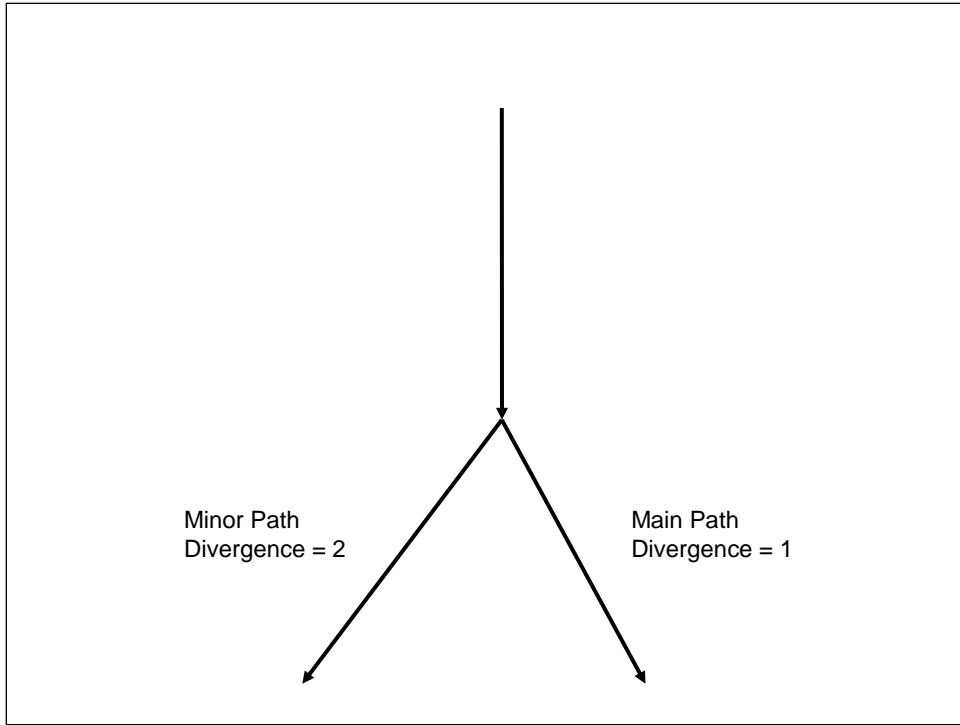


Figure 8: Main and Minor Paths in NHDPlusV2

In many cases, the divergences are “local”, as shown in Figure 9, where the divergence returns to the main network at the next downstream confluence. The red flowlines represent the divergences. The blue lines represent flowlines not affected by these divergences because the divergent streams have rejoined the network upstream of the blue lines.

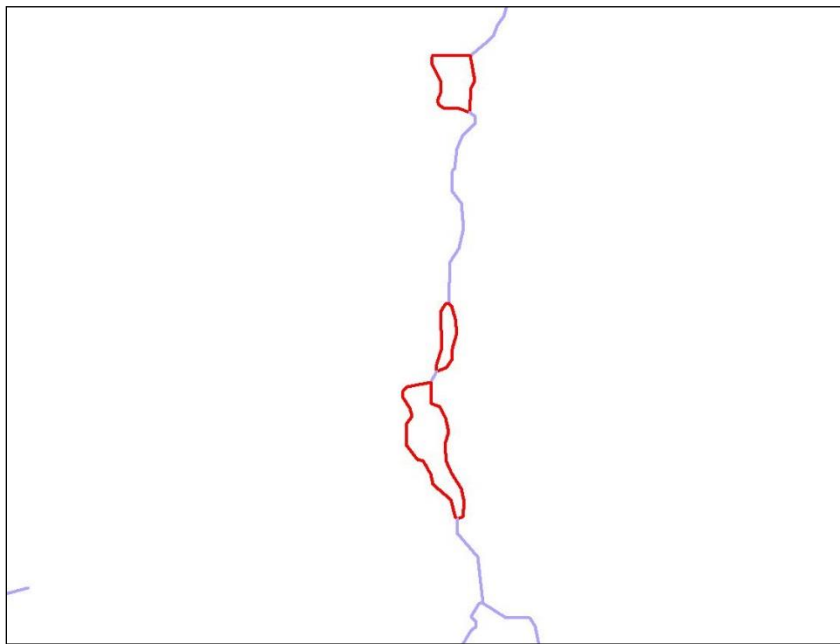


Figure 9: “Local” Divergences

NHDPlusV2 has many complex networks; for example multiple divergences, braided streams, coastal drainage patterns, and divergences where the divergent flowlines never re-join the network downstream. As shown in Figure 10: some complex divergences, 1) do not immediately re-join the main network and may flow into additional divergences and return to the main network many miles downstream, and 2) can affect multiple flowlines. When routing and accumulating attribute values, cumulative values will be affected by divergences (on the red flowlines) while non-divergent features (the blue flowlines) are not affected.

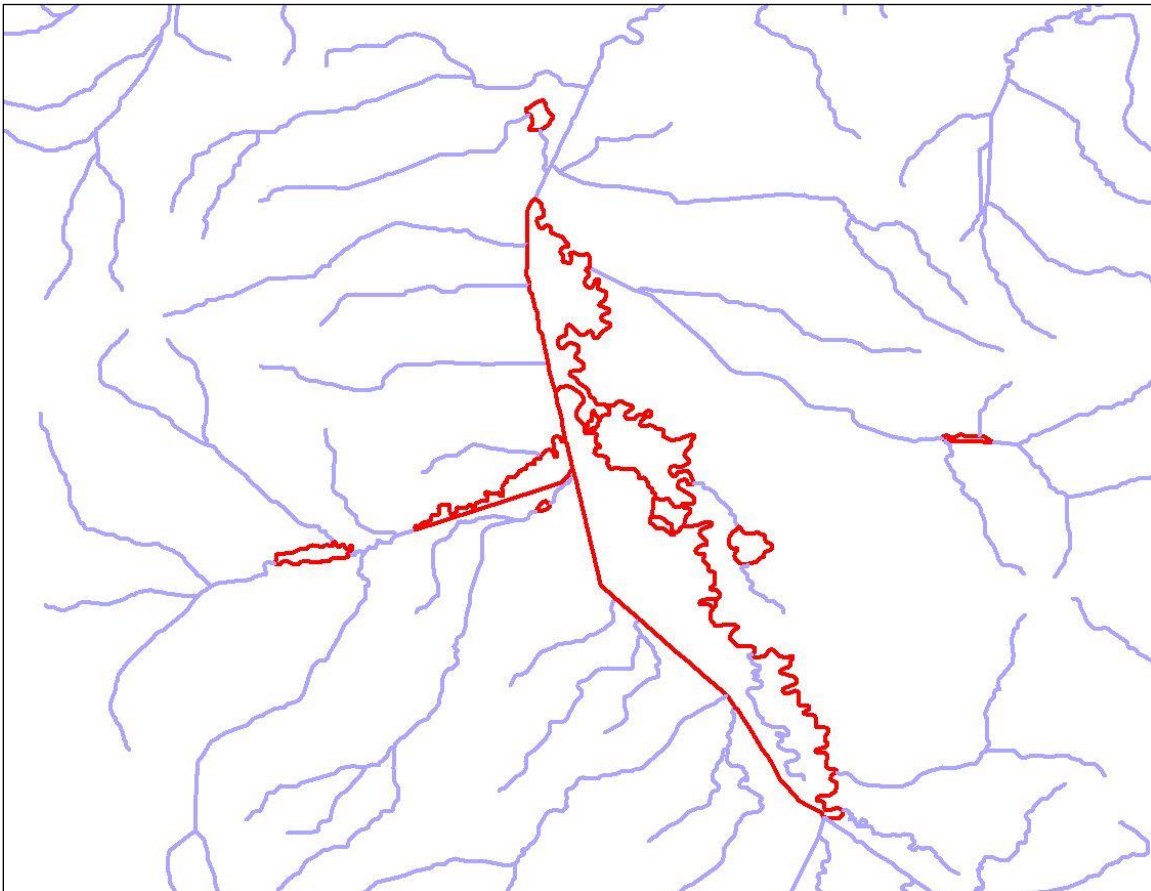


Figure 10: More Complex Divergent Junction Example

Total Upstream Accumulation and Divergence-Routed Accumulation

NHDPlus has implemented two approaches for accumulating attributes downstream along the NHDPlusV2 network. The first approach, “total upstream accumulation” accumulates the attribute for each NHDFlowline feature along the network, the total value of the attribute upstream of the bottom (downstream node) of the NHDFlowline feature. The second approach “divergence-routed accumulation” apportions the attribute value at each divergence a portion of the accumulation is routed down each divergence path that the sum of the divergence portions is 100% of the accumulation. For each NHDFlowline feature along the network, the divergence-

routed accumulation values for an attribute will not include routed down minor divergent paths that have not returned to the main network.

For a vast majority of divergences, it is not known how to appropriately apportion divergence paths. Where there is no knowledge, NHDPlusV2 uses defaults that route 100% down main paths (PlusFlowlineVAA.Divergence=1) and 0% down minor paths (PlusFlowlineVAA.Divergence=2). During NHDPlusV2 production, the NHDPlusV2 table called DivFracMP enabled, assigning percentages, other than 100% and 0%, to be routed down the main and minor paths, respectively. Occasionally, stream gage information provided values, other than a 100%/0%, apportionments for the DivFracMP table.

Using the Divergence-Routed accumulation method, without information from DivFracMP, minor divergent flowlines (and the flowlines downstream of the minor divergences) will not include the cumulative values upstream of the divergence, until the divergence rejoins the main path (Figure 11).

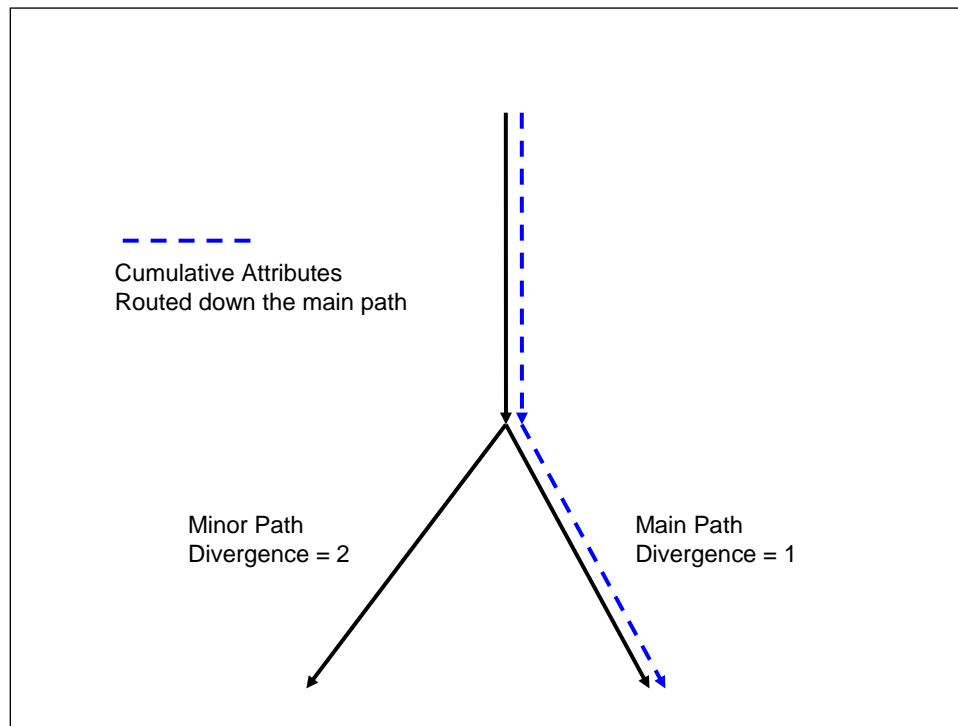


Figure 11: Divergence-Routed Accumulation Method: Attributes are routed down the main path

Building an NHDPlusV2 Attribute Accumulator

There are two types of requirements for attribute accumulation: site specific accumulation or entire network accumulation. Site specific accumulation can be easily completed with upstream navigation followed by aggregation, of any attributes assigned to NHDFlowline features (or their associated catchments) using the navigation results. When implementing an entire network accumulation method, the desired attributes are accumulated for each NHDFlowline feature and saved in an attribute table for future use. Entire network accumulations will need a program or

script to complete the accumulation task. Specifications for such a program or script are provided in this section.

The objective of accumulation is to aggregate the incremental values such that, at any particular NHDFlowline feature/catchment in the network, the cumulative attribute value for the area upstream of the feature/catchment is computed. Depending on the attribute being aggregated, different mathematical operations are used. For example, a “drainage area” attribute is additive, while “percent of area in forest” is computed using an area-weighted average.

As previously discussed, two techniques were used for accumulating attributes for every flowline: Total Upstream Accumulation and Divergence-routed Accumulation (see the previous section entitled “Total Upstream Accumulation and Divergence-Routed Accumulation”). In the NHDPlusV2 accumulated attributes, both accumulation methods are used and cumulative values are provided for both methods.

The Divergence-Routed accumulation method starts at the top of the network and moves downstream aggregating the incremental values for features’/catchments’ and storing the result at each feature/catchment. The advantage of this is that values can be computed quickly. The disadvantage of this method is that decisions about routing and accumulation must be made when the flow diverges. The total accumulated value cannot be routed down both paths of a divergence because, if those diverging paths rejoin (which is frequently the case), the total accumulation value will be repeated for each divergence. The Divergence-Routed Accumulation method is very sensitive to errors in divergence classifications. When the wrong path is designated as the major path, accumulation values traverse the wrong path. In addition, NHDFlowline features downstream of divergences that have not returned to the major network path will not receive the full accumulated value from upstream features. This may be appropriate for some attributes and not for others, but the user should be aware of these distinctions.

The Total-Upstream Accumulation Method is similar to the site specific method, discussed above, where the accumulation for each NHDFlowline feature is the aggregation of all the incremental upstream values. The advantages of this method are divergence classifications are less sensitive to error and fully accumulated values are returned, regardless of unresolved divergences. The disadvantage of this method is values are not quickly computed.

The following example contains specifications for a script which performs the Divergence-Routed method. In this example, begin with a file containing NHDFlowline feature ComIDs or Catchment FeatureIDs and the incremental value for a single attribute assigned to each NHDFlowline feature or catchment. For this example, assume the file is called IncrementalAttributeFile and contains fields ComID and AttrValue.

1. Add a field to the IncrementalAttributeFile for the cumulative value for the attribute. The new field is “CumAttrValue.”
2. Join IncrementalAttributeFile with \NHDPlusAttributes\PlusFlowlineVAA using ComID. For performance purpose, delete from the joined file, every record that has

hydroseq = 0. These lines are not in the NHDPlusV2 stream network, therefore, are not needed in an accumulation.

3. Sort the joined file by Hydroseq, in descending order.
4. Outline of the Accumulation procedure/algorithm:
 - 4.1. Get next record from the sorted file. If end of file, quit.
 - 4.2. If PlusFlowlineVAA.Startflag = 1 (i.e., this is a headwater and there is nothing upstream) or PlusFlowlineVAA.Divergence = 2 (i.e., nothing is routed down the minor paths of the divergence), then set CumAttrValue = AttrValue and go to step 4.1.
 - 4.3. Else, find all the inflows to this current NHDFlowline feature: inflows are records in the joined file where the PlusFlowlineVAA.tonode = PlusFlowlineVAA.fromnode of the current flowline.
 - 4.4. Set CumAttrValue = AttrValue + the CumAttrValue for each inflow.
 - 4.5. Go to step 4.1.

This procedure routes the accumulation down the main path at each divergence. Alternatively, the accumulation may be apportioned to the different paths in the divergence using the contents of \NHDPlusAttributes\DivFracMP table or other apportioning method, as long as 100% (neither less nor more) of the accumulation is routed down the paths from any single divergence.

Understanding NHDPlus Slope

NHDPlus slope is unit-less and can be viewed as cm/cm or m/m or km/km. (Cm/cm appears elsewhere in this documentation).

Minimum in the \NHDPlusAttributes\ElevSlope table, minimum and maximum smoothed elevations for flowlines, are expressed in meters. In the NHDFlowline feature class, NHDFlowline feature length is in kilometers. Therefore when slope is calculated with these fields the result is slope in meters per kilometer (m/km):

$$\frac{\text{maxelevsmo(m)} - \text{minelevsmo(m)}}{\text{LengthKM(km)}} = \text{slope in m/km}$$

To get the unit-less slope provided in \NHDPlusAttributes\Elevslope.slope the units must be converted as follows:

$$\text{slope in m/km} * 1 \text{ km}/1000\text{m} = \text{slope (unit-less)}$$

NHDPlus slopes are constrained to be greater than or equal to 0.00001.

Finding the Upstream Inflows to an NHDPlus Dataset

All NHDPlusV2 VPU workspaces are hydrologically complete drainage areas except the datasets that make up the Colorado River (NHDPlus14 and NHDPlus15) and the Mississippi River (NHDPlus05, NHDPlus06, NHDPlus07, NHDPlus08 (including the 4-digit HUC 0318), NHDPlus10L, NHDPlus10U, and NHDPlus11). When navigating the stream network in either of

these areas, it is necessary to determine if the navigation should be continued in an upstream or downstream NHDPlusV2 VPU workspace.

Finding all the Tributaries to a Stretch of River

First, find the stretch of interest along the main river using one of these methods:

Method 1: Navigate upstream mainstem on the major river from the desired starting flowline for the desired distance.

Method 2: Use the attributes in the \NHDPlusAttributes\PlusFlowlineVAA table. Establish the StartPathlength as the Pathlength attribute of the starting NHDFlowline feature. Query all NHDFlowline features with Levelpathid of the major river's where $(\text{Pathlength} - \text{StartingPathlength}) \leq \text{desired distance}$. If the desired stretch of river does not start at the mouth of the river, remove any NHDFlowline features from the query that have $\text{Hydroseq} < \text{Hydroseq}$ of the starting NHDFlowline feature.

Then, find the tributaries to the stretch:

Join the \NHDPlusAttributes\PlusFlow.ToComID to the list of ComIDs from Method1 or Method2.

All the \NHDPlusAttributes\Plusflow.FromComID's in the joined records are the ComIDs of the downstream NHDFlowline features of the tributaries to the desired stretch of the main river.

NHDFlowline Features with "Known Flow" vs. Features with "Unknown Flow"

There are approximately three million NHDFlowline features in NHDPlusV2. Most, but not all of these features have a known flow direction. Flow direction information is contained in the attribute "FlowDir" in the NHDFlowline feature class attribute table. FlowDir can have the values "With Digitized" (known flow direction) or "Uninitialized" (unknown flow direction). The features having unknown flow direction are primarily: isolated stream segments, canal/ditches, and some channels inside braided networks. The features with known flow direction are the subset of the NHDFlowline feature class which makeup the NHDPlusV2 surface water network. The "Plus" part of NHDPlusV2 is constructed for the flowlines with known flow direction. Catchments and associated catchment area attributes are only populated in NHDPlusV2 features with known flow direction. When using NHDPlusV2, it is useful to symbolize the NHDFlowline feature class using the FlowDir attribute. This helps eliminate displaying of features considered to be in the NHDPlusV2 surface water network. In Figure 12:, the dark blue lines indicate NHDFlowline features with known flow direction and, consequently, are included in the "plus" part of NHDPlusV2. The cyan lines are NHDFlowline features with unknown flow direction and, consequently, are not part of the "Plus" portion of NHDPlusV2.

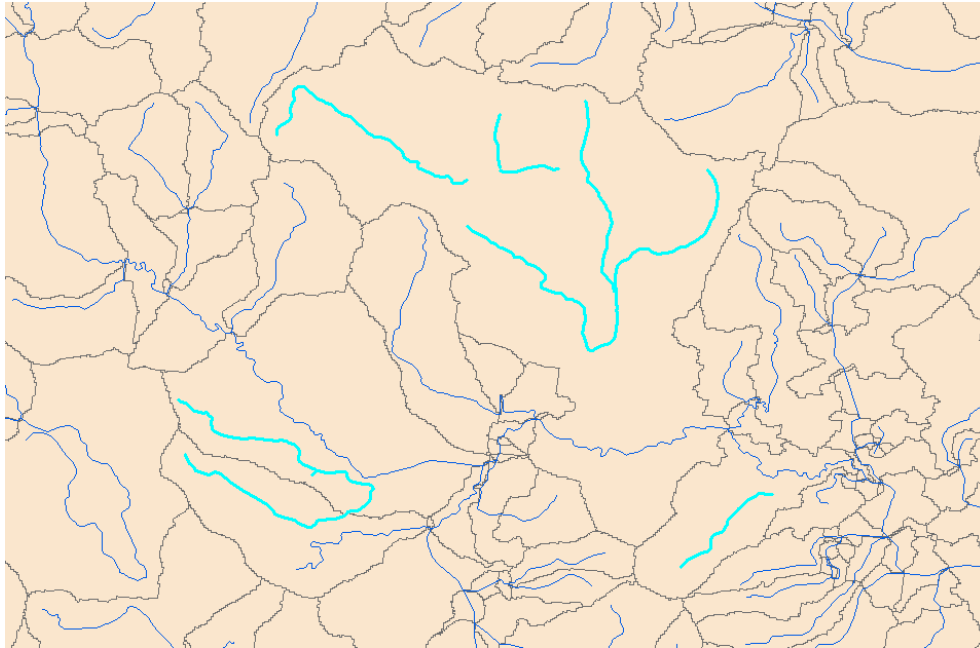


Figure 12: NHDFlowline Features With Known and Unknown Flow Direction

How WBD Boundaries Relate to NHDPlusV2 Catchment Boundaries

The latest available WBD version was used for each hydrologic region VPU during NHDPlusV2 processing. The WBD stewardship team performed an edit pass across the U.S. in advance of the NHDPlusV2 processing, to ensure the WBD was current for each of the NHDPlusV2 VPUs. NHDPlusV2 data includes the WBD boundaries used during catchment delineation in the \WBDSnapshot folders.

The date of the WBD snapshot used for each VPU's NHDPlusV2 processing is provided in the NHDPlusV2 metadata (found in the \NHDPlusV2nn_Metadata folder). The chronology of WBD updates that occurred during the NHDPlusV2 production is provided in the \NHDPlusV2nn_Metadata\wbd_poly_seamless_yyyymmdd.met. The process descriptions are chronological and users can view the updates in each snapshot.

Prior to public release, the NHD snapshot ReachCodes on NHDFlowline and NHDWaterbody features were adjusted to reflect the HUC8s value in the February 1, 2012 version of WBD. This means in some NHDPlusV2 workspaces, it is possible the NHDFlowline and NHDWaterbody features may have ReachCodes that reflect a different hydrologic region than the VPU in which the features are stored. For example, the \NHDPlusNE\NHDPlus01\NHDSnapshot has ReachCodes that start with "0415".

How do Catchment Boundaries differ from WBD Snapshot Boundaries

This topic is discussed in detail in Appendix F.

Main Flowline Network vs. Isolated Networks

The majority of the NHDPlus surface water network features drain to the Atlantic Ocean, Pacific Ocean, Gulf of Mexico, Canada, Mexico, or to one of the Great Lakes. These features comprise the NHDPlus “main” flowline network. In addition, NHDPlus contains many isolated networks throughout the U.S. An isolated network appears to terminate into the ground or has no outflow. Many isolated networks either seep into the ground or end due to excess evaporation. These are often called “non-contributing” networks and, while they can occur in any part of the country, they are found primarily found in the Southwestern U.S. and in southeastern parts of Hydrologic Region 17 (Pacific Northwest). Some isolated networks are mapping errors. These networks should be connected to the main NHDPlus network. Figure 13: and Figure 14 illustrate isolated networks that are non-contributing and mapping errors, respectively.

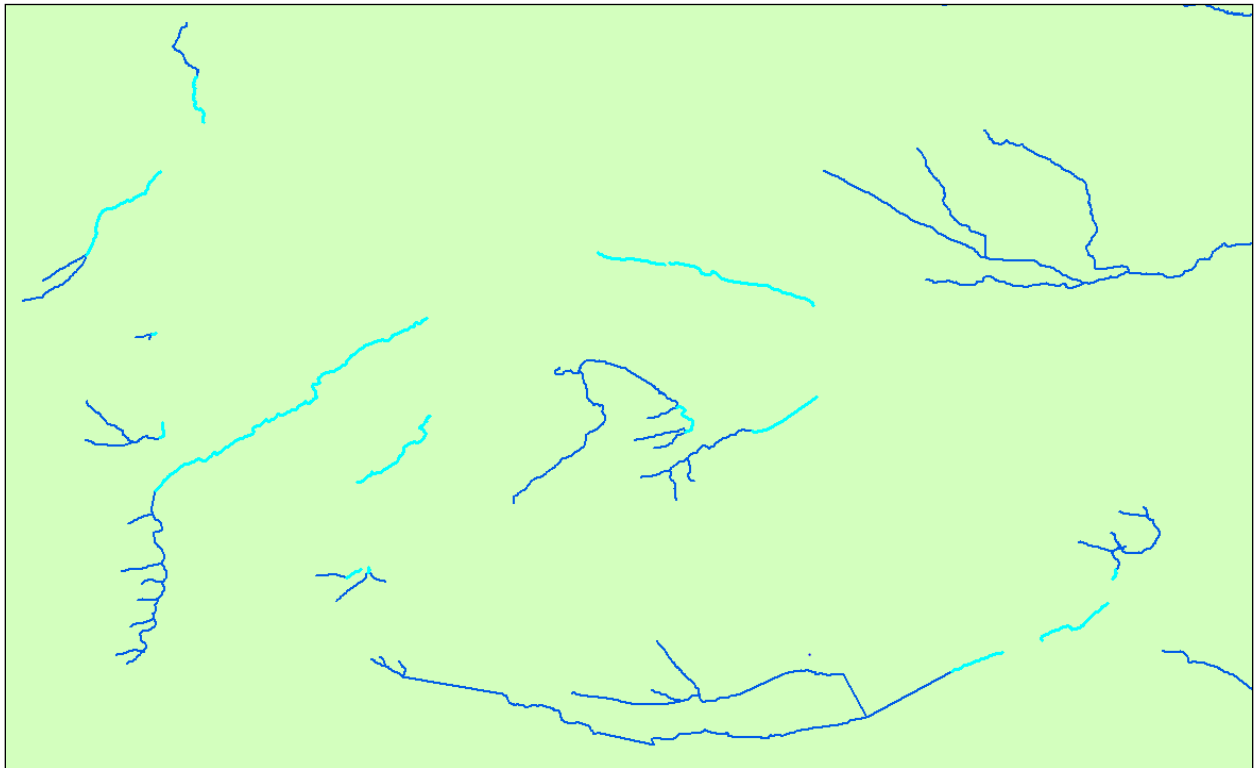


Figure 13: Non-contributing Isolated Networks Teal lines are terminal segments of isolated networks.

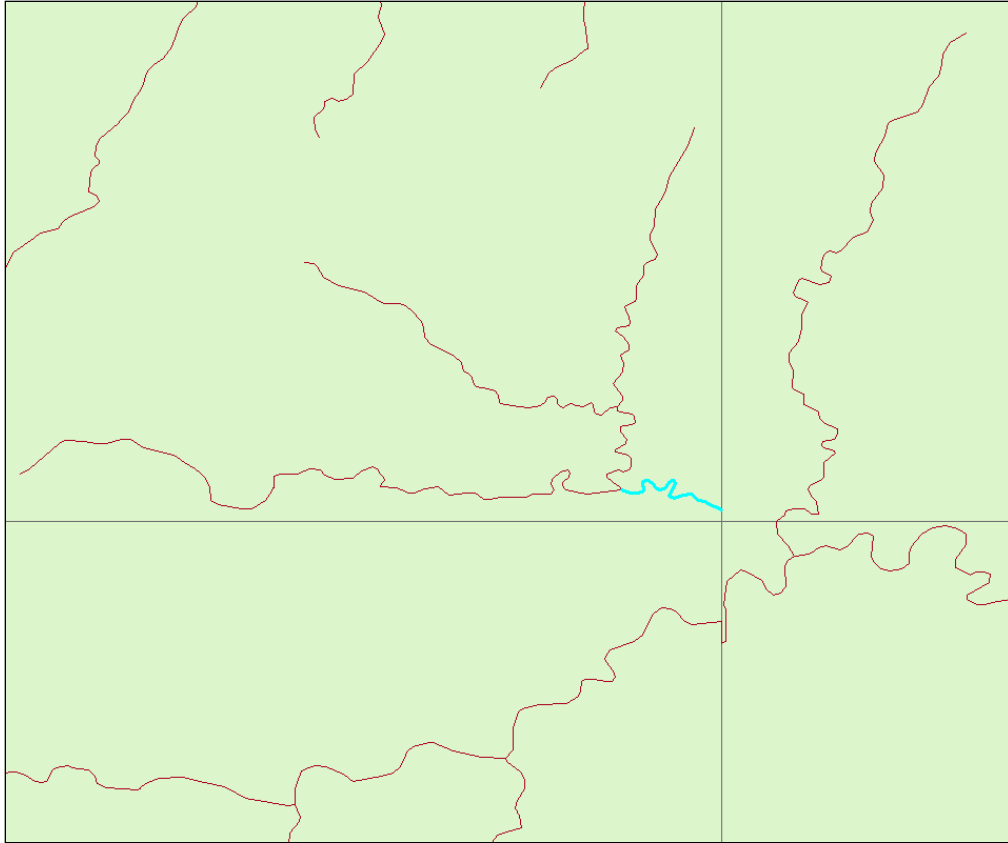
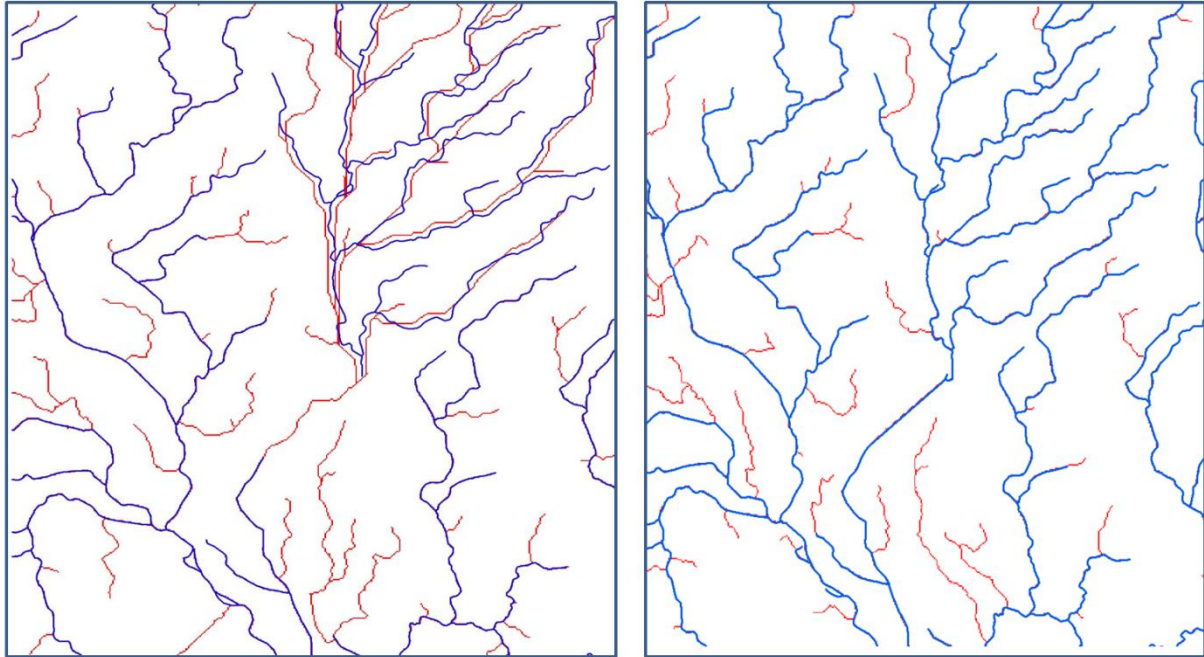


Figure 14: Map error - The cross-hairs are the edges of USGS quad maps.

Isolated networks may be located in any NHDPlusV2 Drainage Area. To find isolated networks, join the PlusFlowlineVAA attribute table to the NHDFlowline feature class using the ComID field in each. Then select all flowlines with PlusFlowlineVAA.Terminalfl = 1. The flowlines selected have known flow direction and are considered by the NHD Snapshot as terminal flowlines.

Catchment delineation and flow grids for isolated networks are much improved between NHDPlusV1 and NHDPlusV2. This occurred for two reasons: 1) for networks that were isolated because of mapping error, an extensive effort was made to connect isolated networks to the main network, 2) sinks were placed at the terminal ends of the networks that remained isolated in NHDPlusV2. Figure 15 compares NHDPlusV1 to NHDPlusV2 by showing synthetic networks generated from the *fdr* and *fac* grids for the same area. The improved alignment of the NHD streams with the synthetic network results in catchment delineation.



NHDPlus Version 1

NHDPlus Version 2

Figure 15 – Illustration showing the horizontal displacement between the NHD streams of an isolated network, in blue on the left image (NHDPlusV1) to the synthetic streams of the “filled” HydroDEM in red. In NHDPlusV2 shown on the right, the previously isolated network is connected to the main network and the displacement has been eliminated. Placement of Sinks at the ends of isolated networks in NHDPlusV2 also eliminates similar displacement for isolated networks that remain isolated.

NHDFlowline Features With and Without Catchments

In general catchments are generated for networked NHD flowlines (FlowDir = “With Digitized”). However, in NHDPlusV2, some networked flowlines were intentionally removed from the set of features used for catchment generation. Examples include pipelines, elevated canals, flowlines that conflict with the WBD, and other data conditions documented in the VPU Release Notes. The CATCHMENT field in BurnLineEvent identifies the flowlines that were designated as “N” for no catchment.

A common reason for flowlines without catchments is due to the resolution of the NED data. Catchments were not generated for many very short flowlines, those approximately 42 meters or less in length (42 meters is the diagonal distance across a 30 meter grid cell). When longer flowlines fell within the same area (stream cells) a very short flowline the stream cells were typically assigned to the longer flowline. And no catchment is delineated for the very short flowline.

In rare circumstances, flowlines longer than 42 meters may not have been assigned a catchment. Depending on the spatial configuration of a flowline with other flowlines, flowlines may run parallel with each other within a given cell (and may continue for several cells over the entire length of the smaller flowlines). In this case, all of the cells used as seeds to delineate the catchments were assigned the longer flowlines and no catchments will be delineated for the short flowline.

Using the NHDPlus Value Added Attributes (VAAs) for Non-Navigation Tasks

The attributes in the \NHDPlusAttributes\PlusFlowLineVAA table provide several powerful capabilities for users. Below are several examples which use the PlusFlowlineVAA for non-navigation tasks. All of the figures in the following examples use Hydrologic Region 2, the Mid-Atlantic.

Details on the computation of the VAAs can be found in **Appendix A, Steps 6 and 10**.

Example 1: Using LevelPathID to Generalize the Stream Network based on Stream Length

The mainstem of each stream is assigned a unique identifier VAA called “LevelPathID”. LevelPathID is equal to the Hydroseq value of the most downstream flowline on that river. LevelPathID can be used in conjunction with NHDFlowline feature LengthKM (also in the VAA table) to build a table of the total lengths for each mainstem of every networked stream/river. The SQL statement is as follows:

```
SELECT PlusFlowlineVAA.LevelPathID, Sum(PlusFlowlineVAA.LengthKM) AS strmlength
INTO strmleng
FROM PlusFlowlineVAA BY PlusFlowlineVAA.LevelPathID
HAVING (PlusFlowlineVAA.LevelPathID)>0);
```

The above SQL statement creates a variable named strmlength as the sum of the lengths of all NHDFlowline features by LevelPathID and puts the LevelPathID and strmlength variables into a table named “strmleng”. Figure 16 highlights the main rivers greater than or equal to 100 Km in length. Note that any length threshold criteria can be used as desired.

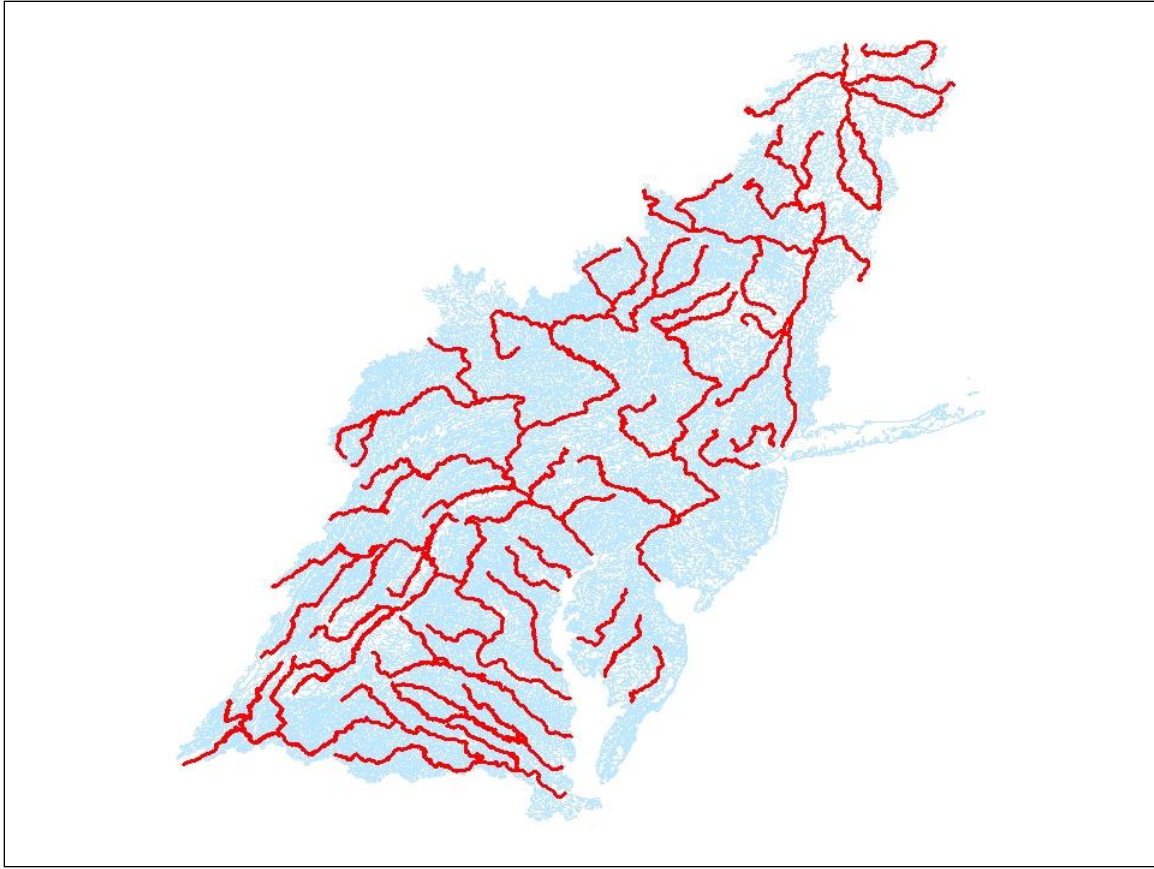


Figure 16: Streams Greater than or Equal to 100 Kilometers in Length

Example 2: Selecting an Individual River or an Individual Terminal River Basin

TerminalPathID is a VAA that contains the same value for the NHDFlowline features in an entire drainage area. For convenience, TerminalPathID is set to the Hydroseq VAA of the terminal NHDFlowline feature in the drainage. For example, the terminal feature of the Potomac River has a Hydroseq-value of 9169600001. This means, the LevelPathID for the Potomac mainstem is assigned the same value and, since the Potomac is the terminus of the drainage area, every networked NHDFlowline feature in the Potomac Basin is assigned the same value as the TerminalPathID. Figure 17: shows the selection of LevelPathID = 9169600001, which selects the mainstem of the Potomac River. Figure 18: shows the selection of TerminalPathID = 9169600001 which selects the entire Potomac River Basin.

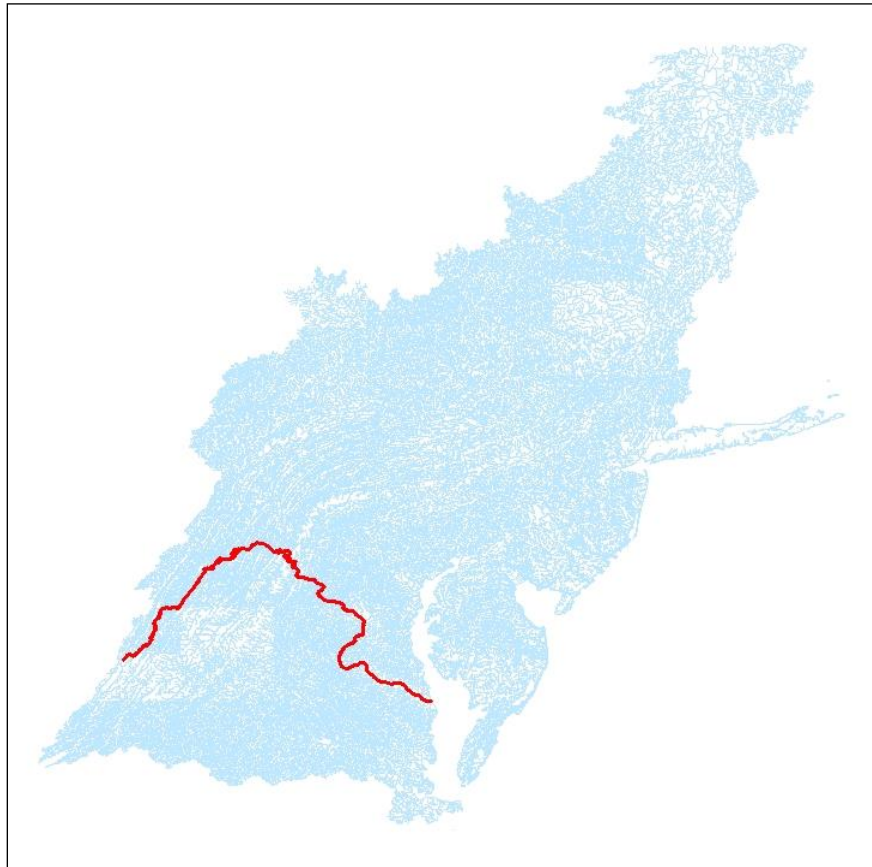


Figure 17: The Mainstem of the Potomac River by Selecting LevelPathID=9169600001

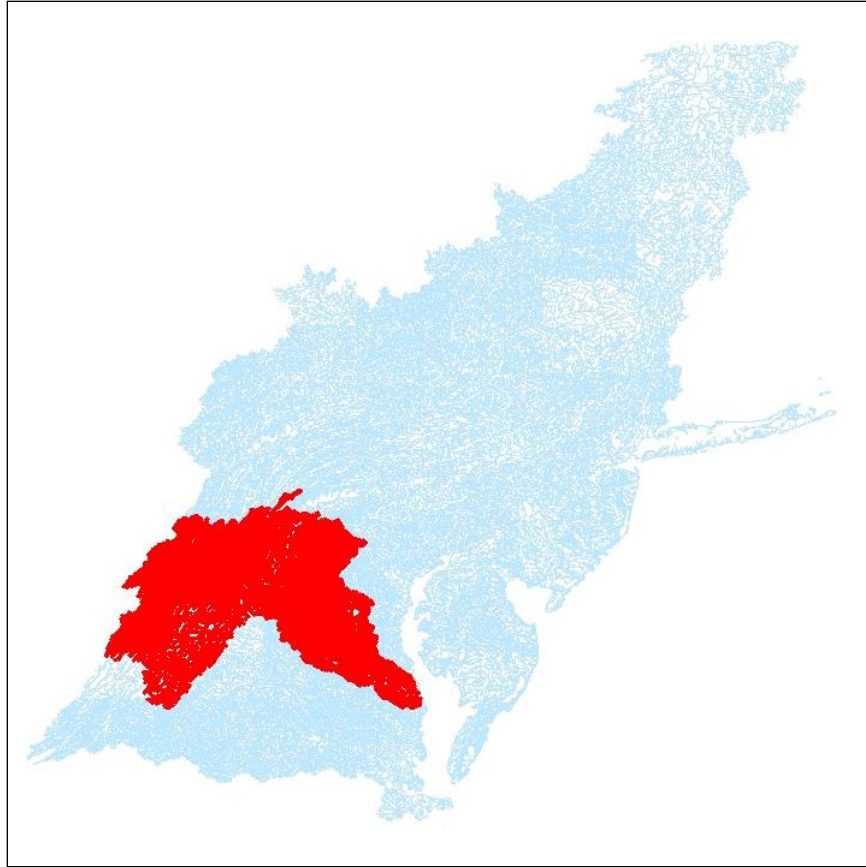


Figure 18: The Potomac River Basin by Selecting TerminalPA = 9169600001

Example 3: Profile Plots

Plots of data along a river where the x-axis is the river mile (or river kilometer) are widely used for showing data and modeling results. The NHDPlusV2 VAAs contain the basic information to readily develop profile plots. Previous VAA examples demonstrated how the LevelPathID can be used to identify every flowline on a river. Another VAA, PathLength, is the length from the bottom of the NHDFlowline feature to the end of the network. For instance, every flowline in the Missouri drainage basin has a PathLength value that tells how far away it is from the mouth of the Mississippi River.

Basic profile plotting procedure is to select the NHDFlowline features using the LevelPathID for the river of interest and assign data value (for example, a modeling result) to the ComIDs of the selected NHDFlowline features. By including the VAA PathLength in the dataset, the user can plot data using PathLength as the x-axis and data value as the y-axis.

Figure 19 uses the mainstem of the Potomac River PathLength variable as the x-axis and `\NHDPlusAttributes\ElevSlope.MinElevSmo` (minimum smoothed) elevation values for the y-axis. This particular profile is interesting because the elevation change near PathLength 180 is dramatic; this is where the Potomac River changes from free-flowing to estuarine. The profile displays the data from downstream to upstream the x-axis can be easily reversed.

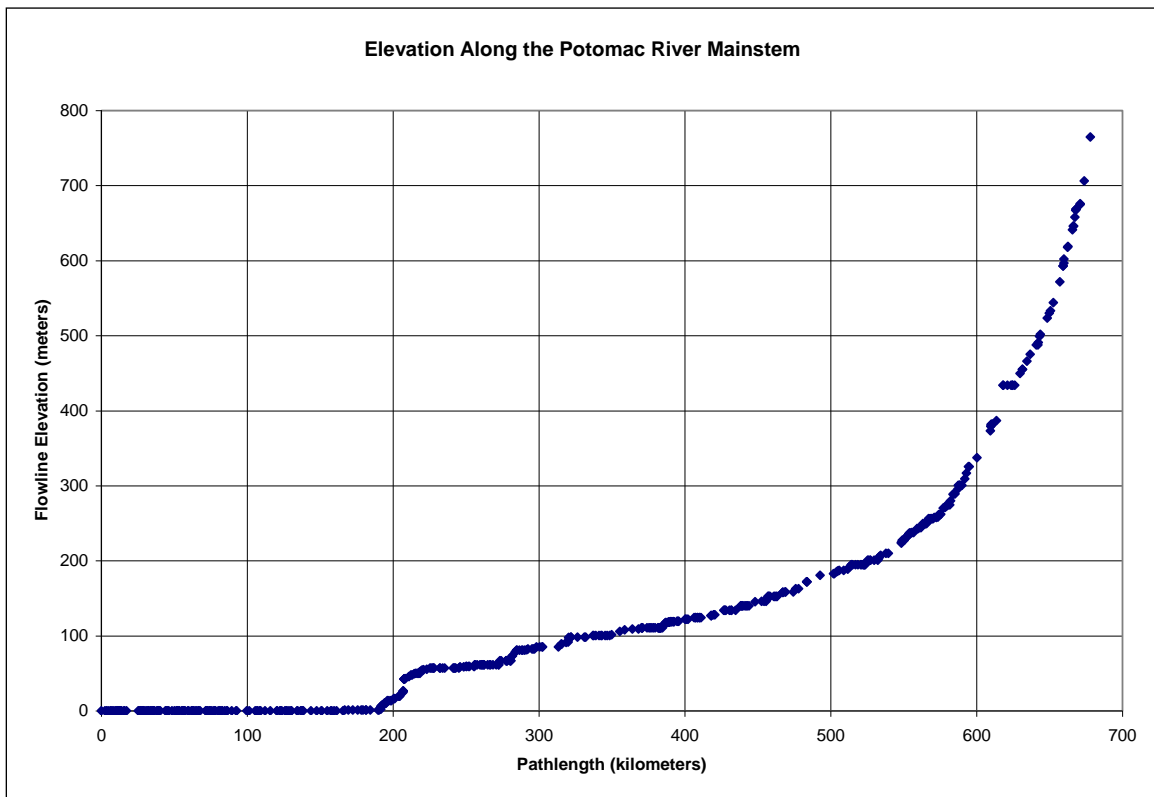


Figure 19: An Elevation Profile Plot of the Mainstem of the Potomac River

Example 5: Stream Order

The NHDPlusV2 stream order is based on a modification of the Strahler Method. Stream order is a classic method for ranking streams according to relative size or position in the network.

Mapping or classifying NHDFlowline features on the basis of stream order can assist with ranking features by relative size within the network, selecting out streams of only certain orders, or aggregating data by stream order. Some examples of mapping by stream order are shown below.

Figure 20: shows different colors for each stream order for an area in the Mid-Atlantic Region. This figure illustrates how stream order helps rank streams by relative size. Figure 21: shows the same area but with stream order 1 removed. This is one method to “thin” the network based on hydrologic criteria. There are other quantitative methods to rank or thin the NHDPlusV2 network, by using mean annual flow as criteria (this method is not illustrated here).

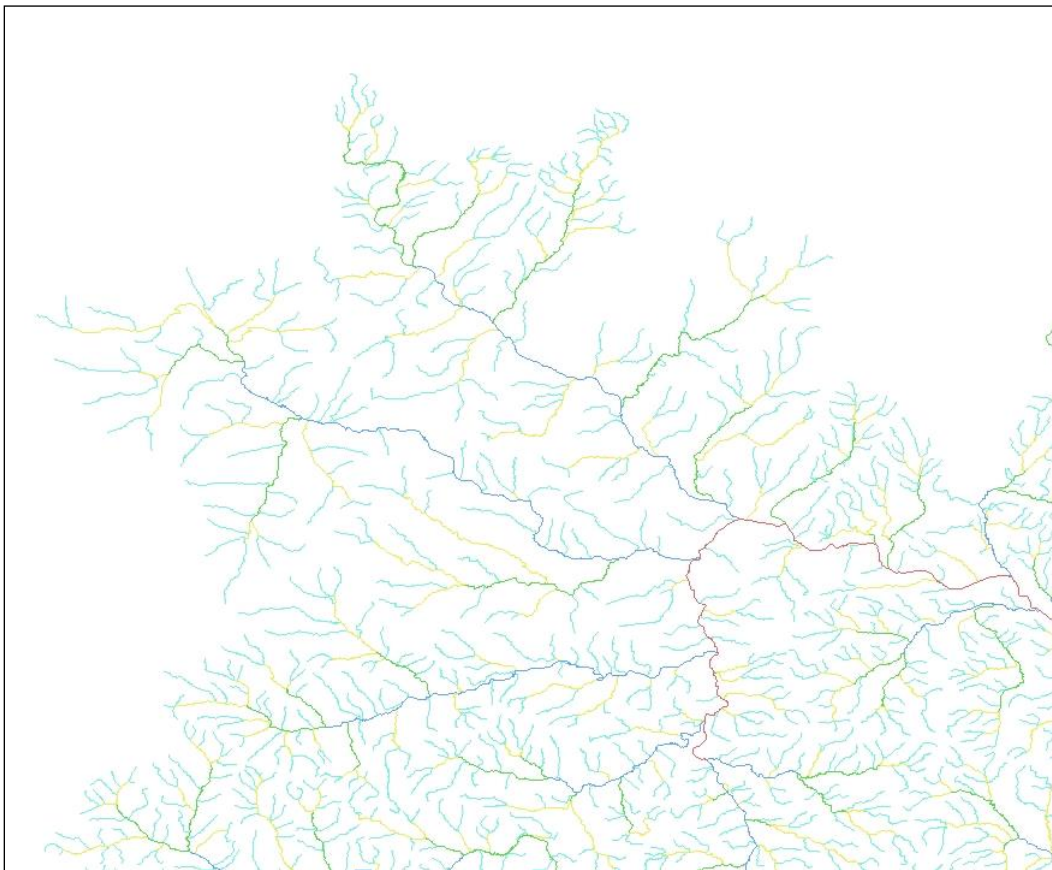


Figure 20: Stream Orders in Part of the Mid-Atlantic Hydrologic Region

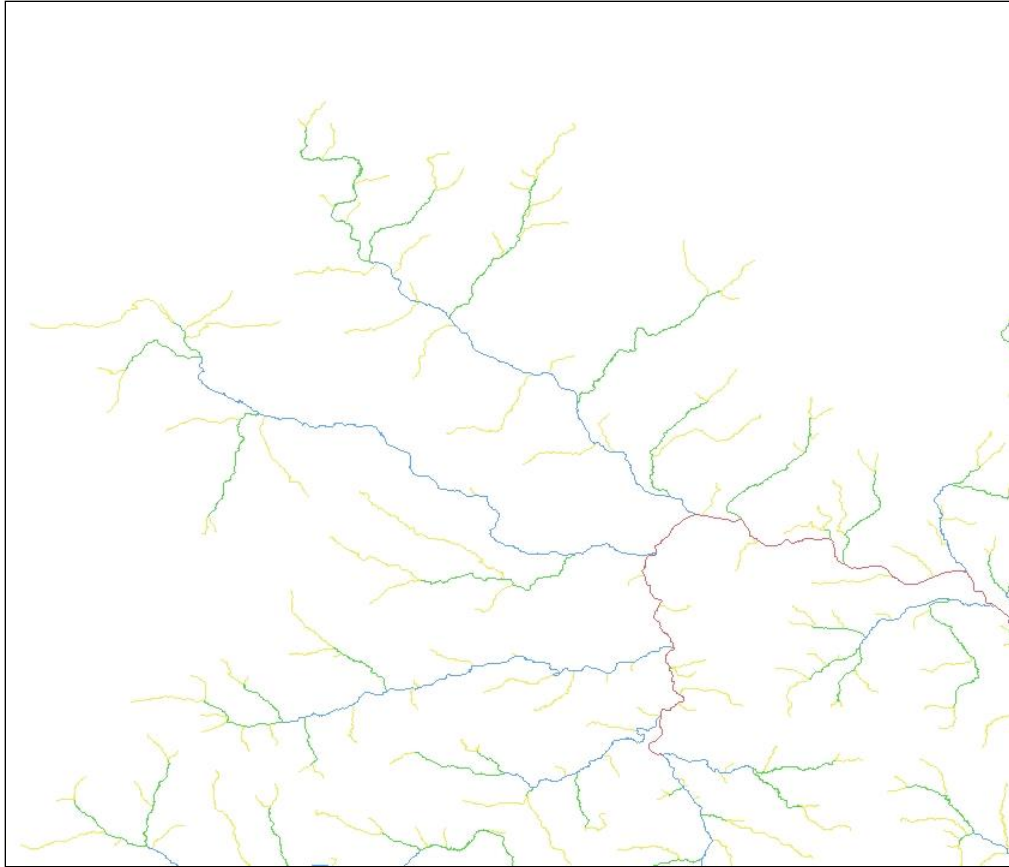


Figure 21: Stream Orders in a Part of the Midatlantic Region with Order 1 Streams Removed

Example 6: Stream Level

StreamLevel VAAs are often misunderstood or misused by users. Users often think of StreamLevel “as the opposite of Stream Order”. However, this is not true in any sense. Streamlevel = 1 will apply to the Mississippi mainstem but also to every small or large stream that terminates on the coastline. Therefore, StreamLevel has nothing to do with relative stream size.

The only valid use of StreamLevel is to identify- the mainstem and tributary at a particular junction. The lower valued stream levels are the mainstem and the higher valued stream levels are the tributaries. Figure 22 illustrates this. The flowlines are labeled with the StreamLevel values. The NHDFlowline features going in the north-south direction are StreamLevel = 2, and the features coming in from the West is StreamLevel=3. Therefore, the North-South features are the mainstem and the feature coming in from the West is the tributary.

There are additional aids in the VAAs, for instance, to determine flow direction on the North-South stream, check the Pathlength values of both of these features. In this case, the Pathlength of the southern feature is 400.1 and the Pathlength of the northern feature is 397.5. Therefore, the northern feature is closer to the network terminus, so the flow is going from south to north. The Hydroseq can also be used to determine the flow direction at this junction. The smaller Hydroseq value will be the downstream feature.

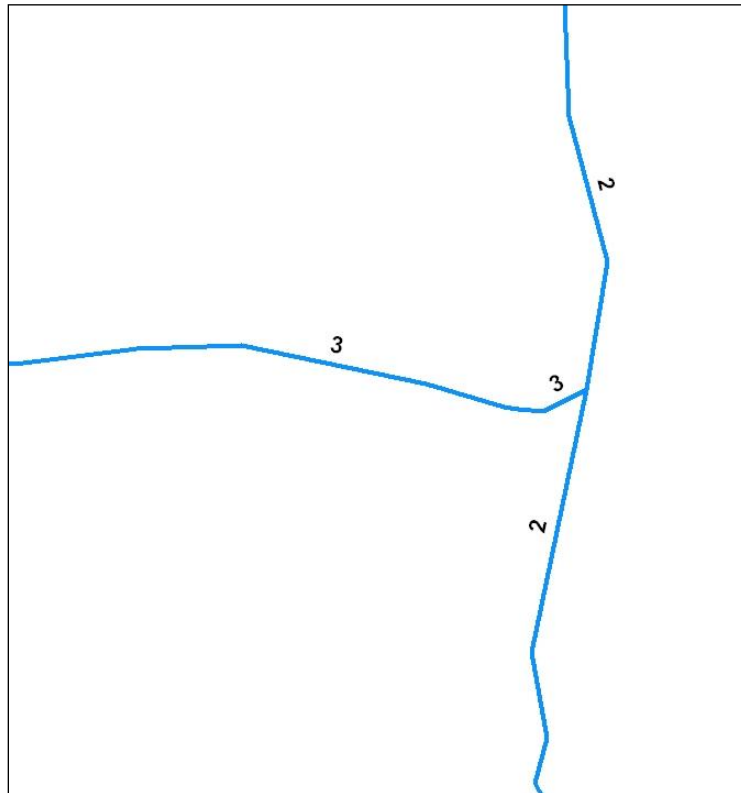


Figure 22: StreamLevel Values at a flowline Junction

Why do EROM flow estimates sometimes differ from Gage-reported flow?

A full discussion about how EROM computes mean annual and mean monthly flow estimates is covered in Appendix A. This discussion is intended to address why the EROM gage-adjusted flow estimates may not match the flow reported at a given gage location.

To perform the flow adjustment based on gage flows, EROM screens gages based on number of years of record, the period of record, and a comparison of the NWIS-reported drainage area with the NHDPlus calculated drainage area. Only gages that pass the screening are used in EROM's gage adjustment process. Consequently, at locations where a gage exists but the gage does not pass the screening criteria, the EROM flow estimate may differ from the gage flow measurement. Such a case is illustrated in the figures below.

Figure 23 shows the area in question, central California. The red dot is a gage location.

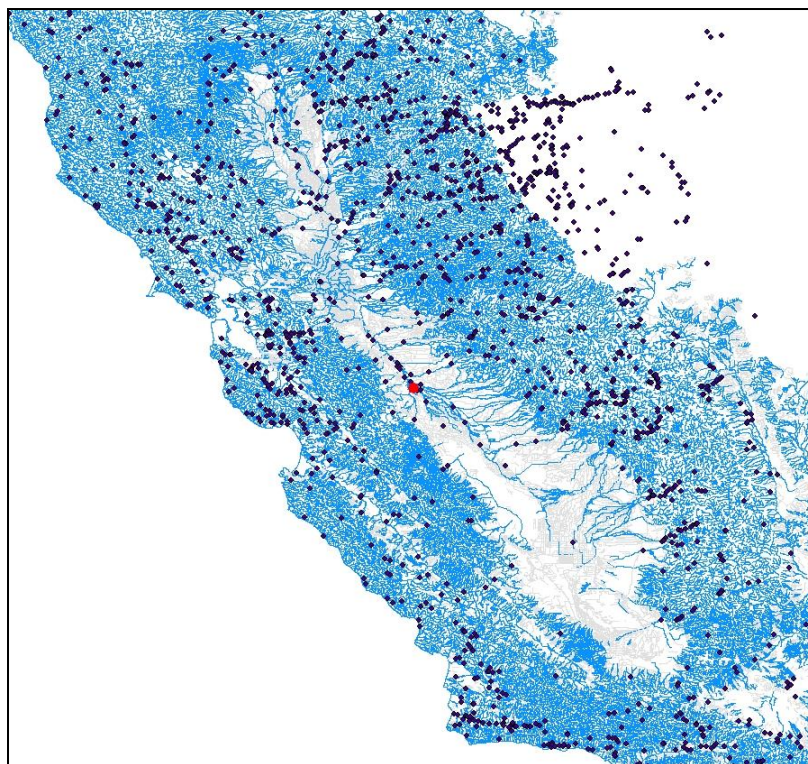


Figure 23: Central California Gage Locations

Figure 24 is a picture of the NHDFlowline features near the gage. The dashed lines are NHDFlowline features that are coded as FlowDir="Uninitialized" and therefore are not included in the NHDPlus network. Many of these dashed line features are irrigation withdrawals and returns. The solid lines are NHDFlowline features that are coded as FlowDir="With Digitized" and therefore are included in the NHDPlus network. The arrows show the direction of flow. The numeric labels on the solid lines represent the EROM mean annual flow estimates (in cfs) after

all EROM steps have been performed. The highlighted feature has an EROM flow of 0.637 cfs. A gage is located on the highlighted feature and this gage reports a mean annual flow of approximately 33 cfs. Why does the EROM estimate differ so dramatically from the gage measurement?

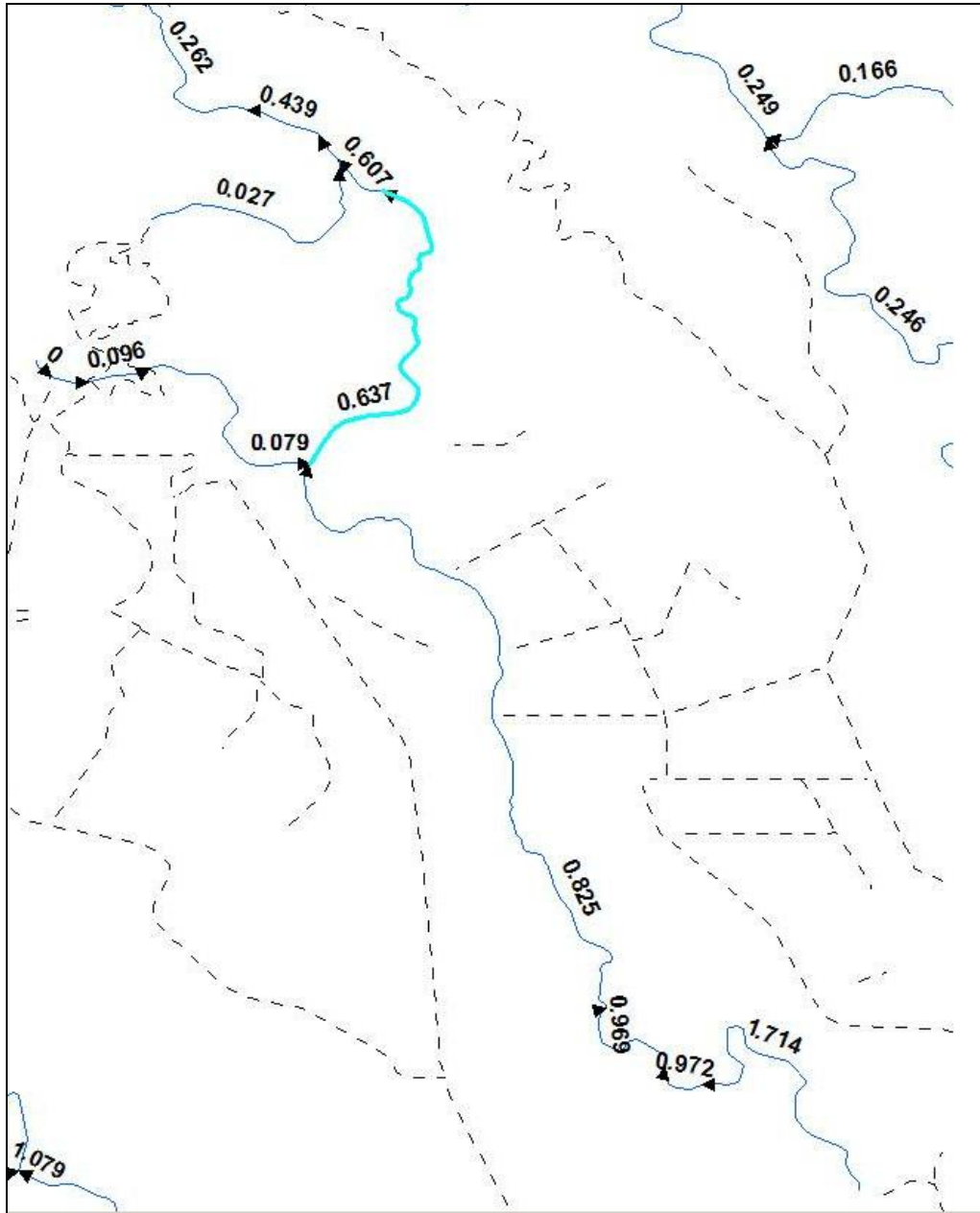


Figure 24: NHDFlowlines near a Gage

1. First, let us look at the EROM estimate. The runoff in this area is approximately 16 mm/year, from which EROM estimates a mean annual runoff flow (EROM step A) of 2.5 cfs. After the EROM adjustments for EET (EROM step B) and a reference gage regression (EROM step C), the flow is reduced to 0.637 cfs. In EROM step D, flow additions and removals are applied from the NHDPlusV2 PlusFlowAR table. There are

no entries in the table for this location, so the EROM flow after step D remains unchanged at 0.637 cfs. In EROM step E, the flow estimate is adjusted based on gages in the vicinity. There is a single gage in the vicinity and it's located on the feature highlighted in Figure 2. However, this gage "failed" the gage screening criteria used during the NHDPlusV2 processing because the NWIS-reported drainage area for this gage is missing. Therefore the gage's drainage area cannot be compared to the NHDPlusV2 computed drainage area which is a required comparison.

Since the gage did not pass the screening criteria, it was not used in EROM step E, where the flows are adjusted based on the gage flow. Therefore the step E flow estimate remains unchanged at 0.637 cfs.

How might the EROM estimates be improved? There are two possible ways to accomplish improvement in this particular case. First, enable the gage to pass the screening criteria, by including an NWIS-reported drainage area and reducing the number of years of record required. Second, this NHDFlowline feature is most likely influenced by irrigation returns. Entries in the PlusFlowAR table for this feature and/or upstream features can be used to adjust the flow based on estimated irrigation returns.

Using the NHDReachCrossReference Table to Transfer to NHDPlusV2 Data that is Linked to NHDPlusV1

If you have linked data to NHDPlusV1, it's possible to transfer that data to NHDPlusV2 by using the NHDReachCrossReference table.

NHDFlowline and NHDWaterbody contain two keys: ComID and Reachcode. ComIDs change frequently and the changes are not tracked. On the other hand, Reachcodes are fairly stable and change infrequently. Reachcode changes are tracked in the NHDReachCrossReference table.

Transferring Links to NHDWaterbody

If you have linked data to NHDWaterbody ComIDs, you can easily associate NHDPlusV1 Reachcodes with your data, as follows:

1. For your data linked to NHDWaterbody features, join your data table's ComID with NHDWaterbody.ComID. Create a field in your data table called Reachcode (Character(14)) and set it to the NHDWaterbody.Reachcode.

Once you have NHDPlusV1 NHDWaterbody Reachcodes you can translate to NHDPlusV2 Reachcode using the NHDReachCrossReference table. The translation procedure is:

1. Search for your NHDPlusV1 Reachcode in NHDReachCrossReference.OldReachcode.
2. If there is no such entry, then the NHDPlusV2 Reachcode is the same as the NHDPlusV1 Reachcode. Measure values on the Reach should be the same as well.

3. If an entry is found and the NHDReachCrossReference.ChangeCode = “D”, then there is no translation to an NHDPlusV2 Reachcode and you will need to associate your data to NHDPlusV2 manually.
4. If an entry is found and the NHDReachCrossReference.ChangeCode \neq “D”, then you must find the NHDPlusV2 Reachcode that now represents your NHDPlusV1 Reachcode. The NHDPlusV1 Reachcode may have been modified more than once, in which case, you will need to follow the consecutive links in the NHDReachCrossReference table. For the value NewReachcode (“NextReach”) in the table entry found above, search the table for an entry where NHDReachCrossReference.OldReachcode = NextReach. Repeat this step until no additional entries are found. The final value for NewReachcode is the NHDPlusV2 Reachcode that corresponds to your NHDPlusV1 Reachcode.

Transferring Links to NHDFlowline

If you have linked data to NHDPlusV1 NHDFlowline ComIDs, first you must associate NHDPlusV1 Reachcodes with your data.

1. Join your data table’s ComID with the Tnavwork.tblVAAFromTo.ComID. Create a field in your data table called Reachcode (Character(14)) and set it to the tblVAAFromTo.Reachcode. Note: Tnavwork data is available as an NHDPlusV1 Data Extension.
2. If you don’t have a feature class that shows the location of your data, you must derive a feature class for your data from the NHDPlusV1 NHDFlowline feature class:
 - a. If your data is linked to the bottom point of the NHDFlowline feature, create a field in your data table called Measure (Double(9,5)) and set it to Tnavwork.tblVAAFromTo.ToMeasure.
 - b. If your data is linked to the top point of the NHDFlowline feature, create a field in your data table called Measure (Double(9,5)) and set it to Tnavwork.tblVAAFromTo.FromMeasure.
 - c. If your data is associated with the entire NHDFlowline feature, you will need the from-measure and to-measure of the NHDFlowline feature. Create fields in your data table called FromMeasure (Double(9,5)) and ToMeasure (Double(9,5)) and set them as follows: FromMeasure = Tnavwork.tblVAAFromTo.ToMeasure and ToMeasure = Tnavwork.tblVAAFromTo.FromMeasure.
 - d. Using your data table with the fields added in step 2, run the ArcGIS Linear Referencing Toolbox tool called “Make Route Event Layer” to build a feature class with the geometry locations of your data.

Once you have NHDPlusV1 Reachcodes and a feature class with the geometry of the locations of your data, you can translate the NHDPlusV1 Reachcode into the NHDPlusV2 Reachcode using the NHDReachCrossReference table. This translation procedure is repeated for each entry in your data table:

1. Search the NHDReachCrossReference table for entries where NHDReachCrossReference.OldReachcode = your NHDPlusV1 Reachcode.

2. If there is no such entry, then the NHDPlusV2 Reachcode is the same as the NHDPlusV1 Reachcode.
3. If an entry is found and the NHDReachCrossReference.ChangeCode = "D", then there is no translation to an NHDPlusV2 Reachcode and you will need to associate your data to NHDPlusV2 manually.
4. If one or more entries are found and the NHDReachCrossReference.ChangeCode <> "D", then you must find the set of NHDPlusV2 Reachcodes that now represent your NHDPlusV1 Reachcode. If an NHDPlusV1 Reach became more than one NHDPlusV2 Reach, there will be more than one entry found in the NHDReachCrossReference table.
5. The NHDPlusV1 Reachcode may have been modified more than once, in which case, you will need to follow the consecutive links in the NHDReachCrossReference table. This can be done by saving the NHDReachCrossReference.NewReachcode value from each of the entries found in step 4 above. For each NewReachcode value ("NextReach"), search NHDReachCrossReference.OldReachcode = NextReach. Repeat this step until no additional entries are found. The final set of values for NextReach are the NHDPlusV2 Reachcodes to which your NHDPlusV1 Reachcode corresponds.
6. Using GIS tools to conflate your data onto NHDFlowline feature. In other words, locate your data on the set of NHDPlusV2 NHDFlowline features that represent the Reachcodes found during step 5.

Appendix A: NHDPlusV2 Build/Refresh Process Description

NHDPlusV2 starts with a snapshot of the National Hydrography Dataset (NHD), a snapshot of the National Elevation Dataset (NED) and a snapshot of the Watershed Boundary Dataset (WBD). From these three inputs, the NHDPlusV2 Build/Refresh Tools process produces NHDPlusV2 workspaces. The NHDPlusV2 Build/Refresh Tools are a collection of database and geo-spatial functions that are used to build NHDPlusV2.

The first 24 steps in the Build/Refresh process are incorporated into a single graphical user interface, called NHDPlusBuildRefresh, which creates and manages the workflow of steps necessary to execute the build/refresh process. Several additional tools, each under its own graphical user interface, are used to assist in steps classified as “External” and also to build the NHDPlusV2 data extensions. The data extensions (with tool names in parentheses) are EROM Flow Estimates (EROM), EROM Flow QAQC (EROMQAQC), Vogel Flow Estimates (VogelFlow), and Jobson Velocity Calculations (VelocityCalculator). In addition, various attributes allocated to NHDPlusV2 catchments and accumulated down the NHDPlusV2 stream network are produced with the Catchment Attribute Allocation and Accumulation Tool (CA3TV2). Finally, time of travel is populated (TOT).

The diagrams on the next two pages (Figure A-1) illustrate the workflow for the first 24 steps and the NHDPlusV2 data extensions, respectively.

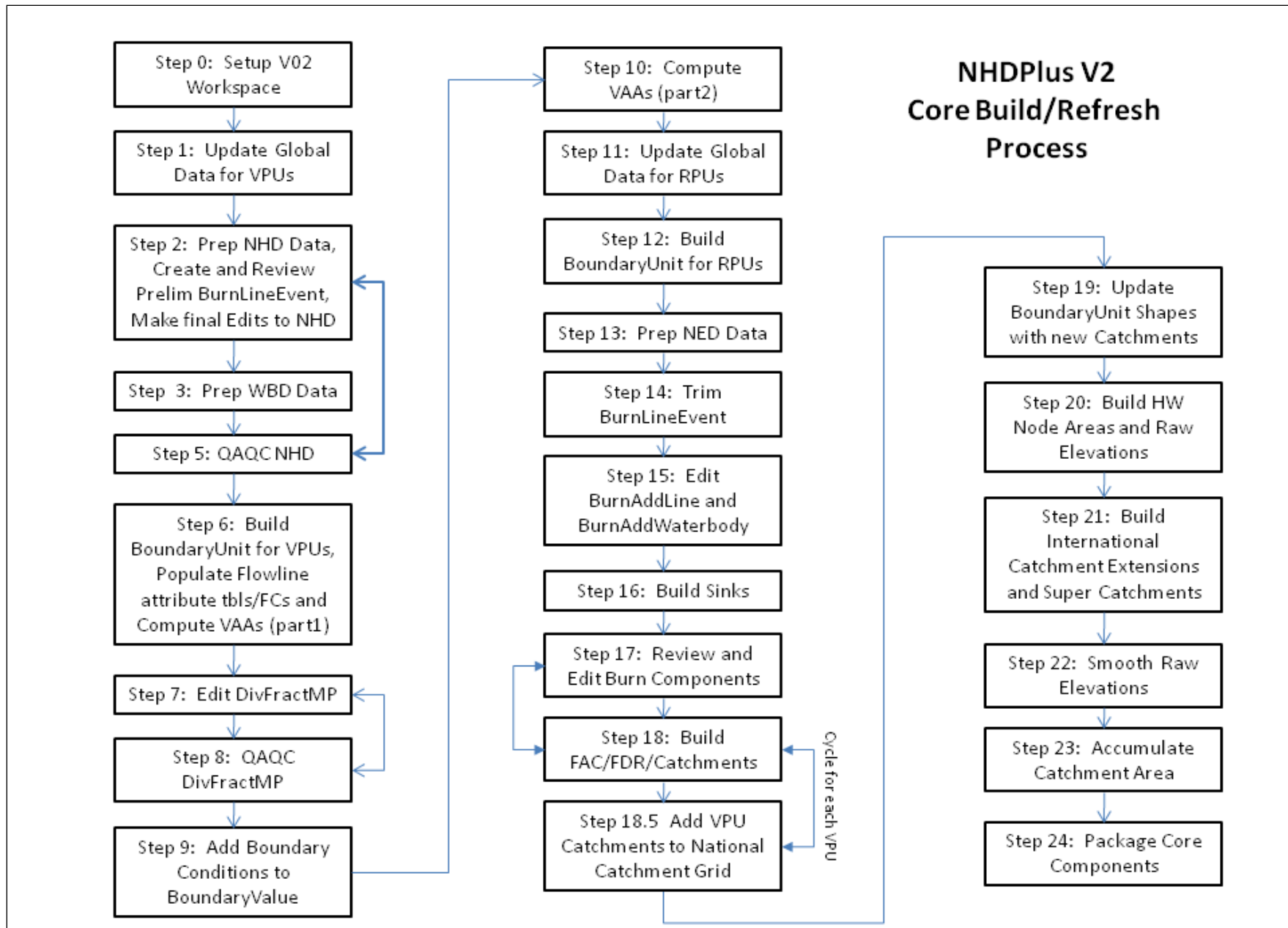


Figure A-1: (a) NHDPlus V2 Core Build/Refresh Process

NHDPlus V2 – Extended Build/Refresh Process

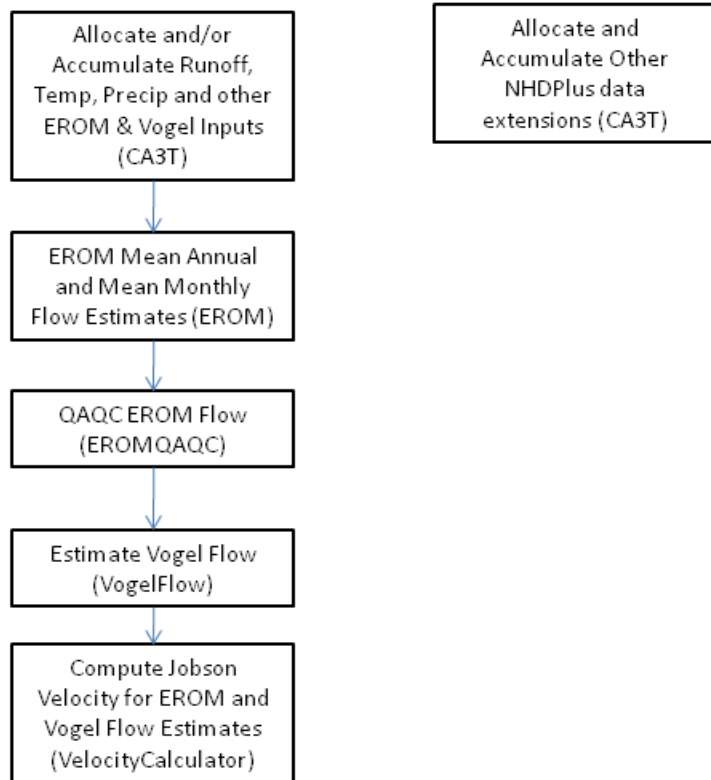


Figure A-1: (b) NHDPlusV2 Extended Build/Refresh Process

Step 1 – Edit Global Data to set up VPUs and Setup the Build/Refresh Work Flow (External)

During this step the NHDPlusV2 Global Data is configured for a drainage area. This involves defining the geographic area included in the drainage area and defining the divisions of the drainage area that comprise the VPUs. The \NHDPlusGlobalData\BoundaryRel table contains a list of HUC8s assigned to the drainage area and to VPUs within the drainage area.

Step 2 – Prepare NHD Data (External)

The NHD data is edited in HUC04 shapefile workspaces using a NHD Edit Tool bar built specifically for NHDPlusV2 Build/Refresh. The following edits are performed:

1. Names are applied or corrected on NHDFlowlines and NHDWaterbodies.
2. Incorrect isolated networks are connected to the network.
3. NHD and WBD are reconciled based on the WBD designation of “open” or “closed” and downstream HUC.
4. Coastline dangles are fixed.
5. Microgaps are fixed.
6. Non-linear NHDFlowline features, reaches and named paths are corrected.
7. Invalid Connectors are corrected.
8. Flow directions are corrected.

After editing is complete and the data passes the NHDPlusV2 network QA/QC checks, (1) LengthKM and AreaSQKM in the appropriate NHD feature classes are re-computed, ReachCodes are assigned to new reaches, M-values are assigned to each linear reach, and the HUC4 workspaces are appended into HUC2 hydrologic regions.

A flow table (\NHDPlusAttributes\Plusflow) is built from the geometry of the NHDFlowlines where FlowDir = “With Digitized”. Non-spatial connections at international return flows, underground connections, and other locations are added to the flow table.

Step 3 – Prepare WBD Data (External)

During Step 3, the latest version of the WBD is acquired. The WBD polygons and lines are used to populate \WBDSnapshot\WBD\WBD_Subwatershed and \NHDPlusBurncomponents\Wall, respectively. The source WBD data is processed in the following manner:

- From the national seamless snapshot of the WBD, HUC 12 polygons are selected in order to define a given NHDPlusV2 VPU.
- These polygons are exported to \WBDSnapshot\WBD\WBD_Subwatershed (see Appendix D). A field is added to WBD_Subwatershed, named GAZ_ID. Geographic Names Information System (GNIS) will contain a unique identifier assigned to each WBD HUC - NHDPlusV2 names the associated field "GAZ_ID". At the time of NHDPlusV2 processing, these unique values had not been assigned by GNIS. To accommodate NHDPlusV2 processing needs, GAZ_ID was populated with a unique value using the feature ID.

The Wall feature class is created from the national WBD HUC 12 line feature class using a spatial overlay selection with the WBD_Subwatershed. Any international boundary lines, coastal closure lines, and shorelines are removed from the newly created Wall feature class.

Step 4 – Reserved for Future Use

Step 5 – NHD QAQC – For each VPU in Drainage Area

During Step 5, the NHDPlus NHD QAQC checks are run using the edited NHDSnapshot. If severe errors are found, the NHD is returned to Step 2 for additional editing. The Build/Refresh process does not proceed beyond step point until the NHDSnapshot passes the QAQC checks. Below are the checks completed in this process step and, when available, the scope of the error (severe, warning, informational, etc.) is reported.

NHDFlow.Direction valid values used in the descriptions of the QAQC checks are:

- 712 – Network Start
- 713 – Network End
- 709 – Flowline Connection
- 714 – Non-flowline connection at Coastlines

Check 1 - Flow Table Entry Never Navigated (Severe)

A downstream global navigation is performed beginning with all "Network Start" flow table entries (including incoming workspace connections). The navigation proceeds downstream such that a flow table entry is never processed until all inflows to that entry have been processed. When no additional navigation can be performed, a Check 1 error is generated for each flow table entry not processed during the navigation.

Check 2 - Improper Network End (Severe)

ToComID in flow table does not appear as a FromComID (except inflowing connections). FromComID in flow table on "Terminal" flow record (i.e. ToComID = 0) also exists as a FromComID where ToComID

Check 3 - Invalid Flow Table Entry (Severe)

FromComID = ToComID
Neither FromComID nor ToComID are in NHDFlowline
Direction not 712, 713, or 714
Direction = 712 and (ToComID = 0 or FromComID > 0)
Direction = 713 and (FromComID = 0 or ToComID > 0)
Direction = 709 and (FromComID = 0 or ToComID = 0)
Direction = 714 and FromComID = 0 and ToComID = 0

Check 4 - Improper Network Start (Severe)

FromComID in flow table does not appear as a ToComID in flow table (except outflowing connections).
ToComID in flow table on "Start" flow record (i.e. FromComID = 0) also exists as a ToComID where FromComID <> 0

Check 5 - Potential Loop (Severe)

When Check 1 errors are found, a Check 5 value is generated at each location where the Check 1 navigation stopped. Check 5 can be used to locate the problems found by Check

1. Check 5 requires Check 1 to be executed. If only Check 5 is selected, Check 1 will be run but the results will not be included in the error report.

Check 6 - Possible Outflowing Connection (Informational)

A flow table entry exists where the FromComID is in NHDFlowline and the ToComID is not.

Check 7 - Possible Inflowing Connection (Informational)

A flow table entry exists where the ToComID is in NHDFlowline and the FromComID is not.

Check 8 - Duplicate Flow Table Entry (Severe)

Based on FromComID, ToComID flow table entry occurs more than once

Check 9 - Incomplete Divergence

Identify incomplete divergences - where all the inflows to the divergence do not each flow to all the outflows from the divergence. For example, A -> C, A-> D, B->C, but B->D is not in the flow table. Error report entry is for one of the ComIDs containing multiple outflows.

Check 10 - Flow Table and Flowline FType Disagree

ToComID in a coastline (714 - Non Flowing) flow table entry does not have an NHDFlowline.FType of "Coastline"

709 (In) Flow table entry where either FromComID or ToComID has NHDFlowline.FType of "Coastline"

Check 11 - Flow Table and Flowline FlowDir Disagree

NHDFlowline.ComID is in the flow table as ToComID or FromComID and NHDFlowline.FlowDir = "Uninitialized"

NHDFlowline.ComID is neither ToComID nor FromComID in the flow table and NHDFlowline.FlowDir = "With Digitized"

Check 12 - Isolated Network

PlusFlow.Direction = 713 (Network End)

Check 13 - Coordinate Order and Flow table Disagree

The common endpoints of PlusFlow.FromComID and PlusFlow.ToComID are not last 'point' and first 'point' respectively.

Check 14 - Flowlines Relate in Flow Table But Do Not Touch

PlusFlow.FromComID and PlusFlow.ToComID do not contain a common endpoint

Check 15 - Flowlines Touch But Do Not Relate in Flow Table (not Canal/Ditch)

Flowlines A and B contain a common endpoint (last "point" and "first" point, respectively) and A does not relate to B in the flow table and neither A nor B is a canal/ditch.

Check 16 - Reserved

Check 17 - Flowline Not in Linear Reach

Flowline is not part of a linear reach (i.e. NHDFlowline.ReachCode is empty or blank)

- Check 18 - Circular Reach
Merged geometry for all NHDFlowlines with a particular ReachCode has 0 endpoints
- Check 19 - Nonlinear Reach
Merged geometry for all NHDFlowlines with a particular ReachCode has other than 2 endpoints (and not 0 endpoints).
- Check 20 - Circular Flowline
Geometry for a particular NHDFlowline has 0 endpoints.
- Check 21 - Flowline With LengthKM = 0
Value of NHDFlowline.LengthKM is 0
- Check 22 - Reachable Waterbody Not in Area Reach (Warning)
LakePond waterbody is not part of an area reach (i.e. NHDWaterbody.ReachCode is empty or blank).
- Check 23 - Circular Named Path (Warning)
Merged geometry for all NHDFlowlines with a particular Gnisid has 0 endpoints
- Check 24 - Nonlinear Flowline (Severe)
Geometry for a particular NHDFlowline has other than 2 endpoints (and not 0 endpoints).
- Check 25 - Nonlinear Named Path (Severe, but there can be false positives)
Merged geometry for all NHDFlowlines with a particular Gnisid has other than 2 endpoints (and not 0 endpoints)
- Check 26 - Flowline with both flowing and non-flowing flow table entries (Severe)
Flowline has both flowing and non-flowing flow table entries.
- Check 27 - Waterbody reach has multiple waterbodies that do not touch (Severe?)
Waterbody reach contains multiple waterbodies and at least one of the waterbodies does not share an edge with any of the remaining waterbodies in the waterbody reach.
- Check 28 – Microgaps (Severe)
Identify microgaps between NHDFlowlines.
- Check 29 - Duplicate NHDFlowline features (Warning)
Identify NHDFlowline features that intersect with a cluster_tolerance of 0. (shapes are overlapping or directly on top of each other).
- Check 30 - Duplicate NHDWaterbody features (Warning)
Identify NHDWaterbody features that intersect with a cluster_tolerance of 0. (shapes are overlapping or directly on top of each other).
- Check 31 - Duplicate NHDArea features (Warning)
Identify NHDArea features that intersect with a cluster_tolerance of 0. (shapes are overlapping or directly on top of each other).
- Check 32 - Reach Surrounded by Different HUCS (Warning)

Identify NHDFlowlines in one HUC that contain HUC values, on both ends, of NHDFlowlines in one or more different HUCs.

Check 33 - Coastline Dangles (Severe but there can be false positives between Hydrologic Regions)

Identify coastline dangles.

Step 6 – Build GlobalData.BoundaryUnit for VPUs, ComID-based NHDPlusV2 tables, and VAAs Part 1

Step 6 partially populates PlusFlowlineVAA by calculating and completing QAQC checks for twelve Value Added Attributes (VAAs) (stored in \NHDPlusAttributes\PlusFlowlineVAA). The VAAs are populated from the PlusFlow table content and the NHDFlowline feature class.

The VAAs are calculated only for NHDFlowline features with NHDFlowline.FlowDir = “With Digitized”. Step 6 computes values for the following VAAs:

Frommeas: Set to the m-values at the bottom of the NHDFlowline feature.

Tomeas: Set to the m-values at the top of the NHDFlowline feature.

Fromnode/Tonode: A node is defined as one of the following:

- The top of an NHDFlowline feature that has a flow table record with Direction = 712 (i.e. a headwater node).
- The bottom of an NHDFlowline feature that has a flow table record with Direction = 713 (i.e. a terminal node).
- The “point” of flow exchange represented by a flow table record with Direction = 709 (i.e. a node between two or more NHDFlowline features).
- The “point” of a non-flowing connection represented by a flow table record with Direction = 714 (i.e. a coastline connection)

Within Drainage Area (DA), each node is given a unique number beginning with 1. The numbers are made unique across DAs by multiplying the node number by nn0000000, where nn is unique to each drainage area. For example, DA 17 nodes are multiplied by 170,000,000.

The Fromnode is the top of the NHDFlowline feature and the Tonode is at the bottom of the NHDFlowline feature.

StartFlag: Set to 1 if the NHDFlowline feature has a flow table record with Direction = 712 or if the Direction = 714 and the FromComID =0.

TerminalFlag: Set to 1 if the NHDFlowline feature has a flow table record with Direction = 713 or if the Direction = 714 and the ToComID =0.

VPUIn: Set to 1 if the NHDFlowline feature has a flow table record with Direction = 709 or 714 and the FromComID is not in the DA.

VPUout: Set to 1 if the NHDFlowline feature has a flow table record with Direction = 709 or 714 and the ToComID is not in the DA.

DnDrainCount: Set to the number of flow table records where the NHDFlowline feature is the FromComID and Direction = 709.

LengthKM: Set to NHDFlowline.LengthKM of the NHDFlowline feature.

ReachCode: Set to NHDFlowline.ReachCode of the NHDFlowline feature.

Fcode: Set to NDHFlowline.Fcode of the NHDFlowline feature

Step 7 – Edit Divergence Fraction Mainpath Table (External)

During step 7, the DivFracMP table is edited, when necessary, to specify main paths at points of flow divergence. If gaged stream flow data is available, the DivFracMP table may also specify the percentage of stream flow that flows down each of the divergent paths.

Step 8 – QAQC Divergence Fraction Mainpath Table – For Each VPU in Drainage Area

Step 8 is an automated QA/QC that confirms that the divergence fractions for a given divergence (i.e. the set of DivFracMP records with the same NodeNumber) sum to 1.0.

Step 9 – Edit Global Data BoundaryValue Table for incomplete DA (External)

When a drainage area is processed in parts by NHDPlus Build/Refresh Tools, it is necessary to establish boundary values for some NHDPlus attributes at the edge of the partial drainage area. Places where flow enters and leaves the partial drainage area require boundary values. Regardless of the use of boundary values, the drainage area parts must be run in hydrologic order from upstream to downstream.

The NHDPlusV2 Build/Refresh process was performed on partial drainage areas for the Mississippi and Colorado drainages.

Step 10 – Compute VAAs Part 2

Step 10 completes the VAA computation task started in Step 6. Each VAA is computed and QAQC'ed against other VAAs to confirm the VAAs are internally consistent. All VAA must pass their respective QAQC checks in order for Step 10 to be considered successful. In the discussion below, only NHDFlowline features with FlowDir="With Digitized" are assigned VAA values. The following VAAs are computed in Step 10:

Divergence: Divergence is a flag that distinguishes between the main and minor paths at a network flow split. At a network split, one NHDFlowline feature is designated as the major path (Divergence=1) and all other paths in the split are designated as minor paths (Divergence=2). All features that do not participate in a flow split have Divergence=0. Divergence always agrees with StreamLevel. This agreement insures that navigating upstream and downstream along the main

path give the same navigation results. The main path at a flow split is selected from the out-flowing NHDFlowline features according to the following rules:

- A NHDFlowline feature that has the same name, ultimately flows to a coast and has an FType of StreamRiver, Artificial Path or Connector, otherwise
- A NHDFlowline feature that has the same name, that does not ultimately flow to a coast and has an FType of StreamRiver, Artificial Path or Connector, otherwise
- A NHDFlowline feature that has a positive DivFract value in the DivFracMP table and that value is the maximum such value at the divergent node, otherwise
- any named stream/river, artificial path, or connector that ultimately flows to a coast, otherwise
- unnamed stream/river, artificial path, or connector that doesn't ultimately flow to a coast, otherwise
- any named canal/ditch or pipeline that ultimately flows to a coast, otherwise
- any NHDFlowline feature that ultimately flows to a coast, otherwise
- any named stream/river, artificial path, or connector that doesn't ultimately flows to coast
- unnamed stream/river, artificial path, or connector that does not ultimately flow to coast, otherwise
- named canal/ditch or pipeline that does not ultimately flow to coast, otherwise
- any flowline that does not ultimately flow to coast

In the rules above, if there is more than one NHDFlowline feature that matches the rule criteria, the one with the lowest ComID value is selected.

ArbolateSum: ArbolateSum is computed starting at the headwaters of the NHDFlowline network. The NHDFlowline.LengthKM is summed along the network such that each feature has an ArbolateSum of its length plus the length of every upstream feature.

StreamLevel: StreamLevel is a numeric code that traces main paths of water flow upstream through the drainage network. StreamLevel is assigned starting at the terminus of a drainage network. If the terminus stopped at a coastline NHDFlowline feature (i.e. at the Atlantic Ocean, the Pacific Ocean, the Gulf of Mexico, or one of the Great Lakes), a stream level of 1 is assigned to the terminus and all the NHDFlowline features in the main path upstream to the headwater of the stream. If the terminus drains into the ground or stops at the Canadian or Mexican border, a stream level of 4 is assigned to the terminus and all the NHDFlowline features in the main path upstream to the headwater of the stream. After the initial stream level of 1 or 4 is assigned to the terminus and its upstream path, all tributaries to that path are assigned a stream level incremented by 1. Then the tributaries to those stream paths are assigned a stream level incremented by 1. This continues until the entire stream network has been assigned stream levels.

If possible, StreamLevel follows a named path. In other words, at any confluence, if there is an NHDFlowline feature immediately upstream with the same name, that feature is selected as the main path. If there is no matching name immediately upstream, the NHDFlowline feature with the maximum ArbolateSum value is selected. To ensure agreement with Divergence, StreamLevel assignment does not follow a minor path at or downstream of an NHDFlowline feature with Divergence=2.

HydroSeq: Hydroseq is assigned by starting at the headwaters of the NHDFlowline network and assigning a sequential number proceeding downstream. To begin each headwater is assigned a

value. Next, all of the outflows from the headwater streams are assigned values. Then all of the outflows of the outflows of the headwater streams are assigned values. This process continues until all network features have values. The features are sorted by descending values (i.e. downstream to upstream) and the final Hydroseq values are assigned in an ascending sequence. The final Hydroseq values are smallest at the downstream end of the network and largest at the upstream end of the network.

The primary characteristic of the HydroSeq number is that if the features are processed by descending HydroSeq values (i.e. upstream to downstream), when any feature is processed, all the features upstream have already been processed. Likewise, if the features are processed by ascending HydroSeq values (i.e. downstream to upstream), when any feature is processed, all the features downstream have already been processed.

DNLevel: This is the value of StreamLevel of main path NHDFlowline feature immediately downstream. When $DnLevel <> StreamLevel$, the stream is about to discharge into another stream pathway.

LevelPathID: LevelPathID is set equal to the HydroSeq value of the most downstream feature on the same level path. For example, all the features along the Mississippi River have the same value for LevelPathID.

TerminalPathID: TerminalPathID is set equal to the HydroSeq value of the most downstream feature in the drainage system. In other words, the HydroSeq of the network terminus will become the TerminalPathID of all the features that flow to that terminus. For example, all the features that flow to the mouth of the Delaware River will have the name value for TerminalPathID.

UpLevelPathID: This is the LevelPathID of the main path NHDFlowline feature immediately upstream.

UpHydroSeq: This is the HydroSeq value of the main path NHDFlowline feature immediately upstream.

DnMinorHydroSeq: When there is a flow split at the downstream end of a feature, this is the HydroSeq value of a minor path in that divergence. If there is more than one minor path in the divergence, the one with the lowest ComID value is used to set DnMinorHydroSeq.

PathLength: Pathlength is the sum of the NHDFlowline.LengthKM downstream, along the main path, to the terminus of the network. For example, the Pathlength of the mouth of the Missouri River will be the distance to the mouth of the Mississippi River.

RTNDiv: RTNDiv stands for returning divergence and is set to 1 when one or more of the paths from an upstream flow split return to the network at the upstream end of the NHDFlowline feature.

StreamOrder/StreamCalc: StreamOrder order in NHDPlus is a modified version of stream order as defined by Strahler. The Strahler stream order algorithm does not account for flow splits in the network. The NHDPlus algorithm for stream order does take flow splits into consideration. StreamCalc is the flag for the stream calculator a variable created to assist with tracking divergences and is computed with StreamOrder. These VAAs are computed from upstream to

downstream. The methodology used for assigning StreamOrder and StreamCalc is described below.

All headwater or “start” reaches are assigned a Strahler order of “1”. Strahler calculator is assigned the same value as StreamCalc for all headwater flowlines. If there are no divergences, StreamOrder and StreamCalc have the same value – both values are increased in the defined manner for calculating Strahler order. When a main path divergence is reached, the defined main path (DIVERGENCE = 1) is assigned the same value for StreamOrder and StreamCalc based on the inflows to the divergence. The defined minor path divergence (DIVERGENCE = 2) is assigned the StreamOrder value based on the inflows to the divergence, but StreamCalc is assigned the value “0”.

As the minor path divergence continues downstream, the StreamCalc value remains “0” and the StreamOrder value cannot increase until the flowline is combined with another flowline having a StreamCalc value greater than “0”. This allows multiple minor path divergences to intertwine without increasing the Strahler order of the minor path. When two minor path flowlines with StreamCalc values of “0” and different StreamOrder values join, the larger StreamOrder value is maintained and StreamCalc remains 0. Also, because StreamOrder cannot increase if StreamCalc is equal to 0, when a minor path rejoins the main path, the main path Strahler order value is maintained.

Step 11 – Edit Global Data to set up RPUs (External)

During Step 11, the NHDPlusGlobalData\BoundaryRel is edited to assign HUC8s to the RPUs in the Drainage Area.

Step 12 – Build GlobalData.BoundaryUnit for RPUs

Using the HUC8 boundaries in \NHDPlusGlobalData\BoundaryUnit and the assignments of HUC8s to RPUs found in NHDPlusGlobalData\BoundaryRel, Step 12 builds polygons for the RPUs in the Drainage Area.

Step 13 – Prepare NED (External)

The purpose of Step 13 is to prepare the original/raw elevation data for the production of the HYDRODEM in Step 18. One-arc-second NED data was acquired from the USGS EROS Data Center. If the Drainage Area extends into Canada, elevation data for the Canadian area was acquired, as available, from the Canadian Digital Elevation Data. The Canadian data was then appended to the NED data. The NED data currently includes data for Mexico.

The RPU polygons in \NHDPlusGlobalData\BoundaryUnit are used to select the set of WBD sub-watershed polygons (see “\WBDSnapshot\WBD\WBD_Subwatershed”) within to each RPU. For each RPU in the Drainage Area, the set of sub-watershed polygons are buffered and the buffered area is used to create the \NEDSnapshot\NEDRRRRRRRRR\elev_cm for the RPU. The elevation data were extracted, merged, projected to the Albers Equal-Area projection, and converted to integer centimeters in ESRI Grid format. Integer grids were used because they utilize internal compression (making files more compact). Also, the data was converted from meters to centimeters to retain precision.

Step 14 – Trim BurnLineEvent for Raster Processing

Step 14 shortens the length of some features in \NHDPlusBurncomponents\BurnLineEvent to improve the hydro-enforcement process. To avoid the possibility that headwater features will cut through the ridge lines in the elevation data, the headwater features are trimmed by 150 meters. To ensure that the NHDPlus flow direction grids (see “\NHDPlusFdrFacRRRRRRRRR\fdi”) follow the main path at flow divergences, the minor path of divergences are also trimmed or shortened by 150 meters.

Occasionally, a headwater feature or a minor divergent path feature is shorter than 150 meters. When this occurs, the feature is removed entirely from BurnLineEvent. Features removed from BurnLineEvent are not included in the NHDPlusV2 raster processing and consequently, they are not hydro-enforced into the DEM and they do not receive catchments. When these features are headwater features, they will not have values for the attributes that depend upon the raster processing such as endpoint elevations, slope, headwater node area, and flow estimates.

Step 15 – Edit BurnComponents (External)

The purpose of Step 15 is to edit the hydro-enforcement components found in \NHDPlusBurnComponents. The BurnLineEvent, BurnAddWaterbody, BurnAddLine, and Wall feature classes are edited as needed and the LandSea feature class is created.

The process used in this step includes:

- A. Create LandSea polygons (if a coastal VPU): This is created using the NHD coastline features. A buffer polygon area is created for each sides of the coastline: a polygon for the landward side and a polygon for the ocean. Estuary polygons are optional features which can be created to separate coastal bays from the ocean polygon areas.
- B. Find and Resolve Stream-Wall Conflicts: Headwater stream conflicts with the WBD are identified by locating headwater NHDFlowline features that intersect a wall when both the feature and the wall are rasterized. The selected streams are then trimmed back, leaving only the lower 30% of the feature. This action minimizes breaching of 1:24,000-scale WBD divides by 1:100,000-scale headwater NHDFlowline features. Further conflicts are identified for any NHDFlowline feature that, when rasterized, intersects the outermost boundary of the VPU wall. Conflicts are resolved by either trimming a headwater feature further; setting a feature or set of features to “N” for the Burn and Catchment attributes in BurnLineEvent; or when necessary, editing the Wall feature class to remove the conflict with the NHDFlowline feature(s).
- C. Resolve “Empty” HUCs: This step identifies HUC 12 polygons in WBD_Subwatershed that are not closed basins (as identified by the WBD) and do not have any BurnLineEvent features within them. HUC 12s that meet these criteria are termed “empty hucs” and lack any NHDFlowline connection to drain these areas correctly in the HydroDEM. Once the empty hucs are identified, a WBD attribute in the polygon data is used to identify the next downstream HUC 12 to which that the HUC flows. The line feature between these HUCs is then removed from the Wall feature class.

An alternative process was used early in the production process; a line was added to the BurnAddLine NHDPlus feature class to breach the wall between the “empty huc” and the next downstream HUC in the HydroDEM conditioning process. This early method was abandoned after the automated method was developed to remove wall segments, as described above.

- D. Identify and attribute closed lakes: In NHDPlusV2, numerous sources are used to determine non-contributing, including the WBD. Within the WBD, information on non-contributing areas (termed “closed basin” in WBD) is available at the HUC 12 level. An attribute in the WBD_Subwatershed feature class named HU_12_DS is used to locate closed basins. Within closed systems an attempt was made to identify closed lakes (i.e. lakes with no outflows). Identifying closed lakes provided greater detail of the non-contributing HUC 12 areas. In many cases, a closed lake could be identified by checking for a lake name in the attribute HU_12_Name in WBD_Subwatershed.

In the aforementioned cases, the named lake drains the closed HUC 12. In other cases, several lakes within these closed systems are identified by review of the topographic maps and imagery. Lakes in the NHD that are deemed closed, are coded in BurnWaterbody by setting the attributes Purpcode = 5 and Purpdesc = “NHD Waterbody closed lake”. Closed lakes in BurnAddWaterbody are coded with PurpCode = 8 and Purpdesc = “BurnAddWaterbody closed lake.” Step 16 places a point at the centroid of these closed lakes in the Sink feature class. In step 18, catchments for these sinks are generated along with catchments for BurnLineEvent features.

- E. Check InRPU field in BurnLineEvent: This step reviews the RPU id (in BurnLineEvent.InRPU) assignments for the BurnLineEvent features. The PlusFlow table was used to detect where flowlines flow from one RPU to another. The flowlines were reviewed manually to ensure no flowlines were assigned to the wrong RPU.
- F. Review Burn Components: This step involves reviewing the features classified in \NHDPlusBurnComponents and processing status of data conditions observed. The following conditions are checked:
- Review features in BurnLineEvent coded as FType=“Pipeline” and determine the appropriate values for fields “Catchment” and “Burn” in BurnLineEvent. Often, these features should not have a catchment generated and/or should not be used for hydro-enforcement. In these cases, the Catchment and/or Burn attributes can be set to “N” (no).
 - Review features in BurnLineEvent coded as FType=“CanalDitch” or “Connector”. Similar to “Pipeline”, these features may also need the Catchment and/or Burn attributes can be set to “N” (no).
 - This step also accommodates other scenarios that involve setting the Catchment and Burn attributes in BurnLineEvent and adding features to BurnAddLine. It is beyond the scope of the User Guide to identify all possible scenarios; however, some are discussed when appropriate in the Release Notes of the distribution data for a given VPU.
- G. Create Burn Components for International areas (if applicable): For VPUs along international borders, hydrography data from Canadian or Mexican sources are included in the NHDPlusV2 Burn Components: BurnAddLine and BurnAddWaterbody. In some cases, these international data sources are part of “harmonized” high resolution NHD data, while others are datasets available from Canadian or Mexican agencies such as the Canadian National Hydrographic Network (NHN). Inclusion of additional hydrography is intended to improve catchment delineations where NHDFlowline features receive contributing drainage from international areas. In some cases, lake polygons in international areas are coded as closed lakes when such information on non-contributing areas is known.
- H. Add Burn Components at inter-VPU connections (if applicable): In cases, where VPU’s are connected (whether as an inflow or outflow with an adjacent VPU) the connecting

BurnLineEvent features from the adjacent VPU are added to BurnAddLine of the VPU being processed. This ensures that catchment delineations for the VPU being processed are constrained by the adjacent VPU flowlines. In addition, flowlines are needed in BurnAddLine from downstream associated VPUs to ensure proper hydro-enforcement of the DEM. Downstream VPU flowlines are selected to extend to the edge of the DEM. In some cases, waterbodies from the adjacent VPUs are integrated into BurnAddWaterbody if features are at or near the inter-connection areas between the VPUs.

Step 16 – Prepare Sinks and Update BurnWaterbody and BurnAddWaterbody

This automated step first populates the fields PolyId in BurnAddWaterbody and GAZ_ID in WBD_Subwatershed with unique feature ids. An NHDPlusV2 web service is used to assign unique identifiers.

Next, the OnOffNet fields in the BurnWaterbody and BurnAddWaterbody are populated. OnOffNet is used to differentiate waterbodies that (1) intersect a burn line from either BurnLineEvent or BurnAddLine or (2) are closed waterbodies (whether or not they intersect BurnLineEvent or BurnAddLine) that contain sinks. Only features in BurnLineEvent with a Burn property of “Y” (yes) are used in the spatial intersect selection. All features in BurnAddLine are used in the spatial intersect selection with BurnWaterbody and BurnAddWaterbody. Any waterbody that intersects a burn line is coded as “1” in the field OnOffNet. Also, if a waterbody is coded as a playa or closed lake, these are also coded with a value of “1”. Later, in Step 18, the hydro enforcement process handles the enforcement of these features in the DEM differently than waterbody features that do not intersect with a burn line or are not identified as a closed lake or playa (OnOffNet = 0).

The sink shapefile is then created for the following scenarios in the following order where all sinks created are written to one Sink shapefile.

- A. Create sinks at network ends of isolated networks: Network ends are identified by finding PlusFlow records that have Direction = 713). Sinks are created for the corresponding BurnLineEvent feature’s most downstream point. The network end feature’s InRPU assignment is carried over from BurnLineEvent into the InRPU field of the Sink feature. These Sink features are assigned PurpCode = 1 and PurpDesc = ‘BurnLineEvent network end’. The Sink features SourceFC field is set to “NHDFlowline” and FeatureID field is set to the BurnLineEvent feature’s ComID. Sinks are removed if they are within 60-meters of a BurnLineEvent or BurnAddLine that is not associated to the isolated network.
- B. Create sinks at the ends of networks that are non-spatially connected to another flowline network: These network ends are identified from the PlusFlow table where the values in field GapDistKM exceed 0.03 kilometers. The InRPU value is carried over from the BurnLineEvent feature into the Sink InRPU field. These Sink features are assigned PurpCode = 2 and PurpDesc = ‘BurnLineEvent non-spatial connection’. The Sink features’ SourceFC field is set to “NHDFlowline” and FeatureID field is set to the BurnLineEvent features’ ComID.
- C. Create sinks at the centroids of polygon features in BurnWaterbody that are classified as a playa (FCODE > 36099 and FCODE < 36200): These Sink features’ fields are set as follows:
 - Purpcode = ‘3’
 - PurpDesc = ‘NHD Waterbody Playa’

- SourceFC = 'NHDWaterbody'
 - FeatureID equal to the NHD Waterbody ComID that the sink represents.
 - InRPU is set using a spatial overlay intersect with the NHDPlusV2GlobalData\BoundaryUnit feature class.
- D. Create sinks at the centroids of polygon features in BurnWaterbody that are classified as a closed lake (PurpCode = '5'): These Sink features' fields are set as follows:
- Purpcode = '5'
 - PurpDesc = 'NHD Waterbody closed lake'
 - SourceFC = 'NHDWaterbody'
 - FeatureID = to the NHD Waterbody ComID that the sink represents.
 - InRPU is set using a spatial overlay intersect with the NHDPlusV2GlobalData\BoundaryUnit feature class.
- E. Create sinks at the centroids of polygon features in BurnAddWaterbody that are classified as a playa (FCODE > 36099 and FCODE < 36200): These Sink features' fields are set as follows:
- Purpcode = '4'
 - PurpDesc = 'BurnAddWaterbody Playa'
 - SourceFC = 'BurnAddWaterbody'
 - FeatureID = to the BurnAddWaterbody PolyID that the sink represents.
 - InRPU is set using a spatial overlay intersect with the NHDPlusV2GlobalData\BoundaryUnit feature class.
- F. Create sinks at the centroids of polygon features in BurnAddWaterbody that are classified as a closed lake (PurpCode = '8'): These Sink features' fields are set as follows:
- Purpcode = '8'
 - PurpDesc = 'BurnAddWaterbody closed lake'
 - SourceFC = 'BurnAddWaterbody'
 - FeatureID = to the BurnAddWaterbody PolyID that the sink represents.
 - InRPU is set using a spatial overlay intersect with the NHDPlusV2GlobalData\BoundaryUnit feature class.
- G. Create sinks in WBD closed 12-digit HUCs coded as closed basin (HU_12_TYPE = 'C' OR HU_12_DS = 'CLOSED BASIN'): Sinks are placed at the minimum elevation point(s) within closed HUC 12s. If sinks were placed from any other scenario (A-F) in these closed basins, another sink is not created for this scenario. The NED snapshot is used to determine the minimum elevation within a given closed HUC 12. These Sink features' fields are set as follows:
- Purpcode = '6'
 - PurpDesc = 'WBD Closed HUC 12'
 - SourceFC = 'WBD_Subwatershed'
 - FeatureID = GAZ_ID in WBD_Subwatershed.
 - InRPU is set using a spatial overlay intersect with the NHDPlusV2GlobalData\BoundaryUnit feature class.

Step 17 – Review all Burn Components – For each VPU in Drainage Area (External)

This manual step reviews a variety of the NHDPlus burn component feature classes and includes:

- Check and populate missing InRPU assignments in the Sink feature class.
- For sinks associated with HUC 12s which are missing InRPU assignments, populate the InRPU to the correct RPU id and move sink to the lowest elevation in the HUC.
- Determine if additional sinks are needed and digitize these manually in the Sink feature class; populate the sink fields appropriately. Manually adjusted sinks carry a StatusFlag = 'M'.
- Remove sinks not associated to flowlines that are within a distance of 45 meters from any Wall feature.
- Find and remove any playa sinks if the playa is on the flowline network.
- Fix gaps caused by trimming of headwater streams along the international border. For these headwaters, international drainage in BurnAddLine most likely connects to these flowlines and need to have their automatic trimback reset to the original position as they are represented in NHDFlowline.
- Finalize the review of all burn components and make changes as needed. Unique edits are recorded in the VPU release notes.

Step 18 – Build Catchments, FDR, and FAC Grids – For each VPU in Drainage Area

This processing step prepares the input vector data by VPU, then runs the raster processing steps for each RPU within the VPU.

The purpose of this step is to create a HydroDEM and resultant flow direction and accumulation grid for a RPU. Catchments are generated for each RPU and then merged into one catchment grid for the entire VPU. The catchments for the VPU are converted to a shapefile and projected into geographic coordinates. Minimum elevations for each flowline catchment are written to ElevSlope. A version of the flow direction grid with NoData cell values in NHD streams is provided in the grid FDRNULL. The source grid used to generate catchments is also provided for each RPU in the grid CatSeed. A grid showing filled cell areas for each RPU is provided in grid FilledAreas.

Section A. Preparation of input vector data: Below list the general steps in preparing the input vector data from the NHDPlusBurnComponents folder:

- Assign / Update new gridcodes for all flowlines in BurnLineEvent and sink points in Sink feature class.
- Assign feature ids for NULL values in Sink, BurnAddWaterbody, BurnAddLine, LandSea, and Wall.
- Extract features from BurnLineEvent with BURN properties set to "Y". Write selected records to TmpBurnLineEvent.
- Append all features from BurnAddLine to TmpBurnLineEvent. TmpBurnLineEvent is used later in Section B of Step 18 for hydrologic enforcement of the NHD streams and additional features from BurnAddLine (stream-burning process).
- Extract features from BurnLineEvent with CATCHMENT properties set to "Y". Write selected records to TmpCatchLine.
- Select features from BurnAddLine with a GRIDCODE > 0. Append selected features to TmpCatchLine. TmpCatchLine will later be used in Step 18 to generate catchments.
- Combine waterbodies from BurnWaterbody and BurnAddWaterbody to one temp shapefile (tmp_wball). These are used for hydro-enforcement of all waterbody features later in Section B of Step 18.

- Select OnOffNet features = 1 from BurnWaterbody and BurnAddWaterbody and combine these to a new temp shapefile (TmpWBodyOn). These are used for the bathymetric gradient processing later in Section B of Step 18.
- Select Sinks with BURN properties NOT equal to “N” for hydro-enforcement of these sink features.
- Calculate STEP values in TmpBurnLineEvent for hydro-enforcement. This process computes the step values from the NHDPlus VAA hydro sequence numbers.

Section B. Raster processing

Below is a general overview of the main raster processing steps in building the HydroDEM for each RPU. The step is repeated for each RPU of the VPU being processed.

- Clip VPU vector data to the RPU buffer area
- Assign negative grid code values in TmpCatchLine that do not belong to the RPU being processed.
- Select flowlines based on each unique stream level and export these to unique stream level feature classes. Next the stream level feature classes are converted to grids using gridcode as the cell value. The stream level grids are then merged together as one NHD grid. Main paths override lesser paths at confluence grid cells in the merge operation. This ensures correct representation of the flowline network in the grid data model.
- Assign negative grid code values for sink features that do not belong to the RPU being processed.
- Convert sinks to a grid using gridcode as the cell values.
- Merge the sink grid with the NHD grid, this merged grid named CatSeed will be used as input later on as the “seed” source grid for catchment delineation.

Descriptions of Hydro-enforcement Processes

Waterbody Enforcement

Certain waterbody features from the NHD were used in the HydroDEM enforcement process. Included are “Lake/Pond”, “Playa”, and “Reservoir” features from NHDWaterbody and “Stream/River” features from NHDArea. Step 6 of the NHDPlus BuildRefresh production process selects these features from both NHD sources and writes these to the BurnWaterbody shapefile. In addition to NHD features in BurnWaterbody, additional waterbodies collected in BurnAddWaterbody are also enforced. For this processing, the features from both are combined into a temporary or “temp” waterbody shapefile.

The waterbody enforcement is a two stage process. The first stage is new for NHDPlus Version 2 and fixes issues identified in Version 1 where catchments can sometimes subdivide a NHD waterbody in error. In this process all the waterbodies are enforced by determining the minimum DEM elevation and by setting the overlapping waterbody cells in the HydroDEM to the minimum DEM elevation value found for each waterbody. These elevation cells are then dropped by subtracting 100 meters from the previously set minimum elevation values. Dropping the waterbody elevations ensures these cells are well below the surrounding terrain. Later, when the FILL process is applied to the HydroDEM, the waterbodies will fill and drain to one location, the result of which will lead to better agreement with the catchment delineations in relation to these features.

The second stage process of the waterbody enforcement, termed applying a “bathymetric gradient” is similar to the Version 1 NHDPlus process with some slight modifications. The bathymetric gradient ensures that the catchments generated for artificial path flowlines within waterbodies are based on a

gradient directed towards the artificial path flowlines. This process involves enforcement of just the waterbodies that intersect the flowline network (OnOffNet = 1) or have a sink within them. The results of the bathymetric gradient process are shown in Figure A-2.

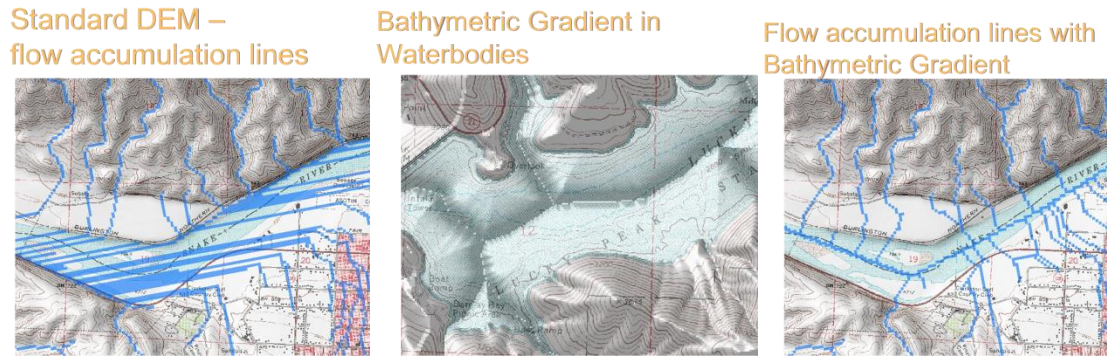


Figure A-2: (a) Standard DEM Flow Accumulation Lines, (b) Bathymetric Gradient in Waterbody, (c) Flow Accumulation Lines in Bathymetric Gradient

Stream-Burning using the AGREE Method

Modifications were applied to the source DEMs (elev_cm grids included in the NEDSnapshot folder) to produce the HydroDEM. These modifications were considered necessary because often the drainage path (flow path) defined by the NED surface does not exactly match the 1:100,000-scale NHD. In many cases, the NHD streams and NED-derived streams are parallel or offset from each other. Figure A-3 (a) illustrates a common example of the differences in the horizontal positions of NHD streams and NED-derived streams. If this offset distance is greater than one grid-cell width, then some cells may not be identified as being upslope from the NHD stream segment and therefore would be erroneously excluded from the delineated catchment (Figure A-3 (b)).

To mitigate this mismatch of stream locations, the NHD vector drainage was integrated into the raster NED data, often referred to as “stream burning” (Saunders, 2000). This process uses computer algorithms originally written in the Arc Macro Language (AML) program called AGREE, developed by Hellweger (1997). Figure A-3 (c) illustrates how the AGREE program corrects for DEM flow path displacement errors when delineating catchments.

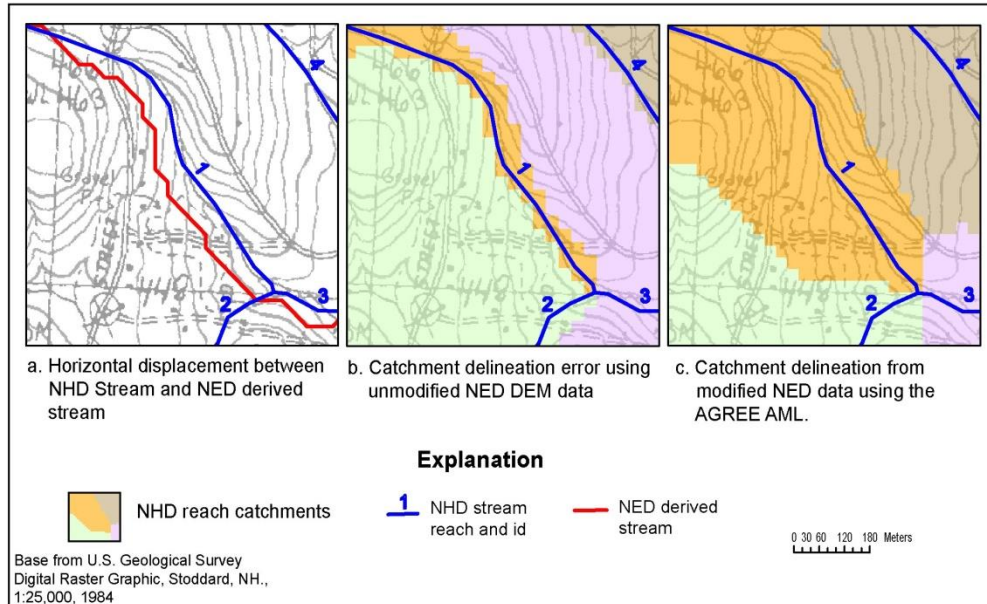


Figure A-3: (a) Differences in drainage between the NHD and flow paths of a NED-derived stream, (b) Resultant NHD catchment delineations using unmodified NED DEM data, and (c) Resultant NHD catchment delineations using AGREE-modified NED data.

AGREE “burns” a “canyon” into the NED-based DEM by subtracting a specified vertical distance from the elevation beneath the NHD vector streamlines. The vertical exaggeration of the canyon is controlled by specifying a “Sharp Drop/Raise Distance.” For the HydroDEM, a negative “sharp” drop distance (10,000 meters) was applied to retain the new NHD stream flow path after subsequent depression filling processes needed for catchment delineation.

AGREE also “smooths” the elevation adjacent to NHD stream cell locations in the DEM within a buffer distance specified by the AGREE program user. Typically, the buffer distance is related to a common horizontal displacement error between NHD and NED-derived streams; this error is seldom exceeded. For HydroDEM production, the buffer distance was set to 160 meters on each side of the NHD streamline. The smoothing process changes the DEM grid-cell elevations within the buffer area to create a downward sloping gradient towards the modeled canyon beneath the NHD streams. The steepness of the slope within the buffer is controlled by the AGREE “Smooth Drop/Raise Distance” option. For the HydroDEM, a smooth drop distance of 500 meters was specified, with acceptable results. Figure A-4 illustrates how AGREE changes the original DEM using all the specified parameters of AGREE.

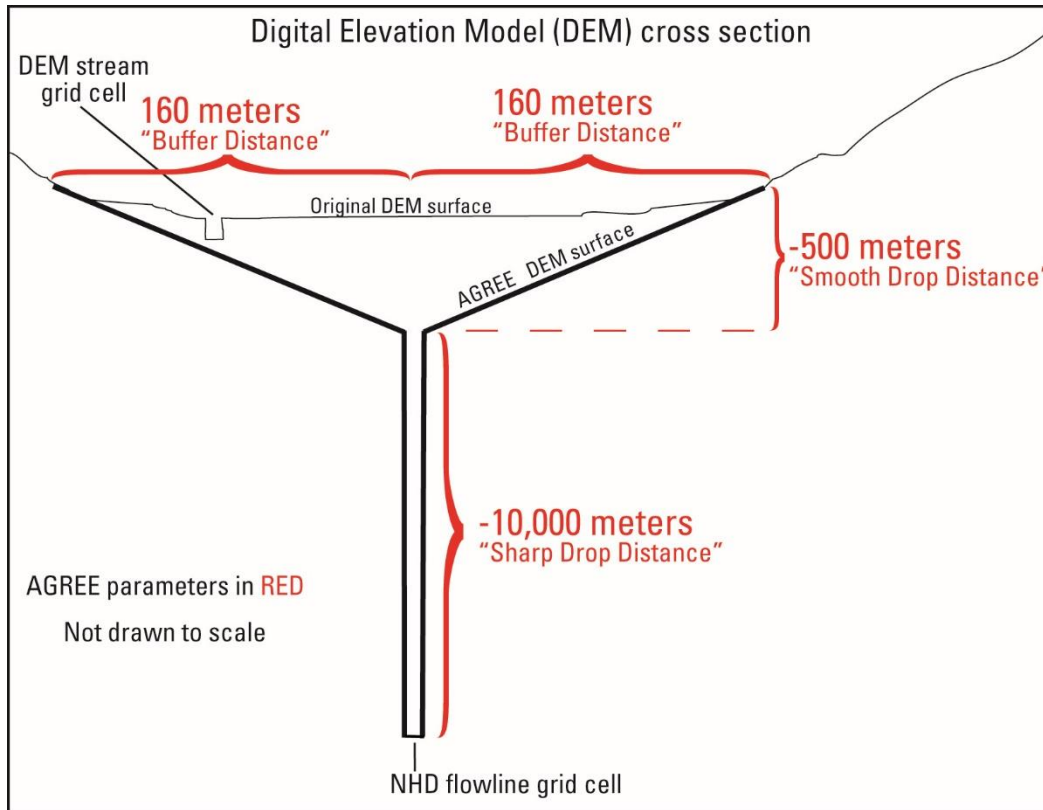


Figure A-4: Schematic of AGREE process

The use of AGREE's 160 meter smooth/drop buffer distance of the NHD streams may cause potential problems at headwater flowlines because they begin at or near drainage divides in the DEM. The 160 meter buffer distance at these headwater streams may extend across the DEM drainage divides and into the adjacent basin area, thereby including areas outside the true catchment area.

To minimize the problem of extending headwater streams into adjacent watersheds, these headwater streams were trimmed back earlier in the NHDPlus BuildRefresh production process (Step 14). In addition, headwater streams still in conflict with the WBD 12-digit HUC divides in the Wall feature class were trimmed back 70% of their original length (Step 15). The trimback positions are noted in the ToMeas field of BurnLineEvent.

Enforcement of WBD divides as "Walls"

A seamless nationwide HUC 12 drainage divides of the Watershed Boundary Dataset (WBD) are integrated into the HydroDEM as "Walls" in the Wall feature class. The process of conditioning DEM data to WBD drainage divides is called "walling", which vertically exaggerate DEM elevations corresponding to the location of WBD ridgelines. The vertical distance used to exaggerate the cells is a specified constant added to the elevation grid cells above the WBD. Breaks in the walls were created at locations where the stream network crosses the WBD to ensure proper passage of water from one WBD HUC 12 to another. A graphic 3-D representation of a hydrologically-conditioned DEM with WBD walling and the NHD "burning" is shown in Figure A-5.

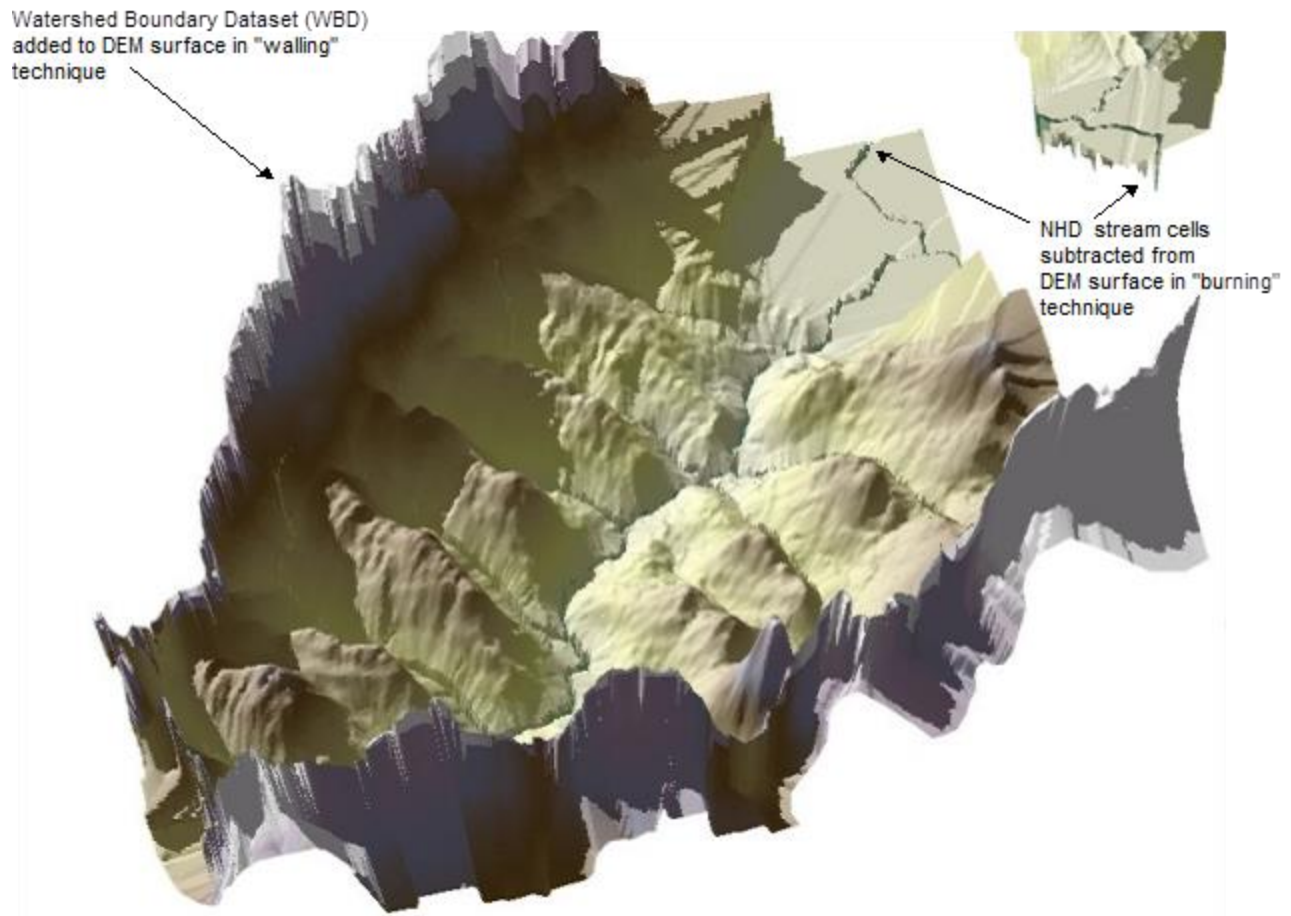


Figure A-5: 3-D Perspective view of modified DEM with walling of existing Watershed boundaries and burning of NHD streams

Figure A-5: 3-D DEM with WBD walling and NHD “burning”

Step Elevations for Flowlines

New for NHDPlusV2, is the replacement of elevation cell values within the NHD stream channel cells during the stream burning Agree process. This improvement utilizes the NHDPlus VAA attribute, HYDROSEQ (hydrosequence) values to compute a unique elevation value for each flowline, hereby creating a stepping sequence within the burned in stream canyon from Agree. This improvement enhances the HydroDEM flow path’s ability to follow the main path navigation defined by NHDPlus, and resolves issues that sometimes occur in Version 1 NHDPlus flow direction grids where the FILL process reversed the direction of water forcing uphill flow to an adjacent RPU/VPU inflow connection. While catchment delineations are unaffected by flow directions of the streams, the use of stepped values for the stream channels in NHDPlusV2 greatly enhances the usability of the flow direction and accumulation grids for watershed delineations.

Enforcement along the NHD Coastline (LandSea)

Another new enhancement for NHDPlusV2 is the hydro-enforcement of areas along the NHD coastline. In NHDPlusV1, the ocean side of the NHD coastline was set to NoData in the HydroDEM. Now with NHDPlusV2, the ocean areas within a buffer area of the NHD coastline has elevation values lower than any NHD feature on land. For coastal bays of interest, a two-tiered ocean stepping can be imposed in the HydroDEM to allow for DEM based watershed delineation within a bay to capture all drainage to the bay by selecting just one grid cell.

The new NHDPlus Burn Component feature class LandSea is used for coastal enforcement. The enforcement is only applied for VPUs with NHD coastline (the Great Lakes region is the one exception). LandSea is a polygon feature class that typically contains two or three unique polygon categories coded in the “Land” field. The polygon coded as land (LAND = 1) is used to resolve any disparity of landward elevations in the HydroDEM between the NHD coastline and coastline defined by the NED.

The ocean polygon (Land = -2) in LandSea is used to drop the oceanic surface elevation cells in the HydroDEM below the imposed elevations of the NHD coastline. Estuary polygons (Land = -1) are optional features along the coast for those bays where it is preferable to have these differentiated from the ocean cells. The estuary cells are 1 cm higher than the ocean areas, and one centimeter lower than the lowest NHD coastline in the VPU.

Flow paths can be imposed into the estuary and ocean elevations cells as a burned in canyon to direct drainage to these flow paths using the NHDPlus BurnAddLine feature class.

Enforcement of Sink points

For VPUs with sinks, the sink points are converted to a grid where a sink is represented as one grid cell. These sink cells are set to NoData in the HydroDEM so that sink drainage areas flow to these points. Later, when the NHDPlus section grid (FDR) is created, these NoData cell values are replaced with 0 (zero) values within the FDR grid in order to ensure proper functionality with their use for point based watershed delineation.

Final HydroDEM, Catchments, FDR/FAC and Other NHDPlus Outputs

After all the NHDPlus Burn Components are processed through the various hydro-conditioning steps, the HydroDEM for each RPU is finalized after applying the FILL process. FILL is used to resolve any depressions in the DEM by “filling” these areas so the cells drain to the lowest surrounding grid cell. All low points are filled except for those areas imposed in the HydroDEM with NoData cell sinks. The NHDPlus FILLEDAREAS grid shows grid cells raised by the fill process, and is available with the HydroDEM data for each RPU.

From the final filled HydroDEM, the flow direction (FDR) and flow accumulation (FAC) grids are computed and written to each NHDPlus RPU folder. Flow direction and flow accumulation grids are not merged for each VPU because the accumulation values only represent upstream cells within the RPU; they do not include cells in upstream production units or buffer areas.

New in NHDPlusV2, a second version of this flow direction grid is produced where the burned in hydro layer is replaced by NoData cells. This variant flow direction grid is named FDRNULL and is also written to each RPU’s NHDPlus HydroDem folder. The FDRNULL grid can be used with the ArcGIS Spatial Analyst function, FLOW LENGTH, to determine the overland flow path length to a NoData stream cell

or coastline for each grid cell. Flow length grids are useful for a variety of applications including determining riparian buffer areas.

The standard NHDPlus FDR grid is used in conjunction with the NHDPlus CatSeed grid to determine the catchments for the NHD flowlines and NHDPlus sinks. Catchments generated for flowlines or sinks can be determined by the catchment attribute, FeatureID and SourceFC fields. In general, positive values in FeatureID are catchments delineated for NHDFlowlines while negative FeatureID values are sink related catchments. The table, Featureidgridcode can also be used as a look up for coded gridcode values in relation to their feature ids and feature class source.

The catchments data are available in GRID format (CAT) and as a vector polygon shapefile (Catchment). It is important to note that catchment features in a shapefile may be composed of one or more vector polygon features. Multiple polygon features occur as a result of the source 30 meter grid-cell resolution and the grid-to-vector conversion process. In these situations, one or more cells with directional flow traveling diagonally into an adjacent cell along a catchment boundary may create a separate polygon in the vector data model when these data are converted from a GRID (see Figure A-6). These multiple polygons are “dissolved”, however, into single multi-part polygons, so there is only one polygon record in the catchment shapefile for each catchment.

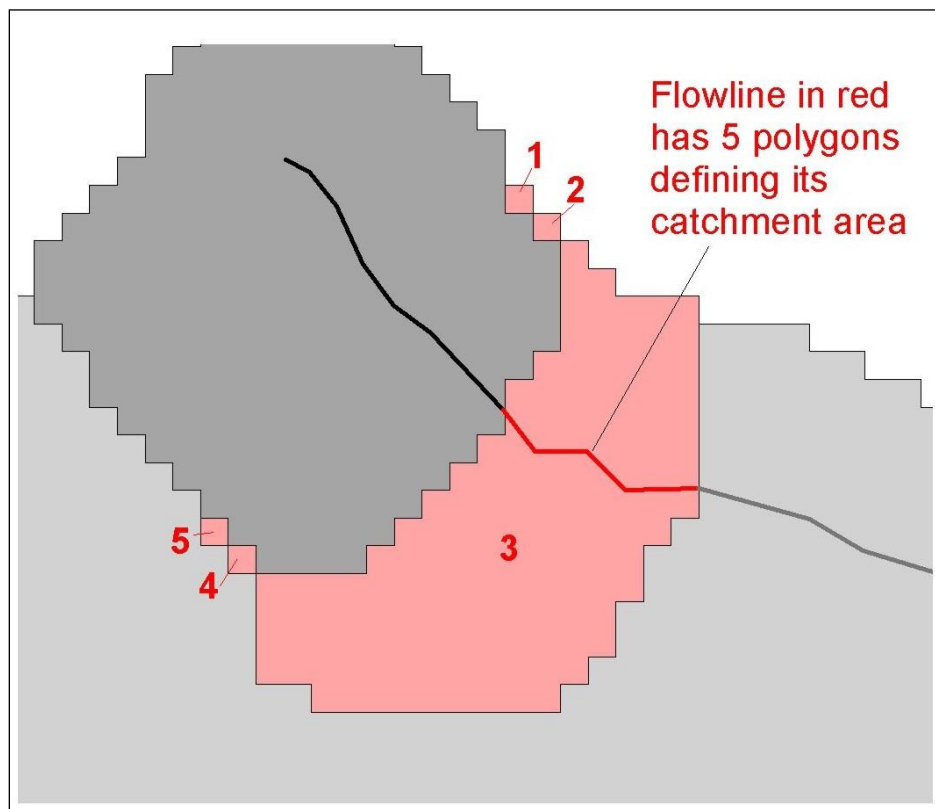


Figure A-6: Illustration of multiple polygon features defining an NHDFlowline feature catchment area. The final catchment is represented by a single multi-part polygon.

Step 18 also determines the minimum elevations for each flowline catchment and writes the values to the NHDPlus ElevSlope table found in the NHDPlusAttributes folder. These minimum elevations are recorded as the flowline’s minimum raw elevation in field MinElevRaw.

Step 18.5 – Build National Catchment Grid – For each VPU in Drainage Area

This automated step merges the VPU catchments to a grid of catchments for the nation. This national catchment grid is used in Step 18 to ensure seamless coverage of the catchments as subsequent VPUs are processed.

Step 19 – Build Final GlobalData.BoundaryUnit for VPUs and RPUs

During Step 19, the newly created catchments from Step 18 are dissolved into new boundaries for VPUs and RPUs. The new boundaries are stored in the NHDPlusGlobalData\BoundaryUnit feature class replacing the preliminary boundaries built in Steps 6 and 12.

Step 20 – Build HW Node Area and Raw Elevations – For each VPU in Drainage Area

This step determines raw elevations for the headwater nodes and the area of a headwater catchment draining into the headwater node of the flowline. This process is accomplished by delineating the portion of the total catchment area draining into the headwater node. The minimum elevation within the headwater node catchment is obtained, from the NED snapshot grid, elev_cm. The minimum elevation within this headwater node catchment becomes the maximum raw elevation for the headwater flowline in field MaxElevRaw of ElevSlope table. The headwater node areas are recorded in the NHDPlus attribute table, HeadWaterNodeArea in the field HwNodesqkm. Also, the minimum elevations for catchments are calculated and this value is stored in the “Minelevraw” field in elevslope, values which are used in Step 22.

Step 21 – Edit Catchments to Add International Areas (External)

Detailed data sets for most areas along the international borders have been included in the data used for developing the NHDPlus Version 2 HydroDEM. However, in some areas catchments needed further extension so they would encompass the entire drainage area contributing to a NHD flowline. The largest examples of extended catchments are in Region 17 (the Pacific Northwest). In these cases, Canadian elevation data and hydrography data were acquired for 8-digit hydrologic units that straddle the border. Catchment delineations in these areas were based on the HydroDEM constructed using these data. Areas that drain into the border hydrologic units were represented by extending the catchments using either the “container” polygons from the Canadian NHN dataset (see <http://www.geobase.ca/geobase/en/data/nhn/description.html>), or the Atlas of Canada 1:1,000,000-scale Fundamental Drainage Areas (FDA) dataset (Natural Resources Canada, 2008).

Because the 1-arc-second NED data now includes all of Mexico, the catchments for NHD flowlines having drainage area in Mexico were developed entirely using the HydroDEM. None of the catchment areas in Mexico were extended.

An additional process was completed to ensure drainage areas flowing out of the U.S. to streams in Canada or Mexico are all covered by the flow direction and flow accumulation grids.

Step 22 – Smooth Elevations

The raw flowline elevations developed in Step 20 provide upstream elevations at most headwater flowlines and downstream elevations for most flowlines. The situations where upstream and/or downstream elevations are not available are described below under Special Considerations. These raw elevation values may result in negative slopes where elevations decrease as the flowlines are traversed from downstream to upstream. To develop non-negative slope estimates for all flowlines and consistent elevations at nodes, several steps are performed in elevation smoothing. The post-processing and elevation smoothing take full advantage of advanced NHDPlus network traversal capabilities. The elevations go through the following processes:

First, the minimum elevations for flowlines joining at a downstream node are independently developed and may not be equal. The elevations at each node are made equal by taking the maximum elevation of the one (or more) flowlines that are immediately upstream of the node.

Second, the node elevations are also assigned as the maximum elevation for each flowline that is immediately downstream of the node.

The results of these two processes are consistent node elevations for flowlines with catchments. When all of the flowlines immediately upstream of a node are too short to generate catchments, the node will have an elevation equal to the downstream smoothed elevation.

Third, raw elevations are smoothed so that most flowlines will have non-negative slopes. With raw elevations, flowlines can have a minimum elevation greater than the maximum elevation which results in a negative flowline slope; essentially, the water flows “uphill.” This problem is not uncommon when using digital elevation models for estimating flowline slopes. The solution used in NHDPlusV2 is to smooth the elevations along a flow path so that the negative slopes are removed. This process involves interpolating between elevations upstream and downstream of flowlines that have negative slopes. The result of the smoothing is that all of the flowlines will have a positive (“downhill”) or zero slope. NHDPlusV2 slopes are constrained to be greater than or equal to 0.00001 m/m even when the elevation smoothing process produces equal upstream and downstream elevations on a flowline. Another important reason to perform smoothing is to ensure that all networked flowlines have elevations and slopes. For nodes with missing elevations, as described above, the smoothing process fills in these elevations and slopes based on the elevation values of the flowlines upstream and downstream. There are some cases where the smoothed elevations produce a zero slope, but the slope is set to missing (-9998), which is described below under Special Considerations.

Fourth, because “Raw” elevations are based on the values determined in the catchment building process, many flowlines are “trimmed”, which means that these elevations are computed based on the trimmed flowline. Therefore, the elevation smoothing length used for calculating slope (SLOPELENKM) uses the flowline lengths from the BurnLineEvent table.

The results of the elevation processing are stored in the ElevSlope Table in the NHDPlusAttributes folder.

One of the many powerful features of NHDPlusV2 is the ability to extract all of the flowlines for a stream path and sort in an upstream or downstream order. This capability permits smoothing to be completed on a stream level path basis (e.g., the Ohio River mainstem). Also, the elevation smoothing is done sequentially, going from the mainstem to tributaries.

Smoothing Techniques

Three basic approaches to elevation smoothing have been evaluated. The first approach, referred to as “downstream smoothing,” interpolates progressively downstream. This approach generates a smoothed elevation set that forms the lower envelope of the elevation profile. An example of this approach is shown in Figure A-7. The second approach, “upstream smoothing,” interpolates in the upstream direction and forms the upper envelope of the elevation profile. An example is shown in Figure A-8. A third approach, a hybrid downstream-upstream approach, was also evaluated. The hybrid approach mainly uses the downstream elevation smoothing technique and then uses the upstream smoothing technique until a slope greater than zero is produced (Figure A-9).

Smoothed Elevations and Slopes for NHDPlus

Of the three smoothing techniques evaluated as part of the development of NHDPlus, the upstream smoothing technique was selected. The downstream smoothing proved unsatisfactory because of ramifications of the method used for assigning downstream elevations of flowlines. The downstream elevations are determined using the lowest elevation in the catchment. While this method works in most cases, sometimes the minimum elevation is in a low-lying area, such as a rock quarry or mine, that is at a much lower elevation than the true downstream elevation of the flowline. The downstream and hybrid smoothing techniques will then set all flowline elevations downstream of an artificially low elevation equal to this artificially low value, until a flowline elevation is encountered that is higher than this low elevation. The effect of this process results in many flowlines having artificially low elevations and zero slopes. The upstream smoothing technique avoids this problem.

In NHDPlusV2, the ElevSlope table contains the “Raw” (Step 20) and smoothed elevations (Step 22), using the upstream smoothing approach, with slopes constrained to be greater than or equal to 0.00001 (except situations described below). A relatively small number of flowline connections exist where elevations of all flowlines at a node are not consistent. These elevation inconsistencies occur only where some level paths meet, particularly in areas with complex divergences. As a result of elevation smoothing, most (>99%) flowlines in the network receives a slope greater than, or equal to, 0.00001.

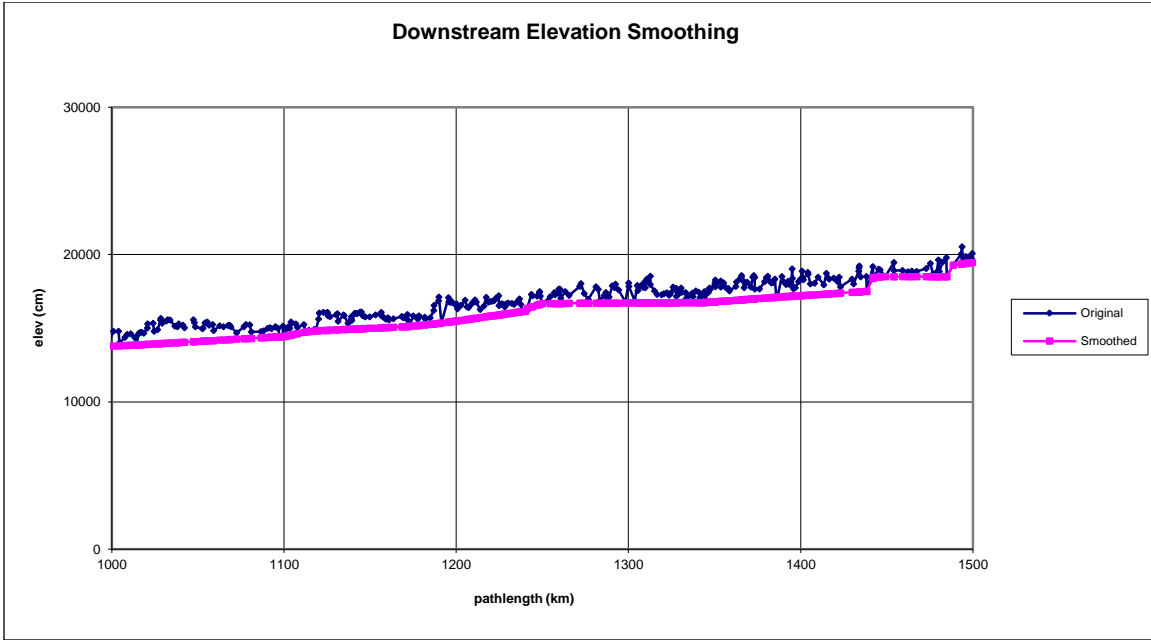


Figure A-7: Downstream Elevation Smoothing

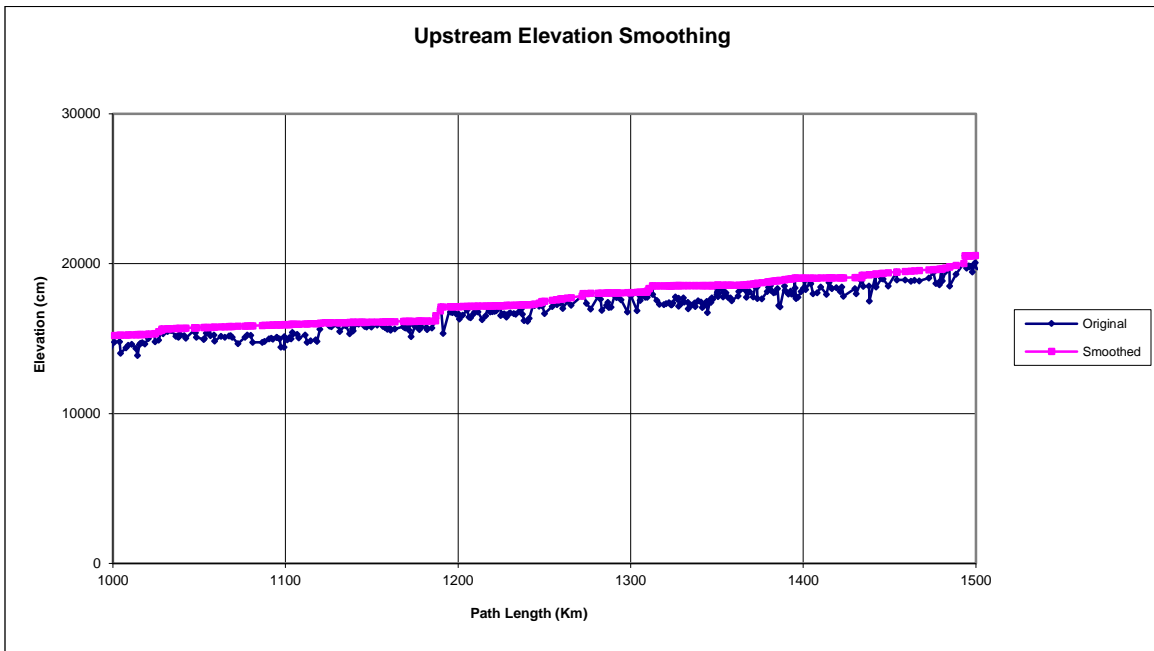


Figure A-8: Upstream Elevation Smoothing

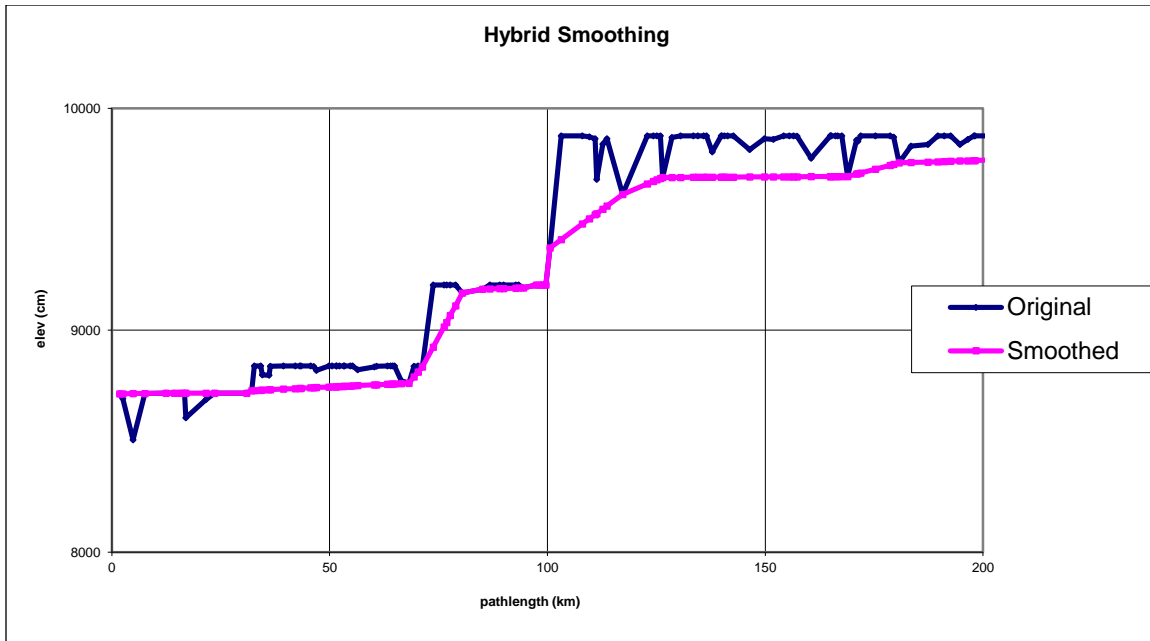


Figure A-9: Hybrid Elevation Smoothing

Special Considerations

1. Missing Slopes

Sometimes headwater flowlines or minor path flowlines are trimmed back to the point where a catchment cannot be built. In these cases, both upstream and downstream “raw” elevations are missing (-9998). Also, where catchment or burn is set to “N”, the actual slope cannot be determined, but should not be considered to be zero, so the slope is set equal to missing (-9998). In addition, in some cases, where the downstream junction is a simple junction, the downstream flowline also has a slope set to missing; this is because there is no way to determine an upstream elevation, but there is no reason to expect it to be zero. The elevation smoothing process does assign elevations in these situations, but the upstream and downstream elevations are equal. In cases where the slope is missing the Velocity Extension module uses the Jobson “Unknown-Slope” method.

2. Non-Spatial Connections

Non-spatial connections occur at places where the NHDPlus editors have determined that a flowline, or a network of flowlines, are connected to another networked flowline, but no digitized flowline is provided for this connection. This situation also exists at international borders, where a network enters Canada or Mexico and later re-enters the U.S. at another flowline. The connection exists logically in the PlusFlow table and the NHDPlusVAA table, but there is a “Gapdist” > 0 computed. In these situations, the elevation smoothing process does not continue upstream to the non-spatially connected flowline/network. It treats the upstream flowline(s) of the non-spatially connected flowline/network as an “isolated” network.

3. Cross-VPU Connections

In the Mississippi and Colorado River Basins, there are multiple VPUs. The upstream connectors for VPUs downstream of another VPU are not start reaches, so they do not have upstream elevations assigned based on the upstream flowline elevations. In these situations, the final processing of these VPUs will run first in an upstream-to-downstream sequence, determining the elevation that should be used for the most upstream flowline(s) in the downstream VPU. These

elevations are stored in the BoundaryValue table, for later use when the elevation smoothing is run in a downstream-to-upstream VPU sequence. These elevations stored in the BoundaryValue table are used as the “raw” upstream elevations. The elevation smoothing process may change these elevations, and the smoothed elevations at these upstream connections are stored in the BoundaryValue table, to be used in the elevation smoothing when the upstream VPU is run.

Step 23 – Accumulate Catchment Area

Step 23 uses functions from the NHDPlusV2 Catchment Allocation and Accumulation Tool (CA3TV2) to accumulate the catchment areas processing downstream to establish the cumulative upstream catchment area for each NHDFlowline feature where NHDFlowline.FlowDir = “With Digitized” and NHDFlowline.FType <> “Coastline”. Cumulative catchment areas are stored in the \NHDPlusAttributes\CumulativeArea table.

Step 24 – Package NHDPlusV2 for Distribution

Step 24 is primarily a manual process where the NHDPlusV2 Build/Refresh Tools output are rearranged into the publicly available copy of NHDPlusV2 described in this User Guide.

Build NHDPlusV2 NationalWBDSnapshot

As described above, the NHDPlusV2 process incorporated a number of snapshots from the national WBD. As each VPU was processed, the latest version of the national WBD was acquired and used to extract the WBDSnapshot for the VPU. After NHDPlusV2 build/refresh production was completed, the WBDSnapshots for all the VPUs were assembled into a single national WBDSnapshot. The following steps were performed to build the national WBDSnapshot:

- Attribute each VPU's WBDSnapshot SubWatershed shapefile with the WBD snapshot date (WBD_Date) and VPU Identifier (VPUID).
- Append all attributed snapshots together and load into an fgdb.
- Create and Validate a topology with rules "Must not overlap" and "Must not have gaps", using a tolerance of 0.00000556 decimal degrees (approximately 0.6 meter).
- Use the topology error inspector to zoom to and fix overlaps by keeping the polygon from the earlier WBD snapshot.
- Use topology error inspector to examine gaps. Flag as exceptions all gaps resulting from islands that are single or multipart islands in WBD.
- Use topology error inspector to fix remaining gaps by converting to features, and merging with an adjacent polygon.

Catchment Attribute Allocation and Accumulation Extensions (CA3TV2)

The purpose of CA³TV2 is to integrate of landscape attributes with the NHDPlus Catchments. CA³TV2 has two main functions: Allocation and Accumulation. The Allocation function takes a user-supplied raster dataset, either continuous numeric or categorical, of landscape attributes and allocates the attribute(s) to the NHDPlusV2 Catchments. The Accumulation function builds, for each NHDPlusV2 stream network feature, the upstream accumulated values from the allocated attributes. During the NHDPlusV2 Build/Refresh Tools process, CA3TV2 is used to allocate and accumulate the attributes contained in the \VPUAttributeExtension folder. These attributes are then used in the EROM Extension and VogelFlow Extension to estimate stream flow.

Enhanced Unit Runoff Method (EROM) Flow Estimation

The Enhanced Unit Runoff Method (EROM) for estimating stream flows in NHDPlusV2 has extended beyond the original Unit Runoff Method (UROM) used in NHDPlusV1. UROM estimated a unit runoff (cfs/km²) for each catchment and conservatively routed and accumulated these incremental flows down the stream network. EROM contains enhancements which result in a 6 step flow estimation procedure as follows:

1. The unit runoff step uses a grid produced from a flow balance model (McCabe, et al.) that is at a finer resolution than the NHDPlusV1 HUC8 runoff values.
2. Incorporates a “losing streams” (losses in stream flow that can occur due to excessive evapotranspiration in the stream channels) methodology. This step is no longer run because of QA issues, so the flows from this step are equal to the flows in the runoff step.
3. Initial releases of the EROM results with MA and MM data limited the Reference Gage Regression (RGR) adjustments to the lower and upper bounds of the regression. This was done to eliminate possible over-adjustment at higher stream flows. However, there were unintended consequences with this limitation, such as gaps in flow values between flows that are and flows that are not subject to the RGR. Therefore, this limitation has been removed in the current releases of EROM.
4. A new table in NHDPlusV2, PlusFlowAR, provides a method to take flow transfers, withdrawals, and augmentation into account.
5. A gage adjustment component is incorporated that adjusts flows upstream and downstream of a gage based on the observed flow at the gage. Only gages that meet certain criteria are used to perform gage adjustment. The gage-adjusted flow estimates should be considered the “best” NHDPlusV2 flow estimates for use in models and analyses.
6. Because the gage adjustment is performed on all gages there is no way to perform a QA on how good the gage adjusted flows are on ungaged NHDFlowline features. In the sixth step, a proportion (typically 20%) of the gages are randomly removed from the gage adjustment process, which then provides a basis for an estimate of the accuracy of the flow estimates created in Step 5. Ideally the gage sequestration should be run multiple times to provide a best estimate of the effects of the gage adjustment step, but this is currently not feasible because of the long run times for EROM.

Note that the input data for EROM in CONUS (runoff, temperature, precipitation and gage flow) is coordinated to reflect the 1971 to 2000 time period. Therefore, the CONUS EROM flow estimates are valid for the 1971 to 2000 time period. EROM flow estimates in areas other than CONUS use different methods and time periods, as explained later in this section.

In addition to the six steps in flow estimation, other enhancements have been incorporated into the NHDPlusV2 EROM flow procedures:

- The flows for all six of the above steps are retained in the EROM output file. A separate module calculates the velocity estimates for the flows produced by the first five steps. The EROM output file contains several additional output values that are used for QA and can be used for various user analyses.
- The EROM interface enables adjustments to various parameters that control EROM computations.
- The EROM flow estimates are examined by a QA module which calculates and reports statistical QA measures.

EROM computes mean annual (MA) and mean monthly (MM) flows. The initial release provided only the MA flows. The MM flows were not released because of QA issues. These QA issues have now been resolved so that the MM flows are now available along with updated MA flows. Below is a description of the upgrades to EROM that were implemented to provide the MM flow estimates:

1. Upgraded from the “Falcone” to the more recent GAGESII dataset for defining Reference Gages.
2. The minimum number of years of gage data has been changed from 20 years to 10 years. This change significantly increases the number of gages used by EROM.
3. The Reference Gage Regression (RGR) step limits the adjustments to the lower and upper bounds of the regression. This change effectively eliminates the “over-adjustment” at higher stream flows that sometimes occurred in the first release of the EROM MA flows.
4. In 17 cases of VPU-level MM flow estimates, a runoff regression method is applied in place of the runoff grids. This occurs in winter months in the Great Plains when the runoff model was unable to account for the predominance of base flow under very cold, low flow situations.
5. There are now options for running or not running the Excess Evapotranspiration (EET) and/or the RGR steps by VPU/time period (MA, MM). The options used by EROM for the VPU/time periods are in the table \NHDPlusGlobalData\EROMOPTS.DBF. Users are encouraged to refer to the EROMOPTS table to determine the specific options used for their flows of interest.

Below is the file layout of the EROMOPTS.DBF table:

Field Name	Description
VPU	The 3 character identifier for the VPU, e.g., “10L”
Timeperiod	“MA” = mean annual, “01” = January, “02” = February, etc.
SkipEET	0 = Run the Excess Evapotranspiration (EET) step, 1 = do not run the EET step. This field is currently set to 1 for all runs.
SkipRGR	0 = Run the Reference Gage Regression (RGR) step, 1 = Do not run the RGR step
RUNOFFREG	0 = Do not use a Runoff (RO) Regression, 1 = Replace the Runoff grid values with the regression in the RO Step
ROA	RO Reg. Coefficient 1; intercept term
ROB	RO Reg. Coefficient 2; Drainage Area (DA) term (Sq Km)
ROC	RO Reg. Coefficient 3; Mean Monthly Precipitation term (cm/month)
ROD	RO Reg. Coefficient 4; Mean Monthly Temperature term (deg. C)
ROE	RO Reg. Coefficient 5; Mean Annual Base Flow Index (0 to 100)
ROBCF	RO Reg. Bias Correction Factor (BCF)
TPOS	Temperature (Deg. C) to be added to the Mean Monthly Temperature needed to produce positive temperature values for the log transform in the RO Reg.

Step 1 Unit Runoff Calculations (Continental U.S. only)

Step 1 uses MA and MM runoff grids as the baseline unit runoff values (McCabe and Wolock, 2011). The runoff grids were produced as part of the U.S. Global Change Research Program (USGCRP), where a water balance approach was used to estimate runoff. The water balance approach takes precipitation, potential evapotranspiration (PET), evapotranspiration (ET), and soil moisture storage into account. In this process, ET losses are not allowed to exceed precipitation. These grids are overlaid onto the NHDPlusV2 catchments to compute runoff within each catchment. The catchment runoff values are conservatively routed downstream to arrive at the first estimate of stream flows for each networked NHDFlowline feature. Figure A-10 shows the mean annual runoff grid. For use in NHDPlusV2, note the runoff grids were expanded to include areas of Canada and Mexico.

Incremental runoff flows for each NHDFlowline feature are labeled “QIncr0001A”. The Qincr0001A flows are routed and accumulated to produce the Step 1 flow estimates which are labeled Q0001A.

Step 1: Mean Annual Runoff Grid

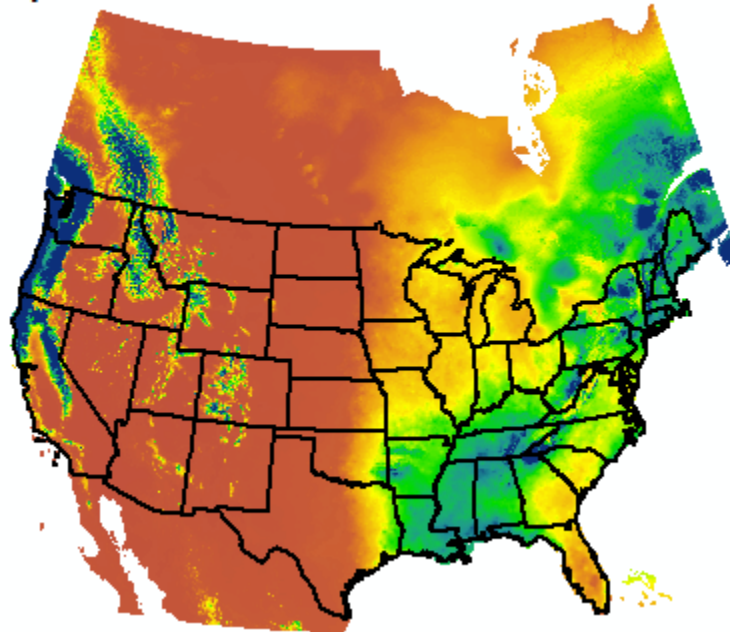


Figure A-10: Mean Annual Runoff

Runoff Using the Regression Method:

In 17 MM flows the QA statistics were particularly poor, with Standard Errors of the Estimate (SEEs) in the hundreds of thousands. All of these cases occurred in Great Plains VPUs (10U, 10L, 11, and 07) in the winter. An investigation of these cases found that the reason for these poor results is that the runoff flow is dominated by base flow with surface runoff being close to zero. A log-log runoff regression method is used in these cases, replacing the runoff grids with the unit runoff regression equations. The best unit runoff equation was found to be:

$$\text{URO (cfs/Km}^2\text{)} = 10^a * \text{Pcm}^c * \text{TDegC}^d * \text{BFI}^e * \text{BCF}, \text{ where}$$

a, c, d, e = regression coefficients
Pcm = Mean monthly Precipitation (cm)

TDegC = Mean monthly temperature (Deg. C),
 BFI = Mean Annual Base Flow Index (see /http://water.usgs.gov/GIS/dsdl/bfi48grd.zip),
 BCF = Bias Correction Factor (see Duan, 1983)

The VPUs/months, and the regression coefficients, where this method is applied can be found by querying the EROMOPTS.DBF table.

The regression method worked well, providing QA statistics for these months that are comparable to other months in the VPU. An example of the runoff QA statistics with and without the use of the regression method is shown below for VPU 10U. The regression method is used for November, December, January, February, and March.

Table 1: Statistics For All Gages:

Period	N	Gage Runoff		
		Qbar	Qbar	SEE
MA	192	2.2063	2.2736	74.514
JAN	374	1.2779	-0.066	99104.
FEB	208	1.8748	-0.036	178722
MAR	212	2.2023	0.9551	92947.
APR	226	2.2094	2.1082	145.95
MAY	229	2.3863	2.5760	108.98
JUN	230	2.3899	2.6061	117.85
JUL	231	2.1482	2.4821	170.78
AUG	230	1.8719	2.3017	252.98
SEP	230	1.7638	2.1900	303.92
OCT	214	1.8355	2.1646	190.80
NOV	206	1.7642	0.9022	9389.9
DEC	206	1.6406	0.3981	94164.

VPU 10U Runoff QA before Regression

Table 1: Statistics For All Gages:

Period	N	Gage Runoff		
		Qbar	Qbar	SEE
MA	348	1.9369	1.9788	93.188
JAN	374	1.2779	1.4894	205.23
FEB	377	1.5911	1.8313	178.56
MAR	388	1.9364	2.1166	131.31
APR	410	1.9447	1.8483	180.22
MAY	417	2.1205	2.2880	135.99
JUN	415	2.1216	2.3123	144.21
JUL	419	1.8560	2.1872	198.35
AUG	416	1.5692	2.0113	319.88
SEP	417	1.4904	1.9071	360.69
OCT	382	1.5327	1.8628	276.21
NOV	370	1.4204	1.6260	187.68
DEC	371	1.2869	1.5361	245.70

VPU 10U QA after Regression

Note that the count of gages (N) and the QA statistics are different for MA and all MM values for the before and after cases. This is because all of the other changes to EROM were applied to the “after” runs.

Step 1 Unit Runoff Calculations (Hawaii)

There are no runoff grids for Hawaii equivalent to the runoff grids used in the NHDPlusV21 CONUS VPU's. In place of the runoff grids, the following method is used for the Q0001A Flows. This method estimates median annual flows. The EROM Reference Gage Regression and Gage Adjustment steps are done using the same methodology as the other EROM flow estimates. Velocity and QA are computed using the same methods as documented in the NHDPlusV21 User Guide.

The regression-based median annual flow estimates in Hawaii are based on the work of Fontaine, et. al. (1992).

In subbasins 20060000, 20050000, and 20010000 (Oahu, Molokai, and Hawaii, respectively) the median annual flow is computed as:

$$Q_{50} = 4.25 * (DA)^{1.04}$$

In subbasins 20070000 and 20020000 (Kauai and Maui, respectively) the median annual flow is computed as:

$$Q_{50} = 4.49 * (DA)^{0.808} * (CE)^{-0.641} * (P)^{0.985}$$

Where:

Q₅₀ = Median annual flow (cfs),

DA = Drainage area (square miles),

CE = mean altitude of the main stream channel (feet), and

P = mean annual precipitation (inches)

CE is calculated by averaging the altitudes at points located at 10 percent and 85 percent along the main channel. For each networked flowline the main channel is determined by using the current flowline and all flowlines upstream along the same PlusflowLineVAA.LevelPathi. Velocity and QA are computed using the same methods as for the flows in CONUS

Step 1 Unit Runoff Calculations (Puerto Rico)

There are no runoff grids for Region 21 equivalent to the runoff grids used in the NHDPlusV21 CONUS VPU's. In place of these runoff grids, the following method is used for the Q0001A Flows on the Puerto Rico (PR) mainland. This method estimates mean annual flows. The EROM Reference Gage Regression and Gage Adjustment steps are done using the same methodology as the other EROM flow estimates. Note that no reliable method for estimating mean annual runoff was found for the other Caribbean islands. Velocity and QA are computed using the same methods as for the flows in CONUS.

To develop mean annual grids for PR, figure A-9 below is used as the EROM source, which contains the citation for the figure.

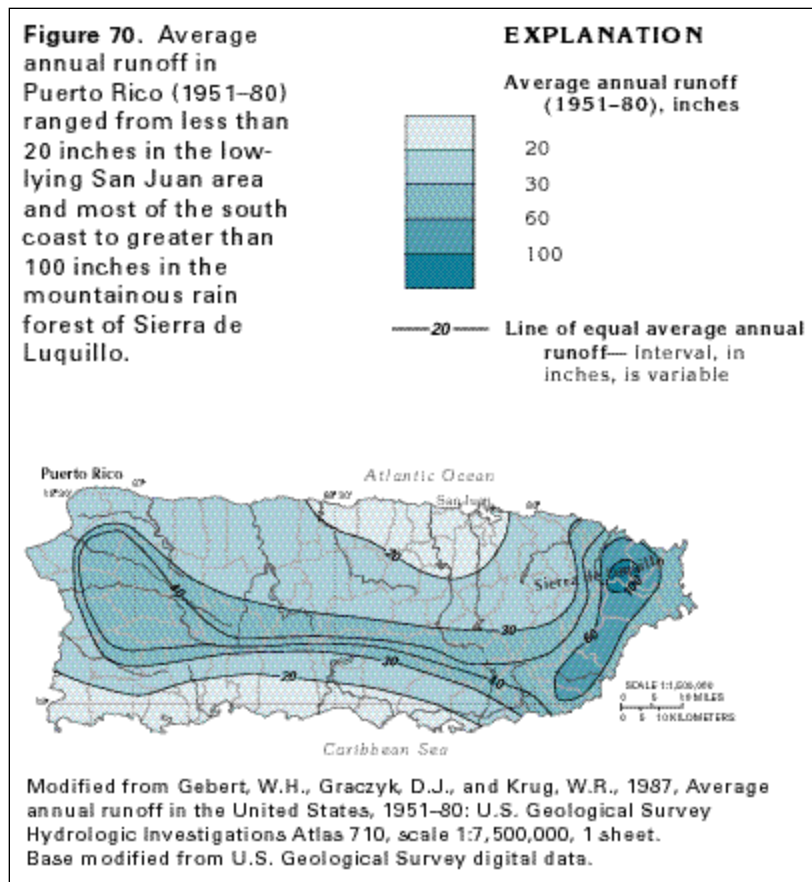


Figure A-9. Average Unit Runoff on Puerto Rico Mainland

A digital format of the runoff isopleths was not available, so the map was extracted, registered to the Puerto mainland and then the isopleth lines were digitized. Figure A-10 shows the original runoff map with the digitized lines.

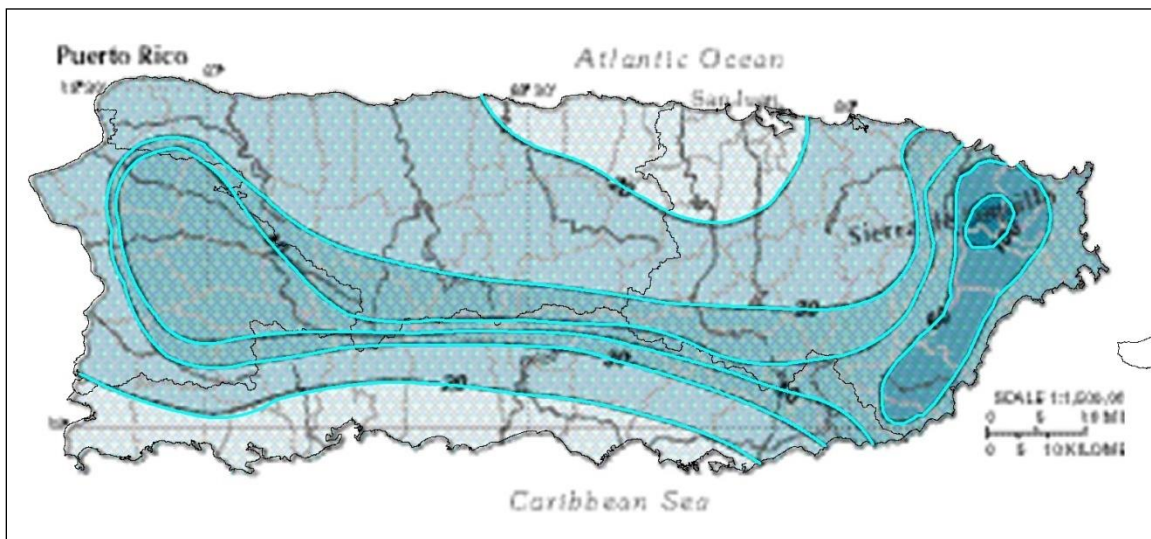


Figure A-10. Digitized Mean Annual Runoff Values on Puerto Rico

The next step is to develop a rasterized version of the digitized lines to interpolate between the runoff isopleths. The ArcGIS TOPO-TO-GRID function was used for this. The basic results of this process are shown in Fig. A-11. This map uses the same runoff category ranges as the original runoff isopleths, but it is important to note that the individual rasterized values vary based on the interpolation technique in the ArcGIS processing.

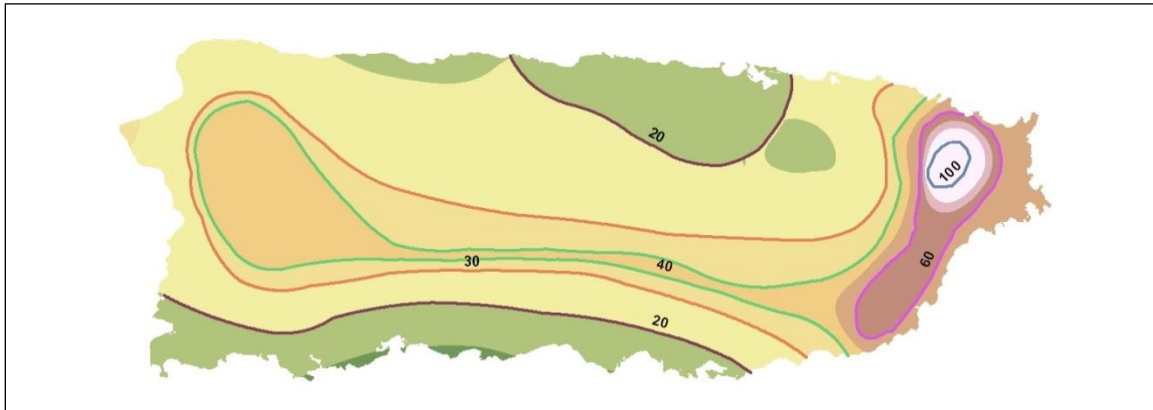


Figure A-11. Results of using TopoGrid to Develop an Interpolated Raster Grid of Mean Annual Runoff on Puerto Rico

The rasterized data was then overlaid onto the catchments, which assigned an EROM mean annual runoff value (cfs/sq km) to each catchment.

The EROM QA produced reasonable results. During the overall QA process for the initial EROM run in Puerto Rico a problem was found in that there were no gages located in HUCs 21010002 and 21010003. This problem has been rectified in a more recent release of the NHDPlus GageLoc data. EROM in Puerto Rico has been re-run with this updated set of gages. Figure A-12 shows the currently available gages in PR.

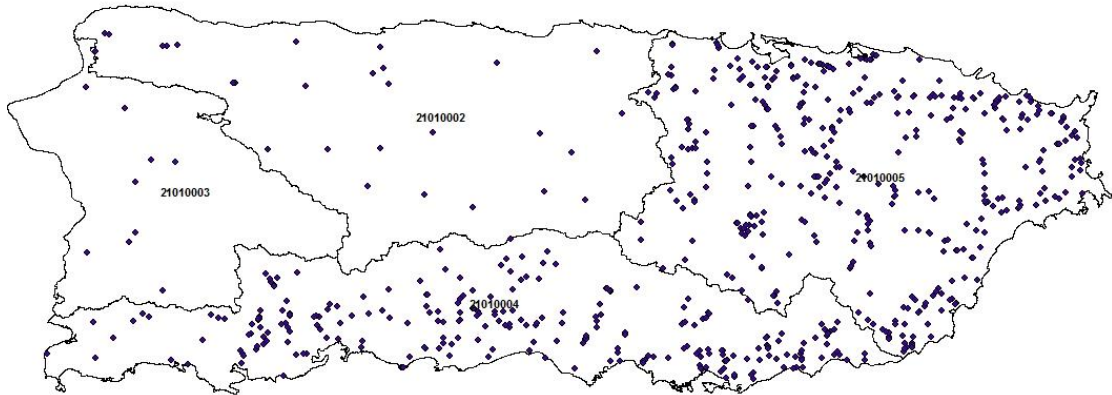


Figure A-12. Gage Locations in Puerto Rico

Step 2 Computations

Step 2 implements a method that takes “excess ET” into account. This method, developed by Dave Wollock of USGS (personal communication), considers the total available water in a given catchment to compute additional losses due to ET. The ET losses can exceed the total water available in a catchment, resulting in a net loss in stream flow.

As stream flow is routed through the NHDFlowline network, some portion of the flow can be “lost” in a downstream catchment through evapotranspiration (ET). The quantity of lost stream flow is assumed to be a function, in part, of excess potential ET (PET) in the hydrologic unit, which is defined as the PET that is in excess of actual ET (AET) computed by the water-balance model. The model assumes that the excess PET within the river corridor itself places a demand on water entering the catchment from upstream flow and that the river corridor is 30% of the total catchment area. Furthermore, it is assumed that the amount of upstream flow that can be lost to satisfy excess PET is limited to 50% of the total upstream flow. These percentages were determined by subjective calibration of the model to measured stream flow in arid regions that clearly lose water in the downstream direction. Runoff consumption in a catchment occurs when locally generated stream flow, computed from the water-balance model, is less than stream flow loss due to excess potential evapotranspiration.

For mean annual and each monthly flow, there is an option to not perform this step. If the error statistics are greatly increased over Step 1 flow estimates or other issues are found, EROM is re-run with the option to not compute EET flows. In this case, Step 2 flows are set equal to the Step 1 flows. The VPU, where Step 2 is not run for mean annual flow and/or one or more mean monthly flows, are identified in the EROMOPTS table described above.

Input Data:

- PPT – The mean annual precipitation in the catchment from PRISM.
- Temp: The mean monthly temperature of the catchment using Prism; it is the (average max T + Average Min T) / 2.
- XLAT: The average latitude of the catchment for the NHDFlowline feature.
- QAUS: The sum of flows that enter the catchment based on the Step 1 values.
- Qincr0001A: The incremental flow in the catchment from Step 1.
- Julian Day: For each month, the Julian Day for the middle of the month.
- Fract1, Fract2 are inputs; default values are 0.3 and 0.5, respectively.

Step 2 calculations are performed as follows:

Note: The method described below is the Hamon Method (Hamon, 1961).

1. Sum the monthly PET values to arrive at total PET.
2. $AET (actual\ ET) = \text{Max}(PPT - PET, 0)$
3. $ExtraPET = \text{MAX}(PET - AET, 0)$
4. $Q0001B = QAUS + Qincr0001A - \text{Min}(QAUS * Frac2, ExtraPET * Frac1)$
5. $Qincr0001B = Q0002B - QAUS$. Qincr0001B is the incremental Step 2 inflow for the catchment/NHDFlowline feature.

For headwater NHDFlowline features, the calculations will not change the Step 1 flow estimates because $QAUS = 0$

Steps 1 and 2 are designed to estimate “natural flow”. Step 1 uses the flow balance runoff grids, which reflects “natural runoff” at a much finer resolution than the HUC8-basedNHDPlusV1 runoff. Step 2, “Excess ET”, is designed to take instream losses into account due to natural hydrologic processes. This loss of instream flow is a significant, observed phenomenon, especially in areas west of the Mississippi River. Step 2 was introduced to overcome a major problem in the NHDPlusV1 flow estimates, which tended to over-estimate flows in areas arid regions because the flow estimation process in NHDPlusV1 had no loss component. Together, Q0001B flow estimates, produced by Step 2, are designed to provide the “best estimates” of natural flow.

Step 3 Reference Gage Regression Flow Adjustment

In the course of performing detailed QA/QC of flow estimates in HydroRegion 04, it was discovered that Steps 1 and 2 tended to fairly consistently under-estimate flows. Based on the knowledge and experience of the USGS hydrologists working with the NHDPlus team (Al Rea, Dave Wolock, and Kernell Ries), it was hypothesized that Steps 1 and 2 may “miss” a key part of the natural stream flow, which could be an underlying, fairly consistent negative bias in base flow. Additional analyses using gages that are primarily “natural flow” (known as the “Falcone Reference Gages”) reinforced this point.

Through evaluations of the flow at the Falcone gages versus EROM Step 2 flow estimates, a log-log regression adjustment of the EROM flow estimates after the first two steps helped to correct for this observed bias in the EROM flows in HydroRegion 04. Based on this analysis, Step 3 uses the results of the regression to adjust the EROM Step 2 flows.

The phenomenon found in HydroRegion 04 is not expected to occur in all HydroRegions. However, there is every reason to expect that different situations occur. For instance, there may be a consistent loss of base flow to groundwater, which might then lead to an over-estimation of stream flow in EROM.

The regression step has been found to improve EROM flow estimates in several VPUs, while in some VPUs it has a marginal effect; refer to the EROMQA_0001.pdf files for each VPU to see what impacts the regression step has in improving EROM flow estimates.

Based on the EROM QA, if there are no particular “issues” in a VPU that result in a consistent under or over-estimation of stream flows, then the regression equation has a minor effect on the stream flow estimates. The QA statistics and the regression coefficients (described in the section on “EROM Flow Estimation QA”) provide the information needed to determine whether or not, and by how much, the regression process changes stream flows.

The Reference Gage Regression applies a regression-based adjustment to the Q0001B flow which is then referred to as Q0001C. The regression is determined as follows:

1. The reference gages are screened based on two criteria. First, the NHDPlusV2 drainage area for the gage must be within a certain plus or minus percentage of the NWIS-reported drainage area. Second, the gage must have a required minimum number of years/months of complete record in the 1971 to 2000 time period. The criteria used for each VPU is shown in the EROM QA report.
2. The screened reference gages are used to develop a log-log regression comparing the gage flow to the Q0001B flow. The regression is of the form:

$$Q0001C = a * Q0001B^b * BCF, \text{ where} \quad (1)$$

a and b = regression coefficients and

BCF = Bias Correction Factor

Equation (1) is then applied to all networked NHDFlowline features.

3. Regression variables and calculations:

N = number of Reference gages being used

i = the gage being used, from 1 to N, Note: summations are for all N

$Y_i = \log_{10}(Q_F_i)$, where Q_F_i = Falcone Reference gage Q adjusted to the bottom of the stream segment

$X_i = \log_{10}(Q0001B_i)$, where $Q0001B_i$ is the Q0001B flow for the NHDFlowline feature containing the gage

$$X_{\text{bar}} = \sum X_i / N$$

$$Y_{\text{bar}} = \sum Y_i / N$$

$$x_i = X_i - X_{\text{bar}}$$

$$y_i = Y_i - Y_{\text{bar}}$$

$$b = (\sum x_i * y_i) / \sum x_i^2$$

$$a = (Y_{\text{bar}} - b * X_{\text{bar}})$$

$$r^2 = b * \sum (x_i * y_i) / \sum (y_i^2)$$

For the BCF using a “smearing” approach (Duan, 1983):

$$e_i = Y_i - 10^a * X_i^b$$

$$BCF = \sum (10^{e_i} / N)$$

The regression uses the log10 of Q_F_i and $Q0001B_i$. If either of these flows is zero then the log10 transformation will result in an error. Therefore, all occurrences where either of these flows is zero are screened out from use in the regression calculations. An analysis has shown that there are very few occurrences of these zero flow conditions at reference gages. Therefore, the effects of removing these zero flows are minimal.

Figure A-13 shows a simple junction with network features numbered 1, 2, and 3. This will be used to illustrate how the reference gage regressions and incremental flows are computed.

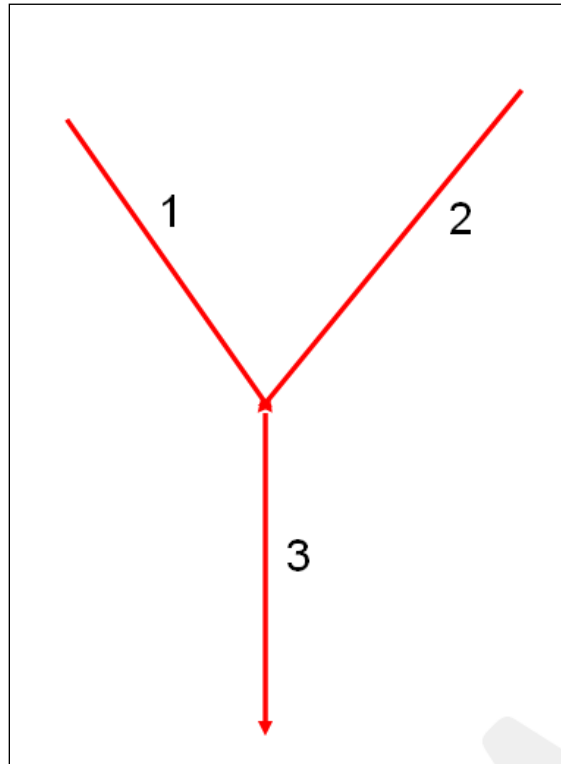


Figure A-13: A Simple Junction for Flow Routing

Step 4 Flow Computations

The calculations are performed for NHDFlowline features 1 and 2 and all networked features above 1 and 2. Also, ALL flows are ≥ 0 ; no negative flows are allowed. Incremental flows may be negative.

$Q0001B_n$ = Flow on NHDFlowline feature n from the EET step

$Q0001C_n$ = Flow on NHDFlowline feature n with the reference gage equation applied

$Qincr0001C_3$ = Incremental flow on NHDFlowline feature 3 in the reference gage step

$Divfract_3$ = If NHDFlowline feature number 3 was part of a divergence, this would be the fraction of the upstream flow to route to feature number 3.

a, b, BCF = reference gage regression coefficients

$$Q0001C_1 = 10^a * Q0001B_1^b * BCF$$

$$Q0001C_2 = 10^a * Q0001B_2^b * BCF$$

$$Q0001C_3 = 10^a * Q0001B_3^b * BCF$$

$$Qincr0001C_3 = Q0001C_3 - (Divfract_3 * (Q0001C_1 + Q0001C_2))$$

Note 1: Flow balance is preserved because accumulated flows are a sum of incremental flows.

Note 2: The reference gage regression is, in effect, applied to incremental flows in cases where the network feature is a headwater or a minor path of a divergence without flow split values (Divfract=0 for the minor path).

Step 4 PlusFlowAR Flow Adjustments

Step 4, PlusFlowAR adjustments, is an opportunity to incorporate flow withdrawals, augmentations, and inter-basin transfers, into the flow estimates. A data table has been added to NHDPlusV2, named “PlusFlowAR”, that provides a place for flow additions, removals, and transfers of flow to be taken into account. This table can hold, for instance, upstream boundary conditions from Lake Erie to the Niagara River, flow transfers from the Colorado River to other basins or locales (e.g., Phoenix or California), flows withdrawn for irrigation, and irrigation return flows. As EROM routes down the NHDFlowline network, flows are added and removed based on the addition and removal points and quantities in PlusFlowAR. The Qincr0001C values are modified and saved as Qincr0001D.

Over time the PlusFlowAR table can be used to store many flow removals, additions and transfers, including irrigation and drinking water withdrawals, karst areas flows, and losses/gains from groundwater.

Situations arise where the total available flow is less than the flow that is to be transferred from a given NHDFlowline feature. In this case, all Q0001D flow will be transferred/withdrawn, resulting in a zero flow at that NHDFlowline feature. In these cases, there is a field in the EROM output tracking the amount of flow in the PlusFlowAR table that is not available for transfer/withdrawal.

The cumulative and incremental flows after the PlusFlowAR adjustments are referred to as Q0001D and Qincr0001D, respectively. Using the example in Figure A-11, Q0001D and Qincr0001D are computed as follows:

$$\begin{aligned} Q0001D_n &= Q0001C_n \pm \text{PlusFlowAR where } n \text{ is the NHDFlowline feature number 1, 2, or 3} \\ Qincr0001D_3 &= Q0001D_3 - (\text{Divfract} * (Q0001D_1 + Q0001D_2)) \end{aligned}$$

Step 5 Gage-based Flow Adjustments

Step 5 performs a gage-based flow adjustment on NHDPlusV2 network features above the gages. Step 5 is a way to (1) provide much better flow estimates upstream of gages, and (2) “adjust” flow estimates downstream of gages to better reflect flow alterations not taken into account in the first four steps. Step 5 adjusts stream flow estimates based on observed gaging station data. Only gaging stations linked to the NHDPlus network are used to adjust flows. The adjustment process includes the following steps:

1. Only gages where the NHDPlusV2 drainage area for the gage is within +/- 20% of the NWIS gage drainage area are used for gage adjustment. The drainage area comparison removes gages that are incorrectly located on the minor path of a divergence or on a tributary rather than on a mainstem. An example of these outliers is shown in Figure A-14. The circled gage points are gages that would be removed in this process. The gage flows are computed for the 1971 to 2000 time period, and there needs to be at least 10 complete years (for mean annual) or 10 complete months (for mean monthly) of flow data in this time period for the gage to be used in gage adjustment.

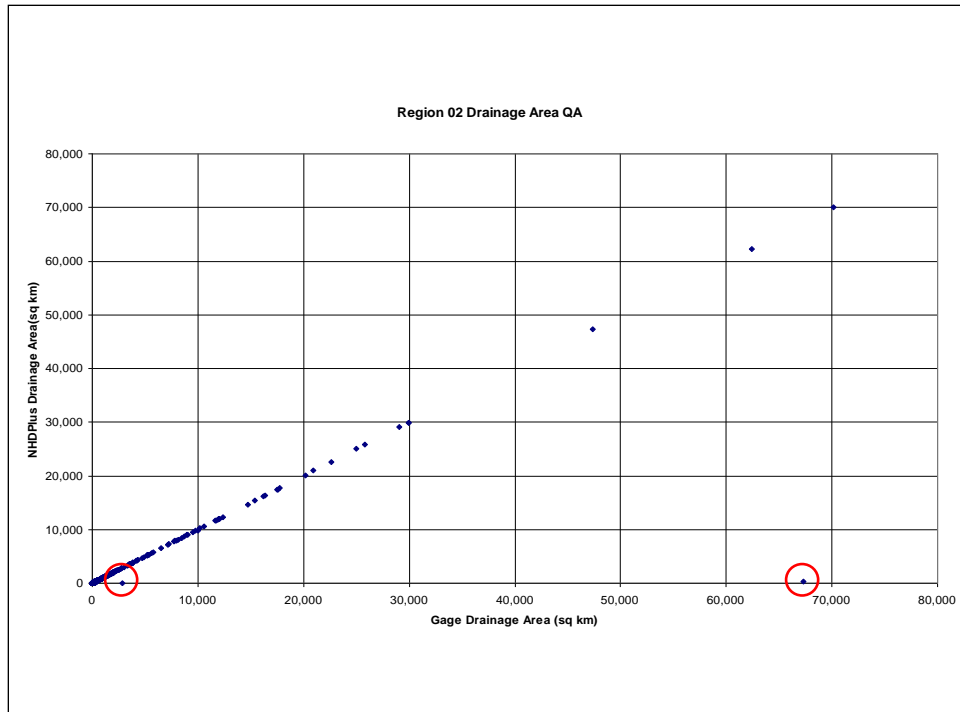


Figure A-14: Gage Mismatch Removal

2. The gage flows and drainage areas are adjusted to reflect values at the downstream end of the NHDFlowline feature. Drainage area is adjusted by adding the catchment area below the gage to the gage drainage area. The gage flow is adjusted by taking the catchment unit runoff from Step 1 (cfs/km²), and adding that incremental flow based on the catchment area below the gage.
3. Incremental flows are adjusted as follows:
 - a. For Upstream gages (no other gages upstream).
 - i. Apportion the adjustments in the incremental stream flows (Q000D) so that the NHDFlowline features that are closer to the gage receive more of the adjustments than NHDFlowline features farther away from gage. The adjustment is apportioned based on the ratio of an NHDFlowline feature's drainage area to gage drainage area.
 - ii. Stream flow adjustment is made only where the NHDFlowline feature's cumulative drainage area is greater than or equal to 0.5 of the NHDPlus gage drainage area.
 - iii. A "flow balance" will usually be maintained such that the incremental flows from Step 5 can be summed to get the Step 5 stream flows.
 - b. For a gage that lies below another gage on the same mainstem. Main stems are defined as the Level Paths in NHDPlusV2 (See PlusFlowlineVAA.LevelPathID).
 - i. The adjustments are apportioned to incremental flow such that the NHDFlowline features that are closer to the gage receive more of the adjustments than NHDFlowline features farther away from gage.
 - ii. The flows will be adjusted for all NHDFlowline features between the two gages regardless of the gage drainage ratios.
4. The flows on NHDFlowline features are not adjusted per se for gages that are upstream. However, the gage-adjusted flows upstream of gages are routed downstream so that the gage

adjustment effects will impact NHDFlowline features downstream of gages. This helps to improve flow estimates on all NHDFlowline features downstream of gages.

The gage flow adjustments are computed as follows:

1. There is no gage upstream:
 - a. The change in flow necessary for the Step 4 flow and the gage flow to match is $\Delta Q = Q_{\text{gage}} - Q_{0001D}$.
 - b. The NHDFlowline features to which ΔQ must be apportioned is found by navigating upstream from the gage, “flagging” all NHDFlowline features with a cumulative drainage area ≥ 0.5 times the gage drainage area. Each NHDFlowline feature’s cumulative drainage area is referred to as “CumDA”.
 - c. Sum of the cumulative drainage areas for the NHDFlowline features to be adjusted is computed. This will be referred to as “CumCumDA”.
 - d. The incremental flow adjustment for each of the NHDFlowline features from (2) is calculated as: $\Delta \text{incr}Q = \Delta Q / \text{CumCumDA} * \text{CumDA}$. $Q_{\text{incr}0001E} = Q_{\text{incr}0001D} + \Delta \text{incr}Q$
 - e. All of the NHDFlowline features that are adjusted are flagged such that no further flow adjustments can be made to them.

2. The gage is below another gage on the same Level Path:
 - a. The revised flow at the upstream gage(s) is routed and accumulated from the upstream gage down to this gage. The accumulation is based on the $Q_{\text{incr}0001D}$ values on the NHDFlowline features between the gages. At this gage the $\Delta Q = Q_{\text{gage}} - Q_{0001D}$ based on the downstream gage values.
 - b. The NHDFlowline features are navigated from this gage to the next upstream gage(s). This routing includes all NHDFlowline features between the two gages as well as any tributary NHDFlowline features that have (1) not already been flagged as being adjusted, for instance, NHDFlowline features adjusted above (no gage upstream); and, (2) tributary NHDFlowline features where the cumulative drainage area is ≥ 0.5 times the downstream gage drainage area.
 - c. The drainage area criterion is not used for NHDFlowline features on the same Level Path between the gages. This ensures there are no “gaps” in the gage flow adjustments between gages on the same mainstem, which is defined by the Level Path.
 - d. The same flow adjustment method as described in 1.d above is performed, where $\Delta \text{incr}Q = \Delta Q / \text{CumCumDA} * \text{CumDA}$. $Q_{\text{incr}0001E} = Q_{\text{incr}0001D} + \Delta \text{incr}Q$. CumCumDA is the DA sum for all NHDFlowline features being adjusted. These adjustments include all NHDFlowline features between the gages on the Level Path and any tributary NHDFlowline features that meet the DA ≥ 0.5 times the downstream gage DA.
 - e. Large rivers will have adjustments on most of its NHDFlowline features, with adjustments probably occurring on larger tributaries.

3. There are no gages downstream on the Level Path. Flows are accumulated to the bottom of the Level Path using the $Q_{\text{incr}0001E}$ values on the mainstem and tributaries.

Figures A-15 through A-20 illustrate how the gage-based flow adjustments are completed. The example shows the process for Step 1.d above. For ease in understanding the process, a unit flow (e.g., 1 cfs/km²) is assumed so the drainage areas and flows are equal. Note that in this example, NHDFlowline features are adjusted on both mainstem NHDFlowline features and on one tributary NHDFlowline feature. In many situations, a “flow balance” can be maintained such that the accumulation of the adjusted

incremental flows in this process will be maintained. In cases where the gage flow is greater than the Step 3 flow (Q0001C), a flow balance can always be maintained. In many cases but not all cases, where the gage flow is less than the Q0001C flows, a flow balance can be maintained.

There will be cases where the gage-based flow adjustment could result in a negative flow on one or more NHDFlowline features. Because negative flows are not valid, the NHDFlowline feature flow will be set to zero. In this case, the Step 4 flow on the NHDFlowline feature where the gage is located will be set equal to the gage flow.

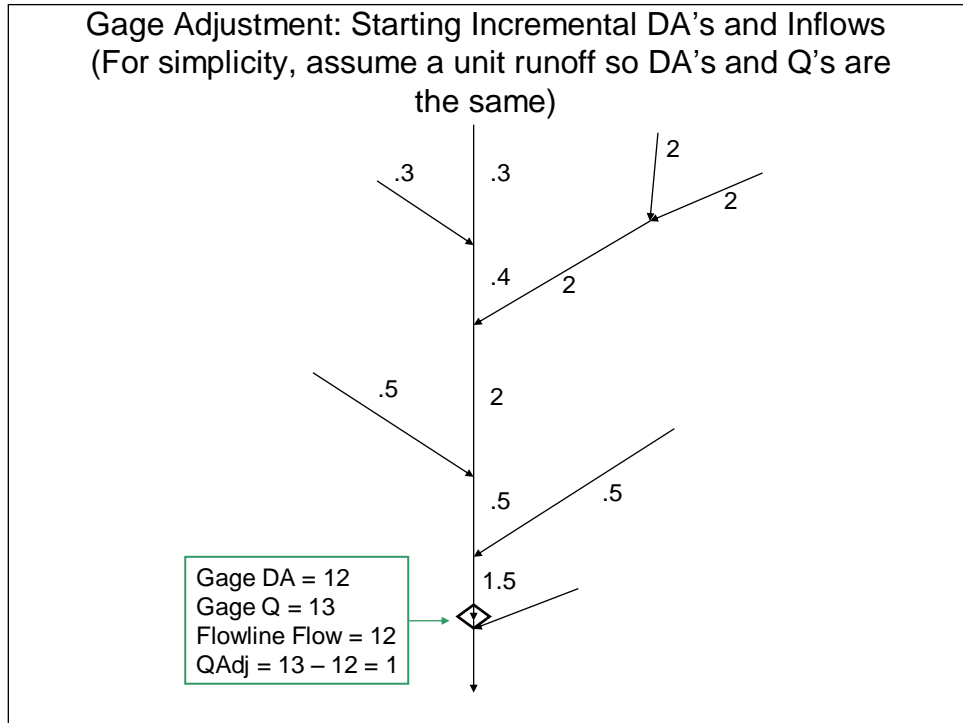


Figure A-15: Incremental Drainage Areas (DA) and Flows (Q)

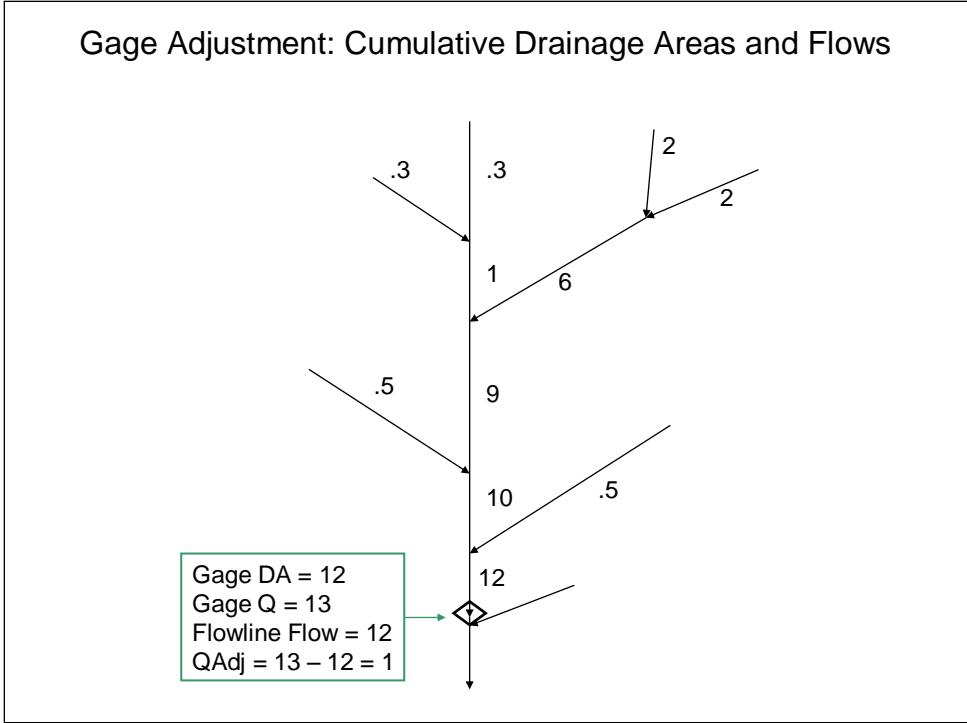


Figure A-16: Cumulative Drainage Areas and Flows

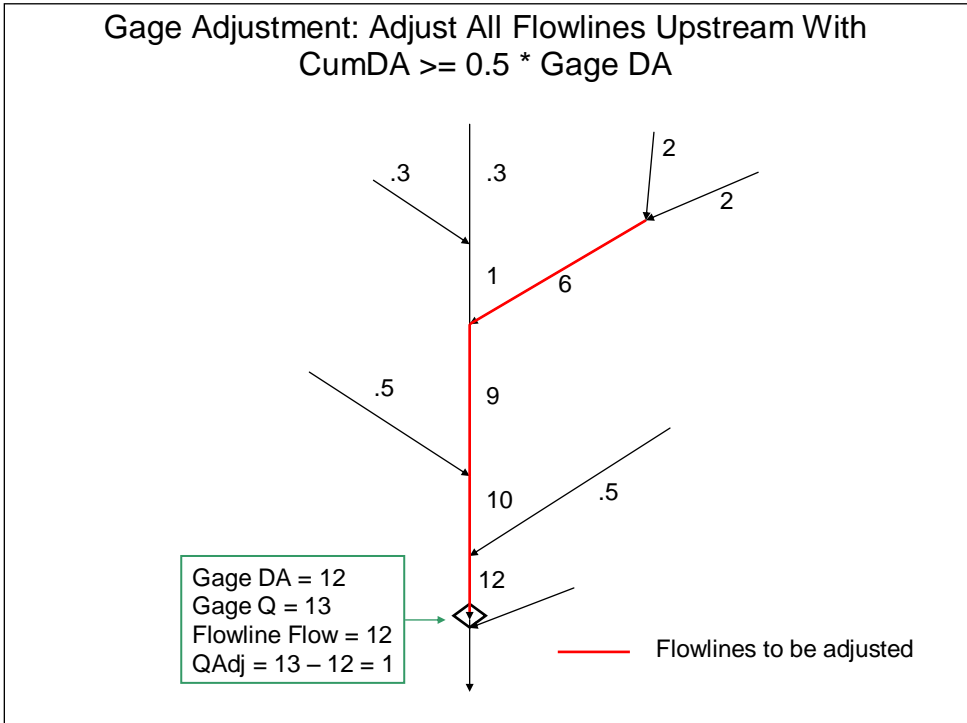


Figure A-17: NHDFlowline features to be adjusted by gage flow

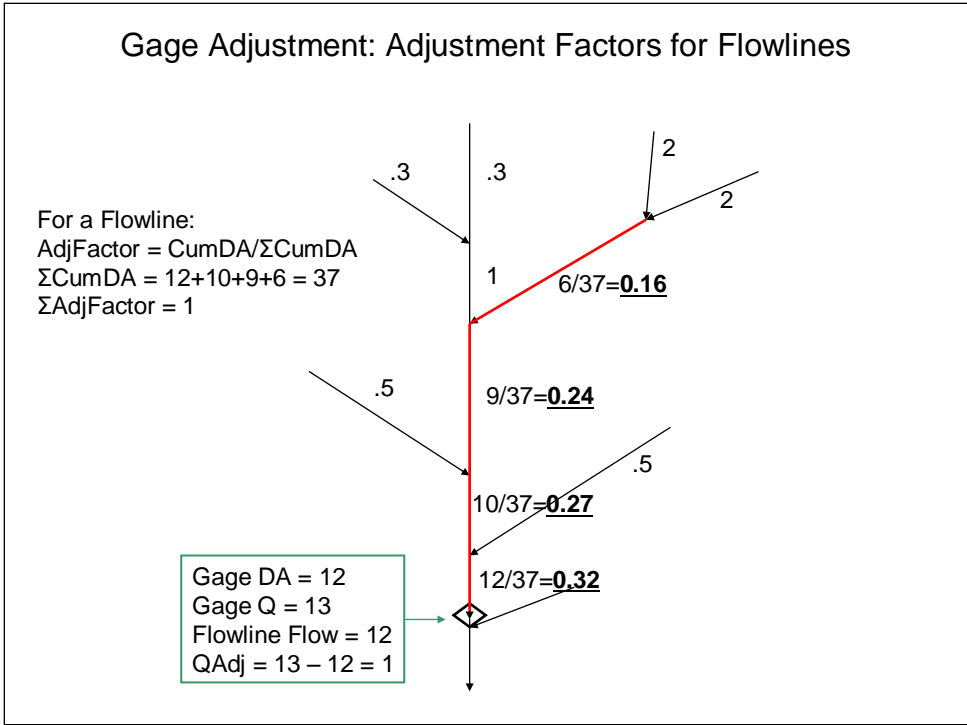


Figure A-18: Compute Adjustment Factors for NHDFlowline features

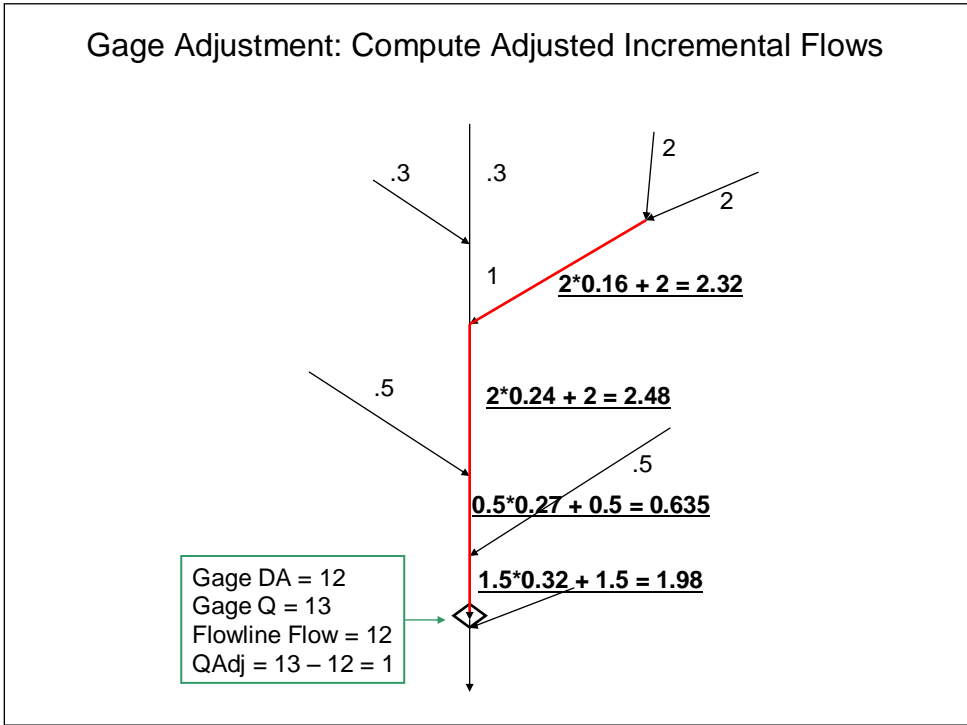


Figure A-19: Compute adjusted incremental flows

EROM Incremental Flows

EROM provides estimated flows and incremental flows for each networked flowline. The flow should be the sum of the incremental flows upstream and on the flowline. An error was found in some of the incremental flows such that they did not properly add up to the flow on a given flowline. This problem occurred primarily on gage-adjusted flowlines. EROM has been corrected so that all of the incremental flows will correctly sum up to the total flow for every networked flowline.

EROM Flow Estimation QAQC

Each run of the QA module produces two outputs: a tabular QA report and QA files. The tabular report preformatted and is saved as EROMQA_0001.pdf in the EROMExtension folder. The format for the QA files is described below.

EROM computes estimates for mean annual (MA) and twelve mean monthly (MM) flows. The QA report shows the results for all of these flows and there is one QA file for each of the thirteen flows.

The EROM tabular report is saved to the EROMExtension folder as EROMQA_0001.pdf.

The EROM QA files are saved to the EROMExtension folder as EROMQA_nn0001.DBF, where nn= "MA" for mean annual, "01" for January, etc.

Summary of the Flow values computed in EROM

Six flow values are computed in EROM, listed as A to F below:

- A. Cumulative runoff based on the runoff grids.
- B. The application of the Excess ET step to the cumulative runoff.
- C. The flow adjustments based on the Reference Gage regression.
- D. The application of PlusFlowAR flow additions and removals.
- E. Gage adjustment, in which the flows at the gages and a distance upstream from the gage are adjusted to match the gage flow. Statistics of the accuracy of this step are not possible because the gage adjustment is performed at every gage; the gage adjustment values will always be a "perfect" match to the gage flows.
- F. The gage adjustment performed with a randomly selected proportion of the gages removed (typically 20%); this process is referred to as gage sequestering. The gage sequestering provides a means to estimate the accuracy of the flows after the gage adjustment step. Ideally the gage sequestration should be run multiple times to provide a best estimate of the effects of the gage adjustment step, but this is currently not feasible because of the long run times for EROM.

See the EROM documentation for more details on the computation of these flow values.

Contents of the QA report

The QA report contains comparisons of the EROM flow estimates and the observed gage flows. Two statistics are used for measuring how well the different flow estimates performed in relation to the gage flows:

1. The Log10 mean flow at the gage as compared to the Log10 of the EROM mean flow estimate.
2. The Standard Error of the Estimate (SEE) in percent; 2/3 of the flow estimates will be within one SEE.

There are four tables included in the EROM QA report:

Table 1 reports statistics for all gages for flow values A, B, C, and D (described above).

Table 2 reports the statistics for only the sequestered gages for flow value F.

Table 3 reports the statistics for only the Reference gages.

Table 4 presents the statistics used in the Reference Gage regression step (flow value C); these values are the log-log regression coefficients, R^2 , and the Standard Error of the regression. These statistics are computed in the EROM Module and saved to the EROM output table.

The third page of the QA report provides documentation of the content of the report.

The best EROM flow and velocity estimates are the gage adjusted values: Q0001E and V0001E, respectively in the EROM_nn0001.DBF table. Table 2 of the EROM QA report provides an estimate of how good these flow estimates are as compared to gage flows. For “natural” flows and velocities, the best estimates are the Reference Gage Regression values: Q0001C and V0001C, respectively, in the EROM_nn0001.DBF table. The “RefGage Reg” column in column 3 of the EROM QA Report provides an estimate of how good these flow estimates are as compared to gage flows.

Below is an example of Page 1 of the QA Report:

EROM QA Report For: VPU = 01 Runid = 0001
 ETFRACT1 = 0.3 ETFRACT2 = 0.5
 Gage Sequestration Proportion = 0.2
 See Page 3 for a brief explanation of the values in the tables.

N = Number of Gages
 Qbar = Log10 Mean Flow (cfs)
 SEE = Standard Error of the Estimate in percent;
 2/3 of the Flow Estimates will have errors that are within one SEE

Table 1: Statistics For All Gages:

Period	N	Gage Runoff			Excess ET		RefGage Reg		PlusFlowAR	
		Qbar	Qbar	SEE	Qbar	SEE	Qbar	SEE	Qbar	SEE
MA	256	2.3011	2.2795	15.367	2.2795	15.367	2.3073	14.810	2.3060	12.761
JAN	260	2.2792	1.8902	121.29	1.8902	121.29	2.2322	48.279	2.2308	47.403
FEB	260	2.2869	1.6464	320.22	1.6464	320.22	2.2025	84.006	2.2008	83.332
MAR	260	2.4884	1.9147	390.84	1.9147	390.84	2.5988	182.52	2.5985	182.20
APR	260	2.6149	2.5263	71.359	2.5263	71.359	2.5263	71.359	2.5259	71.048
MAY	260	2.4383	2.6257	58.679	2.5899	51.097	2.5081	37.831	2.5074	37.343
JUN	260	2.2143	2.4033	67.828	2.3313	59.410	2.1689	51.461	2.1645	53.379
JUL	260	1.9492	2.1458	65.352	2.0367	57.119	1.8862	54.919	1.8795	60.596
AUG	260	1.8777	1.9503	52.311	1.9129	53.079	1.7905	57.283	1.7843	62.850
SEP	260	1.8822	1.9152	62.299	1.9150	62.228	1.7963	62.947	1.7898	68.559
OCT	257	2.1223	2.1952	38.987	2.1952	38.984	2.0879	34.208	2.0852	33.311
NOV	257	2.2506	2.3699	36.847	2.3699	36.847	2.2932	24.975	2.2920	23.279
DEC	257	2.3130	2.1743	46.948	2.1743	46.948	2.3320	37.084	2.3311	36.097

Table 2: Statistics For Sequestered Gages:

Period	N	Gage Seq. Gages		
		Qbar	Qbar	SEE
MA	52	2.2799	2.2696	11.311
JAN	52	2.3123	2.2972	40.513
FEB	52	2.2930	2.2451	70.278
MAR	52	2.5520	2.6129	343.24
APR	52	2.6603	2.6257	72.363
MAY	52	2.3560	2.4009	29.381
JUN	52	2.1144	2.0429	50.387
JUL	52	2.1686	2.1561	51.678
AUG	52	1.9911	1.9037	52.160
SEP	52	1.6353	1.5561	61.056
OCT	52	1.9567	1.9024	38.078
NOV	52	2.0850	2.1220	26.202
DEC	52	2.4993	2.5030	21.735

Figure A-21: EROM QA Report, Page 1.

In the example report in figure A-21, note how the reference gage regression can improve the EROM flow estimates as compared to the runoff flow estimates. As compared to the runoff statistics, the reference gage regression statistics show that the log10 mean values are often much closer to the gage log10 mean, and the SEE in some cases is reduced by more than half. The following section on the QA file will illustrate what happens in the reference gage regression to make these improvements in flow estimates.

The EROM-Gage QA file

The file is saved in the EROMExtension folder, named EROMQA_nn0001.DBF.

The file can be loaded into ArcGIS or Excel. It is especially useful to load the file into Excel, or a similar spreadsheet package for use in graphing the results.

The file layout is designed to facilitate graphical and statistical analyses. All data values are adjusted for the bottom of the NHDFlowline feature. The files are sorted by GageRef so all reference gages are at the top of the file; this is useful for users wishing to view graphs or additional statistics for only the reference gages.

Field Name	Description	Format
ComID	Common identifier of a NHDFlowline feature	Long Integer
Gageid	The NWIS gageid	Text(16)
GageRef	Text field: "Ref" = Falcone Reference Gage. Blank = not Reference gage.	Char(3)
DivDASqKm	The NHDPlusV2 divergence-routed drainage area at the bottom of the flowline.(SqKm)	Num(14,3)
Q_E	The Gage Flow (cfs)	Num(14,3)
Q_A	Cumulative runoff (cfs)	Num(14,3)
Q_B	Q_A – Excess ET (EET) (cfs)	Num(14,3)
Q_C	Q_A - EET +/- Refgage Regression Adjustment	Num(14,3)
Q_D	Q_A – EET +/- Refgage Regression Adjustment +/- PlusFlowAR (cfs)	Num(14,3)
Q_Eunitro	Q_E / DivDASqKm	Num(14,3)
Q_Aunitro	Q_A / DivDASqKm	Num(14,3)
Q_Bunitro	Q_B / DivDASqKm	Num(14,3)
Q_Cunitro	Q_C / DivDASqKm	Num(14,3)
Q_Dunitro	Q_D / DivDASqKm	Num(14,3)
Q_Adelta	Q_E – Q_A	Num(14,3)
Q_Bdelta	Q_E – Q_B	Num(14,3)
Q_Cdelta	Q_E – Q_C	Num(14,3)
Q_Ddelta	Q_E – Q_D	Num(14,3)
Q_Aurodelt	Q_Eunitro – Q_Aunitro	Num(14,3)
Q_Burodelt	Q_Eunitro – Q_Bunitro	Num(14,3)
Q_Curodelt	Q_Eunitro – Q_Cunitro	Num(14,3)
Q_Durodelt	Q_Eunitro – Q_Dunitro	Num(14,3)

Figure A-23 contains a sample of the QA file, imported into Microsoft Excel. The gage flow (Q_E), cumulative runoff (Q_A), and reference gage regression adjustment (Q_C) columns are highlighted.

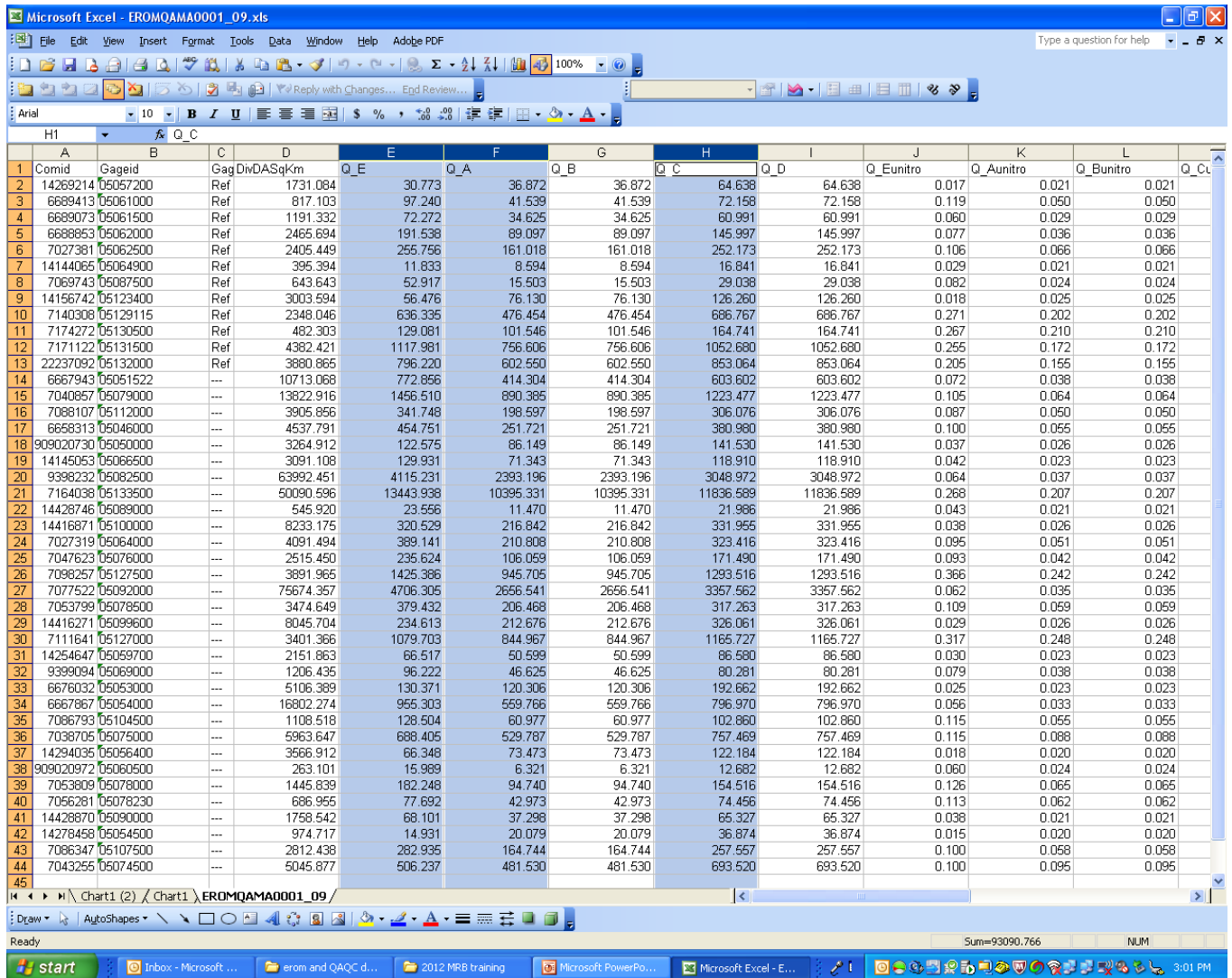


Figure A-23: EROM QA File Example

The graph in Figure A-24 shows a graph of gage flows versus EROM flows with gage flows on the x-axis and EROM flow estimates for runoff and the reference gage regression on the y-axis. The graph is in log-log coordinates to best show the range of flows. The blue triangles are the runoff flow estimates and the orange squares are the flows adjusted with the reference gage regression. The red line is where the gage and EROM flows would be equal. Note how the runoff estimates consistently under-estimate the true (gage) flows. The reference gage regression shifts the flows up to better match the gage flows.

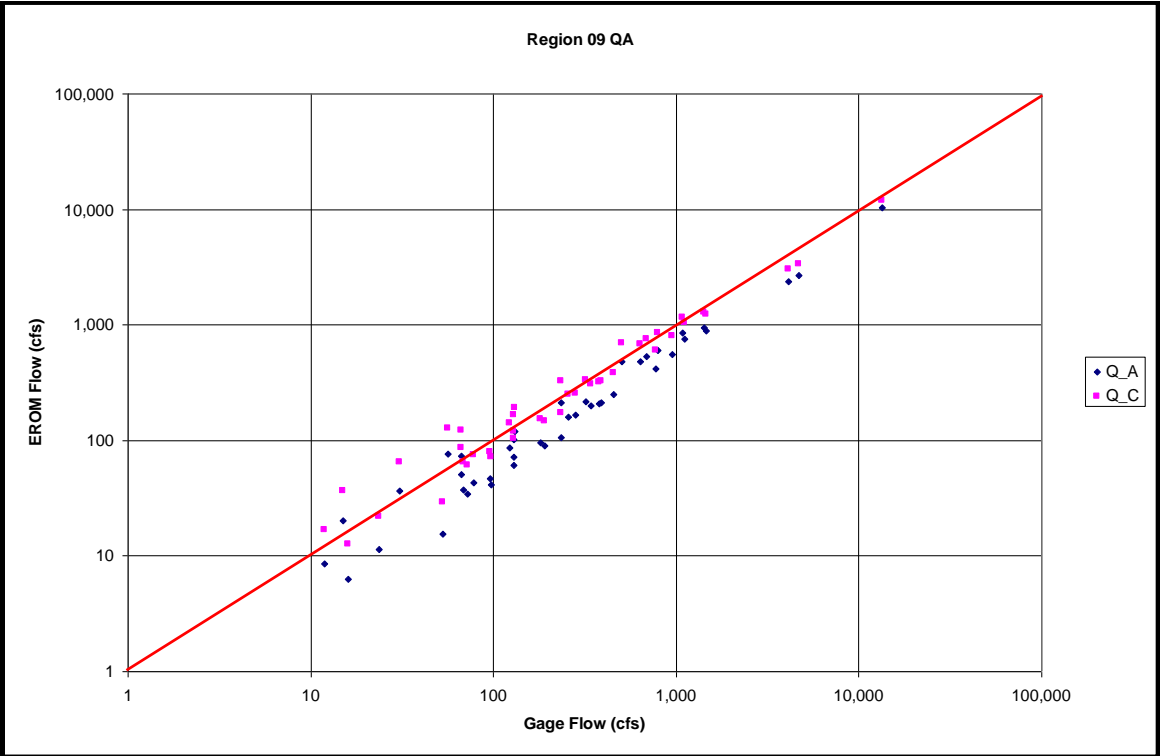


Figure A-24: QA Graph

Vogel Mean Annual Flow Estimation

Mean annual flow estimates for the Continental United States (Hydrologic Regions 01 to 18) are computed based on the work of Vogel et al., 1999. This method uses a log-log regression approach based on drainage area, precipitation, and temperature data using mean annual flow values from the HydroClimatic Data Network (HCDN) of gages. These gages are defined as minimally affected by human activities, such as major reservoirs, intakes, and irrigation withdrawals. Therefore, the “Vogel” mean annual flow estimates are most representative of “natural” flow conditions. Regression parameters are provided for each Hydrologic Region. With this method, the mean annual flow for an NHDFlowline feature is computed as:

$$\text{MAFlowV} = e^a * \text{CumAREA}^b * \text{AreaWtMAP}^c * \text{AreaWtMAT}^d * \text{BCF} * 35.31467$$

Where

- a, b, c, and d are Hydrologic Region-specific regression coefficients,
- BCF = Bias Correction Factor by Hydrologic Region,
- CumAREA = Divergence-routed cumulative area,
- AreaWtMAP = Area-weighted mean annual precipitation,
- AreaWtMAT = Area-weighted mean annual temperature, and,
- 35.31467 = conversion factor from cubic meters per second to cubic feet per second

The BCF is needed because the regression is in log-log space. In addition, the Vogel flow estimates are valid only within the ranges of the original data used for computing the regressions. The regression coefficients, BCFs, and valid drainage area ranges for the Vogel Flow estimates are shown in Figure A-25¹. For cumulative drainage areas that fall outside of these ranges, the Vogel flows and velocities are set to missing values (-9999) in the distributed data.

Hydrologic region	a	B	C	d	BCF	AreaMin (Sq. Km.)	AreaMax (Sq. Km.)
R01	-9.4301	1.01238	1.21308	-0.5118	1.004042	5.179976221	14672.28265
R02	-2.707	0.97938	1.6251	-2.051	1.007174	2.58998811	29940.26256
R03	-10.102	0.98445	2.2599	-1.607	1.014347	12.94994055	44547.7955
R04	-5.678	0.96519	2.2889	-2.3191	1.012719	72.51966709	5982.872535
R05	-4.891	0.99319	2.32521	-2.5093	1.007174	2.58998811	74164.30954
R06	-8.82	0.96418	1.3581	-0.7476	1.009752	12.94994055	6622.599598
R07	-11.861	1.00209	4.5596	-3.8984	1.009752	93.23957197	308208.5851
R08	0	0.98399	3.157	-4.1898	1.011187	132.0893936	7283.046566
R09	0	0.81629	6.4222	-7.6551	1.062826	51.79976221	16757.22307
R10	-10.927	0.89405	3.2	-2.4524	1.156028	10.35995244	53491.02444
R11	-18.627	0.96494	3.8152	-1.9665	1.044031	62.15971465	46236.46775
R12	0	0.84712	3.8336	-4.7145	1.146124	85.46960764	101032.8462
R13	0	0.77247	1.9636	-2.8284	1.122542	28.48986921	25200.58431
R14	-9.856	0.98744	2.469	-1.8771	1.08462	90.64958386	116160.9667
R15	0	0.8663	2.5065	-3.427	1.286895	23.30989299	68634.68492
R16	0	0.83708	2.1672	-3.0535	1.118034	18.12991677	12975.84043
R17	-10.18	1.00269	1.86412	-1.1579	1.059481	20.71990488	35094.3389
R18	-8.438	0.97398	1.99863	-1.5319	1.109234	15.53992866	8062.632987

Figure A-25: Vogel Flow Values by Hydrologic Region⁴

The area-weighted Mean Annual Precipitation (MAP) and Mean Annual Temperature (MAT) values come from PRISM-based grids that are allocated and accumulated using the CA3T tool. The results are stored in the VPUAttributeExtension directory, named CumDivPrecipMA CumDivTempMA, respectively. Cumulative Divergence-routed area comes from the CumulativeArea table in the NHDPlusAtributes folder. The MAP and MAT values are computed by dividing the CA3T accumulated values by the Divergence-routed cumulative area.

The “Vogel” based flow and, therefore, velocity estimates depend upon estimates for mean annual precipitation and temperature, as well as drainage area. It is possible that drainage area, precipitation, or temperature data is unavailable in some cases (for instance where there is drainage entering from Canada or Mexico). The accumulation tool, CA3T, keeps track of “missing” data. If the percentage of missing temperature or precipitation data is greater than or equal to 25 percent of the total drainage area, the Vogel-based flow and velocity estimates are assigned missing values of -9999.

⁴ Figure A-25 contains published and unpublished material from Vogel (2005). The information in columns BCF, AreaMin, and AreaMax is unpublished and was supplied by Vogel through e-mail and telephone communication to Timothy R. Bondelid, Consulting Engineer.

Velocity Calculations

Velocities are estimated for Vogel and EROM mean annual and EROM mean monthly flows using the work of Jobson (1996). This method uses regression analyses on hydraulic variables for over 980 time-of-travel studies, which represent about 90 different rivers in the U.S. These rivers represent a range of sizes, slopes, and channel geometries. Four principal NHDFlowline feature variables are used in the Jobson methods: drainage area, NHDFlowline feature slope, mean annual flow, and the flow associated with the velocity (e.g., mean annual or mean monthly flow). Based on Jobson's analyses, regression equations were developed to relate velocity (meters/second) to drainage area, a dimensionless drainage area, NHDFlowline feature slope, flow, and a dimensionless relative flow.

Note that replication of the velocities using data values in the EROM or Vogel tables may not produce the exact velocities in the table due to round-off in the table values and because the velocity calculations use double-precision intermediate values.

The slope smoothing process does not permit zero slopes on NHDFlowline features. If the elevation smoothing produces a zero slope, the slope is set to a value of 0.00001. There are situations where the slope is set to "missing" (-9998), in which case the Jobson "Unknown-Slope" method is used for the velocity calculation. See Step 22 (Elevation Smoothing) for a description of when these missing slopes occur. For all NHDFlowline features with slope, velocities are calculated using the Jobson "slope" method.

Jobson velocities are calculated for non-tidal NHDFlowline features that are not in lakes and reservoirs. EROM velocities in tidal waters are set to -9998. EROM velocities in lakes and reservoirs are set to -9998.

The equations for the velocity estimates are presented below:

The dimensionless relative discharge (Q'_a) (Jobson, 1996) is expressed as

$$Q'_a = Q/Q_a$$

Where

Q = flow (cubic meters/second), and
Q_a = mean annual flow.

The dimensionless drainage area (D'_a) (Jobson, 1996) is expressed as

$$D'_a = (D_a^{1.25} * g^{0.5})/Q_a$$

Where

D_a = drainage area (square meters),
g = acceleration of gravity (9.8 meters/second/second), and
Q_a = mean annual flow (cubic meters/second).

The "Slope" method NHDFlowline feature velocity equation (Jobson, 1996) is:

$$Vel = 0.094 + (0.0143 * (D'_a)^{0.919}) * (Q'_a)^{-0.469} * (slope)^{0.159} * (Q/D_a)$$

The "Unknown-Slope" NHDFlowline feature velocity equation (Jobson, 1996) is:

$$\text{Vel} = 0.02 + (0.051 * D_a^{0.821} * Q_a^{-0.465} * (Q/D_a))$$

Conversion of velocity from mps to fps:

$$\text{Vel} = \text{Vel} * 3.2808$$

Note that if the flow or drainage area is zero, the “Slope” and “Unknown-Slope” methods become equal to their respective intercept terms. For the “Slope” method, $\text{Vel} = .094 * 3.2808$. For the “Unknown Slope” method, $\text{Vel} = 0.02 * 3.2808$.

Identifying Tidal Flowlines

In order to refine the velocity computations in NHDPlus, a screen for tidal flowlines was applied. The result of the screen is stored in the TIDAL attribute in PlusFlowlineVAA.

The tidal screen was defined as follows:

1. Select NHDFlowline features where PlusFlowlineVAA->MAXELEVSMO < 600 AND PlusFlowlineVAA->MINELEVSMO < 600 AND EROM_MA0001->Q0001A > 0.
2. On each flow path included in step 1, find the most upstream NHDFlowline feature and navigate downstream with divergences.
3. Add NHDFlowline features found in the step 2 navigations to the selected set from step 1.
4. Set PlusFlowlineVAA.Tidal attribute to 1 for each feature in the selected set.

Time of Travel

In NHDPlusV2, mean annual time of travel (TOTMA in days) is included in the PlusFlowlineVAA table. For NHDFlowline features that are not Artificial Paths through lakes and reservoirs, TOT is computed from EROM mean annual velocity (V0001E) using a simple time = distance / rate formula. For Artificial Paths through lakes and reservoirs, TOTMA is computed using lake/reservoir morphology attributes. TOTMA for tidal NHDFlowline features (see PlusFlowlineVAA.TIDAL attribute) is set to -9999.

For lakes and reservoirs, a simple volumetric approach of estimating lake residence times was employed under the assumption that the residence time is the time required to replace lake volume. This technique is used to roughly estimate average travel time through the lake.

Mean lake depths and volumes were estimated for the NHDPlusV1 lakes and reservoirs for the contiguous United States (Hollister and Millstead, 2010; Hollister and others, 2011; USEPA, Data available at <https://edg.epa.gov/clipship/>). Where possible, this information has been transferred to NHDPlusV2. The lake depth estimates are used to estimate residence time for each lake/reservoir. Lake volumes are apportioned to each NHDFlowline Artificial Path feature according to the length and EROM mean annual flow (Q0001E) associated with that feature. Feature TOTMA values were then calculated to be equal to the feature volume / feature mean annual flow. Essentially, the proportion of the lake volume that is associated with each NHDFlowline feature within the lake is used to determine the volume replacement time for each NHDFlowline feature.

The data that went into calculating the lake and reservoir travel times are included in the \NHDPlusAttributes\PlusFlowlineLakeMorphology table and the NHDPlusAttributes\PlusWaterbody LakeMorphology table.

The presence of lake stratification introduces a complication where the average travel time is better represented as the time required to replace the upper strata of the lake. In this case, the transport can be assumed to occur above the depth where stratification occurs. Residence time = adjusted lake volume (above the depth of stratification) / lake outflow. A direct way to calculate the adjusted mean annual time of travel for flowline (in days) for a stratified lake is to calculate it equal to TOTMA times the ratio of (depth of stratification / MeanDUsed). Adjustments for lake stratification are not included in NHDPlusV2, due to lack of information about lake stratification.

Appendix B: National Hydrography Dataset (NHD) Snapshot Feature Class and Table Descriptions

The data contained in the \NHDSnapshot folder is the version of NHD data used to build NHDPlus. Only the NHD features classes and tables of importance to NHDPlusV2 are described here. Additional documentation on these and other NHD components may be found on: <http://nhd.usgs.gov/>

Some fields in the attribute tables contain special coded values as follows:

The value “-9998” signifies that the applicable value for the field is missing or undetermined.

The value “-9999” signifies that there is no applicable value and one will never be assigned.

WHDSnapshotHydrographyNHDFlowline (line feature class)

Description: NHD linear features of types: stream/river, canal/ditch, pipeline, artificial path, coastline, and connector.

Field Name	Description	Format
ComID	Common identifier of the NHD feature	Long Integer
FDate	Feature Currency Date	Date
Resolution	NHD database resolution (i.e. “high”, “medium” or “local”)	Character (6)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name	Character(10)
GNIS_Name	Feature Name from the Geographic Names Information System	Character(65)
LengthKM	Feature length in kilometers	Num(11,3)
ReachCode	Reach Code assigned to feature	Character (14)
FlowDir	Flow direction is “With Digitized” or “Uninitialized” Only flowlines with FlowDir = “With Digitized” are used to define the surface water network used in NHDPlus. All other flowlines are ignored by NHDPlus.	Character (14)
WBAreaComI	ComID of the NHD polygonal water feature through which a NHD “Artificial Path” flowline flows	Long Integer
FType	NHD Feature Type	Character (32)
FCode	Numeric codes for various feature attributes in the NHDFCode lookup table	Num(5)
Shape_Leng	Feature length in decimal degrees	See ESRI documentation
Enabled	Always “True”	Character (6)

WHDSnapshotHydrographyNHDWaterbody (polygon feature class)

Description: NHD polygonal features of types: Playa, Ice Mass, LakePond, Reservoir, SwampMarsh, and Estuary.

Field Name	Description	Format
ComID	Common identifier of the NHD Waterbody feature	Long Integer
FDate	Feature Currency Date	Date
Resolution	NHD database resolution (i.e. "high", "medium" or "local")	Character (6)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name	Character(10)
GNIS_Name	Feature Name from the Geographic Names Information System	Character (65)
AreaSqKm	Feature area in square kilometers	Num(11,3)
Elevation	Feature elevation in feet	Num(10,3)
ReachCode	Reach Code assigned to feature	Character (14)
FType	NHD Feature Type	Character (32)
FCode	Numeric code for various feature attributes; definitions for codes found in the NHDFCode lookup table	Num(5)
Shape_Leng	Feature length in decimal degrees	See ESRI documentation
Shape_Area	Feature area in square decimal degrees	See ESRI documentation

WHDSnapshotHydrographyNHDArea (polygon feature class)

Description: NHD polygonal features of types: Area to be Submerged, BayInlet, Bridge, CanalDitch, DamWeir, Flume, Foreshore, Hazard Zone, Lock Chamber, Inundation Area, Rapids, SeaOcean, Special Use Zone, Spillway, StreamRiver, Submerged Stream, Wash, Water IntakeOutflow, and Area of Complex Channels.

Field Name	Description	Format
ComID	Common identifier of the NHD area feature	Long Integer
FDate	Feature Currency Date	Date
Resolution	NHD database resolution (i.e. "high", "medium" or "local")	Character (6)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name	Character(10)
GNIS_Name	Feature Name from the Geographic Names Information System	Character 65)
AreaSqKm	Feature area in square kilometers	Num(11,3)
Elevation	Feature elevation in feet	Num(9,3)
FType	NHD Feature Type	Character (32)
FCode	Numeric codes for various feature attributes; definitions for codes found in the NHDFCode lookup table	Num(5)
Shape_Leng	Feature length in decimal degrees	See ESRI documentation
Shape_Area	Feature area in square decimal degrees	See ESRI documentation

WHDSnapshot\NHDFCode (Table)

Description: The FCode table describes attribute codes used in the FCode fields of feature tables.

Field Name	Description	Format
FCode	A numeric code that represents the feature type plus its encoded attribute values	Long Integer
Descriptio	Text description of feature type and the encoded attributes	Character (255)
CanalDitch	Canal Ditch Type (aqueduct, unspecified)	Character (32)
Constructi	Construction material (earthen, nonearthen, unspecified)	Character (32)
Hydrograph	Intermittent or perennial	Character (32)
Inundation	Inundation Area Type (debris basin, dewatering area, duck pond, general case, percolation basin, retarding basin)	Character (32)
Operationa	Operational Status (abandoned, operational, under construction)	Character (32)
PipelineTy	Pipeline type (aqueduct, general case, penstock, siphon)	Character (32)
Positional	Positional accuracy (approximate, definite, indefinite, not applicable)	Character (32)
Relationsh	Relationship to surface (abovewater, at or near, elevated, underground, underwater, unspecified)	Character (32)
ReservoirT	Reservoir type (aquaculture, decorative pool, disposal-tailings pond, disposal-unspecified, evaporator, swimming pool, treatment-cooling pond, treatment-filtration pond, treatment-settling pond, treatment-sewage treatment pond, unspecified water storage)	Character (32)
Stage	Elevation stage (Normal Pool, Flood Elevation, Average Water Elevation, Date of Photography, High Water Elevation, Spillway Elevation)	Character (32)
SpecialUse	Special use category (dump site, spoil area)	Character (32)
KCode		Character (30)

WHDSnapshot\NHDRReachCrossReference (Table)

Description: The NHDRReachCrossReference table is used to track changes to Reachcodes and NHD Reach configuration. As distributed with NHDPlus, this table tracks only Reachcodes assigned to Medium Resolution (1:100,000) NHD. This table can be used to track the changes between NHDPlusV1 to NHDPlusV2.

Field Name	Description	Format
OldReachCode	Old Reachcode	Character(14)
OldReachDate	Date OldReachcode was assigned	Date
NewReachCode	New Reachcode	Character(14)
NewReachDate	Date NewReachcode was assigned	Date
OldUpMi	No longer used.	Character(5)
NewUpMi	No longer used.	Character(5)
ChangeCode	A: New Reach was added D: Old Reach was deleted 1-1: Old Reach became one new Reach 1-P: Old Reach became part of new Reach P-1: Part of old Reach became new Reach P-P: Part of old Reach became part of new Reach (rare)	Character(4)
Process	Abbreviation of process which changed the Reaches.	Character(6)
ReachFileVersion	NHD Version	Character (10)
OldHUCCode	Old HUC8	Character (8)
NewHUCCode	New HUC8	Character (8)

Appendix C: National Elevation Dataset (NED) Snapshot Raster and Table Descriptions

The NED snapshot resides in the \NEDSnapshot subfolder of the NHDPlusV2 VPU workspace. The data contained in the \NEDSnapshot folder is the 1-arc-second resolution NED data used to build NHDPlusV2 for the VPU workspace.

Additional documentation about the National Elevation Dataset may be found on: <http://ned.usgs.gov/>. The NED data are updated on a bimonthly basis, and because the NHDPlusV2 production process took place over a period of many months, more than one snapshot of NED data was extracted for processing. The source NED snapshot date is identified in the metadata for each NHDPlusV2 VPU.

Data for Mexico were included in the NED.

Elevation data for areas in Canada are from the Canadian Digital Elevation Data, Level 1 (CDED1). These data generally were derived from 1:50,000-scale topographic maps and sampled at a 0.75-arc-second resolution. The data were downloaded from the web at <http://www.geobase.ca/>. Each file was in DEM format.

Both the NED and CDED1 data were provided as tiled datasets in rectangular tiles. Automated processes were developed to clip the desired areas from each data tile, merge the pieces together, check for and fill any gaps in the data, project the data to the Albers Equal-area map projection and convert the protected grid to an integer grid with elevations in centimeters. A shaded relief grid then was generated.

WEDSnapshot\lev cm (grid)

Description: An integer grid dataset with elevation in centimeters (from the North American Vertical Datum of 1988). This grid contains the source elevation data used to build NHDPlus. This grid is an integer grid, with vertical units of centimeters on the Albers Equal-area map projection. This grid is not hydro-enforced.

Field Name	Description	Format
Value	Elevation in centimeters	See ESRI documentation

WEDSnapshot\shdrelief (grid)

Description: An integer grid dataset that contains the shaded relief generated from elev_cm.

Field Name	Description	Format
Value	0-254	See ESRI documentation
Count	Number of cells with the same value in Value	Long Integer

Appendix D: Watershed Boundary Dataset (WBD) Snapshot Feature Class and Table Descriptions

The WBD snapshot resides in the \WBDSnapshot subfolder of the NHDPlusV2 VPU workspace. The data contained in the \WBDSnapshot folder is the WBD data used to build NHDPlusV2 for the VPU workspace. As NHDPlusV2 was built for each VPU, the most recent WBD snapshot was acquired from the Watershed Boundary Dataset website located at <http://www.nrcd.usda.gov>

\WBDSnapshot\WBD\WBD_SubWatershed (polygon feature class)

Description: Boundaries of 12-digit Hydrologic Units.

Additional documentation about the Watershed Boundary Dataset may be found at:

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/watersheds/dataset/?&cid=nrcs143_021616

Field Name	Description	Format
HUC_8	8-digit Hydrologic Unit Code	Char(8)
HUC_10	10-digit Hydrologic Unit Code	Char(10)
HUC_12	12-digit Hydrologic Unit Code	Char(12)
Acres	Size of 12-digit HUC	Num(,)
NContrib_A	Non-contributing area in 12-digit HUC	Num(,)
HU_10_GNIS	10-digit HUC GNIS name	Char(23)
HU_12_GNIS	12-digit HUC GNIS name	Char(23)
HU_10_DS	Downstream 10-digit HUC	Char(10)
HU_10_Name	10-digit HUC name	Char(80)
HU_10_Mod	Identifies inter-basin transfers (IT), dams at outlet (DM), etc. that modify natural overland flow as modifications are identified from most significant to least significant modification(s). Hydrologic units with no modification are marked with NM. SC - Storm water Canal or Drainage Canal ID - Irrigation Ditch IT – Inter-basin Transfer BC - Barge Canal or Navigation Canal SD - Storm water Ditch PD - Pipe Diversion CD - Channel Diversion NC - Noncontributing Area KA - Karst LE - Levee NM - No Modifications OC - Overflow Channel or Flume DM - Dam at outlet or HU boundary GC - General Canal/Ditch PS - Pumping Station DD - Drainage Ditch SI - Siphon	Char(20)

	<p>AD - Aqueduct RS - Reservoir TF - Transportation Feature (road, railroad, docks etc.) GF - Ground-Water Flow MA - Mining Activity UA - Urban Area GL - Glacier IF - Ice Field OF - Overbank Flow OT - Other</p>	
HU_10_Type	<p>The hydrologic unit type that most closely identifies the watershed.</p> <p>S - "Standard" hydrologic unit - Any land HU with drainage flowing to a single outlet point, excluding non-contributing areas. This includes areas or small triangular wedges between adjacent HU's that remain after classic hydrologic units are delineated. Some examples include "true", "classic", "composite", and "remnant" hydrologic units.</p> <p>C - "Closed Basin" hydrologic unit - A drainage area that is 100% non-contributing. This means all surface flow is internal, no overland flow leaves the hydrologic unit through the outlet point.</p> <p>F - "Frontal" hydrologic unit - Areas along the coastline of lakes, oceans, bays, etc. that have more than one outlet. These HU's are predominantly land with some water areas at or near the outlet(s).</p> <p>M - "Multiple Outlet" hydrologic unit An area that has more than one natural outlet; for example, an outlet located on a stream with multiple channels. This does not include frontal or water hydrologic units, hydrologic units with artificial inter-basin transfers, drainage outlets through karst or ground-water flow, or outlets that cross a stream with an island. This code should be used only in rare instances.</p> <p>W - "Water" hydrologic unit - Hydrologic units that are predominantly water with adjacent land areas, ex. lake, estuaries, and harbors.</p> <p>I - "Island" hydrologic unit - A hydrologic unit that is one or more islands and adjacent water out to the toe of the shore face.</p> <p>U - "Unclassified" hydrologic unit - A hydrologic unit that can't be defined or doesn't fit into one of the types that have been listed.</p>	Char(1)
HU_12_DS	Downstream 12-digit HUC	Char(10)
HU_12_Name	12-digit HUC name	Char(80)
HU_12_Mod	<p>Identifies inter-basin transfers (IT), dams at outlet (DM), etc. that modify natural overland flow as modifications are identified from most significant to least significant modification(s). Hydrologic units with no modification are marked with NM.</p> <p>SC - Storm water Canal or Drainage Canal ID - Irrigation Ditch IT - Inter-basin Transfer</p>	Char(20)

	<p>BC - Barge Canal or Navigation Canal SD - Storm water Ditch PD - Pipe Diversion CD - Channel Diversion NC - Noncontributing Area KA - Karst LE - Levee NM - No Modifications OC - Overflow Channel or Flume DM - Dam at outlet or HU boundary GC - General Canal/Ditch PS - Pumping Station DD - Drainage Ditch SI - Siphon AD - Aqueduct RS - Reservoir TF - Transportation Feature (road, railroad, docks etc.) GF - Ground-Water Flow MA - Mining Activity UA - Urban Area GL - Glacier IF - Ice Field OF - Overbank Flow OT - Other</p>	
HU_12_Type	<p>The hydrologic unit type that most closely identifies the watershed.</p> <p>S - "Standard" hydrologic unit - Any land HU with drainage flowing to a single outlet point, excluding non-contributing areas. This includes areas or small triangular wedges between adjacent HU's that remain after classic hydrologic units are delineated. Some examples include "true", "classic", "composite", and "remnant" hydrologic units.</p> <p>C - "Closed Basin" hydrologic unit - A drainage area that is 100% non-contributing. This means all surface flow is internal, no overland flow leaves the hydrologic unit through the outlet point.</p> <p>F - "Frontal" hydrologic unit - Areas along the coastline of lakes, oceans, bays, etc. that have more than one outlet. These HU's are predominantly land with some water areas at or near the outlet(s).</p> <p>M - "Multiple Outlet" hydrologic unit - An area that has more than one natural outlet; for example, an outlet located on a stream with multiple channels. This does not include frontal or water hydrologic units, hydrologic units with artificial inter-basin transfers, drainage outlets through karst or ground-water flow, or outlets that cross a stream with an island. This code should be used only in rare instances.</p> <p>W - "Water" hydrologic unit - Hydrologic units that are predominantly water with adjacent land areas, ex. lake, estuaries, and harbors.</p> <p>I - "Island" hydrologic unit - A hydrologic unit that is one or</p>	Char(1)

	more islands and adjacent water out to the toe of the shore face. U - "Unclassified" hydrologic unit - A hydrologic unit that can't be defined or doesn't fit into one of the types that have been listed.	
Meta_ID	Most recent Meta_ID which links to content in WBD metadata	Char(4)
States	List of states within the 12-digit HUC	Char(20)
GlobalID	Globally Unique Identifier	Char(38)
GAZ_ID	Identifier assigned by NHDPlus production process	Long Integer
Shape_Leng	Feature length in decimal degrees	See ESRI Documentation
Shape_Area	Feature area in square decimal degrees	See ESRI Documentation

Appendix E: Purpose Code (PurpCode) Values

Sink

<u>PurpCode</u>	<u>PurpDesc</u>
1	BurnLineEvent network end
2	BurnLineEvent non-spatial connection
3	NHDWaterbody Playa
4	BurnAddWaterbody Playa
5	NHD Waterbody closed lake
6	WBD Closed HUC12
7	WBD HUC12 not indicated as closed, but no surface-water connection is seen on maps
8	BurnAddWaterbody closed lake
9	Karst sinkhole
10	Topographic depression
11	Topographic depression (Canada or Mexico)
12	BurnAddLine end (Mexico)

BurnAddLine

<u>PurpCode</u>	<u>PurpDesc</u>
CN	Feature from Canadian NHN
CT	Feature from Canadian NHN, but trimmed. Not whole NHN feature.
CC	Connection between Canadian NHN and US NHD
CO	Feature omitted from Canadian NHN. Added to ensure drainage connectivity.
NO	Feature omitted from NHD. Added to ensure drainage connectivity.
HR	Feature from High resolution NHD
HT	Feature from High resolution NHD, but trimmed. Not whole High resolution Feature.
NH	Feature from High resolution NHD. In Canada or Mexico, from harmonized NHD data.
CH	Connection between High Resolution NHD and Medium Resolution NHD. High resolution may include harmonized Canada or Mexico data.
UF	Feature from Medium Resolution NHD FlowDir=Uninitialized
BA	Feature from adjacent VPU, burned to ensure same catchment boundaries from both VPU's
BW	Line added to breach a wall
AC	Added connector
MB	Modify burn path
AV	Inter-VPU flowline from adjacent VPU
AP	Artificial path in coastal bay
CV	Coastline from adjacent VPU
EN	Stream digitized to exit VPU drainage to NoData extent

Appendix F: How Catchment Boundaries differ from WBD Snapshot Boundaries

A common goal of the NHDPlus and WBD programs is to minimize differences, over time, between catchment boundaries and WBD boundaries. The objective is to have NHDPlusV2 catchments that will nest within WBD HUC12 areas. This, in turn, will enable catchment attributes to be aggregated up to any HUC level. NHDPlusV2 catchments are constructed using a snapshot of the WBD for a particular area and the nesting will only apply to that particular WBD snapshot.

The WBD HUC12 drainage divide lines are incorporated into the NHDPlusV2 hydro-enforced DEM as “walls” so that DEM-derived flow direction cells (i.e. the NHDPlusV2 fdr grid) conform to the WBD. Catchments for NHDFlowline features and Sink features are created using the NHDPlusV2 fdr grid and, theoretically, the catchments should conform to the WBD boundaries within the 30-meter grid cell resolution. In practice, however, catchments and WBD Boundaries are not always closely aligned. At present, the catchment boundaries correspond well at ridge lines but small differences are common at the WBD pour points. Below is a list of common data conditions that result in differences between the catchment boundaries and the WBD boundaries.

- Pour point of the catchment is slightly upstream or downstream of the pourpoint of the WBD. This misalignment between the medium resolution NHD and the WBD can occur at HUC12 outlets. Here, the segmentation of NHD does not always match with WBD outlets. The result is a catchment extending into a portion of the next downstream or upstream HUC12 (Figure F-1).
- The 30-meter grid cell resolution can sometimes be a limiting factor for spatial correspondence between the catchments and WBD divides. This is true when an NHDFlowline feature is within one grid cell width of a WBD divide. This situation can result in an NHDFlowline feature breaching the WBD wall feature in the hydro-enforced DEM. This processing artifact can cause the catchment for the NHDFlowline feature to extend beyond the WBD divide. An example of this is shown in Figure F-2, where the 30-meter cell-size rasterization causes a series of NHDFlowline features to breach nearby WBD wall features.
- Where lake shores are used to define WBD boundaries (see Figure F-3), the NHDPlus catchments associated with artificial paths within the lakes, will not match the WBD boundary. The NHD representation is correct since the artificial path catchment features should include contributing drainage from the surrounding HUC12s.
- In arid areas, some HUC12s may be “empty”, (i.e. may not contain any NHDFlowline features or other water features). If the HUC12 was not identified in WBD as a closed basin, the wall between the HUC12 and the downstream HUC12 was removed during the NHDPlusV2 production process. In these cases, the catchments may not agree with the HUC12 boundaries. In Figure F-4A, the example shows two empty HUC12s. A portion of the boundary of each empty HUC12 is removed from the Wall feature thus hydrologically connecting the empty HUCs to downstream drainage. In the figure, one empty HUC flows to the other empty HUC which drains to the next downstream HUC containing an NHDFlowline feature. The resultant catchment for the NHDFlowline feature includes the area of the HUC 12 the feature is within plus the two upstream empty HUC 12s (Figure F-4B).
- Arid areas present situations where there are isolated NHDFlowline networks within a HUC12, and a sink is placed at the downstream end of each isolated network. Within a HUC12 there may exist an area downhill of the sink with no flowline connecting the area to an adjacent HUC12. If the HUC12 is not identified as a closed basin in WBD and has a downstream HUC12 identified, a section of the wall was removed during NHDPlusV2 processing. By removing the wall section, the downhill portion of the HUC12 drains to the downstream HUC12. In these cases, the areas

downhill of the sink will be assigned to a catchment in the downstream HUC12. Figure F-5 shows a catchment for an NHDWaterbody playa feature (i.e. a sink labeled with a map id of 1) which includes all of the area for an upslope empty HUC12 (same scenario as Figure F-4) and a large portion of another upstream HUC 12 that is partially allocated to catchments for an isolated network.

- All NHDFlowline headwater features are trimmed back by a small distance to reduce possible breaches of ridge lines in the DEM. Further intersecting conflicts of headwater features with the WBD drainage divides are then identified and additional trimming is performed on these conflicting headwater features. These combined trimming actions do not ensure that headwater flowlines will never breach a WBD divide.

In Figure F-6, a headwater NHDFlowline feature extends into an adjacent WBD HUC12 in a manner that appears to contradict what the drainage should be as defined by the WBD. This situation may represent an error NHD or an error in WBD. Visual review of this example with high-resolution oblique aerial photos (source: Bing Maps) suggested that the headwater feature does extend into the adjacent HUC12 via culverts and pipeline features. No additional action was necessary during the NHDPlusV2 processing.

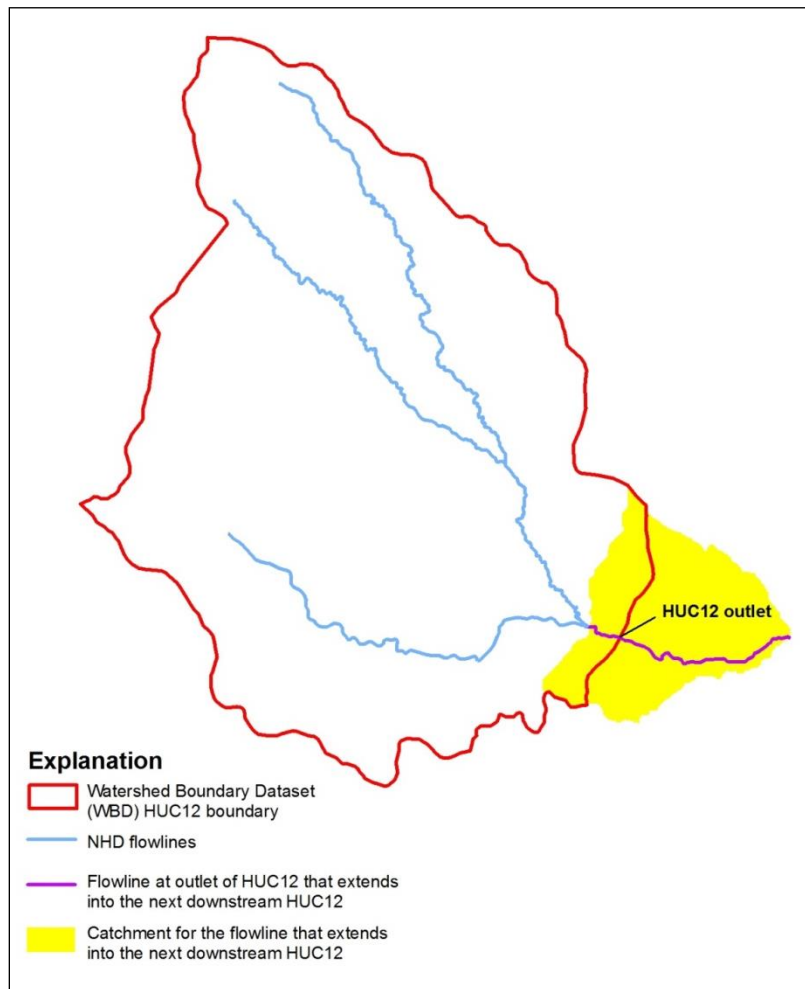


Figure F-1: A catchment extending into a portion of the next downstream HUC12

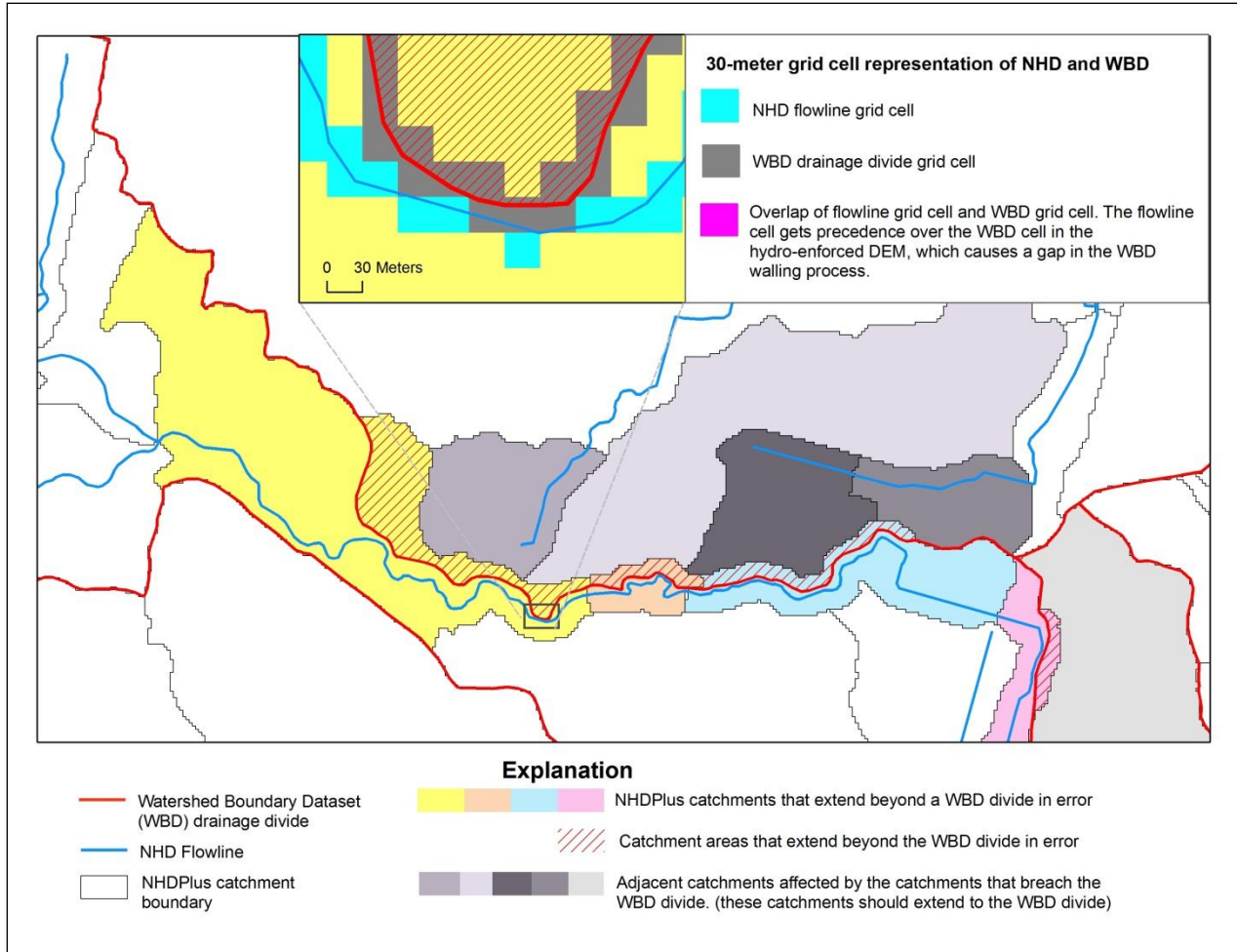


Figure F-2: 30m Grid Cell Representation of NHD and WBD

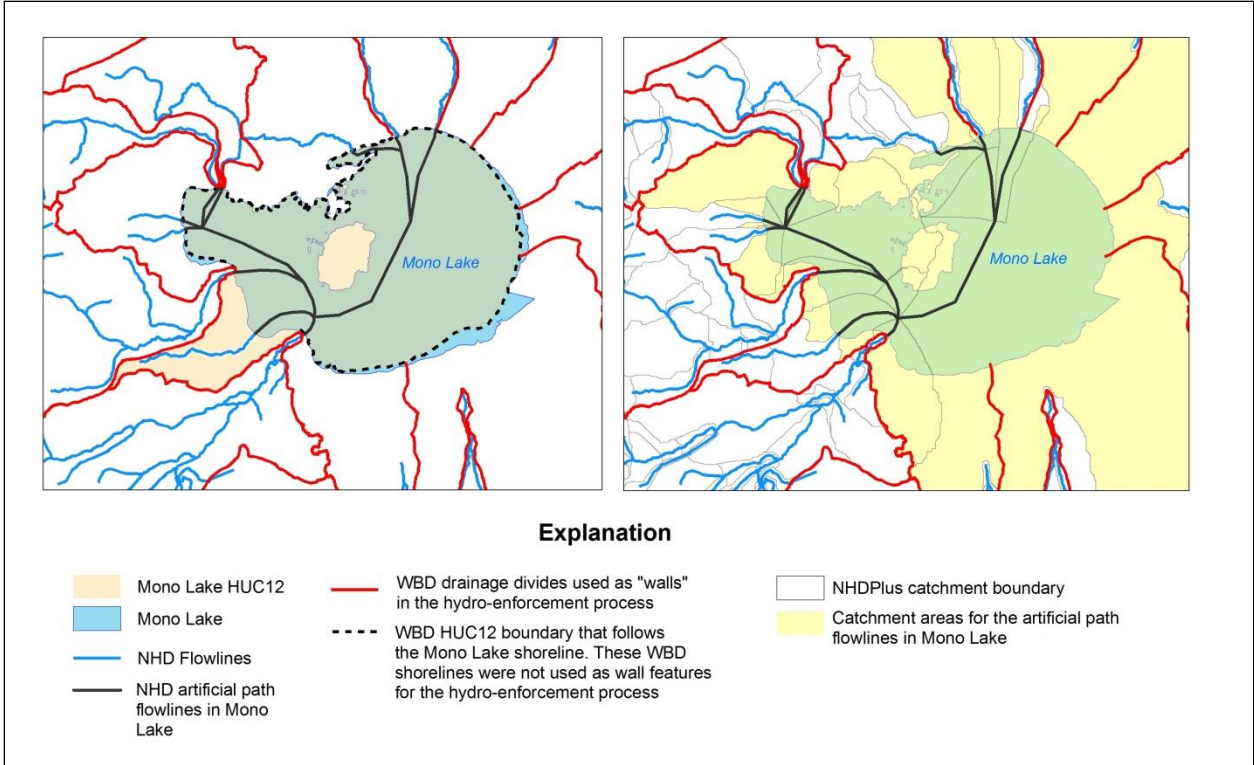


Figure F-3: Lake shorelines are used to define WBD boundaries.

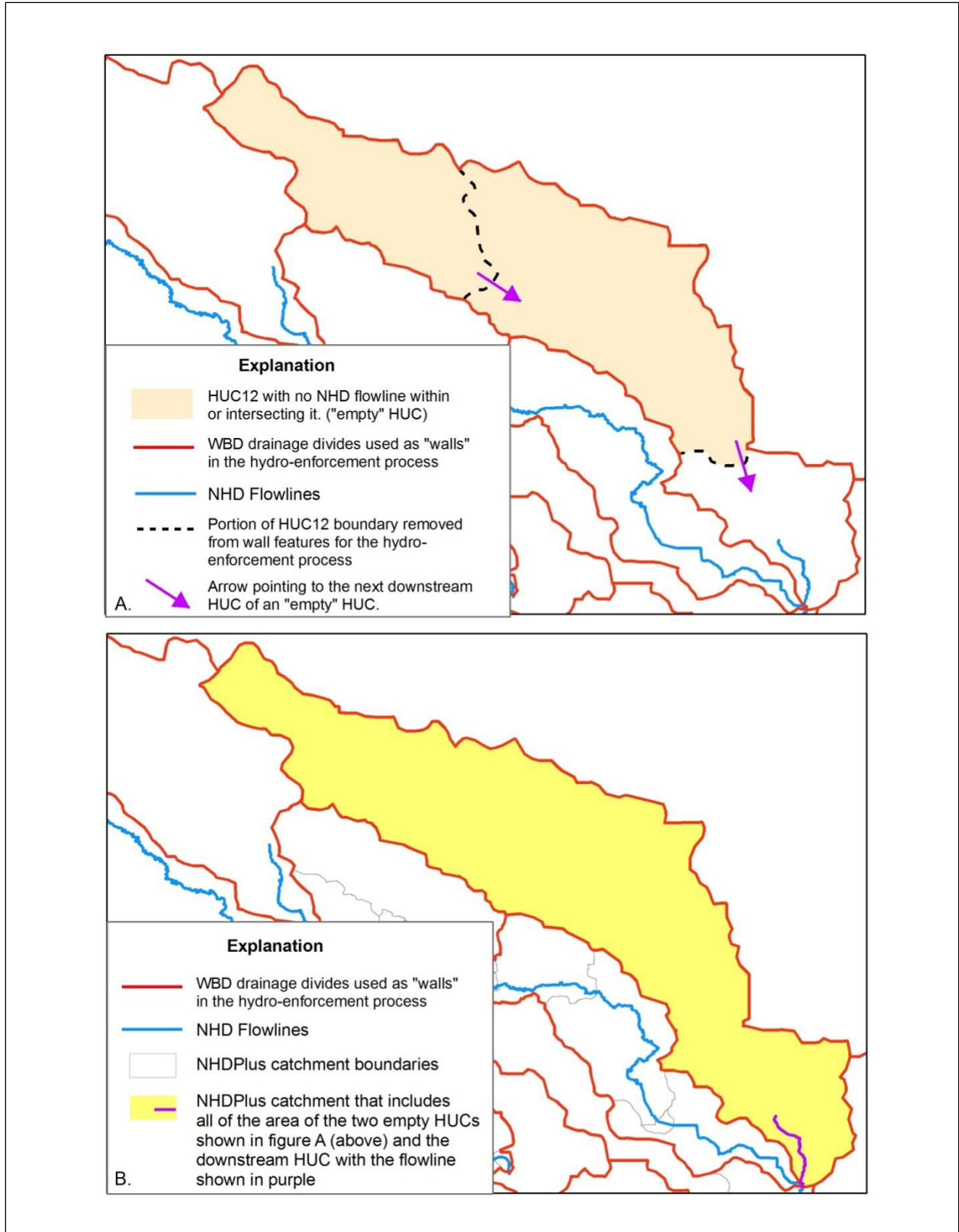
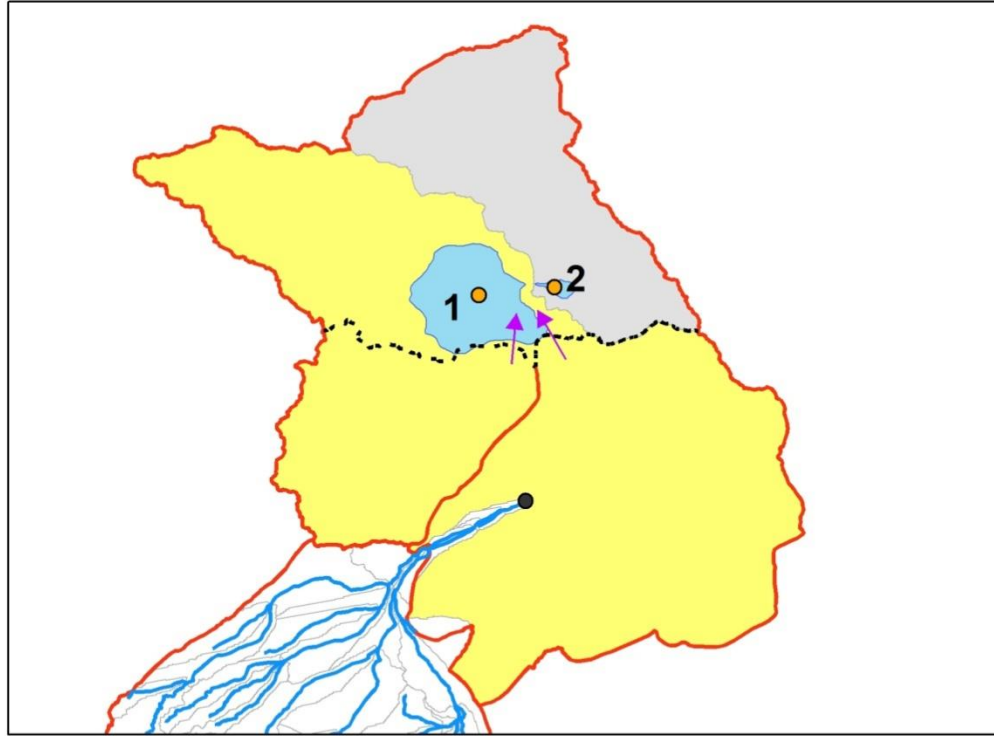


Figure F-4a and F-4b: HUC12s may not contain any NHDFlowline features.



Explanation

- | | |
|---|--|
| <p>1 NHD Waterbody - Playa and map id</p> <p>NHD Flowlines</p> <p>● Playa sink feature used for the hydro-enforcement process and the catchment delineation source for an NHD Waterbody playa feature</p> <p>● Sink feature used in the hydro-enforcement process for a terminal end of an NHD isolated stream network</p> | <p>— WBD drainage divides used as "walls" in the hydro-enforcement process</p> <p>... .. Portion of HUC12 boundary removed from wall features for the hydro-enforcement process</p> <p>↘ Arrow pointing to the next downstream HUC</p> <p>— NHDPlus catchment boundary</p> <p>1 NHDPlus catchment for the NHD playa feature labeled with the map id of 1. The catchment includes upslope areas from an "empty" HUC12 and a HUC12 with flowlines belonging to an isolated network.</p> <p>2 NHDPlus catchment for the NHD playa feature labeled as number 2</p> |
|---|--|

Figure F-5: A catchment for an NHDWaterbody playa feature includes all of the area for an upslope empty HUC12.

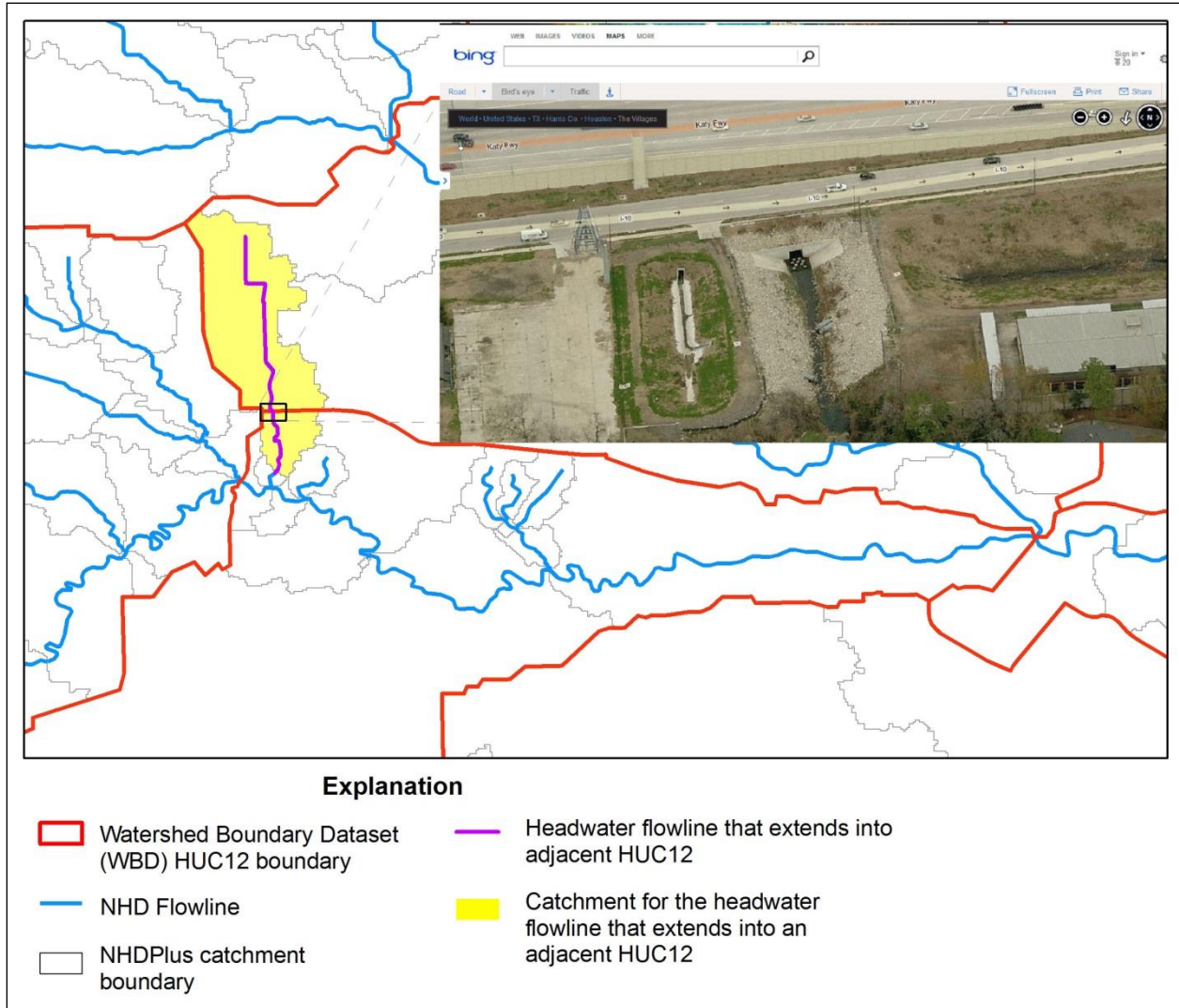


Figure F-6: A headwater NHDFlowline feature extends into an adjacent WBD HUC12.

Glossary

A

Artificial path – A National Hydrography Dataset (NHD) flowline feature type that represents a flow-path through a waterbody in the surface water network of the NHD.

B

Burn Line – A line used to perform hydro-enforcement of the DEM during step 18 of the NHDPlusV2 Build/Refresh production. Burn lines are stored in BurnlineEvent feature class if they are NHDFlowline features or in BurnAddLine if they are additional lines which are not in NHDFlowline features.

C

Catchment – The land surface area that flows directly to an NHDPlus feature. – For most networked surfacewater linear features the catchment represents the incremental area that drains directly to each feature or stream segment. Exceptions include coastline features, where the catchments represents the total drainage area to each individual coastline segment. For off-network sink features, the catchment represents the total drainage area to the sink since there are no upstream features. Similarly, since there are no upstream features, the catchments for headwater linear features represent both the total drainage area as well as the incremental drainage area.

Cumulative drainage area – The total upstream/upslope area that flows to an NHDPlus feature. For surface water network linear features, this is the catchment area for a specific flowline combined with the catchment areas for all upstream flowlines.

D

DEM – Digital Elevation Model is a raster dataset (a grid of squares) representing elevation.

DEM flow-path displacement – The horizontal positional offset between a mapped stream in the NHD and that of a synthetic stream derived from a digital elevation model.

Divergence-routed Accumulation – A method of accumulating attributes downstream along the surface water network features where the attribute is divided into portions at each flow split in the network, and where the total of the portionsequals100%.

Drainage-area boundary – The polygon that defines the perimeter of a drainage area.

Drainage-area divide – The boundary line between two different drainage areas along a topographic ridge.

F

Flowline – A mapped stream segment or a path through a waterbody in the surface-water network of the National Hydrography Dataset. The basic unit of the NHD linear surface-water network.

NHDPlus Flow table (also known as PlusFlow) – A database table that contains the interconnections between the NHD flowlines.

G

Geographic Names Information Systems (GNIS) – A database that contains name and location information for more than two million physical and cultural features located throughout the United States and its territories.

H

Hydrologic Unit – The Hydrologic Unit system is a standardized classification system developed by USGS in the mid-1970s. Hydrologic units are area boundaries organized in a nested hierarchy by size.

Hydrologic Unit Codes (HUC) – The Hydrologic Unit Coding system that sub-divides the U.S. into progressively smaller nested hydrologic units. The largest sub-divisions are assigned a 2-digit code from 01 through 22. 4-digit codes sub-divide the 2-digit areas. 6-digit codes sub-divide the 4-digit areas. This subdivision continues into 8, 10, and 12-digit coded areas. See <http://pubs.usgs.gov/tm/tm11a3/>.

N

National Elevation Dataset (NED) – Seamless elevation coverage of the conterminous United States, Hawaii, Alaska, and the island territories.

National Hydrography Dataset (NHD) – A comprehensive set of digital spatial data representing the surface water of the United States using common features such as lakes, ponds, streams, rivers, canals, and oceans.

National Water Information System (NWIS) – A principal repository of national water resources data.

NHDPlus – An integrated suite of application-ready geospatial datasets that incorporate many of the best features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), the National Land Cover Dataset (NLCD), and the Watershed Boundary Dataset (WBD).

NHD Reach (also Reach) – A uniquely identified linear feature that consists of one or more flowlines.

P

PRISM – Parameter-elevation Regressions on Independent Slopes Model data (PRISM) (<http://www.prismclimate.org>) for the conterminous U.S.

R

Raster – A digital computer format for representing an image or mapped data information. The structure consists of data stored in a rectangular grid array of pixels. Synonymous with grid.

Reach (also NHD Reach) – A uniquely identified linear feature that consists of one or more flowlines.

Reach code – A unique, permanent identifier in the National Hydrography Dataset associated with a NHD Reach.

S

SPARROW – A modeling tool for the regional interpretation of water-quality monitoring data. The model relates in-stream water-quality measurements to spatially referenced characteristics of watersheds, including contaminant sources and factors influencing terrestrial and aquatic transport. SPARROW empirically estimates the origin and fate of contaminants in river networks and quantifies uncertainties in model predictions. See <http://water.usgs.gov/nawqa/sparrow/>.

Stream burning – Overlaying a mapped stream network onto a DEM, creating “trenches” where the stream network exists. Stream burning improves how accurately the resulting DEM flow paths match the streams, to ensure DEM-derived catchment boundaries fit the stream network.

Stream flow – The volume of water flowing past a fixed point in a fixed unit of time.

Stream segment (also see flowline) – Part of a stream, often extending between tributary confluences

T

Total Upstream Accumulation – A method of accumulating attributes downstream along the surface water network features where the accumulated value at any NHDFlowline feature is the total amount of the attribute that is upstream of the network feature.

W

Walling – Using a representation of the known drainage boundaries to build up or mathematically warp a DEM to improve how accurately catchment boundaries replicate known drainage boundaries.

Watershed Boundary Dataset (WBD) – A base-line hydrologic drainage boundary framework, accounting for all land and surface areas of the United States.

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