NHD*Plus Version 1* *(NHDPlusV1)* *User Guide*

September 1, 2010

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This guide is intended for use with the following NHDPlus schema versions.

NHDPlus Component	**Schema Version**
Catchment Grid	01
Catchment Shape	01
Catchment Flowline Attributes	01
Elevation Grid	01
Flow Accumulation & Direction Grids	01
NHD	01
Stream Gage Events	01

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Acknowledgments

NHDPlus is the result of considerable efforts by many organizations and individuals over time. The initial goal of estimating flow volume and velocity for the National Hydrography Dataset (NHD) led us to integrating the NHD with the National Elevation Dataset and the Watershed Boundary Dataset to determine stream segment catchments and their associated drainage areas. This integration made possible many additional geospatial data products found in NHDPlus. We expect that the resulting suite of geospatial products will become a valued data source for the water resources community. A special thank you goes to the primary contributors to the NHDPlus development effort who are listed below.

Tommy Dewald, Project Manager, EPA Office of Water

The NHD*Plus* Team

Tim Bondelid – Independent Consultant (under contract to EPA)
Craig Johnston – U.S. Geological Survey (USGS)
Cindy McKay – Horizon Systems Corporation (under contract to EPA)
Rich Moore – U.S. Geological Survey (USGS)
Alan Rea – U.S. Geological Survey (USGS)

Other Participants in the Initial NHD Catchment Development Evaluation

Jon Goodall – University of Texas at Austin (UT)
Sue Greenlee – U.S. Geological Survey (USGS)
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Greg Schwarz – U.S. Geological Survey (USGS)
Pete Steeves – U.S. Geological Survey (USGS)
Kris Verdin – Hughes STX (under contract to USGS)
Bruce Worstell – Hughes STX (under contract to USGS)

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Chapter 1 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 includes a stream network based on the medium resolution NHD (1:100,000 scale), improved networking, feature naming, and "value-added attributes" (VAA). NHDPlus also includes elevation-derived catchments produced using a drainage enforcement technique first broadly applied in New England, and thus dubbed "The New-England Method." This technique involves enforcing the 1:100,000-scale NHD drainage network by modifying the NED elevations to fit with the network via trenching and using the WBD, where certified WBD is available, to enforce hydrologic divides. The resulting modified digital elevation model (DEM) was used to produce hydrologic derivatives that closely agree with the NHD and WBD. An interdisciplinary team from the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA) found this method to produce the best-quality agreement among the ingredient datasets among the various methods tested.

The VAAs include greatly enhanced capabilities for upstream and downstream navigation, analysis, and modeling. Examples include rapidly retrieving all flowlines and catchments upstream of a given flowline, using structured queries rather than slower traditional flowline-by-flowline navigation; subsetting a stream level path sorted in hydrologic order for stream profile mapping, analysis, and plotting; and calculating cumulative catchment attributes using streamlined VAA hydrologic sequencing routing attributes. VAA-based routing techniques were used to produce the NHDPlus cumulative drainage areas and land cover, temperature, and precipitation distributions. These cumulative attributes are used to estimate mean annual flow and velocity.

NHDPlus contains a static copy of the 1:100,000 scale NHD that has been extensively improved. While these updates will eventually make their way back to the central USGS NHD repository, this will not happen prior to distribution of NHDPlus because the update process for the central NHD database at USGS was under development at the time these improvements were being made. Consequently, NHDPlus will contain some temporary database keys. As a result, NHDPlus users may not make additional updates to the NHD portions of NHDPlus with the intent of sending these updates back to the central NHD database. Once the NHDPlus updates have been posted to the central NHD database, a fresh copy of the improved data can be pulled from the NHD Web site (http://nhdgeo.usgs.gov) and that copy will be usable for data maintenance.

The geospatial datasets included in NHDPlus already have been used in an application to develop estimates of mean annual streamflow and velocity for each NHD Flowline in the conterminous United States. The results of these analyses are included with the NHDPlus data.

EPA and USGS have already linked numerous water quality databases to the underlying NHD by assigning NHD stream (Reach) addresses to these entities, which include gaging stations, water quality monitoring sites, and impaired waters, enabling them to be queried and analyzed in up/downstream order. The USGS gaging stations and associated data that were used to validate the NHDPlus flow volume and velocity estimates are included with the NHDPlus data. Figure 1-1 illustrates the NHDPlus Schema.

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

Data Package Content and Directory Structure

ProductionUnits (shapefile)

\NHDPlusRR, where RR is the Hydrologic Region number
    \drainage
        Cat (grid)
        catchment (shapefile)
        \info (info tables for cat grid)
    \hydrography
        nhdflowline (shapefile)
        nhdwaterbody (shapefile)
        nhdpoint (shapefile)
        nhdline (shapefile)
        nhdarea (shapefile)
    \hydrologicunits
        Basin (empty placeholder[1] shapefile)
        Region (empty placeholder shapefile)
        Subbasin (shapefile)
        Subregion (empty placeholder shapefile)
        Subwatershed (empty placeholder shapefile)
        Watershed (empty placeholder shapefile)
    \elev_unit_a (elevation grids for production unit a)
        elev_cm (grid)
        \info (info tables for grids in unit_a)

    (elevation grids for additional production units)

    \fac_fdr_unit_a (fac and fdr grids for production unit a)
        fac (grid)
        fdr (grid)
        \info (info tables for grids in unit_a)

    (fac and fdr grids for additional production units)

    catchmentattributesNLCD (dBase file)
    catchmentattributesTempPrecip (dBase file)
    flowlineattributesFlow (dBase file)
    flowlineattributesNLCD (dBase file)
    flowlineattributesTempPrecip (dBase file)
    headwaternodearea (dBase file)
    NHDFcode (dBase file)
    NHDFeatureToMetadata (dBase file)
    NHDFlow (dBase file)
    NHDFlowlineVAA (dBase file)

NHDHydroLineEvent (empty placeholder dBase file)
NHDHydroPointEvent (empty placeholder dBase file)
NHDMetadata (dBase file)
NHDProcessingParameters (empty placeholder dBase file)
NHDReachCode_Comid (empty placeholder dBase file)
NHDReachCrossReference (dBase file)
NHDSourceCitation (dBase file)
NHDStatus (empty placeholder dBase File)
NHDVerticalRelationship (dBase file)
openme.txt (text)
StreamGageEvent (shapefile)

Figure 1-1 contains a schema diagram of the NHDPlus. The feature classes and tables contained in the grey area are the standard NHD content. The feature classes and tables outside of the grey area are the components added during the building of NHDPlus.

NHDPlus Schema

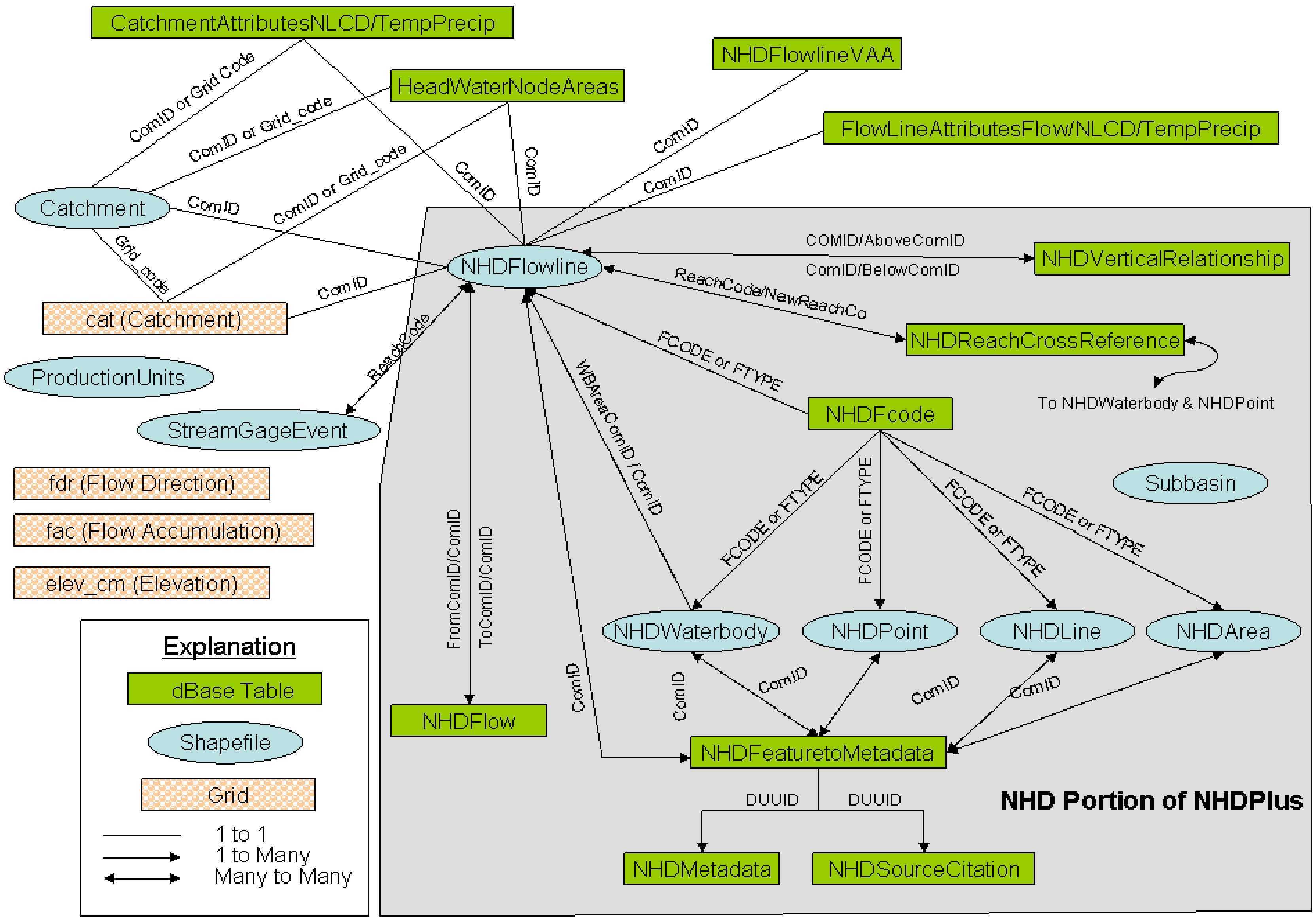

Figure 1-1 – NHDPlus Schema

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Projection Information

All geospatial datasets are stored in one of three projections/coordinate systems.

All vector data in shapefile format use 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) for the conterminous U.S. are stored in an Albers Equal-Area projection:

Projection	ALBERS
Datum	NAD83
Zunits	NO[2]
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)

Grid datasets (cat, fac, fdr, elev_cm) for Hawaii (hydrologic region 20) are stored in the Universal Transverse Mercator (UTM) projection:

Projection	UTM
Zone	4
Datum	NAD83
Zunits	NO[2]
Units	Meters
Spheroid	GRS1980
Xshift	0.0000000000
Yshift	0.0000000000

Grid datasets (cat, fac, fdr, elev_cm) for Puerto Rico and the US Virgin Islands (hydrologic region 21) are stored in the Lambert projection:

Projection	LAMBERT
Datum	NAD83
Zunits	NO[2]
Units	Meters
Spheroid	GRS1980
Xshift	0.0000000000
Yshift	0.0000000000

NHDPlus Versioning System

NHDPlus has a dual versioning system; both the data model schema and the data content are versioned. NHDPlus download .ZIP files each contain the version information in the filename in the form of "Vss_cc", where “ss” is the schema version and “cc” is the data content version. Each component can be versioned and distributed without the need to re-release all components. For example, at any given time, both NHDPlus10LV02_03_CatShape.zip and NHDPlus10LV01_02_NHD.zip might be available for download. In this example, the Catchment shape file has schema version 02 and data content version 03 while the NHD component has schema version 01 and data content version 02.

The NHDPlus download site will contain the most recent version for each component. When a change in NHDPlus 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.

In order to be able to determine which version has been uncompressed onto your computer, the .ZIP files contain a .TXT file with the same name as the .ZIP file. For example, NHDPlus08V01_02_NHD.zip will contain a file called NHDPlus08V01_02_NHD.txt. The file you are reading is one such file.

When NHDPlus .ZIP files are uncompressed, the version text files are stored in the upper level directory of the NHDPlus data. The existence of these .TXT files on your computer means that you, at one time, installed the indicated versions of the indicated NHDPlus components. For example, the presence of the file named NHDPlus08V01_02_NHD.txt means that you have installed Version V01_02 of the NHD component for hydrologic region 08.

If you retain these .TXT files and uncompress updates into the same location, these files will not be overwritten and will serve as a history of what NHDPlus components and versions you have installed.

When you download a current version of an NHDPlus component and wish to replace a previously installed version, you must first delete the existing version of the component from your computer. This is best done with ArcCatalog, but may also be accomplished using Windows Explorer. Once you have deleted the component, use the instructions in the NHDPlus User Guide for unpacking the new version of the component.

Instructions for deleting with ArcCatalog:

Component	Delete
CatGrid	\NHDPlusrr\Drainage\cat
CatShape	\NHDPlusrr\Drainage\catchment
Cat_Flowline_Attr	\NHDPlusrr\catchmentattributesnlcd
	\NHDPlusrr\catchmentattributestempprecip

	\NHDPlusrr\flowlineattributesflow
	\NHDPlusrr\flowlineattributesnlcd
	\NHDPlusrr\flowlineattributestempprecip
	\NHDPlusrr\headwaternodearea
Elev_Unit_x	\NHDPlusrr\elev_unit_x
FAC_FDR_Unit_x	\NHDPlusrr\fac_fdr_unit_x
NHD	\NHDPlusrr\Hydrography
	\NHDPlusrr\HydrologicUnits
	\NHDPlusrr\NHDFcode
	\NHDPlusrr\NHDFeatureToMetadata
	\NHDPlusrr\NHDFlow
	\NHDPlusrr\NHDFlowlineVAA
	\NHDPlusrr\NHDHydroLineEvent
	\NHDPlusrr\NHDHydroPointEvent
	\NHDPlusrr\NHDMetadata
	\NHDPlusrr\NHDProcessingParameters
	\NHDPlusrr\NHDReachCode_Comid
	\NHDPlusrr\NHDReachCrossReference
	\NHDPlusrr\NHDStatus
	\NHDPlusrr\NHDVerticalRelationship
	\NHDPlusrr\TNavwork
	\NHDPlusrr\TNavigation_Events_table
	\NHDPlusrr\TNavigation_Events
ProductionUnits	\NHDPlus\ProductionUnits

Instructions for deleting with Windows Explorer:

Component	Delete
CatGrid	\NHDPlusrr\Drainage\cat
	\NHDPlusrr\Drainage\info
	\NHDPlusrr\Drainage\cat.*
CatShape	\NHDPlusrr\Drainage\catchment.*
Cat_Flowline_Attr	\NHDPlusrr\catchmentattributesnlcd.*
	\NHDPlusrr\catchmentattributestempprecip.*
	\NHDPlusrr\flowlineattributesflow.*
	\NHDPlusrr\flowlineattributesnlcd.*
	\NHDPlusrr\flowlineattributestempprecip.*
	\NHDPlusrr\headwaternodearea.*
Elev_Unit_x	\NHDPlusrr\elev_unit_x
FAC_FDR_Unit_x	\NHDPlusrr\fac_fdr_unit_x
NHD	\NHDPlusrr\Hydrography
	\NHDPlusrr\HydrologicUnits
	\NHDPlusrr\NHDFcode.*
	\NHDPlusrr\NHDFeatureToMetadata.*
	\NHDPlusrr\NHDFlow.*
	\NHDPlusrr\NHDFlowlineVAA.*

	\NHDPlusrr\NHDHydroLineEvent.*
	\NHDPlusrr\NHDHydroPointEvent.*
	\NHDPlusrr\NHDMetadata.*
	\NHDPlusrr\NHDProcessingParameters.*
	\NHDPlusrr\NHDReachCode_Comid.*
	\NHDPlusrr\NHDReachCrossReference.*
	\NHDPlusrr\NHDStatus.*
	\NHDPlusrr\NHDVerticalRelationship.*
	\NHDPlusrr\TNav*.*
ProductionUnits	\NHDPlus\ProductionUnits

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

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Chapter 2 Feature Class Descriptions

cat (catchment grid)

Description: An Environmental Systems Research Institute (ESRI) integer grid dataset that associates each cell with a catchment.

Field Name	Description
Value	The value stored in grid cells A unique identification number for each catchment (compressed numbering system) Also known as Grid_code in related tables
Count	Number of cells with a particular value in the Value field The count equals the number of 30x30 meter grid cells in each catchment
ComID	Common identifier of an NHD Flowline
Prod_unit	Production unit identifier

Catchment (shapefile)

Description: Contains a catchment polygon for each NHD Flowline that received a catchment.

Note: Some polygons may be multipart polygons.

Field Name	Description
ComID	Common Identifier of an NHD Flowline
Grid_code	The value stored in grid cells A unique identification number for each catchment (compressed numbering system)
Grid_count	Number of cells with a particular value in the value field The count equals the number of 30x30 meter grid cells in each catchment Catchment area can be computed from this field
Prod_unit	Production unit identifier
AreaSqKm	Feature area in square kilometers

elev cm (elevation grid)

Description: An ESRI integer grid dataset that gives the elevation in centimeters (from the North American Vertical Datum of 1988). The elevation grid does not contain an associated value attribute table (VAT). The grid was derived from the 30-meter resolution NED and was projected into the national Albers projection.

fac (flow accumulation grid)

Description: An ESRI integer grid dataset that counts the number of cells draining to each cell in the grid. The flow accumulation grid does not contain an associated VAT.

fdr (flow direction grid)

Description: The values in this grid are codes indicating the direction water would flow from each grid cell.

Field Name	Description
Value	The value stored in grid cells. A grid cell can be assigned one of eight possible values: 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
Count	Number of cells with a particular value in the Value field

NHDFlowline (shapefile)[3]

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

Note: The edits made to these features during the building of NHDPlus will be loaded into the National NHD database at USGS sometime after NHDPlus is released. New flowlines, split flowlines, and merged flowlines have temporary ComIDs of the format 9nnnnnnnn. Permanent ComIDs will be assigned when the edits are processed by USGS.

Field Name	Description
ComID	Common identifier of the NHD feature
FDate	Feature Currency Date
Resolution	Always “Medium” (i.e., 1:100K scale)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name
GNIS_Name	Feature Name from the Geographic Names Information System
LengthKM	Feature length in kilometers
ReachCode	Reach Code assigned to feature
Flowdir	Flow direction is “WithDigitized” or “Uninitialized”
WBAreaComI	ComID of an NHD polygonal water feature through which an NHD “Artificial Path” flowline flows
FType	NHD Feature Type
FCode	Numeric codes for various feature attributes in the NHDFCode lookup table
Shape_Leng	Feature length in decimal degrees
Enabled	Always “True”

NHDWaterbody (shapefile) [3]

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

Note: Some waterbody features in the National NHD database at USGS have been merged across quadline boundaries. Therefore, some waterbody features distributed with NHDPlus are slightly different from those in the National NHD database. However, after combining waterbody features by Reach Code in either the National NHD database or in NHDPlus, the waterbody Reaches derived should be the same.

Field Name	Description
ComID	Common identifier of the NHD feature
FDate	Feature Currency Date
Resolution	Always "Medium" (i.e., 1:100K scale)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name
GNIS_Name	Feature Name from the Geographic Names Information System
AreaSqKm	Feature area in square kilometers
Elevation	Feature elevation in feet
ReachCode	Reach Code assigned to feature
FType	NHD Feature Type
FCode	Numeric code for various feature attributes; definitions for codes found in the NHDFCode lookup table
Shape_Leng	Feature length in decimal degrees
Shape_Area	Feature area in square decimal degrees

NHDPoint (shapefile) [3]

Description: NHD point features of types: Gate, Lock Chamber, Rapids, Reservoir, Rock, SinkRise, SpringSeep, Water IntakeOutflow, Waterfall, and Well. The National NHD database contains a small sample of gaging station features in NHDPoint. These have been deleted from NHDPlus and replaced with a separate shapefile of all active stream gages (see StreamGageEvent shapefile below).

Field Name	**Description**
ComID	Common identifier of the NHD feature
FDate	Feature Currency Date
Resolution	Always "Medium" (i.e., 1:100K scale)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name
GNIS_Name	Feature Name from the Geographic Names Information System
ReachCode	Reach Code assigned to feature
FType	NHD Feature Type
FCode	Numeric code for various feature attributes; definitions for codes found in the NHDFCode lookup table

NHDLine (shapefile) [3]

Description: NHD linear features of types: Bridge, DamWeir, Flume, Gate, Lock Chamber, Nonearthen Shore, Rapids, Reef, SinkRise, Tunnel, Wall, Waterfall, Sounding Datum Line, and Special Use Zone Limit.

Field Name	**Description**
ComID	Common identifier of the NHD feature
FDate	Feature Currency Date
Resolution	Always "Medium" (i.e., 1:100K scale)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name
GNIS_Name	Feature Name from the Geographic Names Information System
LengthKM	Feature length in kilometers
FType	NHD Feature Type
FCode	Numeric codes for various feature attributes; definitions for codes found in the NHDFCode lookup table
Shape_Leng	Feature length in decimal degrees

NHDArea (shapefile) [3]

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.

Note: Some of these features in the National NHD database at USGS have been merged across quadline boundaries and split at Subbasin boundaries. Therefore, some area features distributed with NHDPlus are slightly different from those in the National NHD database.

Field Name	Description
ComID	Common identifier of the NHD feature
FDate	Feature Currency Date
Resolution	Always “Medium” (i.e., 1:100K scale)
GNIS_ID	Geographic Names Information System ID for the value in GNIS_Name
GNIS_Name	Feature Name from the Geographic Names Information System
AreaSqKm	Feature area in square kilometers
Elevation	Feature elevation in feet
FType	NHD Feature Type
FCode	Numeric codes for various feature attributes; definitions for codes found in the NHDFCode lookup table
Shape_Leng	Feature length in decimal degrees
Shape_Area	Feature area in square decimal degrees

StreamGageEvent (shapefile)

Description: The StreamGageEvent shape file contains the physical locations of the USGS stream gages as well as their location on NHDFlowline features through events linked to reach codes and measures. More information can be found at: http://water.usgs.gov/GIS/metadata/usgswrd/XML/streamgages.xml and http://www.usbr.gov/pmts/hydraulics_lab/twahl/bfi/index.html.

Field Name	Description
ComID	Not populated
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 Identifier/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
Offset	Always zero
EventType	"StreamGage"
Agency_cd	Gov. Agency responsible for the Stream Gage
Station_nm	Station name
State_cd	2 digit state FIPS code of the WSC maintaining the gage. Puerto Rico is listed as a state.
State	2 character state postal abbreviation of the WSC maintaining the gage. Puerto Rico is listed as a state.
Sitestatus	Active (A) or Inactive (I) where active Stream Gage has streamflow data in water year(s) 2003 and/or 2004
DA_SQ_Mile	Reported drainage area in square miles. Stations with drainage area -999999 means there is no reported drainage area in the National Water Information System.
Lon_site	Longitude of the Stream Gage (site) location - gage house in decimal degrees, NAD83
Lat_site	Latitude of the Stream Gage (site) location - gage house in decimal degrees, NAD83
Lon_NHD	Longitude of the NHD location in decimal degrees, NAD83
Lat_NHD	Latitude of the NHD location in decimal degrees, NAD83
NHD2Gage_d	Distance between Stream Gage and NHD Reach
Reviewed	Flag to indicate location review status - Y or N
BFIyrs	Number of years used in the base-flow index computation
BFI_Ave	Average annual base-flow index value (fraction)

Field Name	Description
BFI_Stdev	Standard deviation of annual base-flow index (fraction)
GotBFI	Flag indicating BFI data (1) or no BFI data (2)
Day1	First date of flow data (yyyymmdd)
DayN	Last date of flow data (yyyymmdd)
NDays	Number of days of flow data
NDaysGT0	Number of days of non-zero flow
MIN_	Minimum daily flow for the period of record (cubic feet per second)
P1	1st percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P5	5th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P10	10th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P20	20th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P25	25th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P30	30th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P40	40th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P50	50th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P60	60th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P70	70th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P75	75th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P80	80th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P90	90th percentile of daily flow for the period of record. Negative

Field Name	Description
	values indicate reverse flow; tidal or backwater. (cubic feet per second)
P95	95th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
P99	99th percentile of daily flow for the period of record. Negative values indicate reverse flow; tidal or backwater. (cubic feet per second)
Max_	Maximum daily flow for the period of record. (cubic feet per second)
Ave	Average daily flow for the period of record. (cubic feet per second)
Stdev	Standard deviation of daily flow for the period of record. (cubic feet per second)
GOTQ	Flag indicating flow data (1) or no flow data (0)
HUC	Hydrologic Cataloging Unit (8-digit HUC) of the Stream Gage
HUC_Reg	Hydrologic Region (2-digit HUC) of the Stream Gage
Subregion	Hydrologic sub-region (4-digit HUC) of the Stream Gage
Accounting	Hydrologic accounting unit (6-digit HUC) of the Stream Gage

Subbasin (shapefile) [3]

Description: Boundaries of 8-digit Hydrologic Units (HUC8) used to assign NHD 1:100,000-scale Reach Codes. These HUC8 boundaries are a derivative of the 1:250,000-scale boundaries published by USGS in 1970. These boundaries are not compatible with the more recent Watershed Boundary Dataset.

Field Name	Description
ObjectID	Internal identifier
Source	Source of boundary: 0 – Watershed Boundary Dataset 1 – NHD 2 – Other
HUC_8	8-digit Hydrologic Unit Code, also known as Subbasin code (formerly known as Cataloging Unit code)
HU_8_Name	Text name of Subbasin
Shape_Leng	Feature length in decimal degrees
Shape_Area	Feature area in square decimal degrees

Region (shapefile) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

SubRegion (shapefile) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

Basin (shapefile) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

ProductionUnit (shapefile)

Description: The sub-divisions used to process the elevation data into flow direction and accumulation grids. The production units are distributed as a national shapefile.

Field Name	**Description**
Prod_Unit	Production unit identifier
Area	Area of the production unit
Perimeter	Perimeter of the production unit

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Chapter 3 Attribute Table Descriptions

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.

CatchmentAttributesNLCD for All Hydrologic Regions Except 20 (Hawaii) (dBase file)

Description: National Land Cover Dataset 1992 (NLCD) attributes derived for each flowline catchment.

Note: The NLCD was available only for the conterminous United States. Percentages of the NLCD categories pertain only to the portion of a catchment within the United States but are computed as a percentage of the total area. Thus, any non-zero percentages in fields PCT_CN or PCT_MX must be added to the percentages in the NLCD categories to account for the entire catchment area.

Field Name	**Description**
ComID	Common identifier of an NHD Flowline
Grid_code	Value field from Catchment Grid
NLCD_11	% of catchment area classified as Open Water in NLCD
NLCD_12	% of catchment area classified as Perennial Ice/Snow in NLCD
NLCD_21	% of catchment area classified as Low Intensity Residential in NLCD
NLCD_22	% of catchment area classified as High Intensity Residential in NLCD
NLCD_23	% of catchment area classified as Commercial/Industrial/ Transportation in NLCD
NLCD_31	% of catchment area classified as Bare Rock/Sand/Clay in NLCD
NLCD_32	% of catchment area classified as Quarries/Strip Mines/Gravel Pits in NLCD
NLCD_33	% of catchment area classified as Transitional in NLCD
NLCD_41	% of catchment area classified as Deciduous Forest in NLCD
NLCD_42	% of catchment area classified as Evergreen Forest in NLCD
NLCD_43	% of catchment area classified as Mixed Forest in NLCD
NLCD_51	% of catchment area classified as Shrubland in NLCD
NLCD_61	% of catchment area classified as Orchards/Vineyards/Other in NLCD
NLCD_71	% of catchment area classified as Grasslands/Herbaceous in

Field Name	Description
	NLCD
NLCD_81	% of catchment area classified as Pasture/Hay in NLCD
NLCD_82	% of catchment area classified as Row Crops in NLCD
NLCD_83	% of catchment area classified as Small Grains in NLCD
NLCD_84	% of catchment area classified as Fallow in NLCD
NLCD_85	% of catchment area classified as Urban/Recreational Grasses in NLCD
NLCD_91	% of catchment area classified as Woody Wetlands in NLCD
NLCD_92	% of catchment area classified as Emergent Herbaceous Wetlands in NLCD
PCT_CN	% of catchment area in Canada and not classified in NLCD
PCT_MX	% of catchment area in Mexico and not classified in NLCD
SUM_PCT	Sum of the % catchment areas

CatchmentAttributesNLCD for Hydrologic Region 20 (Hawaii) (dBase file)

Description: The NOAA Coastal Change Analysis Program (C-CAP) attributes derived for each catchment.

Field Name	Description
ComID	Common identifier of an NHD Flowline
Grid_code	Value field from Catchment Grid
HILC_1	% of catchment area classified as Unclassified in National Oceanic and Atmospheric Administration (NOAA) C-CAP
HILC_2	% of catchment area classified as High Intensity Developed in NOAA C-CAP
HILC 3	% of catchment area classified as Low Intensity Developed in NOAA C-CAP
HILC 4	% of catchment area classified as Cultivated Land in NOAA C-CAP
HILC 5	% of catchment area classified as Grassland in NOAA C-CAP
HILC 6	% of catchment area classified as Deciduous Forest in NOAA C-CAP
HILC_7	% of catchment area classified as Evergreen Forest in NOAA C-CAP
HILC_8	% of catchment area classified as Mixed Forest in NOAA C-CAP
HILC_9	% of catchment area classified as Scrub/Shrub in NOAA C-CAP
HILC 10	% of catchment area classified as Palustrine Forested Wetland in NOAA C-CAP
HILC_11	% of catchment area classified as Palustrine Scrub/Shrub Wetland in NOAA C-CAP

Field Name	Description
HILC_12	% of catchment area classified as Palustrine Emergent Wetland in NOAA C-CAP
HILC 13	% of catchment area classified as Estuarine Forested Wetland in NOAA C-CAP
HILC_14	% of catchment area classified as Estuarine Scrub/Shrub Wetland in NOAA C-CAP
HILC_15	% of catchment area classified as Estuarine Emergent Wetland in NOAA C-CAP
HILC 16	% of catchment area classified as Unconsolidated Shore in NOAA C-CAP
HILC 17	% of catchment area classified as Bare Land in NOAA C-CAP
HILC_18	% of catchment area classified as Water in NOAA C-CAP
HILC_19	% of catchment area classified as Palustrine Aquatic Bed in NOAA C-CAP
HILC_20	% of catchment area classified as Estuarine Aquatic Bed in NOAA C-CAP
HILC 21	% of catchment area classified as Tundra in NOAA C-CAP
HILC_22	% of catchment area classified as Snow/Ice in NOAA C-CAP
PCT_CN	% of catchment area in Canada and not classified in NOAA C-CAP
PCT_MX	% of catchment area in Mexico and not classified in NOAA C-CAP
SUM_PCT	Sum of the % catchment areas

CatchmentAttributesTempPrecip (dBase file)

Description: NHDPlus attributes derived for each flowline catchment.

Note: Precipitation and temperature values are the average values over the catchment from the PRISM 1961-90, 2.5-minute (approximately 4 km) resolution data by Daly and Taylor (1998). If a catchment extends into Canada or Mexico, the value will be the average over only the U.S. portion of the catchment. TEMP values are not provided for Hydrologic Region 20 (Hawaii) because TEMP is not needed for the regression-based flow estimates in that region (refer to Step 6 in Appendix A).

Note: In Hydrologic Region 21 (Puerto Rico and the Virgin Islands) Temp values are not provided and Precip values are provided for Puerto Rico only.

Field Name	Description
ComID	Common identifier of an NHD Flowline
Grid_code	Value field from Catchment Grid
Precip	Mean annual precipitation in mm
Temp	Mean annual temperature in degrees centigrade * 10

FlowlineAttributesFlow for All Hydrologic Regions Except 21 (dBase file)

Description: NHDPlus attributes derived for NHD Flowlines.

Field Name	Description
ComID	Common identifier of an NHD Flowline
Grid_code	Value field from Catchment Grid
CumDrainag	Cumulative drainage area in square kilometers(sq km) at bottom of flowline
MAFlowU	Mean Annual Flow in cubic feet per second (cfs) at bottom of flowline as computed by Unit Runoff Method
MAFlowV	Mean Annual Flow (cfs) at bottom of flowline as computed by Vogel Method. In Hydrologic Region 20 (Hawaii), this value is the median annual flow (cfs) as computed using the method of Fontaine, et. al. (1992).
MAVelU	Mean Annual Velocity (fps) at bottom of flowline as computed by Jobson Method (1996) using the flow in MAFlowU.
MAVelV	Mean Annual Velocity (fps) at bottom of flowline as computed by Jobson Method (1996) using the flow in MAFlowV.
IncrFlowU	Incremental Flow (cfs) for Flowline as computed by the Unit Runoff Method
MaxElevRaw	Maximum elevation (unsmoothed) in meters, populated only for headwater Flowlines, -9998 for all non-headwater Flowlines
MinElevRaw	Minimum elevation (unsmoothed) in meters
MaxElevSmo	Maximum elevation (smoothed) in meters
MinElevSmo	Minimum elevation (smoothed) in meters
Slope	Slope of flowline (m/m)

FlowlineAttributesFlow For Region 21(dBase file)

Description: NHDPlus attributes derived for NHD Flowlines.

Field Name	**Description**
ComID	Common identifier of an NHD Flowline
Grid_code	Value field from Catchment Grid
CumDrainag	Cumulative drainage area in square kilometers(sq km) at bottom of flowline
MAFlowU	Mean Annual Flow in cubic feet per second (cfs) at bottom of flowline as computed by Unit Runoff Method
MAVelU	Mean Annual Velocity (fps) at bottom of flowline as computed by Jobson Method (1996) using the flow in MAFlowU.
IncrFlowU	Incremental Flow (cfs) for Flowline as computed by the Unit Runoff Method
MaxElevRaw	Maximum elevation (unsmoothed) in meters
MinElevRaw	Minimum elevation (unsmoothed) in meters, populated only for headwater Flowlines, -9998 for all non-headwater Flowlines
MaxElevSmo	Maximum elevation (smoothed) in meters
MinElevSmo	Minimum elevation (smoothed) in meters
Slope	Slope of flowline (m/m)

FlowlineAttributesNLCD for All Hydrologic Regions Except 20 (Hawaii) (dBase file)

Description: NHDPlus cumulative attributes derived for NHD Flowlines.

Note: The NLCD 1992 was available only for the conterminous United States. Percentages of the NLCD categories pertain only to the portion of a drainage area within the United States but are computed as a percentage of the total drainage area. Thus, any non-zero percentages in fields PCT_CN or PCT_MX must be added to the percentages in the NLCD categories to account for the entire drainage area. The cumulative values represent values at the bottom of the flowline.

Field Name	**Description**
ComID	Common identifier of an NHD Flowline
Grid_Code	Value field from Catchment Grid
CumNLCD_11	% of cumulative drainage area classified as Open Water in NLCD
CumNLCD_12	% of cumulative drainage area classified as Perennial Ice/Snow in NLCD
CumNLCD_21	% of cumulative drainage area classified as Low Intensity Residential in NLCD
CumNLCD_22	% of cumulative drainage area classified as High Intensity Residential in NLCD

Field Name	Description
CumNLCD_23	% of cumulative drainage area classified as Commercial/ Industrial/Transportation in NLCD
CumNLCD_31	% of cumulative drainage area classified as Bare Rock/Sand/ Clay in NLCD
CumNLCD_32	% of cumulative drainage area classified as Quarries/Strip Mines/Gravel Pits in NLCD
CumNLCD_33	% of cumulative drainage area classified as Transitional in NLCD
CumNLCD_41	% of cumulative drainage area classified as Deciduous Forest in NLCDD
CumNLCD_42	% of cumulative drainage area classified as Evergreen Forest in NLCD
CumNLCD_43	% of cumulative drainage area classified as Mixed Forest in NLCD
CumNLCD_51	% of cumulative drainage area classified as Shrubland in NLCD
CumNLCD_61	% of cumulative drainage area classified as Orchards/Vineyards/ Other in NLCD
CumNLCD_71	% of cumulative drainage area classified as Grasslands/ Herbaceous in NLCD
CumNLCD_81	% of cumulative drainage area classified as Pasture/Hay in NLCD
CumNLCD_82	% of cumulative drainage area classified as Row Crops in NLCD
CumNLCD_83	% of cumulative drainage area classified as Small Grains in NLCD
CumNLCD_84	% of cumulative drainage area classified as Fallow in NLCD
CumNLCD_85	% of cumulative drainage area classified as Urban/Recreational Grasses in NLCD
CumNLCD_91	% of cumulative drainage area classified as Woody Wetlands in NLCD
CumNLCD_92	% of cumulative drainage area classified as Emergent Herbaceous Wetlands in NLCD
Cumpct_CN	% of cumulative drainage area in Canada and not classified in NLCD
Cumpct_MX	% of cumulative drainage area in Mexico and not classified in NLCD
CUMSUM_PCT	Sum of the % cumulative drainage areas

FlowlineAttributesNLCD for Hydrologic Region 20 (Hawaii) (dBase file)

Field Name	Description
ComID	Common identifier of an NHD Flowline
Grid_code	Value field from Catchment Grid
CUMHILC_1	% of cumulative drainage area classified as Unclassified in NOAA C-CAP
CUMHILC_2	% of cumulative drainage area classified as High Intensity Developed in NOAA C-CAP
CUMHILC_3	% of cumulative drainage area classified as Low Intensity Developed in NOAA C-CAP
CUMHILC 4	% of cumulative drainage area classified as Cultivated Land in NOAA C-CAP
CUMHILC 5	% of cumulative drainage area classified as Grassland in NOAA C-CAP
CUMHILC_6	% of cumulative drainage area classified as Deciduous Forest in NOAA C-CAP
CUMHILC 7	% of cumulative drainage area classified as Evergreen Forest in NOAA C-CAP
CUMHILC 8	% of cumulative drainage area classified as Mixed Forest in NOAA C-CAP
CUMHILC 9	% of cumulative drainage area classified as Scrub/Shrub in NOAA C-CAP
CUMHILC 10	% of cumulative drainage area classified as Palustrine Forested Wetland in NOAA C-CAP
CUMHILC_11	% of cumulative drainage area classified as Palustrine Scrub/Shrub Wetland in NOAA C-CAP
CUMHILC 12	% of cumulative drainage area classified as Palustrine Emergent Wetland in NOAA C-CAP
CUMHILC 13	% of cumulative drainage area classified as Estuarine Forested Wetland in NOAA C-CAP
CUMHILC 14	% of cumulative drainage area classified as Estuarine Scrub/Shrub Wetland in NOAA C-CAP
CUMHILC 15	% of cumulative drainage area classified as Estuarine Emergent Wetland in NOAA C-CAP
CUMHILC 16	% of cumulative drainage area classified as Unconsolidated Shore in NOAA C-CAP
CUMHILC 17	% of cumulative drainage area classified as Bare Land in NOAA C-CAP
CUMHILC 18	% of cumulative drainage area classified as Water in NOAA C-CAP
CUMHILC 19	% of cumulative drainage area classified as Palustrine Aquatic Bed in NOAA C-CAP
CUMHILC 20	% of cumulative drainage area classified as Estuarine Aquatic Bed in NOAA C-CAP
CUMHILC_21	% of cumulative drainage area classified as Tundra in NOAA C-

Field Name	Description
	CAP
CUMHILC_22	% of cumulative drainage area classified as Snow/Ice in NOAA C-CAP
CUMPCT_CN	% of cumulative drainage area in Canada and not classified in NOAA C-CAP
CUMPCT_MX	% of cumulative drainage area in Mexico and not classified in NOAA C-CAP
CUMSUM_PCT	Sum of the % cumulative drainage areas

FlowlineAttributesTempPrecip (dBase file)

Description: NHDPlus cumulative attributes derived for NHD Flowlines.

Note: AreaWtMAT values are not provided for Hydrologic Region 20 (Hawaii) because Temperature is not needed for the regression-based flow estimates in this region; refer to Step 6 in Appendix A.

Note: In Hydrologic Region 21 (Puerto Rico and the Virgin Islands) AreaWtMAT values are not provided and AreaWtMAP values are provided for Puerto Rico only.

Field Name	Description
ComID	Common identifier of an NHD Flowline
Grid_Code	Value field from Catchment Grid
AreaWtMAP	Area Weighted Mean Annual Precipitation at bottom of flowline in mm
AreaWtMAT	Area Weighted Mean Annual Temperature at bottom of flowline in degree C * 10

HeadWaterNodeArea (dBase file)

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
ComID	Common identifier of an NHD Flowline
Grid_Code	Value field from Catchment Grid
HwNodesqkm	Catchment area in square kilometers that drains to the headwater node of the flowline indicated by ComID

NHDFCode (dBase file) [3]

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

Field Name	**Description**
FCode	A numeric code that represents the feature type plus its encoded attribute values
Descriptio	Text description of feature type and the encoded attributes
CanalDitch	Canal Ditch Type (aqueduct, unspecified)
Constructi	Construction material (earthen, nonearthen, unspecified)
Hydrograph	Intermittent or perennial
Inundation	Inundation Area Type (debris basin, dewatering area, duck pond, general case, percolation basin, retarding basin)
Operationa	Operational Status (abandoned, operational, under construction)
PipelineTy	Pipeline type (aqueduct, general case, penstock, siphon)
Positional	Positional accuracy (approximate, definite, indefinite, not applicable)
Relationsh	Relationship to surface (abovewater, at or near, elevated, underground, underwater, unspecified)
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)
Stage	Elevation stage (Normal Pool, Flood Elevation, Average Water Elevation, Date of Photography, High Water Elevation, Spillway Elevation)
SpecialUse	Special use category (dump site, spoil area)

NHDFeaturetometadata (dBase file) [3]

Description: Links metadata to features.

Field Name	**Description**
ComID	Common identifier for an NHD feature
DUUID	Metadata identifier

NHDFlow (dBase file) [3]

Description: A geometry-independent flow table that is QA/QC'ed for internal consistency and external agreement with flowline geometry. The flow table contains entries for: (1) every pair of flowlines that exchange water, (2) the beginning of each network, and (3) each network terminus where water flows into the ground. At the shoreline, network flowline features have a "non-flowing" connection to coastline features. Coastline features also have "non-flowing" connections to each other.

Field Name	**Description**
FromComID	Common identifier for an NHD Flowline
ToComID	Common identifier for an NHD Flowline
DeltaLevel	Numerical difference between stream level for FromComID and stream level for ToComID
Direction	714 – coastal connection (FromComID flowline may be a coastline and ToComID flowline is always a coastline) 709 – flowing connection 712 – network start (ToComID flowline is a headwater) 713 – network end (FromComID flowline is a network end)
ToComIDMea	Not valued

NHDFlowlineVAA (dBase file) [3]

Description: Value Added Attributes (VAAs) for each flowline that appears in the NHDPlus Flow table.   The NHDFlowlineVAA table is an official part of the NHD schema, however, with the exception of stream level, the VAAs not populated in the NHD data. It's the NHDPlus building process that populates the VAAs. For additional descriptive information about the VAAs, see Appendix A, "Step 1". "Understanding and Using NHDPlus" contains many examples of how to accomplish tasks using the VAAs.

Field Name	**Description**
ComID	Common identifier of NHD Flowline
StreamLeve	Stream level
StreamOrde	Strahler stream order. Always 0.
FromNode	From node number (top of flowline)
ToNode	To node number (bottom of flowline)
Hydroseq	Hydrologic sequence number
LevelPathi	Hydrologic sequence number of most downstream flowline in level path
PathLength	Distance to terminal flowline downstream along the mainpath (kilometers)
TerminalPa	Hydrologic sequence number of terminal flowline
ArbolateSu	An estimate of miles of stream upstream of a flowline. Always 0. (square kilometers
Divergence	0 – not part of a divergence 1 – main path of a divergence 2 – minor path of a divergence
StartFlag	0 – not a headwater flowline 1 – a headwater flowline
TerminalFl	0 – not a terminal flowline 1 – a terminal flowline
DnLevel	Streamlevel of mainstem downstream flowline
ThinnerCod	Ordinal value used to display various network densities
UpLevelPat	Upstream mainstem level path identifier
UpHydroSeq	Upstream mainstem hydrologic sequence number
UpMinHydro	Upstream minimum hydrologic sequence number
DnLevelPat	Downstream mainstem level path identifier
DnMinHydro	Downstream minor path hydrologic sequence number
DnDrainCou	Number of flowlines immediately downstream

NHDHydroLineEvent (dBase file) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

NHDHydroPointEvent (dBase file) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

NHDMetadata (dBase file) [3]

Description: Holds NHD metadata records that can be linked to individual features through the NHDFeaturetoMetadata table.

Field Name	**Description**
DUUID	Metadata identifier
ProcessDes	Process Description
ProssDat	Process Date
AttributeA	Attribute Accuracy Report
LogicalCon	Logical Consistency Report
Completene	Completeness Report
HorizPosit	Horizontal Positional Accuracy Report
VertPositi	Vertical Positional Accuracy Report
MetadataSt	Metadata Standard Name
Metadata_1	Metadata Standard Version
MetadataDa	Metadata Date
DataSetCre	Dataset Credit
ContactOrg	Contact Organization
AddressTyp	Address Type
Address	Address
City	City
StateorPro	State or Province
PostalCode	Postal Code
ContactVoi	Contact Voice Telephone
ContactIns	Contact Instructions

NHDProcessingParameters (dBase file) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

NHDReachcode_ComID (dBase file) [3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

NHDReachCrossReference (dBase file)[3]

Description: This table tracks the creation, change, and deletion of Reach Codes.

Field Name	**Description**
OldReachCo	Old Reach Code
OldReachDa	Old Reach date
NewReachCo	New Reach Code
NewReachDa	New Reach date
OldUpMI	Not used
NewUPMI	Not used
ChangeCode	Change code "A"dd, "D"elete, "11" = 1-1, "P1" or "1M" = Partial-1, "1P" or "M1" = 1-Partial, PP = Partial-Partial
Process	Process code
ReachFileV	Reach file version
OldHUCode	Substr(OldReachCode,1,8)
NewHUCode	Substr(NewReachCode,1,8)

NHDSourceCitation (dBase file)[3]

Description: This table contains NHD metadata source citation records that can be linked to individual features through the NHDFeaturetoMetadata table.

Field Name	**Description**
Title	Title of data source used as input for creating or updating NHD
SourceCita	Source Citation Abbreviation
Originator	Originator
Publicatio	Publication Date
BeginningD	Beginning Date
EndingDate	Ending Date
SourceCont	Source Contribution
SourceScal	Source Scale Denominator
TypeofSour	Type of Source Media
CalendarDa	Calendar Date
SourceCurr	Source Currentness Reference
DUUID	Digital Update Unit Identifier

NHDStatus (dBase file)[3]

Description: This table is always empty in NHDPlus and is included for completeness of the NHD data model.

NHDVerticalRelationship (dBase file)[3]

Description: This table describes locations where NHD Flowline features cross but do not intersect.

Field Name	Description
ComID	Common identifier for the vertical relationship
AboveComID	Common identifier for an NHD Flowline
BelowComID	Common identifier for an NHD Flowline

Openme.txt

Description: This text file provides a file handle for file browse dialogues in user applications. It also contains a small amount of general information about the NHD data.

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Chapter 4 Geographic Coverage of Data Package

All NHDPlus data (except grids) are distributed by hydrologic region, with two exceptions: Region 10 is split into upper and lower and sub-region 0318 is distributed both inside Region 03 and as a standalone area. For NHDPlus grids, the hydrologic regions are divided into production units and all grids are distributed by these units. Figure 4-1 shows the production units for NHDPlus components.

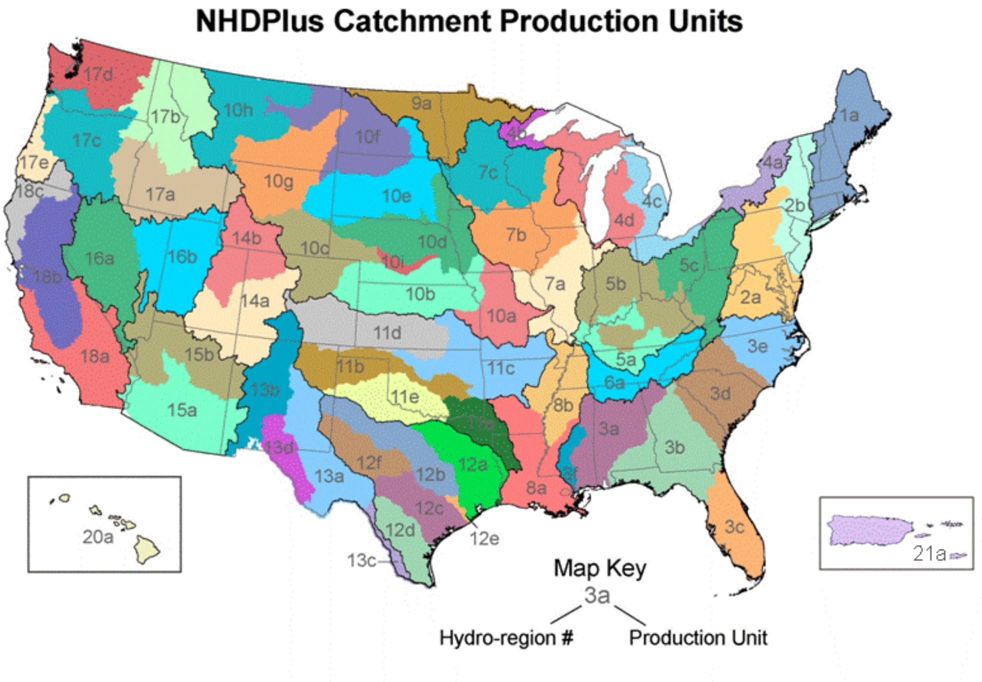

Figure 4-1 – NHDPlus Hydrologic Regions and Production Unit Map

The two-digit Hydrologic Region designations are based on the Hydrologic Unit Coding system in which the United States is divided and sub-divided into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units. Additional information about the coding system is described at
http://water.usgs.gov/GIS/huc.html and
http://www.ncgc.nrcs.usda.gov/products/datasets/watershed/.

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Chapter 5 Understanding and Using NHDPlus

NHDPlus and Divergences

The NHDPlus network includes complex network components, especially divergent and complex flow paths. These types of network components are illustrated in Figure 5-1. Convergent junctions are the simplest types of junctions and pose no problems in downstream routing and accumulating attributes, such as drainage area. Divergent and other types of complex junctions, however, pose particular issues in computing cumulative values. These issues and how the NHDPlus FlowlineAttribute tables compute cumulative values are described below.

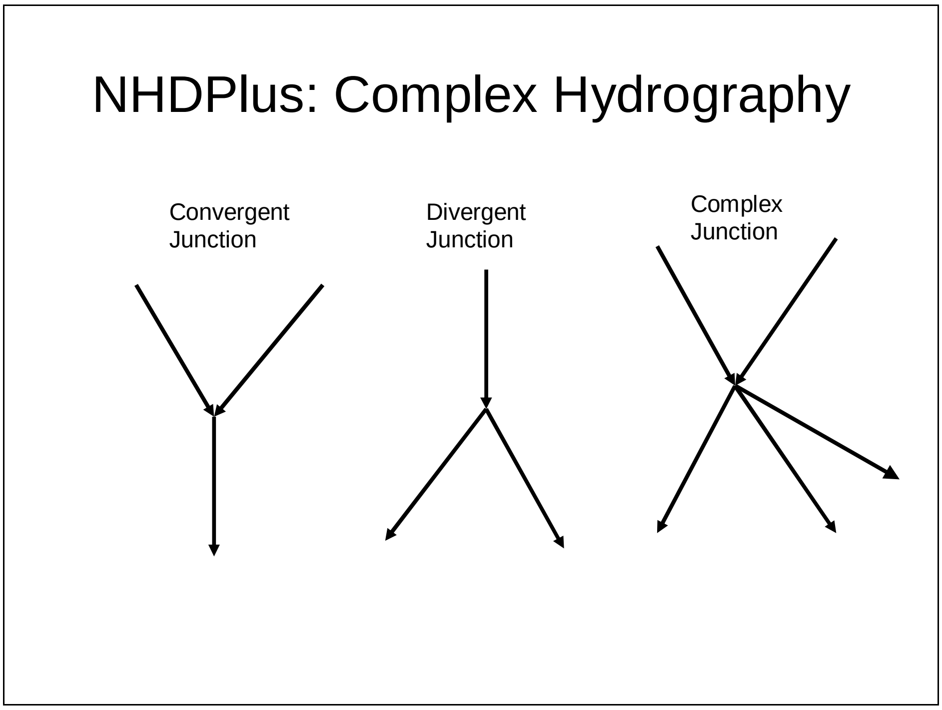

Figure 5-1 – NHDPlus Complex Hydrography

The DIVERGENCE field in the NHDFlowlineVAA Table defines "main" and "minor" paths at divergences. A single 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 5-2.

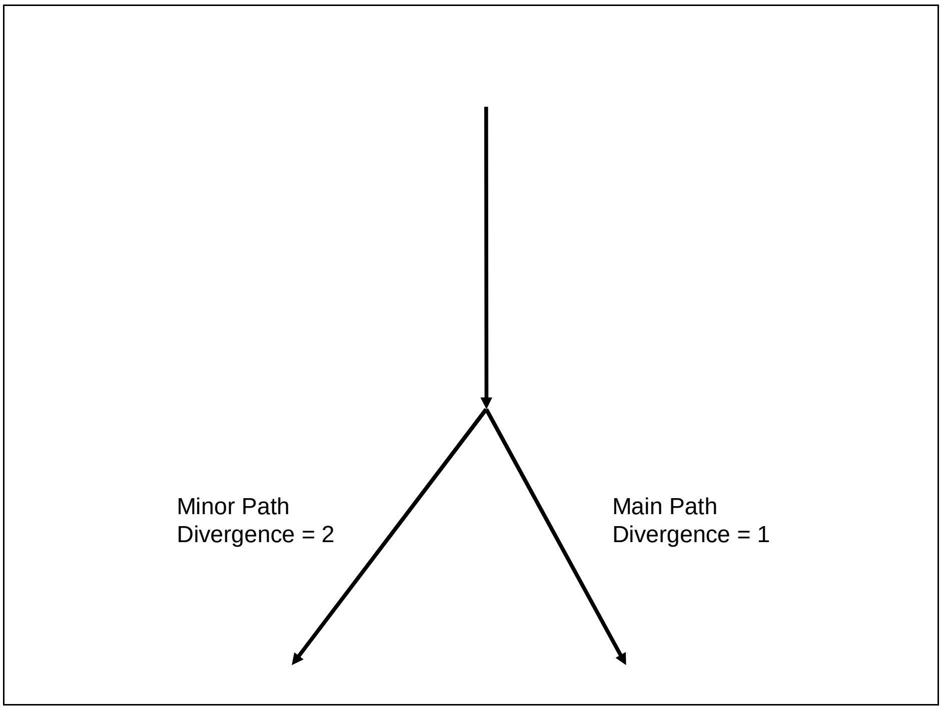

Figure 5-2 – Main and Minor Paths in NHDPlus

In many cases, the divergences are "local", for instance, as shown in Figure 5-3, the red flowlines represent the divergences. The blue lines represent flowlines not affected by these divergences because the divergent streams rejoin at a downstream point.

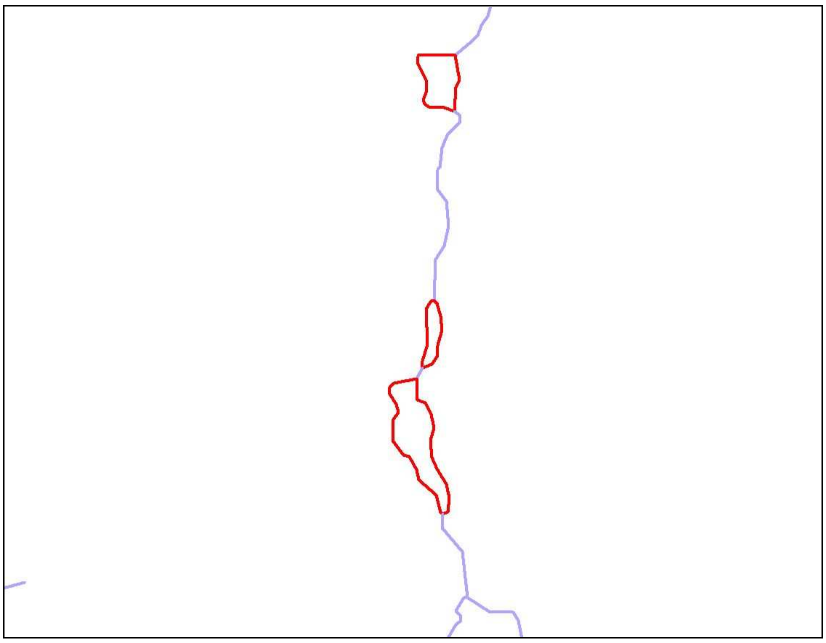

Figure 5-3 – "Local" Divergences

There are many situations in NHDPlus which are much more complex; for instance multiple divergences and divergences where the divergent flowlines never re-join the network downstream. A somewhat more complicated case is shown in Figure 5-4 -. In routing and accumulating downstream, cumulative values will be affected by divergences on the red flowlines while the blue flowlines are not affected by the divergences. As can be seen, the divergences can affect multiple flowlines. There are many divergent areas in NHDPlus which are much more complex; such as braided streams and in coastal areas.

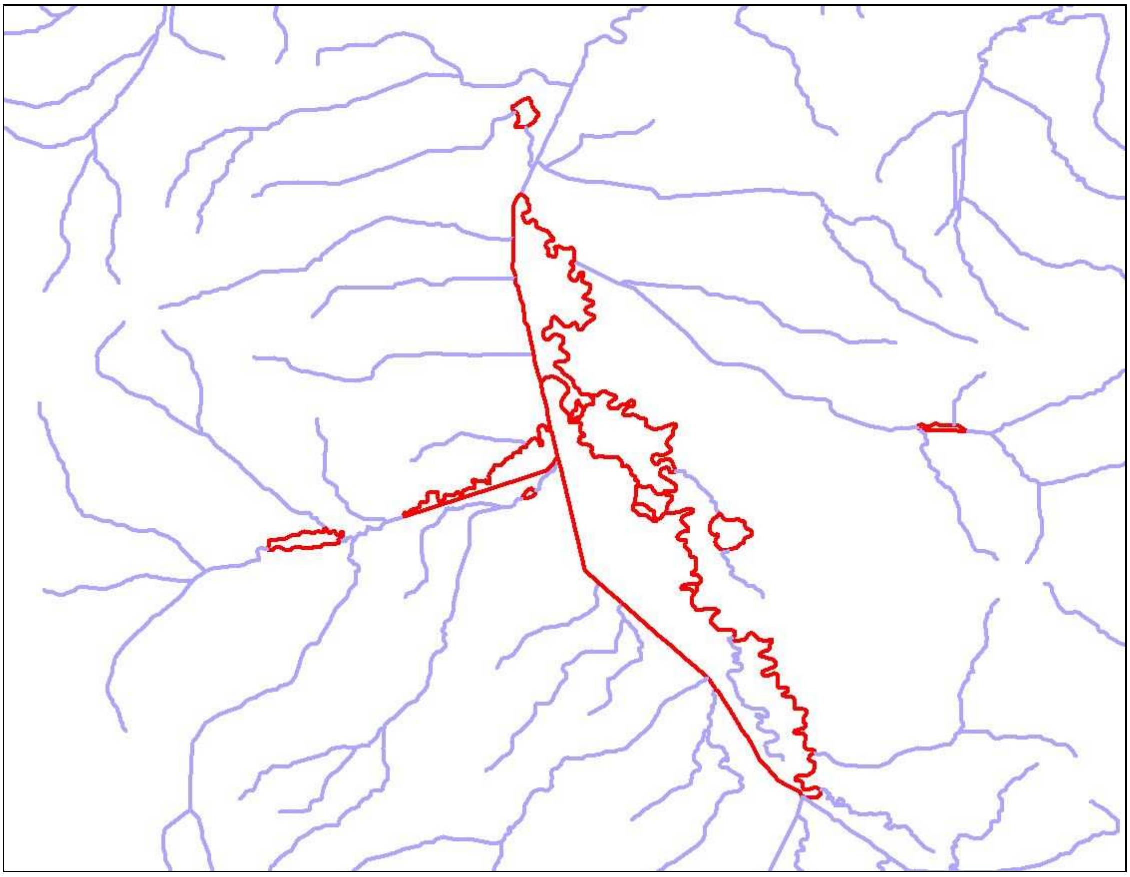

Figure 5-4 — More Complex Divergent Junction Example

<u>How Cumulative Values in the FlowlineAttributeFlow, FlowlineAttributesTempPrecip, and FlowlineAttributesNLCD Tables are valued with Divergences</u>

Various options were considered, such as splitting the drainage areas, flows, etc. evenly between the main and minor paths or setting a default percentage split, such as 75% down the main path and 25% down the minor path. It is essential that the proportional split add up to 100%, or else there would eventually be double-counting of attributes when divergent paths re-entered the network downstream.

The decision made for NHDPlus is to route and accumulate all values down the main path (DIVERGENCE=1), and treat the minor path as essentially a "start/headwater" flowline. This is illustrated in Figure 5-5. The rationale behind this decision is that, given no other contextual information, there is no basis for selecting any particular proportional split. The result of this decision is that, on minor divergent flowlines and the flowlines downstream of the minor divergence that have not re-joined the main path, the values (drainage area, flow, and cumulative Temp, Precip, and NLCD) will not include the cumulative drainage values upstream of the divergence.

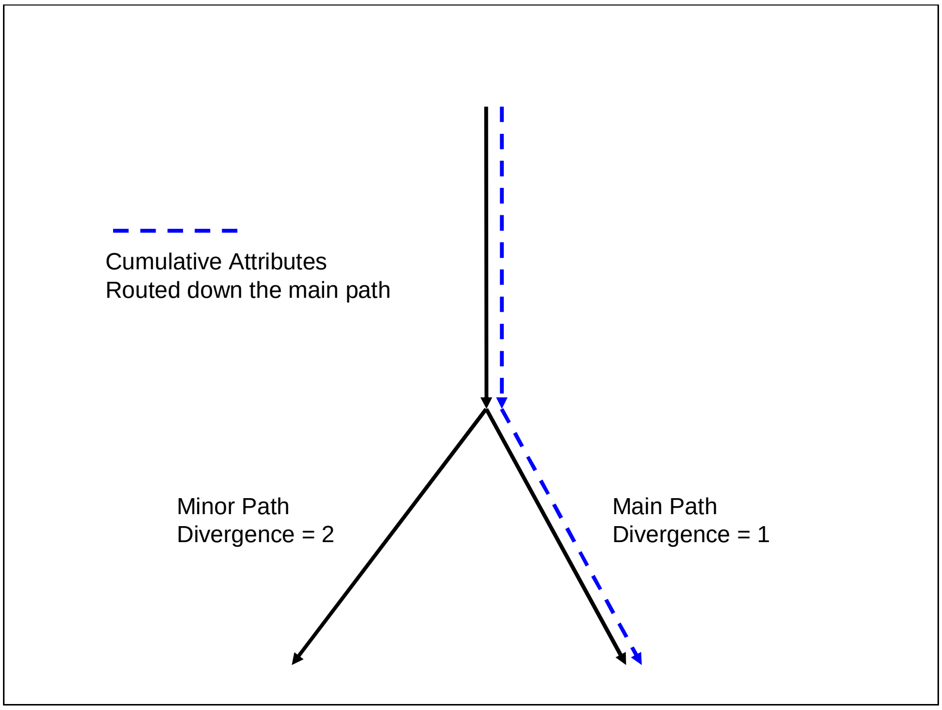

Figure 5-5 – Cumulative attributes routed down the main path

Generating Less Dense Networks from NHDFlowline

A connected network that forms the mainpaths of the 8-digit Hydrologic Unit Codes (i.e., Cataloging Units or Subbasins) may be generated by selecting NHDPlus flowlines that have NHDFlowlineVAA.Thinner = 1. Progressively denser networks may be generated by selecting NHDPlus flowlines that have NHDFlowlineVAA.Thinner <= 2 then 3, 4, 5, and 6.

Understanding NHDPlus Slope

NHDPlus slope is unit-less. It can be viewed as cm/cm or m/m or km/km. The units are the same in both the numerator and denominator and therefore cancel out. Cm/cm appears elsewhere in this documentation to show that it is unit-less.

Minimum and maximum smoothed elevations for flowlines, in the FlowlineAttributesFlow table, are expressed in meters and flowline length, in the NHDFlowline table, is in kilometers. Therefore when slope is calculated with these fields the result is slope in meters per kilometer (m/km):

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

To get the unit-less slope given in NHDPlus the units must be converted as follows:

slope in m/km * 1 km/1000m = slope (unit-less) given in NHDPlus. NHDPlus slopes are constrained to be greater than or equal to 0.00005.

Finding the Upstream Inflows to an NHDPlus Dataset

All NHDPlus regional datasets 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, NHDPlus10L, NHDPlus10R, NHDPlus11, and NHDPlus0318). 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 NHDPlus dataset.

It is possible to determine upstream inflows to any NHDPlus dataset by selecting NHDflow.tocomids where the NHDflow.fromcomid is not in NHDFlowline. If those tocomids are in a particular upstream navigation result, the navigation may be continued in the upstream NHDPlus dataset by starting at the fromcomids.

It is possible to determine downstream outflows from any NHDPlus dataset by selecting NHDflow.fromcomids where the NHDflow.tocomid is not in NHDFlowline. If those fromcomids are in a particular downstream navigation result, the navigation may be continued in the downstream NHDPlus dataset by starting at the tocomids.

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: Query all flowlines with the major river's levelpathid where (pathlength - StartingPathlength) <= desired distance. If the desired stretch of river does not start at the mouth of the river, remove from the query any NHDFlowlineVAA.Hydroseq < the downstream end of the desired stretch NHDFlowlineVAA.Hydroseq.

Then, find the tributaries to the stretch:

> Join the NHDFlow.tocomid to the list of comids from Method1 or Method2.
> All the NHDflow.fromcomid's in the joined records are the downstream flowlines of the tributaries to the desired stretch of main river.

Building an NHDPlus Attribute Accumulator

There are two requirements for attribute accumulation: site specific or throughout the entire network. Site specific accumulation can be done easily with upstream navigation followed by aggregation, based on the navigation results, of any attributes that have been assigned to flowlines or their associated catchments. An entire network accumulation is one where the desired attributes are accumulated for each flowline and saved in an attribute table for future use. Entire network accumulations need a program or script to accomplish the accumulation task. This section addresses the specifications for such a program.

For example, assume that a new attribute has been defined and that incremental values for the attribute have been assigned to each flowline/catchment in the stream network. The objective of accumulation is to aggregate the incremental values such that, at any particular flowline/catchment in the network, the total value of the attribute upstream of the flowline/catchment is computed. Aggregation uses different mathematical operators depending on the attribute being aggregated. For example, drainage area is additive, while the percent of area in forest is computed using an area-weighted average.

There are two essential techniques for accumulating attributes throughout the network: downstream routing and upstream navigation.

The downstream routing method was employed to do the NHDPlus cumulative attributes. This method starts at the top of the network and moves downstream aggregating together the incremental values and storing the result at each flowline/catchment. The advantage of this method is that it is fast, taking only minutes to run. The disadvantage of this method is that it must make decisions at flow splits (divergences) about which way to route the accumulated value. The value may not be routed down both paths of a divergence because, if those diverging paths come back together (which is frequently the case), the accumulation will begin to double-count the attribute. In the NHDPlus accumulation, the decision was made to route the entire accumulated value down the major path of each divergence. (Refer to the "NHDPlus and Divergences" section for additional information.) It is easy to see that the downstream method is very sensitive to errors in divergence classifications. When the wrong path is designated as the major path, the accumulation goes down the wrong path. In addition, flowlines that are downstream of divergences that have not yet returned to the major network path (i.e., unresolved divergences) will not receive the full accumulated value from upstream. This may be appropriate for some attributes but not for others.

The upstream approach is similar to the site specific method where the accumulation for each flowline aggregates all the incremental values from upstream. The advantages of this method are that it is not sensitive to errors in divergence classifications and always gives the full accumulated value regardless of the presence of upstream unresolved divergences. The disadvantage of this method is that it takes some time to run – hours, not minutes.

Since the simplest approach to coding an accumulation script is the downstream routing method, specifications for that method are provided here. As an example, begin with a file that contains flowline/catchment comid and the incremental value for a single attribute that has been assigned to each flowline or catchment. For this specification, assume that the file is called IncrementalAttributeFile and that it has the fields comid and AttrValue.

1. Add to IncrementalAttributeFile a field for the cumulative value for the attribute. Let's call this CumAttrValue.
2. Join IncrementalAttributeFile with NHDFlowlineVAA using comid. For performance, we'll delete from the joined file every record that has hydroseq = 0. These lines are not in the NHDPlus stream network and also do not get catchments, therefore they are not needed in an accumulation.
3. Sort the joined file by Hydroseq descending.
4. Accumulation procedure:
   - 4.1. Get next record from the sorted file. If end of file, quit.
   - 4.2. If Startflag = 1 (i.e., this is a headwater and there is nothing upstream) or 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. Find all the inflows to this current flowline: inflows are records in the joined file where the tonode = 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 mainpath at each divergence. Alternatively, the accumulation may be apportioned to the different paths in the divergence as long as 100% (neither less nor more) of the accumulation is routed.

Flowlines with "known flow" vs. Flowlines with "unknown flow"

There are over 2.9 million flowline features in NHDPlus. Of those, 2.6 million have a known flow direction. This information is contained in an attribute called Flowdir in the NHDFlowline feature class attribute table. Flowdir can have the values "With Digitized" (known flow direction) or "Uninitialized" (unknown flow direction). The flowlines having unknown flow direction are primarily of three types: isolated stream segments, canal/ditches, and some channels inside braided networks. The flowlines with known flow direction are the subset of the NHDFlowline feature class which makeup the NHDPlus surface water network. The "plus" part of NHDPlus is built just for the flowlines with known flow direction. In other words, the catchment shapefile, CatchmentAttributesNLCD, CatchmentAttributesTempPrecip, FlowlineAttributesFlow, FlowlineAttributesNLCD, and FlowlineAttributesTempPrecip contain records for flowlines with known flow direction. When using NHDPlus, it is useful to symbolize the NHDFlowline feature class using the Flowdir attribute. This will help eliminate confusion about what is considered in the NHDPlus surface water network and what is not. In Figure 5-6, the dark blue lines are those NHDFlowlines with known flow direction and, consequently, are included in the "plus" part of NHDPlus. The broad cyan lines are NHDFlowlines with unknown flow direction and, consequently, are not part of the "plus" part of NHDPlus.

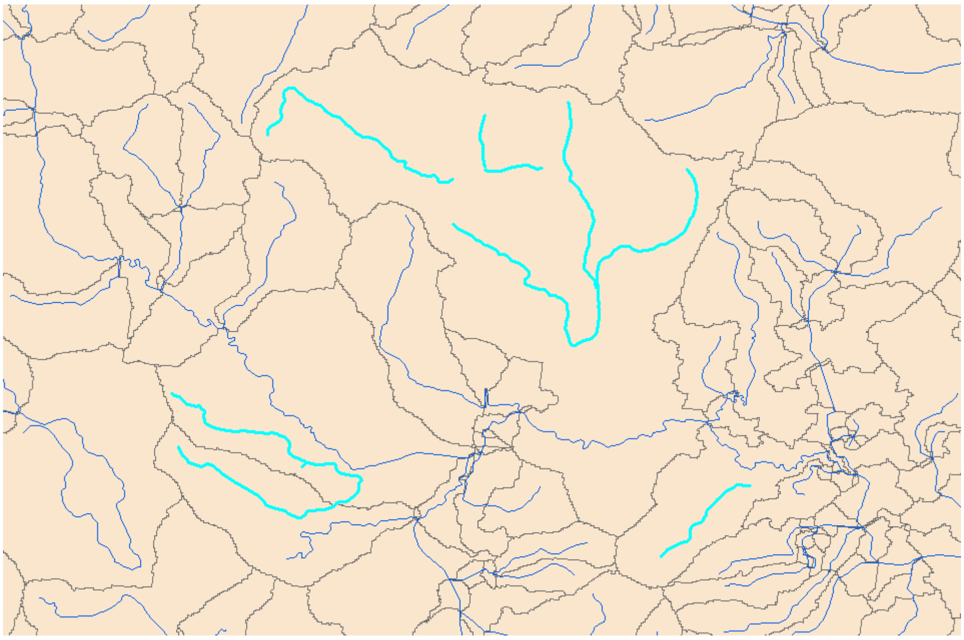

Figure 5-6 – NHD Flowlines With Known and Unknown Flow Direction

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, or to one of the Great Lakes. These features are the ones that compose the NHDPlus "main" flowline network. In addition, NHDPlus contains many isolated networks throughout the U.S. An isolated network is one that appears to terminate into the ground. Many isolated networks truly flow into the ground. These are often called "non-contributing" networks and, while they can occur in any part of the country, they are found primarily found in hydrologic region 16 (The Great Basin) and in south western parts of hydrologic region 17 (Pacific Northwest). Some isolated networks are mapping errors. These networks should be connected to the main NHDPlus network. Figure 5-7 and Figure 5-8 illustrate isolated networks that are non-contributing and mapping errors, respectively.

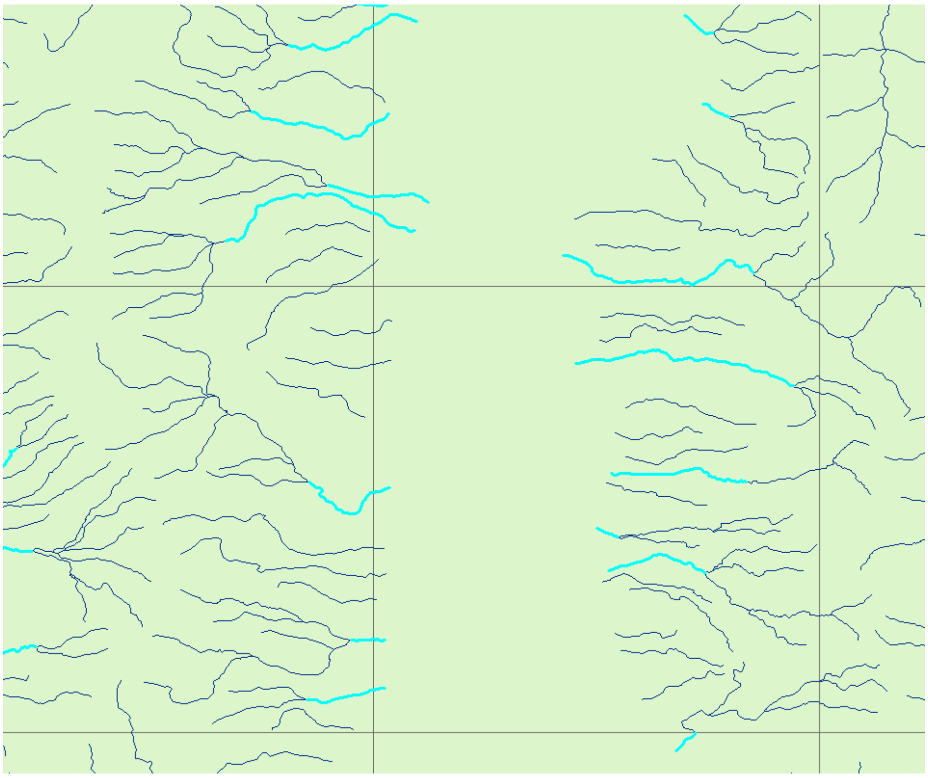

Figure 5-7 – Non-contributing Isolated Networks
Teal lines are the terminal segments of these isolated networks. The straight lines are USGS 7.5-minute quadrangle boundaries.

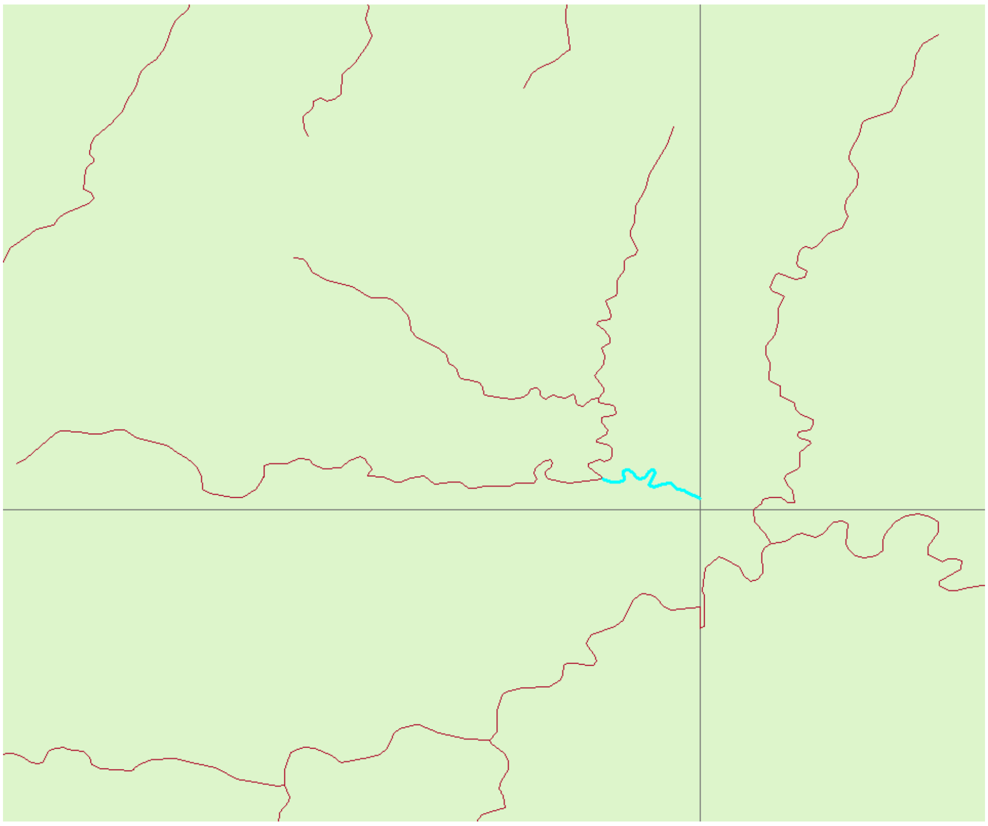

Figure 5-8 – Map error
The cross-hairs are the edges of USGS quad maps.

Isolated networks may be located in any NHDPlus drainage area. To find isolated networks, join the NHDflowlineVAA attribute table to the NHDFlowline feature class using the Comid field in each. Then select all flowlines with NHDFlowlineVAA.Terminalfl = 1. The flowlines selected will be those with known flow direction that are considered by NHDPlus as terminal flowlines.

Disagreements Between the Flow Accumulation Grid and NHD isolated Networks

Figure 5-9 illustrates an uncommon problem between the NHDPlus network and the flow accumulation grid (FAC). The dark blue lines are the drainage channels defined by the FAC. The green lines are the mapped streams in the NHDFlowline feature class. According to the NHD, the teal stream is a terminal flowline of an isolated network. In the NHDFlowline feature class, all the features in this isolated network are flowing toward the teal stream. As shown by the solid blue area of the FAC, this terminal network should have flowed east toward the main network. The flowlines to the southwest of the solid blue area are pointed in the correct direction, while the flowlines north of the solid blue area are pointing north and should be pointed south. A flowline is missing from the NHDPlus near the center of the solid blue area. It should carry flow from the isolated network and connect to the network to the east, approximately following the path taken by the FAC. There is a dam in the area of the missing flowline. Because the flowline was missing, the burning process did not cut through the dam. The filling process filled up the flat area (reservoir) upstream of the dam, resulting in the pattern of flow accumulation that does not follow the flowlines closely, however it did eventually overtop the dam and flow down the stream channel. The smoothed elevations in the FlowAttributesFlow table may also exhibit some strange behavior in areas where the NHD network disagrees with the FAC.

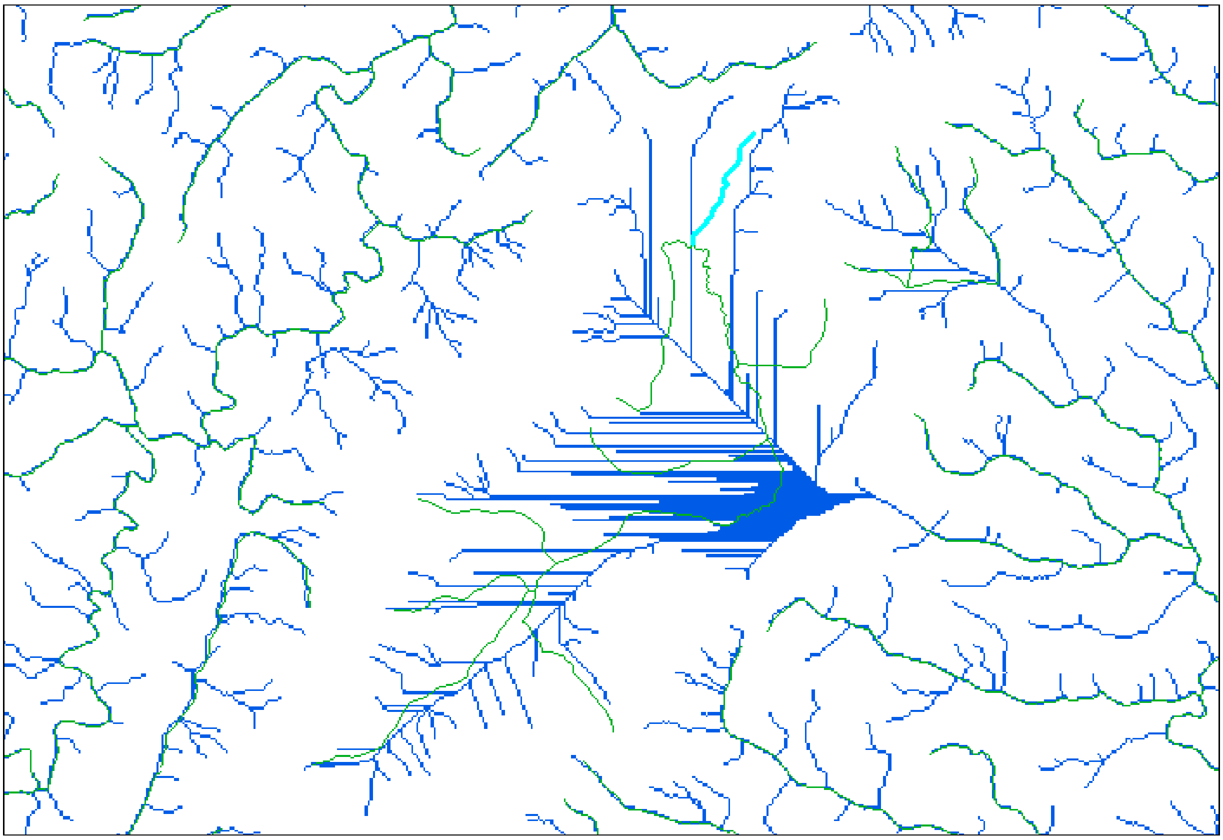

Figure 5-9 – Uncommon problem between the NHDPlus network and the flow accumulation grid

Why does the Identify tool in ArcMap say that the value and ComID from the cat grid are different from the Grid_code and ComID shown in the Catchment shapefile?

In ArcMap version 9.1, the identify tool appears to round grid cell values to six significant digits. Thus a grid cell having the value "2769195" through "2769204" all are reported as having the value "2769200", and the other grid attributes shown are those that go with cell value "2769200". If you select the record in the **cat** grid attribute table, the grid cells having that value are highlighted on the map. You can use this method to verify that the grid values are in agreement with the Grid_code values in the **Catchment** shapefile. This issue has been reported to ESRI and has been fixed in ARCGIS version 9.2..

Why would drainage areas computed using upstream navigation differ from the cumulative drainage areas pre-computed in the NHDPlus?

The cumulative drainage areas pre-computed in NHDPlus are calculated using a downstream routing technique and at divergences all the drainage area is routed down the major path (see section "How to Use NHDPlus" – "NHDPlus and Divergences"). Infrequently, NHDPlus chose the wrong path as the major path and, of those cases, sometimes that path does not return to the main network. In these cases, drainage areas computed using navigation results will be correct and will be greater than the pre-computed NHDPlus drainage which are incorrect. This same issue affects all NHDPlus cumulative attributes such as the NLCD land categories, temperature, and precipitation.

What is the situation with names assigned to artificial paths inside lake/pond waterbodies?

When NHD was originally designed, flowlines inside waterbodies were combined into a single reach, often referred to as a branched reach. When a name was assigned to the reach inside the waterbody, all of the flowlines in the branched reach received that name, thus creating a branched name. When NHD was converted to ArcGIS geodatabase in January 2004, a critical review of the NHD data model was performed and the decision was made to deconstruct the branched reaches into individual reaches; one for each flowline. This affected many thousands of reaches across the U.S. Due to resource constraints, the branched names were not corrected at that time. Therefore, as a named river path is followed, the named path will be linear outside of lake/pond features and branched when it passes through lake/pond features.

Difficulties using NHDPlus Attribute .dbfs in Microsoft Access

When trying to open an NHDPlus attribute table in native dBase format (dbf), you may get the following error message:

"The Microsoft Jet database engine could not find the object 'NHDtable_name.dbf'. Make sure the object exists and that you name its name and path name correctly."

This error message occurs after trying to open the NHDPlus dbf file directly from the Open dialogue box from the MS Access File pull-down menu. The reason for this error is that Microsoft Access 2003 and earlier versions only recognizes dbfs with the DOS 8.3 naming convention, consisting of base file names of 8 characters or less followed by the .dbf file type extension. Many NHDPlus dbf files have much longer names and will not import into Access. To correct the problem, first copy the file and rename it to a name consisting of 8 characters or less, such as "myfile.dbf". It is recommended that you do not rename the original copy of the file because tools built for NHDPlus may need the file and will look for the file using its original file name.

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

The attributes in the NHDFlowLineVAA table provide several powerful capabilities for users. Several of the exercises/tutorials available for the NHDPlus show the power of the VAAs for navigation. The VAAs also provide many other non-navigation capabilities that can be of great value to users of NHDPlus. The objective of this section is to demonstrate several of these non-navigation capabilities and, in the process, these examples can help users better understand and use the VAA data content. 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, Step 2: Computation of Value Added Attributes (VAA)**.

Example 1: ThinnerCod

The ThinnerCod is an ordinal value that helps to display various network densities. The ThinnerCod values range from 0 to 6. ThinnerCod=0 will show all non-networked flowlines, including coastlines and isolated flowlines not included in the network. Figure 5-10 shows an example of ThinnerCod=0 highlighted in red.

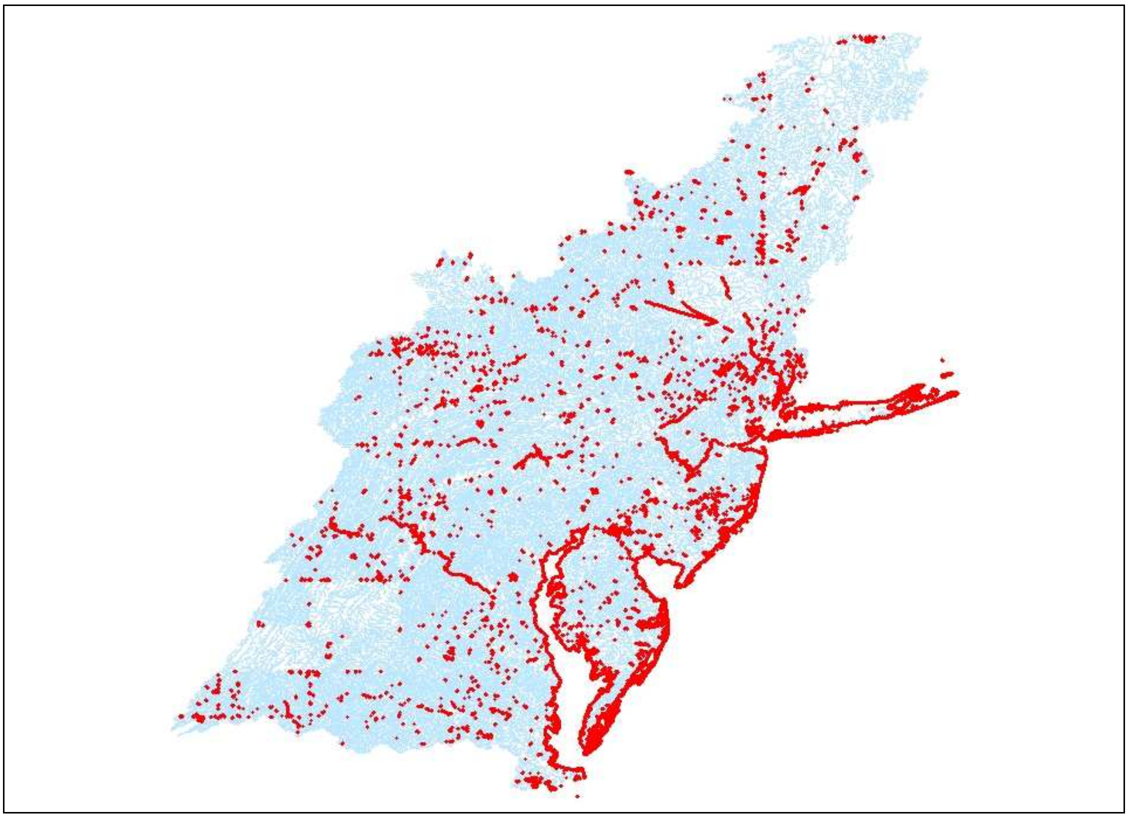

Figure 5-10 – ThinnerCod = 0

A ThinnerCod value of 1 contains the major rivers at a density appropriate for map displays at a small scale. The ThinnerCod = 1 is also very important because it has been built as the backbone network that connects all of the HUC-8's. This can be very useful when you want to extract a complete hydrologically networked set of HUC-8's as a subset of NHDPlus. Figure 5-11 shows ThinnerCod = 1 highlighted in red.

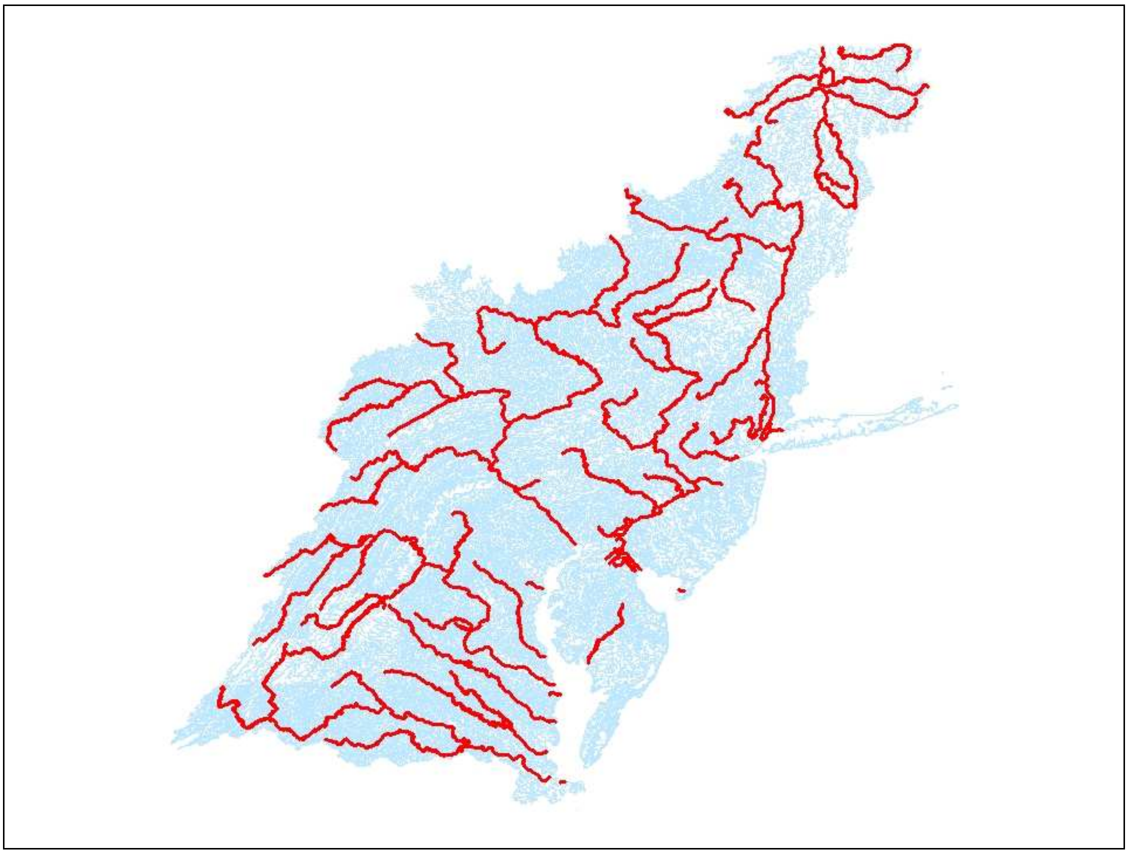

Figure 5-11 – ThinnerCod = 1

Increasing ThinnerCod values provide increasing density of the stream network. For instance, Figure 5-12 shows ThinnerCod values of 1 and 2. Note the increased density in relation to the previous figure. Selection of ThinnerCod values from 1 to 6 will incrementally increase the density until the entire set of networked flowlines is displayed.

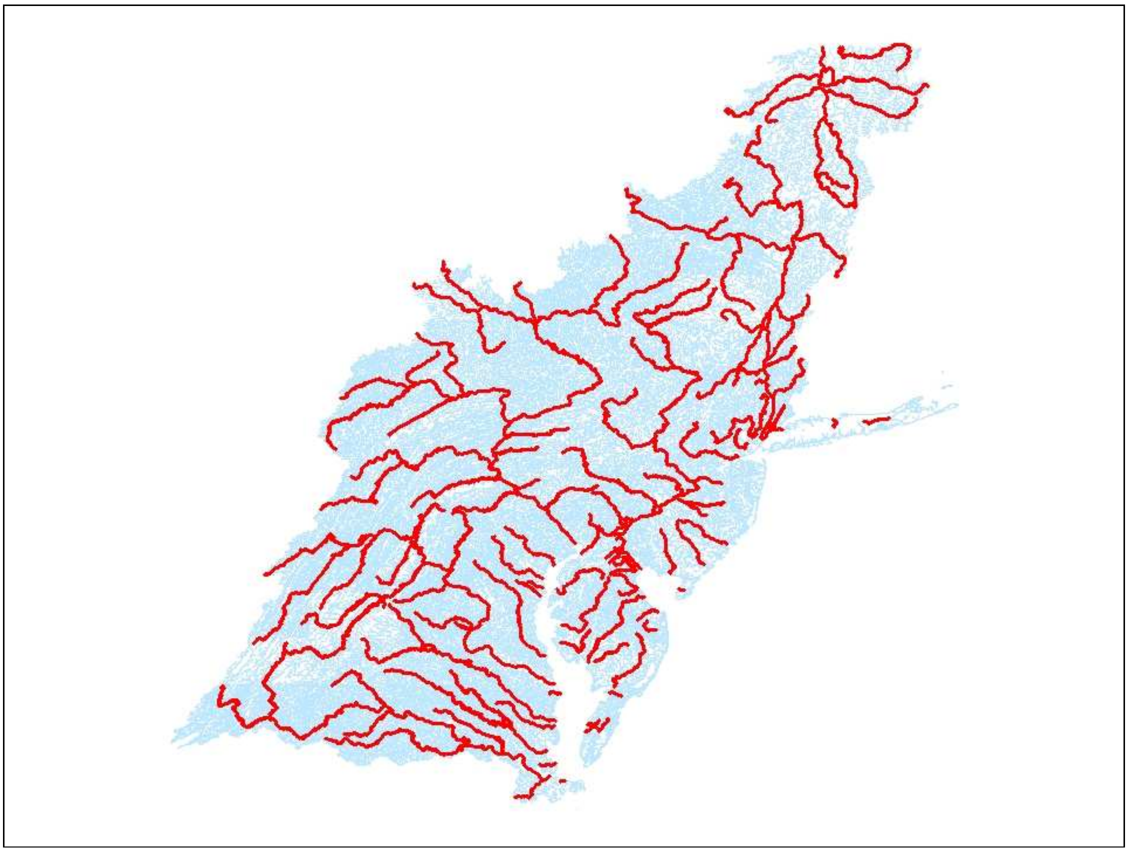

Figure 5-12 – ThinnerCod = 1 or 2

Example 2: Using LevelPathi to Build Your Own "ThinnerCod" based on Stream Length

The mainstem of each stream is assigned a unique identifier named "LevelPathi". LevelPathi is equal to the Hydroseq value of the most downstream flowline on that river. This feature of LevelPathi can be used in conjunction with the flowline Lengthkm attribute found in the NHDFlowline table. The following SQL statement will build a table of the total lengths for each mainstem of every networked stream/river:

SELECT NHDFlowlineVAA.LEVELPATHI, Sum(NHDFlowline!LENGTHKM) AS strmlength INTO strmleng
FROM NHDFlowline INNER JOIN NHDFlowlineVAA ON Flowline.COMID = NHDFlowlineVAA.COMID GROUP BY NHDFlowlineVAA.LEVELPATHI
HAVING (((NHDFlowlineVAA.LEVELPATHI)>0));

The above SQL statement creates a variable named strmlength as the sum of the lengths of all flowlines by LevelPathi and puts the LevelPathi and strmlength variables into a table named "strmleng". Figure 5-13 highlights all of the mainstem rivers greater than or equal to 100 Km in length. Note that any length threshold criteria can be used as desired.

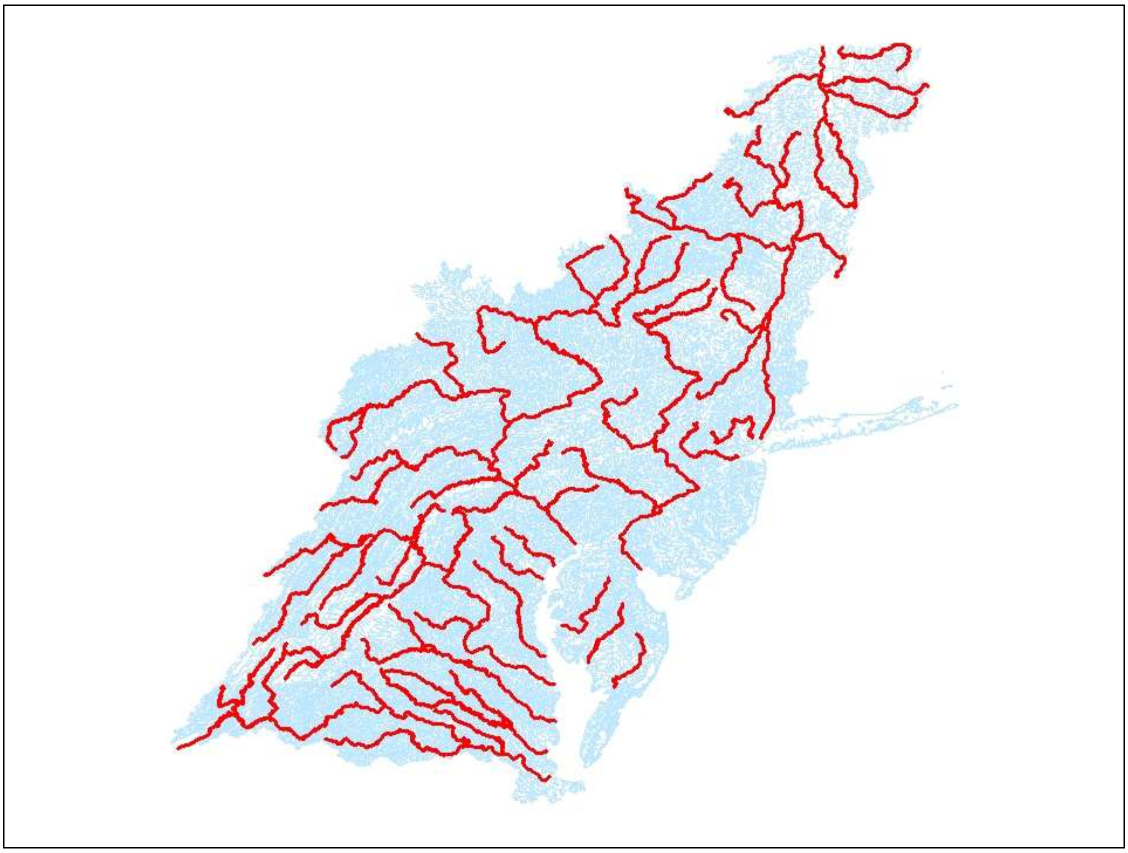

Figure 5-13 – Streams Greater than or Equal to 100 Kilometers in Length

Example 3: Selecting an Individual River or an Individual Terminal River Basin

One use of the LevelPathi was shown in Example 2. That example used the information that every stream has Levelpathi as a unique identifier. In the following examples, uses for LevelPathi and TerminalPa are shown. We will use the Potomac River as our example river. The most downstream Hydroseq for the Potomac River is 9169600001. This means that by the VAA conventions, the LevelPathi for the Potomac mainstem is assigned this value and every networked flowline in the Potomac Basin is assigned this value as the TerminalPA. Figure 5-14 shows the selection of LevelPathi = 9169600001, which selects the mainstem of the Potomac River. Figure 5-15 shows the selection of TerminalPA = 9169600001 which selects the entire Potomac River Basin.

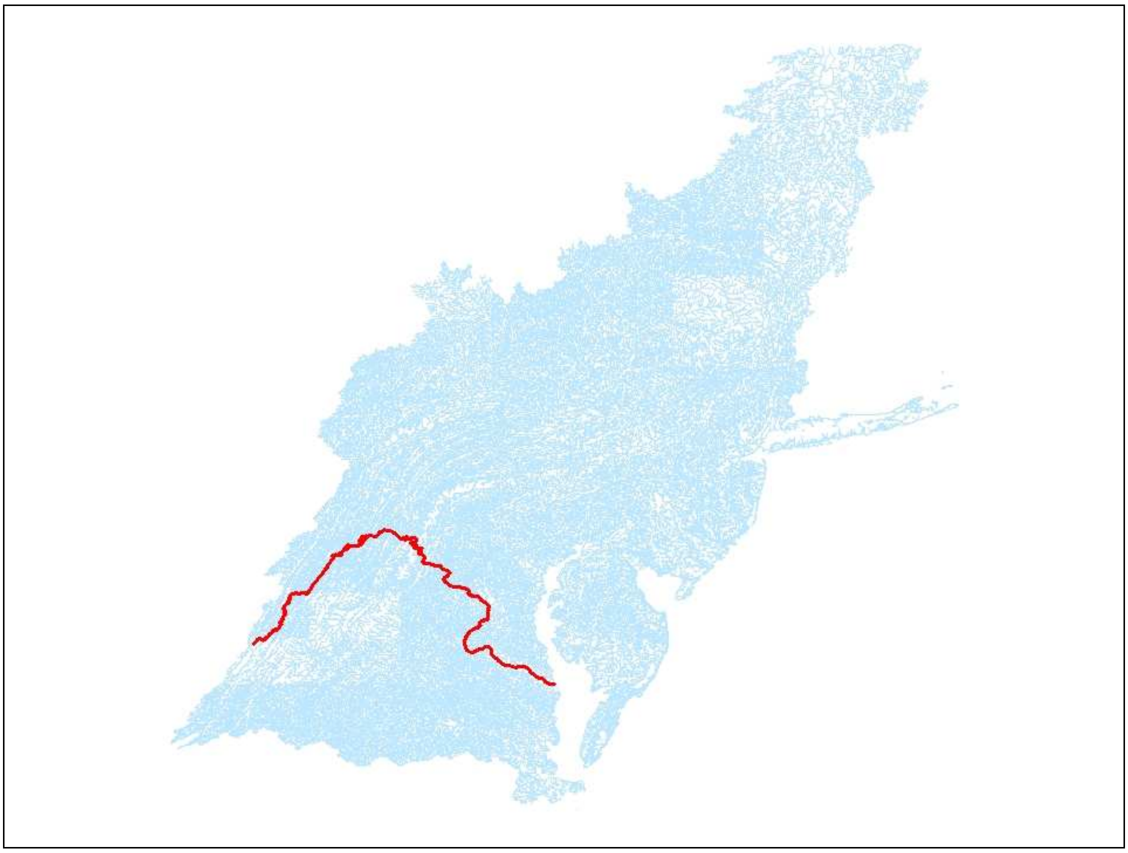

Figure 5-14 – The Mainstem of the Potomac River By Selecting LevelPathi=9169600001

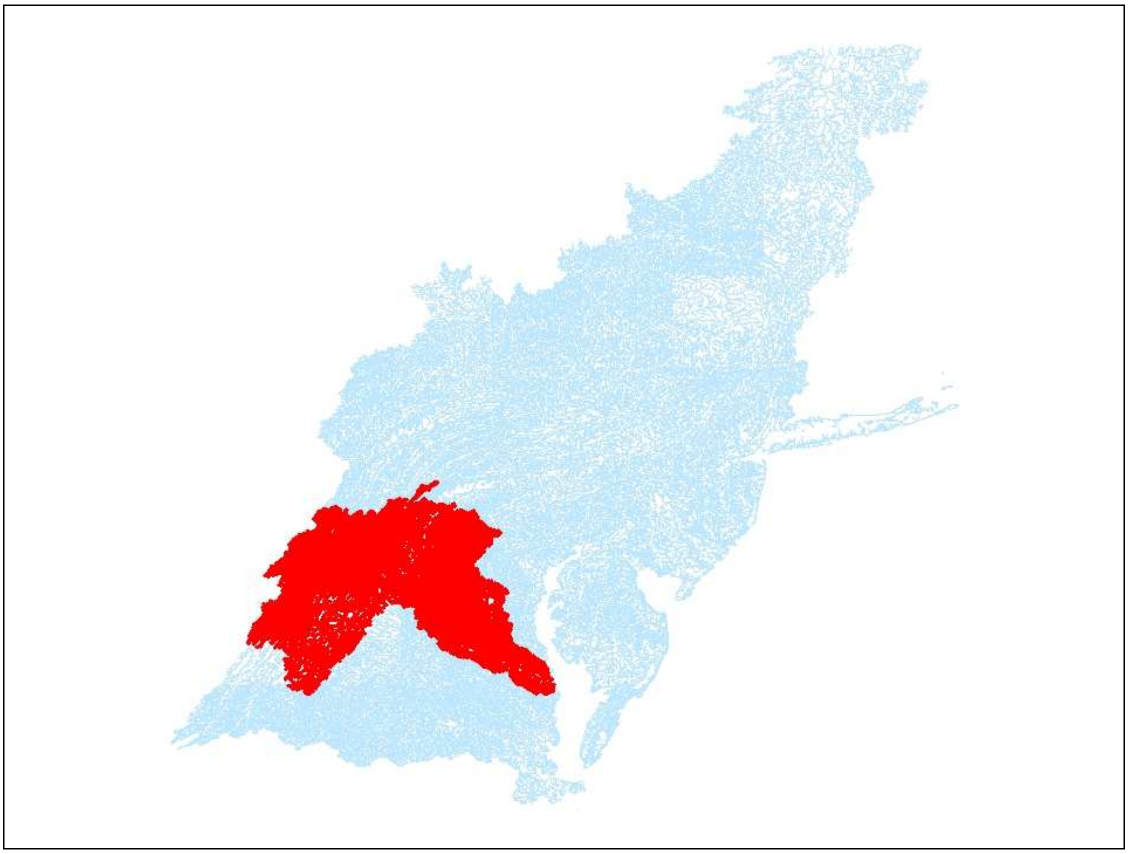

Figure 5-15 – The Potomac River Basin By Selecting TerminalPA = 9169600001

Example 4: 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 VAAs contain the basic information to readily develop profile plots. Previous VAA examples showed how the LevelPathi can be used to identify every flowline on a river. Another VAA, PathLength, is the length from the bottom of the flowline 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.

The basic profile plotting procedure is to select the LevelPathi for the river of interest and assign your data values to the comids of the flowlines of interest. Include the PathLength in the dataset, and then plot your data using PathLength as the x-axis and your data as the y-axis. Of course, multiple types of data can be shown on one graph, such as data versus model results.

This example uses the mainstem of the Potomac River PathLength variable as the x-axis and the “MinElevSmo” elevation values from the FlowLineAttributesFlow table for the y-axis values. This particular plot is interesting because the elevation change near PathLength 180 is dramatic; this is where the Potomac River changes from free-flowing to estuarine. This plot goes from downstream to upstream but it is a simple matter to reverse the x-axis as desired.

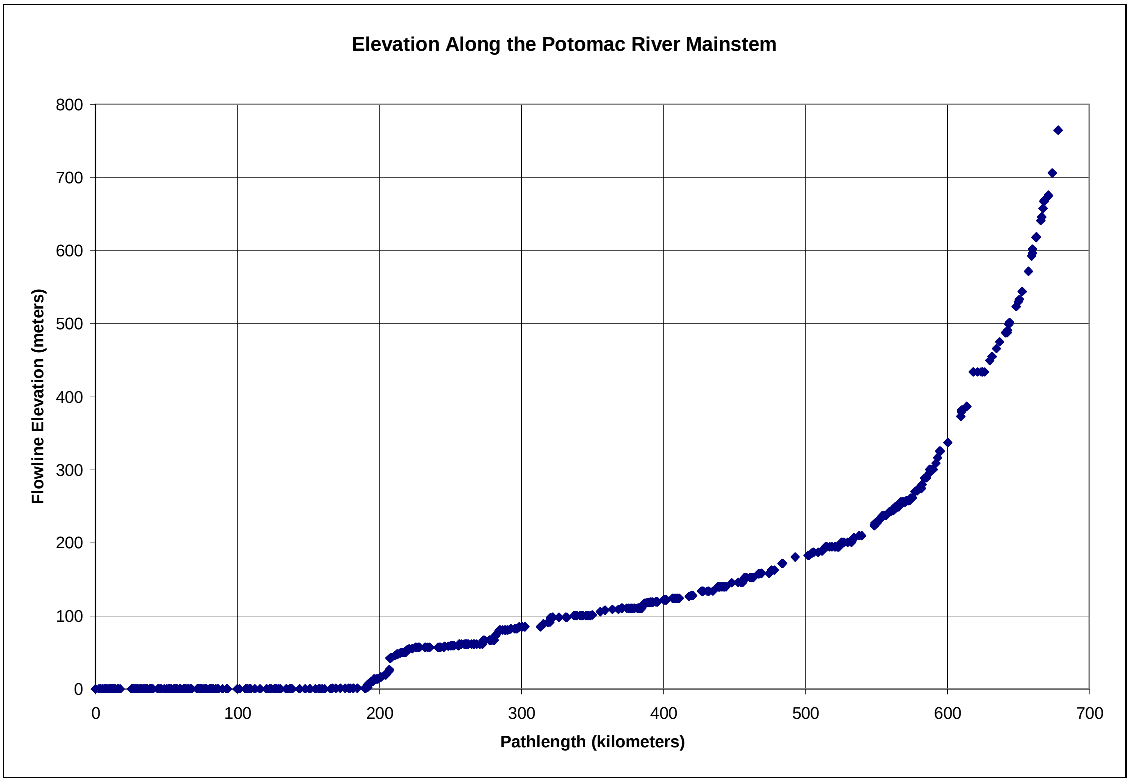

Figure 5-16 – Profile Plot of the Mainstem Potomac River “MinElevSmo” values

Example 5: Stream Order

The NHDPlus stream order is based on the Strahler Method. Stream order is a classic method for ranking streams according to size. Stream order computed for the NHDPlus flowlines is distributed as an NHDPlus data extension in a table called SOSC.dbf

Mapping or classifying flowlines on the basis of stream order can help to rank flowlines by size within the network, selecting out streams of only certain orders, or aggregating data by stream order. A recent example of this last capability, classifying data by stream order can be found in (Alexander, et. al., 2007)

Some examples of mapping by stream order are shown below. Figure 5-17 shows different colors for each stream order for an area in the Midatlantic Region. This figure illustrates how stream order helps rank streams by relative size. Figure 5-18 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 excellent ways to rank or thin the NHDPlus network, especially by using mean annual flow as a criteria; this method is not illustrated here.

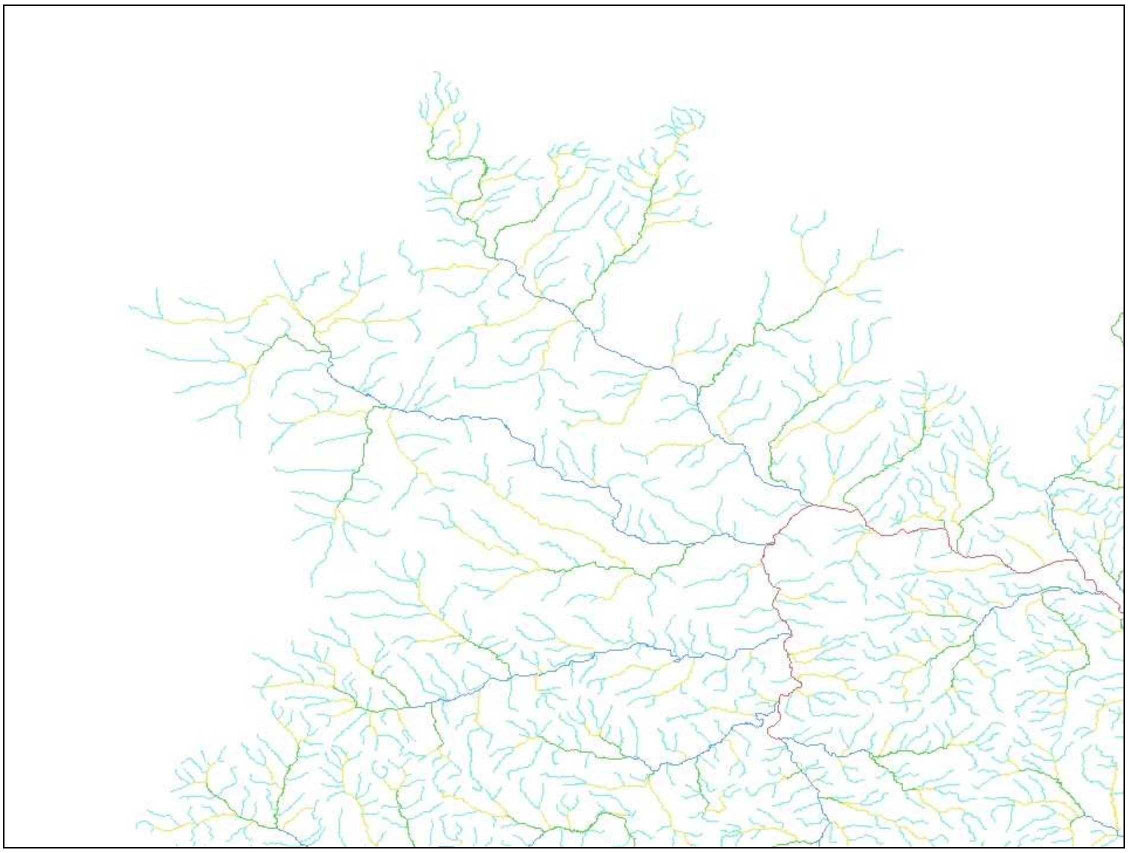

Figure 5-17 – Stream Orders in a Part of the Midatlantic Region

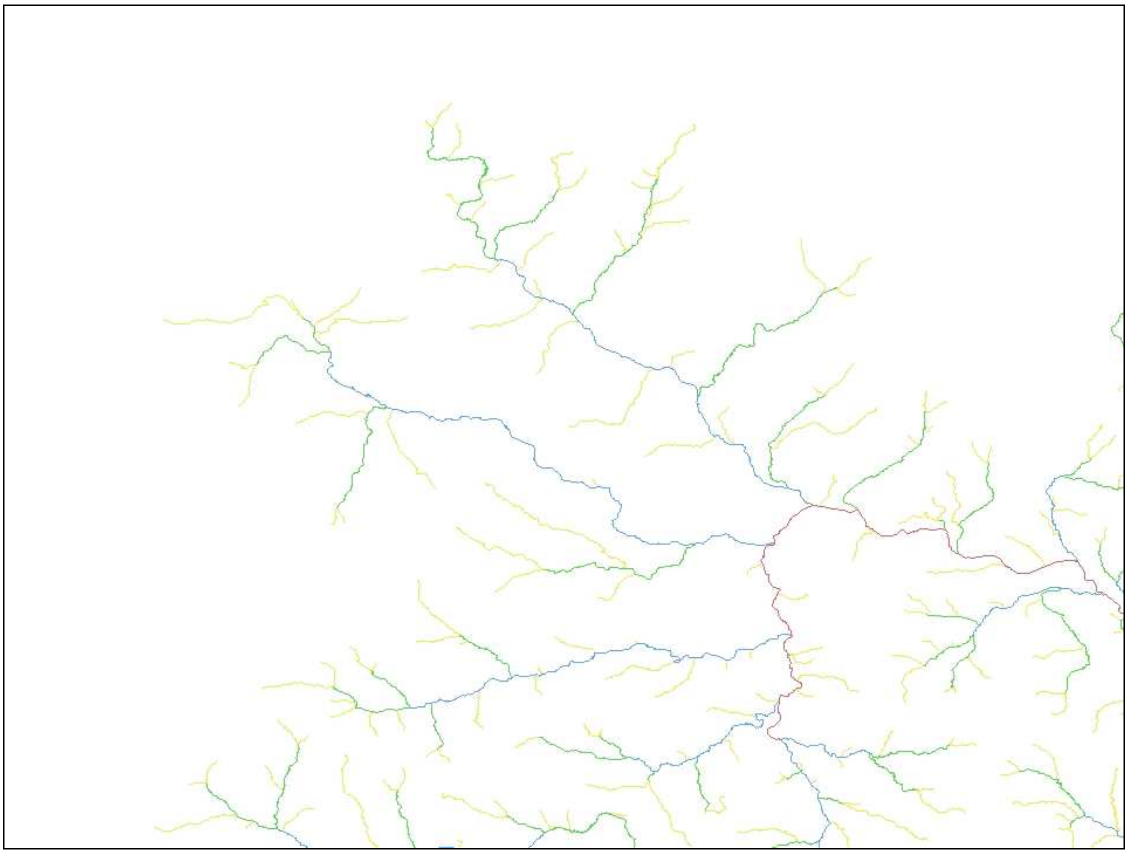

Figure 5-18 – Stream Orders in a Part of the Midatlantic Region with Order 1 Streams Removed

Example 6: Stream Level

The use of Stream Levels, the variable StreamLeve, is often misunderstood or misused by users of the VAAs. Quite often, users think of StreamLeve "as the opposite of Stream Order". But, this is not true in any sense. Streamleve = 1 will apply to the Mississippi mainstem but also to every small or large stream that terminates on the coastline. Therefore, StreamLeve has nothing to do with stream size.

The only valid use of StreamLeve for users is to identify, at a particular junction, what is the mainstem and what is the tributary stream. The lower valued stream levels are the mainstem and the higher valued stream levels are the tributaries. Figure 5-19 illustrates this. The flowlines are labeled with the StreamLeve values. The flowlines going in the north-south direction are Level 2, and the flowline coming in from the West is Level 3. Therefore, the North-South flowlines are the mainstem and the flowline coming in from the West is the tributary.

There are additional aids in the VAAs, for instance using PathLength to determine flow direction. If you want to know which way the North-South stream is flowing, check the Pathlength values of both of these flowlines. In this case, the Pathlength of the South flowline is 400.1 and the Pathlength of the northern flowline is 397.5. Therefore, the northern flowline is closer to the 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 flowline.

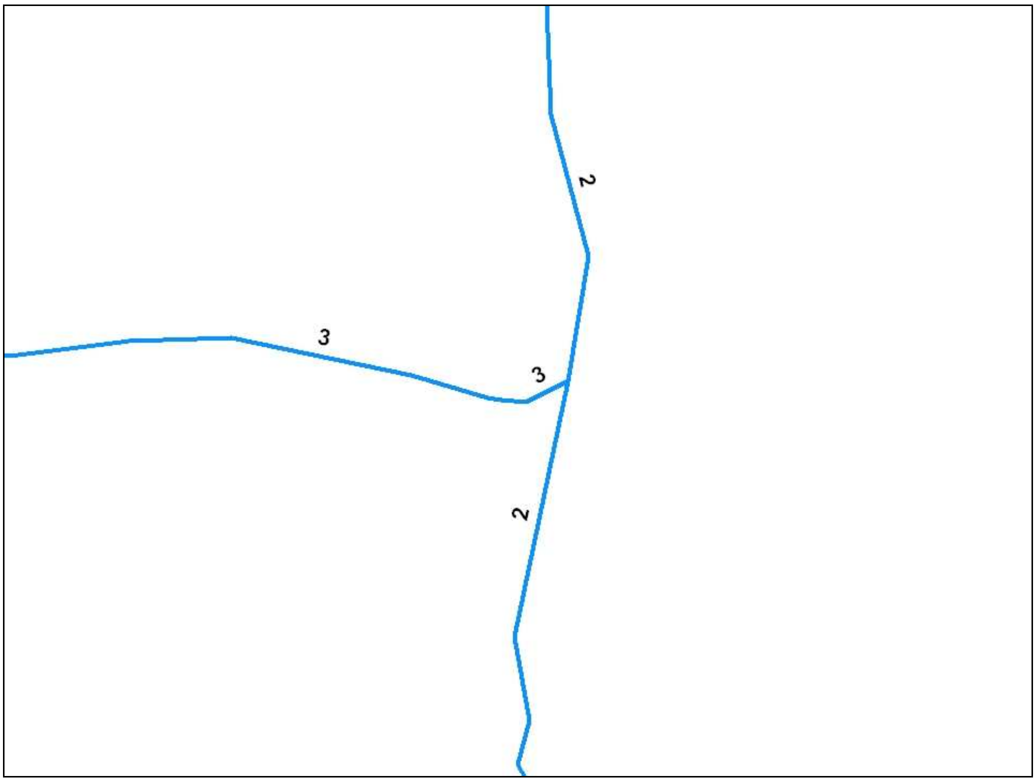

Figure 5-19 – StreamLevel Values at a flowline Junction

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Appendix A – Process Descriptions for NHDPlus

NHDPlus is built in a series of seven steps:

Step 1: Improvements to NHD 1:100K Linear Network and Feature Attributes
Step 2: Computation of Value Added Attributes
Step 3: Development of Catchments, Max/Min Elevations, Flow Accumulation, and Flow Direction Grids
Step 4: Development of International Catchment Areas
Step 5: Development of Catchment Attributes
Step 6: Development of Flow Volume and Velocity Estimates
Step 7: Elevation Post-Processing, Smoothing, and Slope Calculations

Following these seven steps, the data is packaged and QA/QC'ed.

Each of these steps is described in detail in the following sections.

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Step 1: Improvements to NHD[4] 1:100K Linear Network and Feature Attributes

During 2004 and 2005, the 1:100,000-scale NHD surface water network was QA/QC'ed and corrected where necessary. An automatic process was used to identify:

- Reaches with invalid combination of flowline feature types
- Reachable flowline feature that is not part of a linear Reach
- Circular Reaches
- Flowlines that touch internally or more than once
- Non-linear Reaches
- Non-linear flowlines
- Coordinate order that is not consistent with flow or opposing flow, according to flow table
- Flowlines that flow and do not touch, according to flow table
- Flow table entries that are never navigated
- Non-Terminal flowline with no outgoing flow table entry
- Invalid flow table entries
- Non-Start flowline with no incoming flow table entry
- Potential loop in flow table
- Possible outflowing inter-cu connection that needs to be validated
- Possible incoming inter-cu connection that needs to be validated
- Duplicate flow table entry
- Incomplete divergence in flow table

QA/QC and editing was performed at the Subbasin level. Both the flowline geometry and the flow table were edited to correct the network. When a Subbasin was error free, it was navigated from its pour point(s) to find any flowlines that were not connected to the main network. These isolated flowlines were connected where it was possible to determine the proper connection points without reference to external information such as digital raster graphics (DRG) or digital-ortho-photo quads (DOQ)[5].

When all Subbasins in a Hydrologic Region were deemed error free, the Subbasins were appended into a regional dataset, and a regional navigation was performed. Large sets of isolated flowlines were examined with DRGs as a backdrop. If the proper connection points could be determined, the connections were made in both the NHD geometry and the flow table. It was not possible to connect all isolated flowlines.

In addition to the network connectivity QA/QC, the flowline feature names were also QA/QC'ed. Data from the Geographic Names Information System (GNIS) were compared to the names on the NHD Flowlines. Name corrections and additions were made as needed.

Because much of the NHD editing was performed without external reference material, it is possible that flow direction may not be 100 percent correct; however, during Step 7, the NHD network drainage areas are compared to National Water Information System (NWIS) flow gage drainage areas as a final QA/QC procedure.

Step 2: Computation of Value Added Attributes (VAA)

The VAAs are designed to enhance NHD for display, navigation, and analysis. The attributes are computed from existing NHD content rather than additional data collection. The attributes require a fully completed stream network from headwaters to mouth and are computed for large sections of the NHD as follows: Region 01; Region 02; Region 03 (except HUC4 0318); Regions 05, 06, 07, 08, 10, 11, and HUC4 0318; Region 12; Region 13; Regions 14 and 15; Region 16; Region 17; Region18; and Region 20.

The attributes require three full passes of the data. The first pass is from upstream to downstream, followed by a pass from downstream to upstream, with a final pass from upstream to downstream.

There are 20 attributes, as follows:

From Node (FromNode)
A nationally unique ID for the "from" node (i.e. the upstream endpoint) of the flowline. These IDs are independent of the node IDs in an .NAT table in a coverage format workspace. The From Node and To Node numbers provide a node-to-node traversal method used by some modeling software.

To Node (ToNode)
A nationally unique ID for the "to" node (i.e. the downstream endpoint) of the flowline. These IDs are independent of node IDs in an .NAT table in a coverage format workspace. The From Node and To Node numbers provide a node-to-node traversal method used by some modeling software.

Hydrologic Sequence Number (Hydroseq)
A nationally unique sequence number assigned to each flowline; this number places the flowlines into hydrologic sequence. If flowlines are processed by hydrologic sequence number in descending order (i.e., starting at headwaters and proceeding downstream to the network termini), when a flowline is processed, all the flowlines upstream have already been processed. If flowlines are processed by hydrologic sequence number in ascending order (i.e., starting at the network termini and proceeding upstream to the headwaters), when any flowline is processed, all the downstream flowlines have been processed. Hydrologic Sequence Number supports several new navigation methods including traversal through SQL queries.

For a given flowline, it is true that all flowlines upstream have higher hydrologic sequence numbers and all flowlines downstream have lower hydrologic sequence numbers. However, for a given flowline, it is **not true** that all flowlines with higher hydrologic sequence numbers are upstream nor are all flowlines with lower hydrologic sequence numbers downstream.

Start Flag (StartFlag)
Indicates which flowlines are headwaters (i.e., network starts) according to the flowline flow table. This flag is set to "1" if the flowline is a headwater flowline; otherwise, it is set to "0."

Terminal Flag (TerminalFl)
Indicates which flowlines are network ends according to the flowline flow table. This flag is set to "1"" if the flowline is a terminal flowline; otherwise, it is set to "0." A terminal flowline stops at an ocean, the Great Lakes, Canada, Mexico, or it flows into the ground.

Terminal Path Identifier (TerminalPa)
A unique identifier for all the flowlines which flow to the same network terminus based on the flowline flow table. The Hydrologic Sequence Number of the terminal flowline is used as the Terminal Path Identifier. Terminal Path Identifier can be thought of as a "drainage area ID". See also "Terminal Flag".

Level Path Identifier (LevelPathI)
A unique identifier for a stream which is assigned to all the flowlines from the stream's mouth to the stream's headwater. The Hydrologic Sequence Number of the flowline at the mouth of the stream is used for the value of the Level Path Identifier. This attribute is based on the flowline flow table and stream level. Level Path Identifier can be thought of as a "stream ID" and can be used to support applications such as river mile indexes.

Arbolate Sum (Arbolatsu)
Based on the flowline flow table, this is the sum of the lengths of all flowlines above the downstream end of a flowline. This field is empty in the distributed NHDPlus data.

Path Length (PathLength)
Distance from a flowline's downstream end to its terminal flowline's downstream end according to the flowline flow table. Path length is in kilometers.

Thinner Code (ThinnerCod)
An ordinal value designed to allow selection of progressively denser networks. The least dense network is obtained by selecting thinner values of 1 which is the network of major streams and rivers that connect the 8-digit Hydrologic Units (i.e. subbasins or cataloging units). Each successive value of Thinner adds more streams to the network. At any Thinner level, the network is fully connected. Thinner values are designed to be used for improving the performance of Web pages and other applications where the user zooms back and forth between large areas and small areas. There is no hydrologic basis, other than connectivity, for the thinner values and they should NOT be used for stream classification or analysis.

Divergence Flag (Divergence)
If the flow splits into more than one branch (i.e. a flow divergence), and the flowline is one branch of the flow split, the divergence flag is set as follows: "1" if the flowline is the main branch and "2" if the flowline is not a main branch. If the flowline is not a branch of a flow split, the divergence flag = 0.

Stream Level (StreamLeve)
Stream levels are assigned beginning at network termini and working upstream. If the network terminus is at the ocean, the stream level begins with 1. If the network terminus is at the Great Lakes, the stream level begins with 2. If the network ends at the Canadian or Mexican border, the

stream level begins with 3. If the network terminus flows into the ground, the stream level begins with 4. The stream level value is continued upstream, following the main path, until the headwater of the mainpath is reached. Tributaries to the mainpath are assigned the next integral stream level beginning at their mouth and continuing to their headwaters. This process is repeated for each additional level of tributaries until all streams have been assigned a stream level. For example, the Mississippi River is level 1; tributaries to the Mississippi, like the Ohio River, are level 2; and tributaries to the Ohio River, like the Tennessee River, are level 3. Stream level supports upstream mainstream navigation and is NOT intended to be used for stream classification or analysis.

Downstream Level (DNLevel)
Downstream flowline level is the stream level of the downstream mainstem flowline. This attribute supports downstream mainstem navigation.

Stream Order (StreamOrde)
This attribute has been replaced by the Stream Order/Stream Calculator data distributed as an NHDPlus data extension. The table is called SOSC.dbf. The field NHDFlowlineVAA.StreamOrde has been set to 0 to encourage the use of the better values found in SOSC.dbf.

Upstream Level Path Identifier (UpLevelPat)
This is the level path identifier of the mainstem flowline which is immediately upstream. This attribute supports navigation traversals through SQL queries.

Upstream Hydrologic Sequence Number (UpHydroSeq)
Hydrologic Sequence Number of the immediately upstream mainstem flowline. This attribute supports navigation traversals through SQL queries.

Upstream Minimum Hydrologic Sequence Number (UpMinHydro)
Minimum Hydrologic Sequence Number of all immediately upstream flowlines. This attribute supports navigation traversals through SQL queries.

Downstream Level Path ID (DnLevelPat)
This is the level path identifier of the downstream mainpath flowline. This attribute supports navigation traversals through SQL queries.

Downstream Flowline Count (DnDrainCou)
This is the number of flowlines immediately downstream. This attribute supports navigation traversals through SQL queries.

Downstream Minor Hydrologic Sequence Number (DNMinHydro)
At a divergence, the Hydrologic Sequence Number of the immediately downstream minor path flowline. If multiple minor paths exist, this is the maximum hydrologic sequence number of all minor paths.

Step 3: Development of Catchments, Max/Min Raw Elevations, Flow Accumulation and Flow Direction Grids, Max/Min Raw Stream Channel Elevations, and Headwater Node Areas

Catchments

Catchments were generated for each NHD Flowline that appears in the NHDFlow table. To create catchments, the flowlines were rasterized to serve as the source grid for the ARC/INFO GRID module command, WATERSHED (ESRI, 1999). Catchments were developed upslope from these stream-network grid cells. A flow direction grid derived from a Digital Elevation Model (DEM) was also required as input for the WATERSHED command. The flow direction grid was produced using a hydrologically-conditioned DEM called HydroDEM. The source DEM was obtained from the 30-meter resolution NED and was projected into the national Albers projection for each production unit. These projected DEMs (elevation grids), are provided in the NHDPlus product suite.

Modifications were applied to the DEMs to produce the HydroDEM. These modifications were considered necessary because often the drainage path (flowpath) 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-1a 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-1b).

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 in an Arc Macro Language (AML) program called AGREE, developed by Hellweger (1997). Figure A-1c illustrates how the AGREE program corrects for DEM flow path displacement errors when delineating catchments.

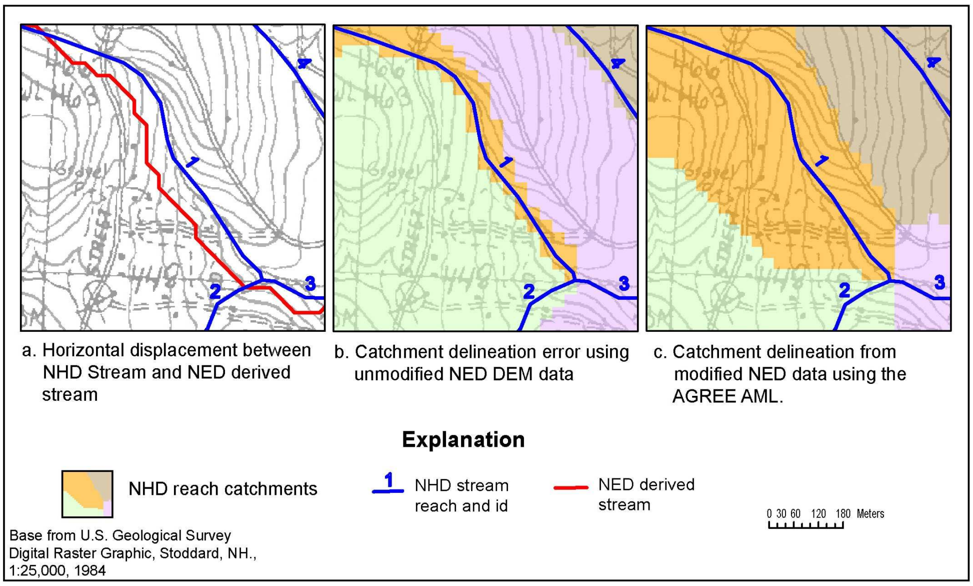

Figure A-1 – (a) Differences in drainage between the NHD and flow paths of a NED-derived stream, (b) Resultant NHD catchment delineations using unmodified NED DEM data, and (c) Resultant NHD catchment delineations using AGREE-modified NED data.

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 "smoothes" 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-2 illustrates how AGREE changes the original DEM using all the specified parameters of AGREE.

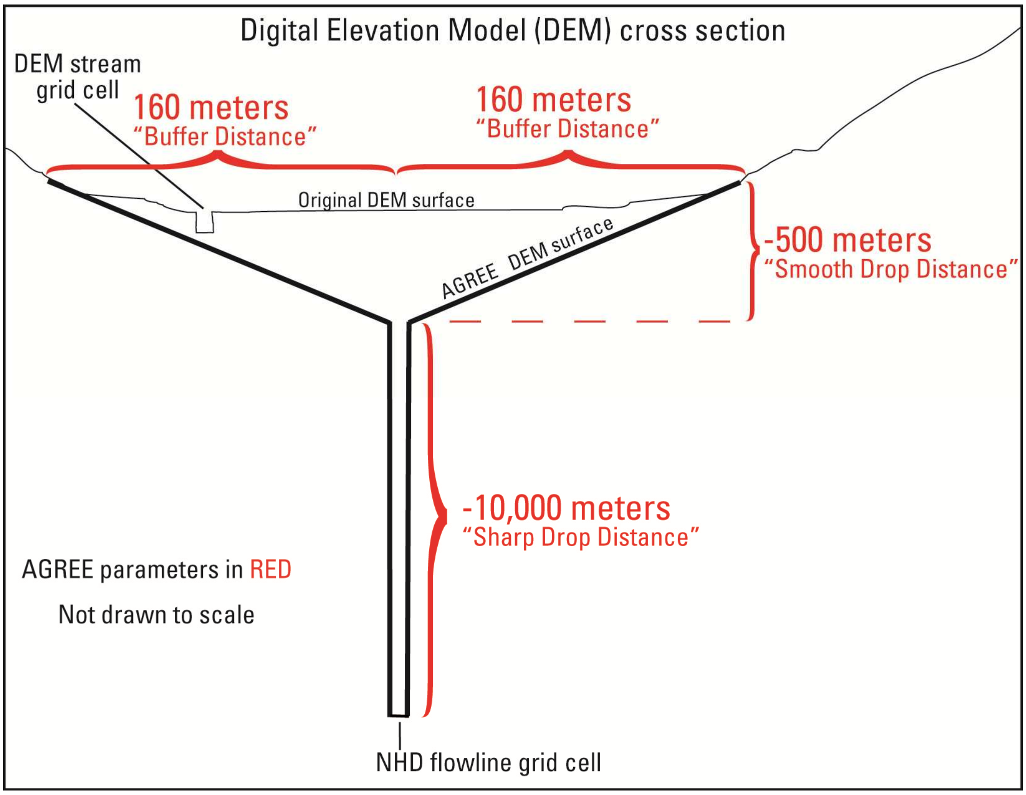

Figure A-2 – Schematic of AGREE process

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, an AML program was created that selects only headwater streams from the NHD stream network and trims the NHD headwater vector streamlines back 90 meters from the starting point. The stream-trimming program is fully automated and is run prior to the AGREE program.

The hydrologic-conditioning of the NED data also includes a process developed for the New England SPARROW water-quality models (Moore et al., 2004). This "New England Method" uses AGREE for drainage enforcement and establishes Watershed divides, if available, from the Watershed Boundary Dataset (WBD). The process of conditioning DEM data to WBD Watersheds is called "walling" and uses an AML, written by Moore and Johnston (2004), to 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 insure proper passage of water from one WBD SubWatershed unit to another. A graphic 3-D representation of a hydrologically-conditioned DEM with WBD walling and the NHD "burning" is shown in Figure A-3.

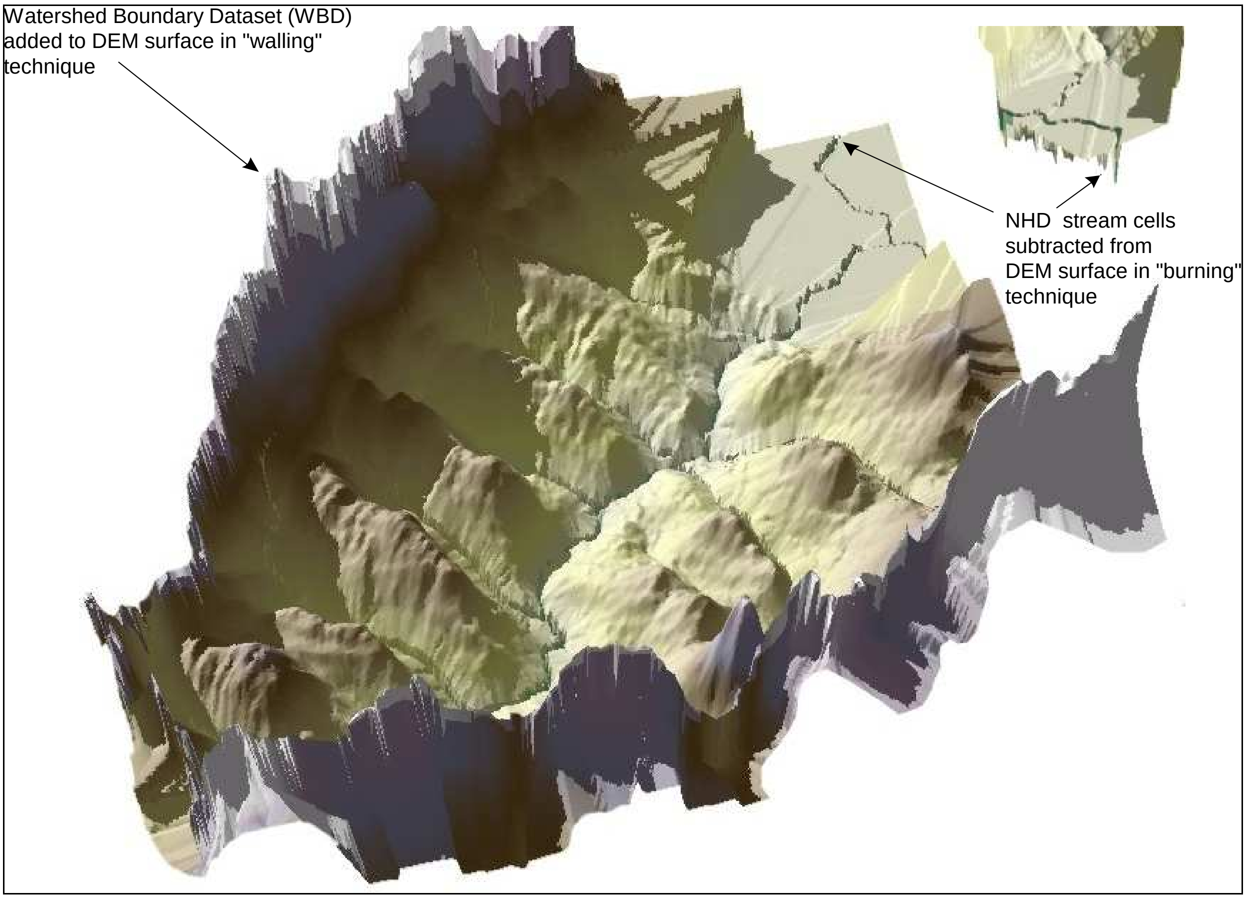

Figure A-3 – 3-D Perspective view of modified DEM with walling of existing Watershed boundaries and burning of NHD streams

The New England Method for producing catchments was compared with other methods in an EPA-sponsored, NHD-NED Synchronization pilot study in cooperation with the USGS. The results of the study showed that the New England Method provides the most accurate catchment delineations, using nationally available data and automated methods.

The New England Method was further refined by the USGS (Rea and Skinner, written commun., 2004) by imposing a "bathymetric gradient" within two-dimensional NHDWaterbody features (i.e., stream/river, lake/pond). 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. The gradient is applied prior to running AGREE. The bathymetric gradient process applies GRID algorithms, similar to those used in AGREE, to create a broad sloping gradient with shorelines upslope from the artificial path flowline(s).

The last step in the HydroDEM creates a "filled" DEM surface grid with the ARC/INFO GRID command "FILL," which removes depressions. This insures all elevation cells in the basin have a defined drainage direction. The required flow direction grid for the WATERSHED command is produced from the filled HydroDEM.

Due to the resolution of the NED data, catchments were not generated for many flowlines approximately 42 meters or less in length (42 meters is the diagonal distance across a 30 meter grid cell).

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. In these cases, flowlines may run parallel with each other within a given cell and may continue for several cells over the entire length of one of the flowlines. In other rare cases, the trimming back of the NHD headwater stream segments did not allow for enough of the remaining flowline to be assigned a catchment and cells were assigned instead to a neighboring flowline. Trimback errors are especially rare since the trim streams program is designed to limit these types of errors. For Region 17, with approximately 237,000 flowlines greater than 42 meters, three catchments were not generated as a result of spatially configured flowlines running parallel to each other, and two catchments were not generated as a result of the trimming back of headwater flowlines.

The catchments data are available in the native GRID format and as vector polygon feature-class shapefiles. 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-4).

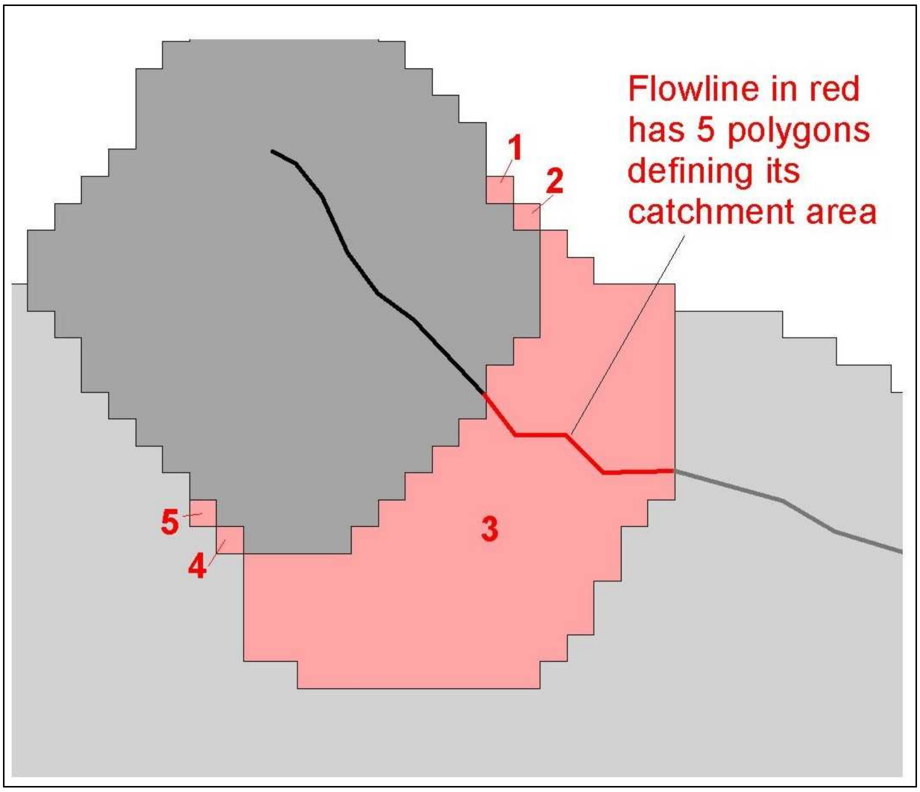

Figure A-4 – Illustration showing multiple polygon features defining a catchment area for a flowline

In creating the catchment shapefiles, the catchment data in GRID format were converted to a vector polygon ARC/INFO Coverage. This polygon coverage of catchments was then combined using the ARC/INFO Regions data model to ensure multiple polygons with the same ComID were represented as one multi-part area feature. The Region feature class coverage was then used to create the catchment shapefile, which retains the combined polygon features as one multi-part polygon. If the catchments are converted from shapefile to Coverage format, it will be necessary to rebuild the Region class features to ensure that each catchment feature, for each ComID, is represented by a single unique area feature.

Flow Direction and Accumulation GRIDs

The flow direction grid was created by using the ESRI ARC/INFO command FLOWDIRECTION. A flow direction grid contains integers representing the direction from each cell to its steepest downslope neighbor. The elevation grid used to compute flow direction was created with the "FILL" command.

The flow accumulation grid was created by using the ESRI ARC/INFO command FLOWACCUMULATION. A flow accumulation grid contains integer values equal to the number of cells uphill from that cell. The flow direction grid was used as input in FLOWACCUMULATION to determine the total number of cells that flow into each downslope cell.

In this process, flow is ultimately directed to "sinks" created by placing "no-data cells" at certain locations, such as at the outlet to each processing unit. For Hydrologic Regions that drain directly into the ocean, the entire coastline is used as a sink. For networks that drain to Canada or Mexico, a sink is also applied at the network's terminus along the international border. Isolated drainage networks are generally eliminated by "filling" to create flow direction and accumulation grids. Sinks are only placed at the network ends of isolated networks if they are within 8-digit Hydrologic Units identified as closed basins (with the exception of Hydrologic Region 16, where sinks were applied region-wide).

A procedure for placing sinks in closed basins was applied to avoid: 1) placement in high precipitation areas (mean annual precipitation greater than 14 inches), 2) 1:100,000-scale map boundaries where network end may be erroneous due to source quadrangle mapping inconsistencies, and 3) placement closer than 90 meters to the main network to which the isolated network either should be connected or there is apt to be highly permeable alluvium.

Figure A-5 shows how isolated networks are treated. Catchments are delineated for the isolated networks in the same manner as any other NHD Flowline. The flowlines are rasterized and converted to "NODATA" or "sinks" in the elevation grid. The FILL process, followed by FLOWDIRECTION, directs flow to these NODATA cells. The rasterized NHD Flowlines are then used as the seeds for catchment delineation using the WATERSHED function. This process produces the best representation of catchments for isolated networks.

The DEM is then processed with FILL a second time - this time to produce the final flowdirection grid. In this process, sinks are established only at the outlet of the processing unit, unless there are Subbasins (8-digit HUCs) identified as closed basins. Therefore, the isolated networks fill up and spill over, producing a drainage network similar to that which would be produced using a DEM without the stream burning process.

The reason for generally letting the accumulated cell counts continue beyond the isolated networks is identification of likely flowlines to which the isolated network should (perhaps) be connected. Using this information, a user could choose to fix isolated networks that should be connected to the main network or determine watersheds that include the isolated network areas.

In Figure A-5, the synthetic hydrography (i.e., the hydrography derived from the DEM FLOWACCUMULATION function) is plotted in red. The NHD Flowlines are plotted in blue over the red. In most cases, the agreement is very good and the blue closely overplots the red. However, the isolated network in the top center of the figure shows a side effect of the AGREE process. For this isolated network, the synthetic streams are horizontally displaced with the NHD and even cross over from one stream to another. Since the trench caused by the isolated network had to be filled back up until it could spill over, the surface became flat within the AGREE buffer area. There seems to have been very little overall slope in this area; therefore, nearly the entire isolated network was affected. Within the flat area, the flow direction and flow accumulation are not well controlled and suffer— to a limited extent— from the same problems occurring in DEMs processed without the benefit of stream burning. These effects are not common or widespread but may occur wherever there are isolated networks.

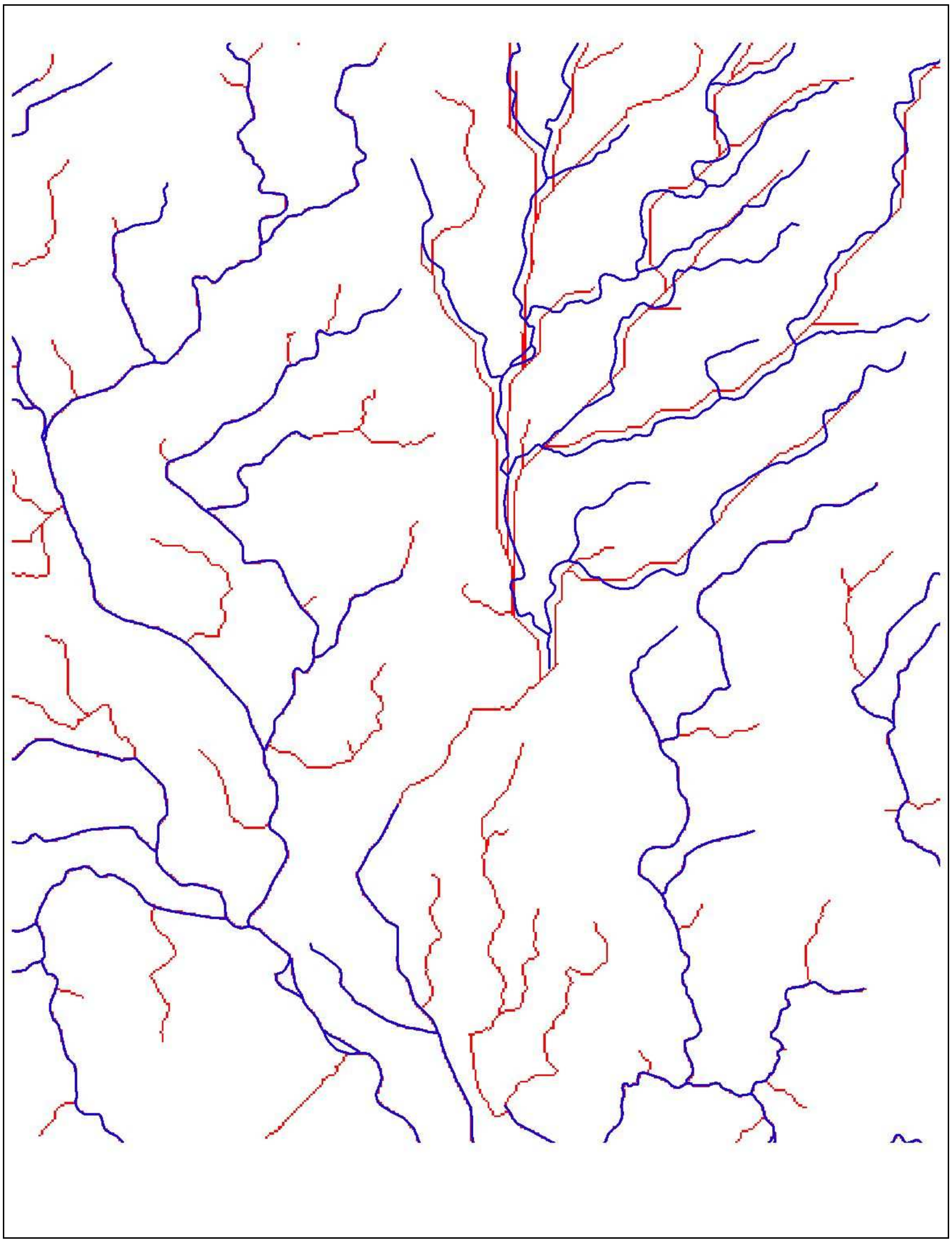

Figure A-5 – Illustration comparing the horizontal displacement between the NHD streams of an isolated network (in blue) to the synthetic streams of the "filled" HydroDEM

The processes outlined above were applied to each "production unit" (an area equal to or less than 73,000 square miles). The restricted size is due to GRID processing limits. The Production Unit map (Figure 4-1) shows the order of processing of the production units. Flow direction and flow accumulation grids are not merged for each Hydrologic Region because the accumulation values only represent upstream cells within a defined area; they do not include cells in upstream production units. Catchment grids, on the other hand, are combined for final distribution. The catchment areas are not affected by excluding upstream accumulations from other processing units. The user should bear in mind, however, that the flow accumulation values (cell counts) include cells accumulated from within a 10 kilometer buffer.

Assigning Minimum and Maximum Raw Stream Channel Elevations (unsmoothed) to NHD Flowlines and Headwater Node Areas

NED was used as the source elevation dataset because the elevations in the "burned" NHD stream paths in the HydroDEM are greatly modified. The maximum flowline elevation represents the elevation at the upstream end of the flowline and the minimum elevation is at the downstream end. Due to the varying degrees of accuracy of the NED, these "raw" elevations can produce negative slopes and, therefore, the elevations were later smoothed as described in Step 7.

A difficulty in estimating minimum and maximum stream elevations is often caused by poor agreement between the location of the stream depicted on the NHD and the flowpath generated by the elevation data alone. The locations of the NHD Flowlines typically are much more accurate. However, the minimum elevation value in the entire catchment is generally a reasonable estimate of the elevation of the stream as it leaves the catchment area. Using this value avoids the problems of horizontal displacement in the two stream networks (see NED-derived stream in red and NHD stream in blue in Figure A-6). The maximum elevation for each flowline is the minimum elevation in the immediately upstream catchments (Figure A-6).

A different process was needed for the maximum elevation on headwater flowlines. Temporary catchments were generated for the upstream node of each headwater flowline. The minimum elevation of that temporary headwater catchment is taken as the maximum elevation of the headwater flowline. Headwater node areas (in square kilometers) are included in the NHDPlus HeadWaterNodeArea table.

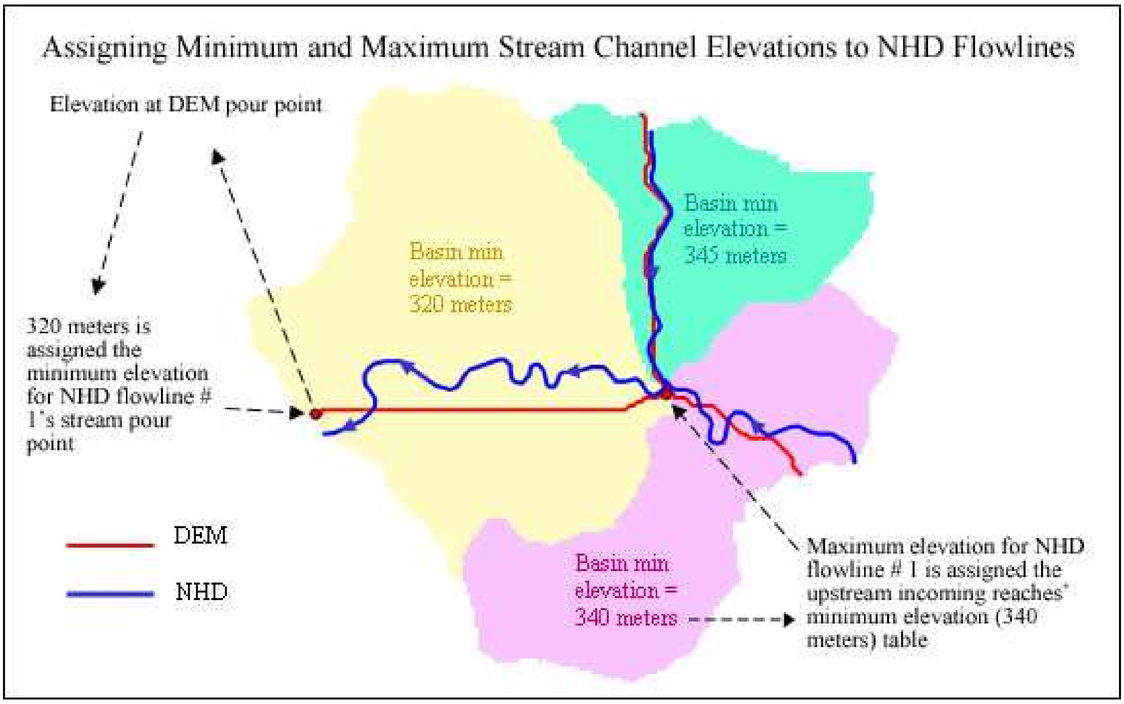

Figure A-6 – Assigning Minimum and Maximum Stream Channel Elevations to NHD Flowlines

Step 4 - Development of International Catchment Areas

Hydrologic Regions with upstream areas in Canada or Mexico present special problems for computing streamflow or other hydrologic factors because many of the datasets are available only for the conterminous United States but not for Canada or Mexico.

Catchment areas for streams receiving flow from Canada or Mexico were identified using generalized hydrography and watershed datasets. The extended catchment area for an NHD Flowline encompassed the entire non-U.S. upstream area for that stream; thus, these catchments are sometimes very large compared to most NHD Flowline catchments. Figure A-7 shows an example along the Canadian border. The light blue lines show the generalized hydrography used for Canada, and darker blue lines show the NHD hydrography. The boundary of the DEM-derived catchment is shown in white, where the light blue line enters the United States. This catchment has been extended to include the entire area, shown in gold. Other catchments are shown in green. All catchments receiving major streams from Canada were expanded in a similar manner.

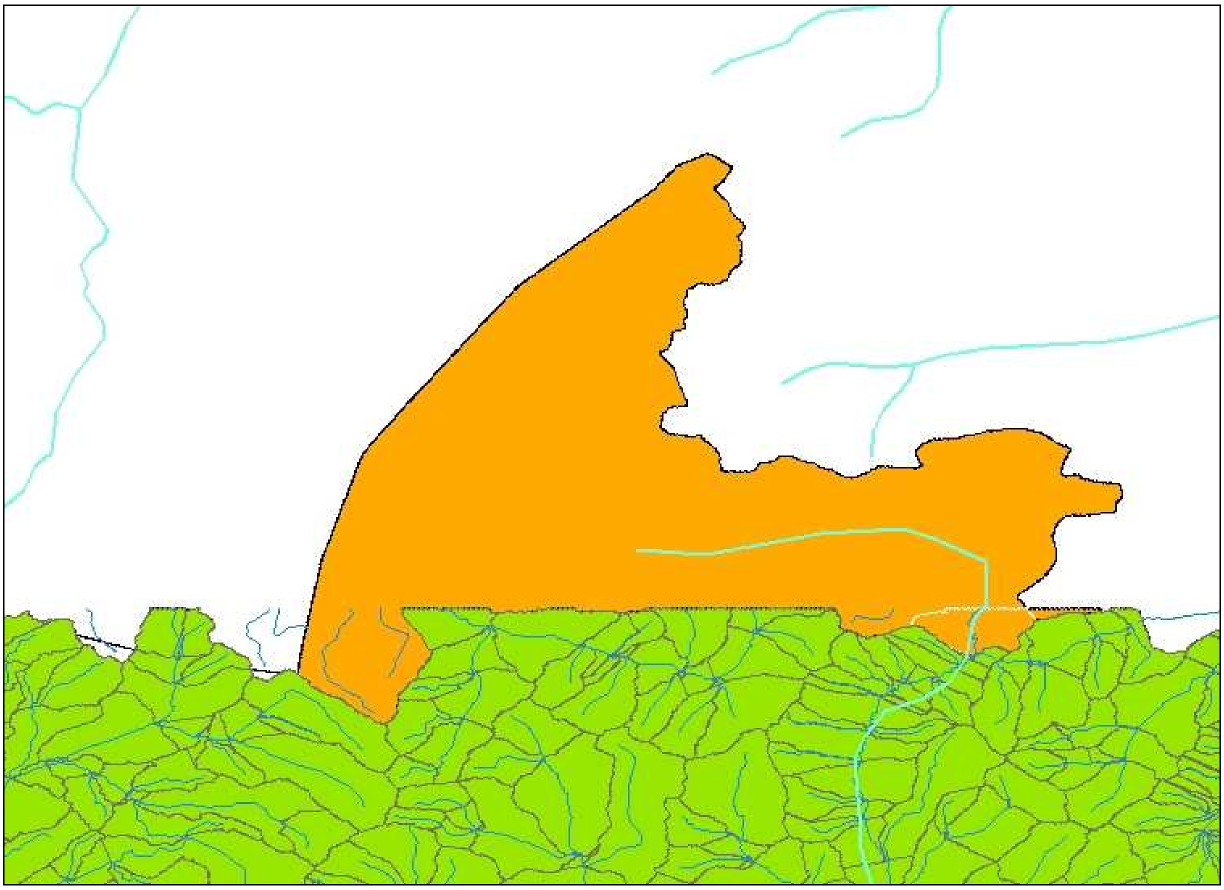

Figure A-7 – Example of an international catchment on the Canadian border

Different datasets were used to develop the catchment areas for different regions. Details on the data sources used may be found in the Release Notes for each region having international catchments.

Because of the previously described data issues, catchment areas and catchment characteristics, as well as cumulative drainage areas and characteristics near an international border, are less accurate than in other areas. This inaccuracy is greatest in catchments touching the border. The greater the percentage of a catchment is in non-U.S. areas, the greater the data inaccuracy. The effect diminishes farther downstream as the ratio of non-U.S. to U.S. catchment areas becomes smaller.

Step 5: Development of Catchment Attributes

Catchment attributes were computed using ArcInfo Grid, version 9.0 (ESRI, 2004). Mean Annual Precipitation and Mean Annual Temperature data for 1961-1990 were obtained from PRISM (Daly and Taylor, 1998). The PRISM datasets were projected from geographic coordinates to Albers Equal Area projection, and the 2.5-arc-minute grid-cell resolution was transformed to approximately 4 km. The ArcInfo Grid function "ZONALSTATS" was used to compute the mean annual precipitation and temperature values for each catchment.

Catchments covering area in Canada or Mexico had missing data in the mean annual temperature and mean annual precipitation grids underlying the non-U.S. portions of the catchments. The values computed for these catchments reflect the mean precipitation or temperature only for the catchment portion in the U.S.

The National Land Cover Dataset (NLCD 1992) data were assembled for the Hydrologic Region being processed. The ArcInfo Grid function COMBINE was used to create a grid with a unique value for each unique combination of catchment number and NLCD category. The cell counts were converted to area percentage of each catchment. A custom program, named GROUP2ROW.AML, reformatted the resulting value attribute table to a table containing one record per catchment, with columns of area percentages for each NLCD category in that catchment. Empty columns were added for any NLCD categories not present.

The NLCD grid was extended to cover the non-U.S. areas, specifying a code of 98 for Canada and 99 for Mexico. Subsequent processes operated on these catchments in the same way as with any other catchments. Attribute summaries for catchments and flowlines may include percentages of catchment areas and cumulative drainage areas in Canada and Mexico. Total drainage areas are generated by combining the percentages of area in Canada or Mexico with the percentages of all NLCD categories.

The PCT_CN and PCT_MX fields in the CatchmentAttributesNLCD.dbf file and the Cumpct_CN and Cumpct_MX fields in the FlowlineAttributesNLCD.dbf file contain the percentages of catchment and total drainage areas in Canada and Mexico, respectively. Wherever these fields contain values other than zero, the user needs to take into account the potential effects of the non-U.S. areas on the particular application.

Step 6: Development of Flow Volume and Velocity Estimates

The Flow Volume and Velocity estimates are contained in the FlowlineAttributes table, and records are matched to the NHDPlusFlow table. The values in the FlowlineAttributes table are integrated from the NHDFlowlineVAA, the CatchmentAttributes tables, and the flowline max/min elevations. The NHDFlowlineVAA provides the data needed to route and accumulate information from the CatchmentAttributes. The process for calculating the smoothed elevation and slope values is described in Step 8.

The FlowlineAttributes table is cumulative for all flowlines and associated catchments upstream of, and including, any flowlines selected or of interest. This accumulation is performed using the hydrologic routing information contained in the VAAs.

The cumulative drainage area at the downstream end of a flowline is calculated as:

$$CumArea = \sum_{i = 1 \text{ to } n} (A_i)$$

where
n = number of catchments upstream of the flowline (including that flowline), and
A_i = the catchment area of the flowline.

Divergences

A flow divergence occurs when two or more drains converge at a junction, and the flow downstream splits into two flowlines. One of the downstream flowlines is designated as the "major" flow path, and the other flowline is designated as the "minor" flow path. At this stage of NHDPlus development, there is no information on the percentage of flow for either the major or minor paths. Therefore, all drainage areas, flows, etc. are routed and accumulated along the major flow path. The minor path is in effect treated as a "start" flowline, with the cumulative values initialized to the values for that minor path flowline. Most flow divergences re-converge with the major flow path and, at the re-convergence point, the total cumulative values will represent the sums from the major path and the minor path.

Climate Data

Mean annual air temperature (MAT) and mean annual precipitation (MAP) data are required for Vogel-based estimates of mean annual flow (Vogel et. al., 1999). These values are accumulated and averaged for each drain:

AreaWtMAP – Area Weighted Precipitation at bottom of flowline in mm

$$= \frac{\sum_{i=1 \text{ to } n} (P_i * A_i)}{\sum_{i=1 \text{ to } n} (A_i)}$$

where

P_i and A_i are the precipitation and catchment area for each flowline upstream.

AreaWtMAT – Area Weighted Temperature at bottom of flowline in degree C * 10

$$= \frac{\sum_{i=1 \text{ to } n} (T_i * A_i)}{\sum_{i=1 \text{ to } n} (A_i)}$$

where

T_i and A_i are the temperature and catchment area for each flowline upstream.

Land Cover Cumulative Characteristics

The cumulative NLCD % areas are computed by aggregating all of the individual NLCD catchment drainage areas:

CUMNLCD_xx = % of cumulative drainage area classified as NLCD Class xx at the bottom of the flowline:

$$= \frac{\sum_{i=1 \text{ to } n} (NLCD\_xx_i * A_i)}{\sum_{i=1 \text{ to } n} (A_i)}$$

where

$NLCD\_xx_i$ = Percent of the catchment area in land cover class xx for flowline I (for instance, "xx"= "11" is land cover class 11=Open Water), and

A_i = the catchment area for the i^{th} flowline.

Mean Annual Flow Estimates

Two methods are used for estimating mean annual flow for each flowline. Values for the attribute "MAFlowU" are based on the Unit Runoff Method (UROM), which was developed for the National Water Pollution Control Assessment Model (NWPCAM) (Research Triangle Institute, 2001). Values in "MAFlowV" are based on methods from Vogel et al., 1999.

NHDPlus utilizes two flow estimation procedures, both developed by using the HydroClimatic Data Network (HCDN) of gages. These gages are usually not affected by human activities, such as major reservoirs, intakes, and irrigation withdrawals; thus, the mean annual flow estimates are most representative of "natural" flow conditions. These estimation methods used the HCDN gages because each method is developed for use at large scales; such as Hydrologic Regions. It was beyond the scope and capabilities of both methods to determine the human-induced effects at this scale. However, the QA comparisons of NHDPlus flow estimates are compared to the full set of gages to provide users with information on the overall performance of each method.

UROM Flow Estimates

The UROM flow estimates use flowline catchment area estimates and unit runoff (cfs/km^2) data from associated watersheds (i.e., 8-digit Subbasin). The USGS stream gages in HCDN were selected for developing the unit runoff values because those gages represent relatively natural hydrologic conditions and are not influenced by controlled releases from reservoirs. Further, only gages with a drainage area smaller than the drainage area of the 8-digit Subbasin where the gage is located were selected, so that the discharge data represents runoff for only that Subbasin. For instance, a gage on the Mississippi River at St. Louis is not representative of the unit runoff from that Subbasin. At the national level, a total of 1,338 HCDN gages were identified for this dataset.

Based on the drainage area comparisons, the dataset of 1,338 HCDN gages and the dataset of associated stream discharge data for these gages were used to derive mean annual and mean summer unit runoffs (ft^3/sec/km^2) for each 8-digit Subbasin. The nearest HCDN gages were identified using a 200 mile maximum search radius from the centroid of an 8-digit Subbasin. In most Subbasins, five gages were selected, but some Subbasins had fewer than five within the 200 mile search radius. Mean annual and mean summer unit runoffs for each 8-digit Subbasin were calculated using a weighted-average technique based on the square of the distance of the selected HCDN gages from the centroid of the Subbasin. The computations are defined as follows:

$$Q_{CU\_MA} = \Sigma(Q_{HCDN\_MA} \times 1/D^2_{CU\_HCDN})/\Sigma(1/D^2_{CU\_HCDN})$$

where

Q_{CU_MA} = estimated mean annual unit discharge for the 8-digit Subbasin of interest,
Q_{HCDN_MA} = mean annual unit discharge for the selected HCDN gage, and
$D^2_{CU\_HCDN}$ = square of distance from the selected HCDN gage to the centroid of the 8-digit Subbasin of interest.

IncrFlowU is the incremental flow at the bottom of the flowline, computed as:

IncrFlowU = A * CU_MA

where

A = Drainage Area of the catchment (km^2), and
CU_MA = Unit Runoff for the 8-digit Subbasin (cfs/ km^2).

The UROM-based mean annual flow for each flowline (MAFlowU) is computed as:

$\sum_{i=1 \text{ to } n} (\text{IncrFlowU}_i)$.

UROM "Tuning" Using Intermittent Flow Adjustment Factors

The development of the UROM was done as part of the development of the National Water Pollution Control Assessment Model (NWPCAM) (Research Triangle Institute, 2001). For Hydrologic Regions west of the Mississippi River, initial NWPCAM estimates of routed discharge generally were observed to be greater than the HCDN gage values. Consequently, for the Western Hydrologic Regions, a method was developed to better match (quasi-calibrate) discharge estimates to observed data. The discharge estimates were lowered by incorporating only a percentage of the stream segment-specific runoff for intermittent segments. The method calculates discharge estimates assuming various contributions (e.g., 100, 50, 25, 10, and 1 percent) of the unit runoff for intermittent flowlines. This method proved successful in improving the match between gage flows and UROM-based flow estimates. The method is employed in the Western Hydrologic Regions in NHDPlus. The best fit is selected based on graphical analyses that compare the UROM flow estimates to the gaging data. As NHDPlus is produced, this tuning process will be completed in each Hydrologic Region west of the Mississippi (Regions 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18). In Hydrologic Region 17, an intermittent unit runoff contribution of 10 percent appears to work best and is included as the UROM estimates in the distribution datasets.

UROM Estimates in Areas with International Drainage

For a given flowline, the UROM bases each incremental flow contribution on unit runoff estimates in the HUC8. There are no unit runoff estimates for areas outside of the U.S.; therefore, international drainage areas do not have equivalent values developed. A multi-step process is employed to compensate for the lack of equivalent values. To begin, the flow volume module is run, assuming a unit runoff in the international area equals the unit runoff for the HUC8 where that drainage area comes into the U.S. Gages on flowlines that enter the U.S. are then identified, and their mean annual flow is compared to the UROM mean annual flow estimate. Finally, unit runoff values are calculated, making the UROM flow equal the gage flow. In Hydrologic Region 17, where the Canadian contribution was relatively small (on the order of the area of one HUC8 or less), the default HUC8 unit runoff produced mean annual flow estimates close to the observed gage flow. In the Columbia River, the unit runoff coefficient for the flowline receiving the Canadian drainage needed to be adjusted to match the gage flow. This adjustment re-sets the UROM flow estimate to be equal to the gage at the border. The process is repeated at each international drainage location. The final run of the flow estimation procedure uses these adjusted values for boundary flowlines.

"Vogel" Mean Annual Flow Estimates

The MAFlowV estimates are 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 from HCDN gages. With this method, the mean annual flow for a drain is computed as:

Convert AreaWtMAP from Deg. C * 10 to Deg. F * 10:
V_AreaWtMAP = (AreaWtMAT / 10 * 9 / 5 + 32) * 10

MAFlowV = e^a * $CumAREA^b$ * $AreaWtMAP^c$ * $V\_AreaWtMAT^d$ * BCF * 35.31467

where

a, b, c, and d are Hydrologic Region-specific regression coefficients, and
BCF = Bias Correction Factor by Hydrologic Region.
35.31467 = conversion factor from cubic meters per second to cubic feet per second

The BCF is needed because the regression is 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 Table 1[6]. For cumulative drainage areas that fall outside of these ranges, the Vogel flow and velocities are set to missing values 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

Table 1: Vogel Flow Values by Hydrologic Region

The "Vogel" based flow and, therefore, velocity estimates depend upon estimates for mean annual precipitation and temperature, as well as drainage area. In cases where there is drainage entering from Canada or Mexico, the temperature and precipitation values for the U.S. portion of that international catchment are assigned to the entire catchment. For small catchments, this probably does not result in large errors, but some international catchments are very large, with only a very small area in the U.S. Therefore, the Vogel-based flow estimates may be erroneous where there is a relatively large international drainage contribution. In this NHDPlus release, if the percentage of cumulative international drainage area for a flowline is greater than or equal to 25 percent, the Vogel-based flow and velocity estimates are assigned missing values of -9998.

Median Annual Flow Estimates For Hydrologic Region 20 (Hawaii)

The regression-based 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:

Q_{50} = Median annual flow (cfs),
DA = Drainage area (square miles),
CE = mean altitude of the main stream channel (feet), and
P = mean annual precipitation (inches)

Mean Annual Flow Estimates For Hydrologic Region 21 (Puerto Rico)

Hydrologoc Region 21, Puerto Rice and the Virgin Islands, has 3 primary issues:

1. A regression model, similar to the “Vogel” method could not be located. Therefore, there will not be a set of regression-based mean annual flow and velocity in the final Region Flowlineattributesflow.dbf file.
2. No data for Mean annual Temperature (MAT), mean annual precipitation (MAP), or land cover (NLCD) were developed for Region 21, so the catchment-level MAP, MAP, and NLCD and the cumulative MAP, MAT and NLCD tables are not available for Region 21. Note that the MAP and MAT values are not needed to support a regression-based estimation method equivalent to the “Vogel” method.
3. There is no equivalent to the HCDN gages that represent “natural” flow that is used as the basis for UROM flows in the continental U.S. The logical alternative to this method is presented below. The Puerto mainland is divided into four HUC-8’s (21010002, 21010003, 21010004, 21010005) and the islands are assigned their own HUC-8 numbers.

A map of the stream gages is shown in Fig. A-8.

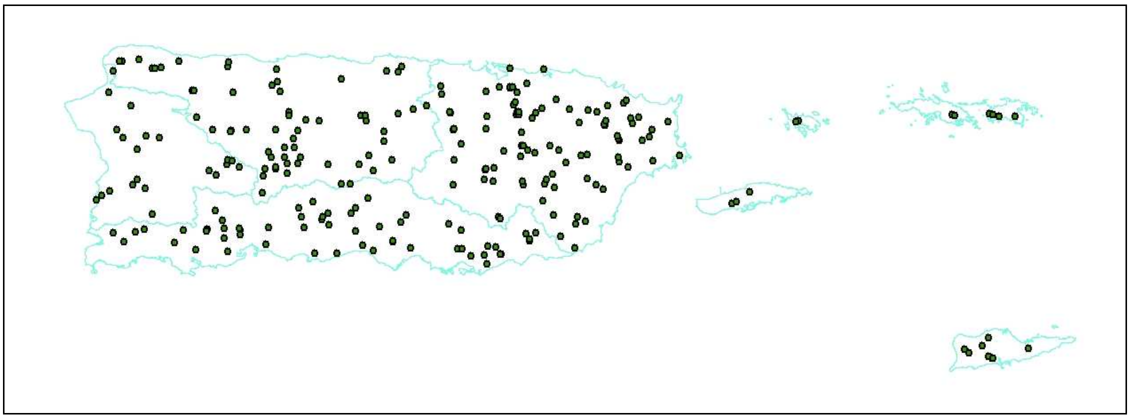

Figure A-8. Stream Gages in Region 21

Developing a Unit Runoff Methodology for the Puerto Rico Mainland

To develop HCDN-equivalent runoff, figure A-9 below is used as the UROM source, which contains the citation for the figure.

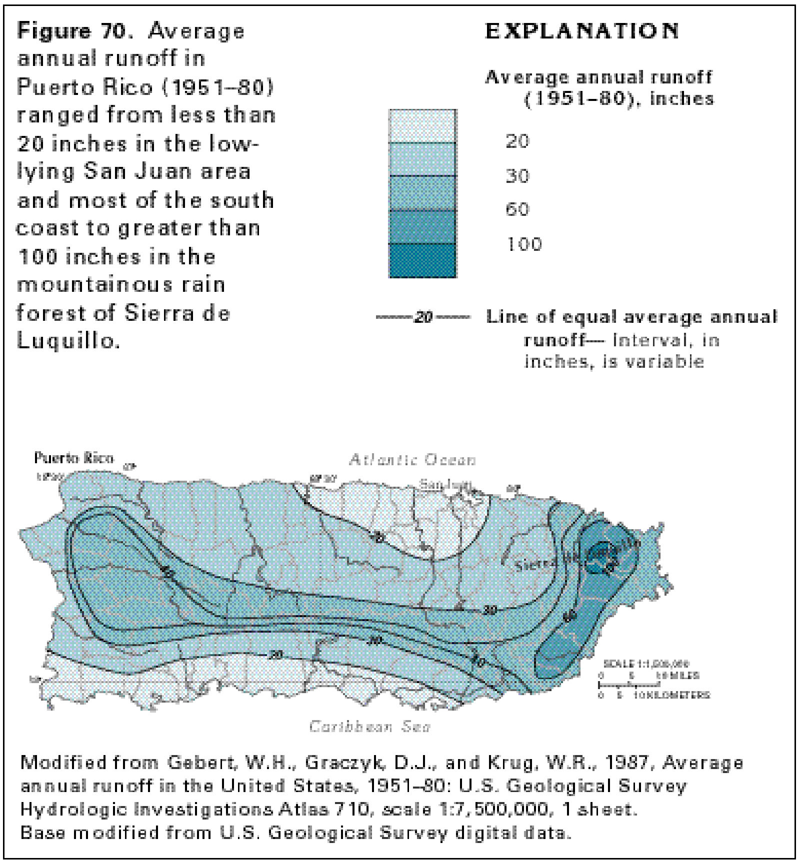

Figure A-9. Average Unit Runoff on Puerto Rico Mainland

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. Note the very high variability in runoff in areas in the eastern portion of HUC 21020005. This shows why a single unit runoff value by HUC would not produce good results.

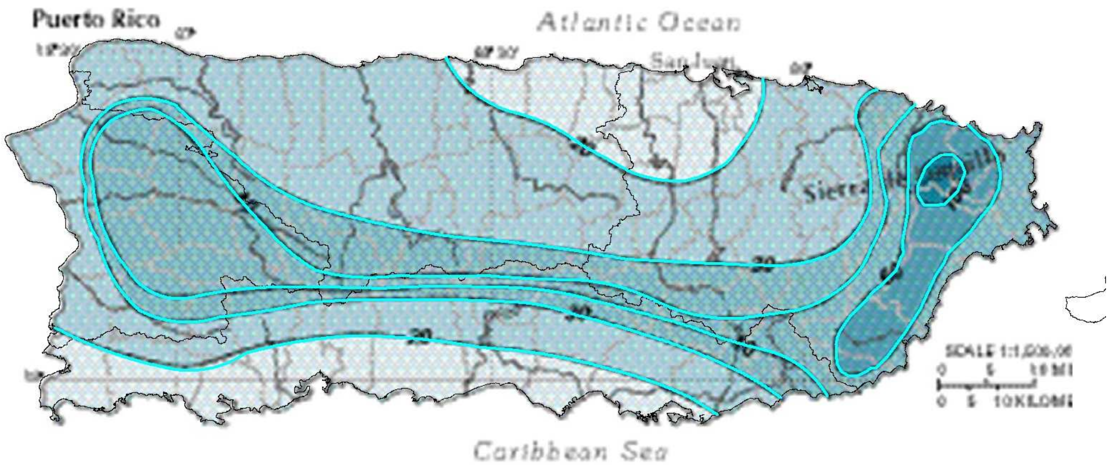

Figure A-10. Digitized Mean Annual Runoff Values On Puerto Rico Mainland

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.

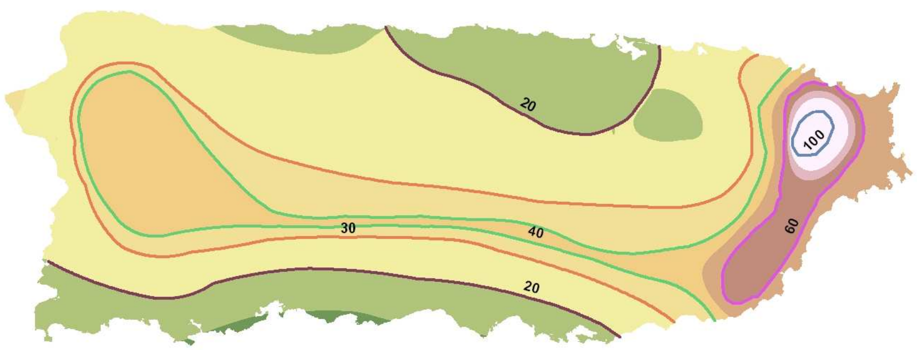

Figure A-11. Results of using TopoGrid to Develop an Interpolated Raster Grid of Mean Annual Runoff

The rasterized data was then overlayed onto the catchments, which assigned a UROM value (cfs/sq km) to each catchment.

The mean annual runoff values for the islands were done based on the gages available in each of the HUC-8's. Due to a lack of gages in 21010006, no UROM flows and velocities were developed. UROM flow and velocity estimates were developed for 21020001 and 21020002.

Velocity Estimates

Velocities are estimated for mean annual flow conditions 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 Flowline variables are used in the Jobson methods: drainage area, Flowline slope, mean annual discharge, and discharge at the time of the measurement. Based on his analyses, regression equations were developed to relate velocity (meters/second) to drainage area, a dimensionless drainage area, Flowline slope, discharge, and a dimensionless relative discharge.

Because all Flowlines have slopes greater than or equal to 0.00005, the "slope" regression method is used. The section "Understanding NHDPlus Slope" in the "Understanding and Using NHDPlus" section of this User Guide provides more information on NHDPlus Slope. Also, see Steps 3 and 7 for additional information on how slope calculations are done.

<u>Caveats and Considerations in Using the NHDPlus Velocity Estimates</u>

Care should be exercised in using these velocity estimates:

1. These velocities represent estimates for flowing streams and rivers and are not applicable to lakes or estuaries. The velocity estimates are computed and reported for all networked Flowlines, but users should exercise care when using them in lakes or estuaries.
2. Artificial path Flowlines that are in lakes (natural and impounded) can be determined as follows: Select all Flowlines in the NHDFlowline table with an FCODE = 55800 (Artificial path). Join these Flowlines to the NHDWaterBody Table using WBAreaComI in NHDFlowline to Comid in the NHDWaterBody table. All artificial path Flowlines with NHDWaterBody FCODE values in the 390xx series are lakes.
3. Users need to be aware that there are impounded waterbodies not identified in the medium-resolution NHD that is the basis for NHDPlus, so there is no way to ensure that all Flowlines in impoundments can be identified.
4. Estuarine Flowlines have not been identified in NHDPlus so performing estuarine-specific velocities is the user's responsibility.

The equations for velocity estimates are described below:

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

$$Q'_a = Q/Q_a$$

where

Q = Flowline discharge at the time of measurement (cubic meters/second), and
Q_a = mean annual discharge.

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 discharge (cubic meters/second).

The "Slope" method Flowline velocity (VelA_p) (Jobson, 1996) is

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

For purposes of NHDPlus, Q is assumed equal to Q_a, so that the dimensionless relative discharge (Q'_a) has a value of 1. Flowline slopes are described in Step 8.

Jobson has also specified a "noslope" velocity equation. However, the noslope equation is not used in NHDPlus.

Because velocities are in part based on flow, velocity estimates are computed for both the UROM (MAVelU) and the Vogel (MAVelV) Methods.

Quality Assurance (QA) For NHDPlus Cumulative Drainage Area and Flow

Overview of Procedures Used

The basic procedure is to compare NHDPlus Drainage Areas and Flows to values reported in the National Water Information System (NWIS) for USGS Gaging Stations. The gaging station drainage areas and mean annual period-of-record flows from the NWIS database are considered as "truth" for the flowline to which the gaging station is assigned. The gaging station values are plotted on the x-axis and the corresponding NHDPlus values are plotted on the y-axis. With both axes at the same scale, a 45 degree line of values indicates agreement between NHDPlus and NWIS. Values not on the line represent the amount that NHDPlus cumulative drainage areas or flows are valid "outliers", a systematic issue, or NHDPlus cumulative values are inaccurate.

The gaging station location data was provided by Dave Stewart, USGS. The gage locations were snapped to the nearest 1:100,000-scale NHD flowline and then reviewed to ensure the snapped location is representative of the position on the stream network being measured by the gage. Summary flow statistics from the gage records were taken from Wolock, (2003).

Each Hydrologic Region release contains a QA spreadsheet with a "QA_notes" worksheet noting specific issues found during the QA of that Hydrologic Region. The spreadsheet is contained in "NHDPlusrrVss_dd_QA/QC_SINKS.zip".

Systematic Issues

There are three types of systematic issues found in the QA results. The first two types of systematic issues usually appear as a sequence of gaging stations that are approximately parallel to the 45 degree line, either above or below. These gaging stations will be along a given river so that the "problem" at the most upstream gaging station is carried downstream to subsequent gaging stations along that river. This situation usually occurs for one of the first two reasons listed below. The third systematic issue can show up at very small drainage areas, where NHDPlus appears to over-estimate the drainage area.

1. NHDPlus has unconnected isolated areas upstream of the gage. The parallel Line will in this case be below the 45 degree line which indicates that NHDPlus is under-estimating the drainage area in relation to USGS gaging station data. This situation can be considered to be caused by a difference between what the USGS considers total drainage area for a gage and what NHDPlus considers total contributing area.

2. NHDPlus connects a large drainage area that is not considered to be part of the gaging station drainage area. The most obvious occurrence of this is in the Klamath River Basin in Hydrologic Region 18; where there is a diversion canal that joins the Lost River to the Klamath mainstem. The gaging stations do not consider the Lost River to be part of the Klamath drainage area, so there is a series of Klamath River gages above the 45 degree line, indicating that NHDPlus is over-estimating the drainage area in relation to the gage data.

3. The NHDPlus cumulative drainage areas include the entire catchment area for the given flowline. A gage may be located at any point along a flowline. Therefore, the gage may be measuring an area that is less than the full catchment area. In these cases, the NHDPlus drainage area will be greater than the gage area. This is not an error, per se, in the NHDPlus drainage area, but it can show up as an overestimation by NHDPlus for these small drainage areas. This issue becomes undetectable and of little consequence with more downstream flowlines having larger drainage areas. Additional processing is possible using the NHDPlus flowdirection grids to split the catchments at the gages in order to eliminate this bias, but this processing was beyond the scope of the QA process.

Outliers

Significant outliers occur primarily in situations where the gaging station is on the minor path of a divergence, the gage is in the wrong location, or the gage is on a tributary in a lake or reservoir. For more information, see the section in the User Guide on Divergences. For examples of these outliers, see the NHDPlus presentations from the February 2006 NHDPlus Workshop titled:

"Tue_1455_CumulativeCatchmentAttributes_Bondelid" and
"Tue_1455_FlowVolumeVelocityEstimates_Bondelid".

These can be found on the NHDPlus website and FTPsite.

Structure of Excel QA file

The QA table is designed to develop graphs and subsequent diagnostic analyses for outliers and other deviations from the 45 degree line as described above.

The data table is in a worksheet named "FVVQARnn", where nn refers to the particular Hydrologic Region. There follows a series of QA graphs, one set for cumulative drainage area and one for mean annual flows. The drainage area graphs start with the prefix "DA QA". The flow graphs start with the prefix "Flow QA". There is always more than one QA graph for DA and Flow. The basic graph shows the full range of data. The other graphs "zoom" to the lower left corner of the data by changing the x and y maximum scale values. These graphs are constructed because the full range of data used in the QA is quite large and the majority of x-y points tend to be clustered at the lower end of the graphs. There can be several graphs, each one "zooming" into the lower sets of data values.

The Excel data table worksheet contains the following data elements:

SITE_NO: The site number of the USGS gaging station
STATION_NM: the name of the USGS gaging station
COM_ID: the comid of the NHDPlus flowline that the gage falls upon
GAGEAREA: The NWIS reported drainage area of the gage in square kilometers. Stations need to have a drainage area value to be considered in these analyses.
CUMDRAINAG: The NHDPlus cumulative drainage area in square kilometers
NDAYS: The number of days the gaging station has been active. Stations need at least 10 years of data to be considered in these analyses.
gageavgQ: The mean annual flow over the period of record reported for that gage in cfs.
MAFLOWU: The UROM Mean annual flow in cfs.
MAFLOWV: The "Vogel" based mean annual flow in cfs. Note that there will be numerous times this field is unvalued (-9999 or -9998). See Step 6 in Appendix A of the NHDPlus User Guide for more information on why this field can be unvalued.
BESTEVENTX: The longitude in decimal degrees that best places the gage on an NHDPlus flowline.
BESTEVENTY: The latitude in decimal degrees that best places the gage on an NHDPlus flowline.

The table is sorted by descending GAGEAREA. All of the graphical QA is built using these data elements.

Step 7: Elevation Post-Processing, Smoothing, and Slope Calculations

The raw flowline elevations developed in Step 3 provide upstream elevations at all headwater flowlines and downstream elevations for all flowlines. 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 post-processing steps are performed. 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 that join at a downstream node are independently developed and may not be equal. The elevations at each node are made equal by taking the minimum elevation of the two (or more) flowlines that are immediately upstream of the node. Figure A-6 in Step 3 illustrates this process.

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 that have catchments. When all of the flowlines immediately upstream of a node are too short to generate catchments, the node will have a “missing” elevation.

Third, raw elevations are smoothing so that most flowlines will have non-negative slopes. With raw elevations, flowlines can have 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 NHDPlus 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”) slope. NHDPlus slopes are constrained to be greater than or equal to 0.00005. Another important reason to perform the 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.

The results of the elevation processing are stored in the FlowlineAttributes table.

One of the many powerful features of NHDPlus is the ability to extract all of the flowlines for a stream path and sort them in an upstream or downstream order. This capability permits smoothing to be done on a stream level path basis (e.g., the Ohio River mainstem). 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-8. 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-9. 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-10).

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 "sink," 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 the "sink" value, until a flowline elevation is encountered that is lower than the "sink" value. The effect of this process results in many flowlines having artificially low elevations and zero slopes. The upstream smoothing technique avoids this problem.

In NHDPlus, the FlowlineAttributes table contains smoothed elevations by LevelPathid, using the upstream smoothing approach, with slopes constrained to be greater than or equal to 0.00005. A relatively small number of flowline connections exist where the minimum elevation of the inflowing flowlines and the maximum elevation of the out flowing flows are not all equal. These elevation inconsistencies occur only where some level paths meet. As a result of elevation smoothing, every flowline in the network receives a slope greater than, or equal to, 0.00005.

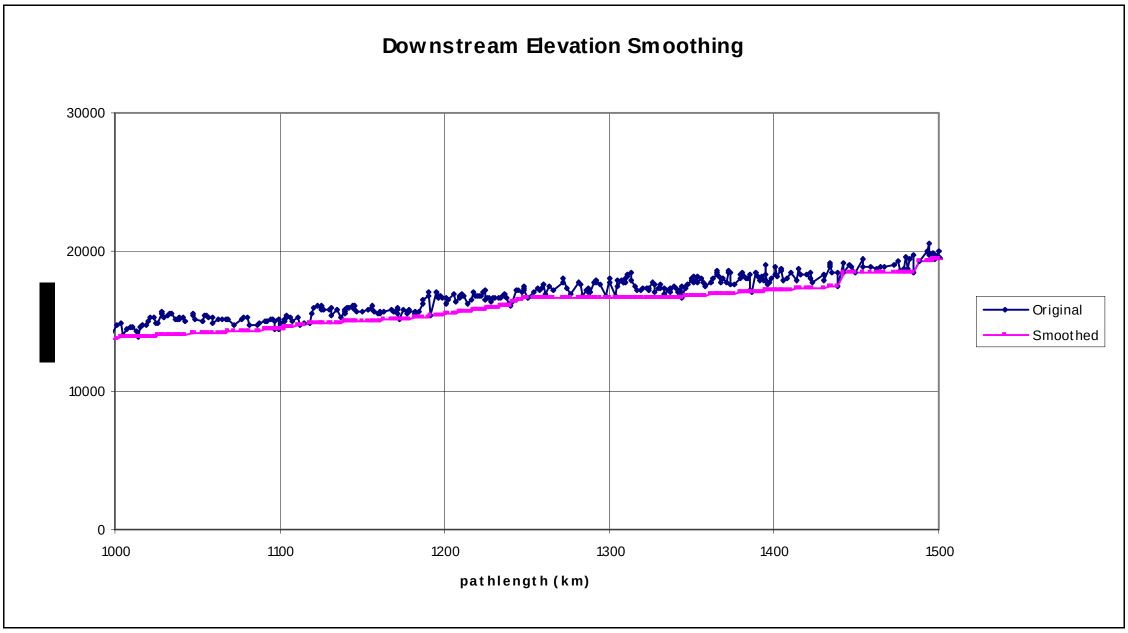

Figure A-12 – Downstream Elevation Smoothing

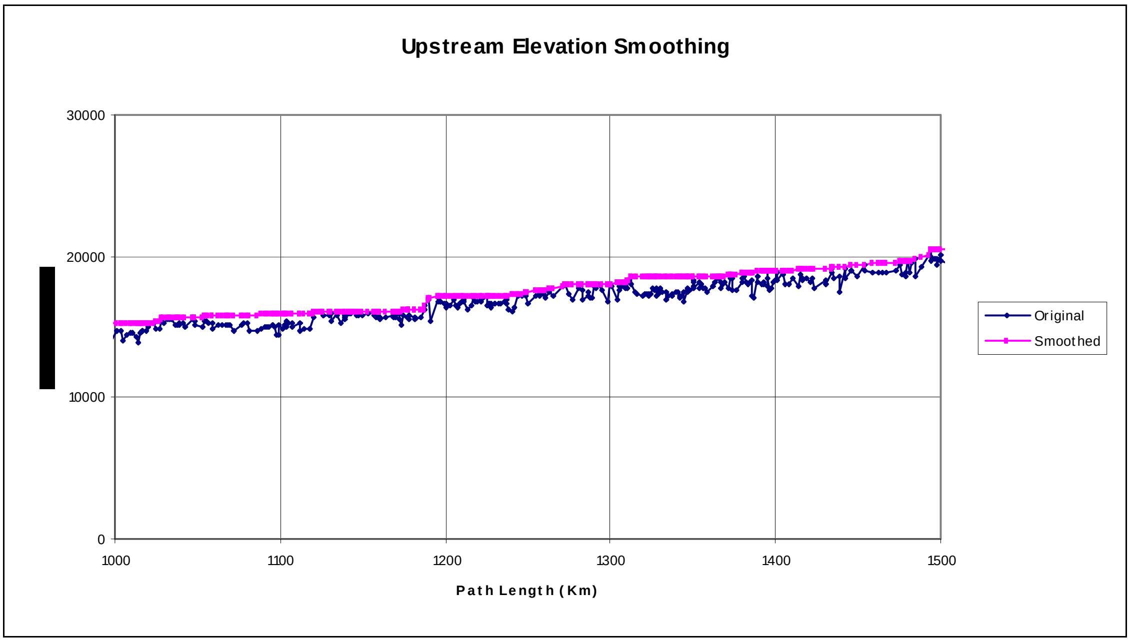

Figure A-13 – Upstream Elevation Smoothing

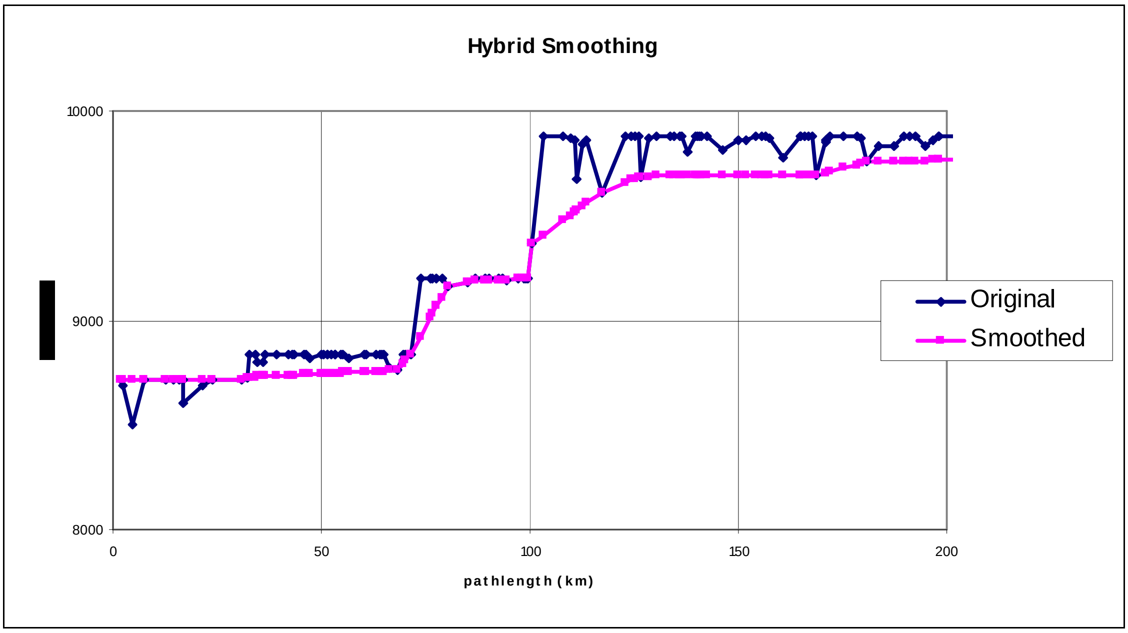

Figure A-14 – Hybrid Elevation Smoothing

Appendix B – Data Dictionary

Accounting – Hydrologic accounting unit (6-digit HUC) of a stream gage
AboveComID – Common identifier of feature that is above another (see BelowComID)
Address – Metadata Address
AddressTyp – Metadata Address Type
Agency_Cd – Gov. Agency responsible for a stream gage
ArbolateSu – An estimate of miles of stream upstream of a flowline. Not populated.
AreaSqKm – Feature area in square kilometers
AreaWtMAP – Area Weighted Mean Annual Precipitation at bottom of flowline in mm
AreaWtMAT – Area Weighted Mean Annual Temperature at bottom of flowline in degree C * 10
AttributeA – Metadata Attribute Accuracy
Ave – Average daily flow for the period of record for a stream gage
BCF – Vogel flow estimate bias correction factor
BeginningD – Metadata Beginning Date
BelowComID – Common identifier of feature that is below another (see AboveComID)
BFIYrs – Number of years used in the base-flow index computation for a stream gage
BFI_Ave – Average annual base-flow index value for a stream gage
BFI_StDev – Standard deviation of annual base-flow index for a stream gage
CalendarDa – Metadata Calendar Date
CanalDitch – Canal Ditch Type
Cat_Area – Area of catchment in square kilometers
City – Metadata City Name
ComID – Common identifier of an NHD feature or relationship
Completene – Metadata Completeness
Constructi – Construction status
ContactIns – Metadata Contact Instructions
ContactOrg – Metadata Contact Organization
ContactVoi – Metadata Contact Voice Telephone
Count – Number of cells with a particular value in the Value field of a grid
CumDrainag – Cumulative drainage area in square kilometers
CUMHILC_1 – % of cumulative drainage area classified as Unclassified in NOAA C-CAP
CUMHILC_2 – % of cumulative drainage area classified as High Intensity Developed in NOAA C-CAP
CUMHILC_3 – % of cumulative drainage area classified as Low Intensity Developed in NOAA C-CAP
CUMHILC_4 – % of cumulative drainage area classified as Cultivated Land in NOAA C-CAP
CUMHILC_5 – % of cumulative drainage area classified as Grassland in NOAA C-CAP
CUMHILC_6 – % of cumulative drainage area classified as Deciduous Forest in NOAA C-CAP
CUMHILC_7 – % of cumulative drainage area classified as Evergreen Forest in NOAA C-CAP
CUMHILC_8 – % of cumulative drainage area classified as Mixed Forest in NOAA C-CAP
CUMHILC_9 – % of cumulative drainage area classified as Scrub/Shrub in NOAA C-CAP
CUMHILC_10 – % of cumulative drainage area classified as Palustrine Forested Wetland in NOAA C-CAP
CUMHILC_11 – % of cumulative drainage area classified as Palustrine Scrub/Shrub Wetland in NOAA C-CAP

CUMHILC_12 – % of cumulative drainage area classified as Palustrine Emergent Wetland in NOAA C-CAP
CUMHILC_13 – % of cumulative drainage area classified as Estuarine Forested Wetland in NOAA C-CAP
CUMHILC_14 – % of cumulative drainage area classified as Estuarine Scrub/Shrub Wetland in NOAA C-CAP
CUMHILC_15 – % of cumulative drainage area classified as Estuarine Emergent Wetland in NOAA C-CAP
CUMHILC_16 – % of cumulative drainage area classified as Unconsolidated Shore in NOAA C-CAP
CUMHILC_17 – % of cumulative drainage area classified as Bare Land in NOAA C-CAP
CUMHILC_18 – % of cumulative drainage area classified as Water in NOAA C-CAP
CUMHILC_19 – % of cumulative drainage area classified as Palustrine Aquatic Bed in NOAA C-CAP
CUMHILC_20 – % of cumulative drainage area classified as Estuarine Aquatic Bed in NOAA C-CAP
CUMHILC_21– % of cumulative drainage area classified as Tundra in NOAA C-CAP
CUMHILC_22 – % of cumulative drainage area classified as Snow/Ice in NOAA C-CAP
CumNLCD_11 – % of cumulative drainage area classified as Open Water in NLCD
CumNLCD_12 – % of cumulative drainage area classified as Perennial Ice/Snow in NLCD
CumNLCD_21 – % of cumulative drainage area classified as Low Intensity Residential in NLCD
CumNLCD_22 – % of cumulative drainage area classified as High Intensity Residential in NLCD
CumNLCD_23 – % of cumulative drainage area classified as Commercial/Industrial/Transportation in NLCD
CumNLCD_31 – % of cumulative drainage area classified as Bare Rock/Sand/Clay in NLCD
CumNLCD_32 – % of cumulative drainage area classified as Quarries/Strip Mines/Gravel Pits in NLCD
CumNLCD_33 – % of cumulative drainage area classified as Transitional in NLCD
CumNLCD_41 – % of cumulative drainage area classified as Deciduous Forest in NLCD
CumNLCD_42 – % of cumulative drainage area classified as Evergreen Forest in NLCD
CumNLCD_43 – % of cumulative drainage area classified as Mixed Forest in NLCD
CumNLCD_51 – % of cumulative drainage area classified as Shrubland in NLCD
CumNLCD_61 – % of cumulative drainage area classified as Orchards/Vineyards/Other in NLCD
CumNLCD_71 – % of cumulative drainage area classified as Grasslands/Herbaceous in NLCD
CumNLCD_81 – % of cumulative drainage area classified as Pasture/Hay in NLCD
CumNLCD_82 – % of cumulative drainage area classified as Row Crops in NLCD
CumNLCD_83 – % of cumulative drainage area classified as Small Grains in NLCD
CumNLCD_84 – % of cumulative drainage area classified as Fallow in NLCD
CumNLCD_85 – % of cumulative drainage area classified as Urban/Recreational Grasses in NLCD
CumNLCD_91 – % of cumulative drainage area classified as Woody Wetlands in NLCD
CumNLCD_92 – % of cumulative drainage area classified as Emergent Herbaceous Wetlands in NLCD

Cumpct_CN – % of cumulative drainage area in Canada and not classified in NLCD
Cumpct_MX – % of cumulative drainage area in Mexico and not classified in NLCD
Cumsum_pct – Sum of the % cumulative drainage areas
DA_Sq_Mile – Reported drainage area in square miles of a stream gage. Stations with drainage area of -999999 means there is no reported drainage area in National Water Information System.
DataSetCre – Metadata Dataset Credit
Day1 –First date of flow data (yyyymmdd) for a stream gage
DayN – Last date of flow data (yyyymmdd) for a stream gage
DeltaLevel – Numerical difference between stream level for FromComID and stream level for ToComID in the NHDFlow table
Descriptio – Text description of feature type and the encoded attributes
Direction – 714 for coastal connection, 709 for flowing connection, 712 for network starts, 713 for network ends
Divergence – 0 if flowline is not part of a divergence, 1 if flowline is the main path of a divergence, 2 if flowline is a minor path of a divergence
DnDrainCou – Number of flowlines immediately downstream
DnLevel – Stream level of mainstem downstream flowline
DnLevelPat – Downstream mainstem level path identifier
DnMinHydro – Downstream minor path hydrologic sequence number
DUUID – Metadata identifier
Elevation – Feature elevation in feet
Enabled – Always "True"
EndingDate – Metadata Ending Date
EventDate – Date an event was created
EventType – Type of entity in an event
FCode – Numeric code that contains the feature type and its attributes as found in the NHDFCode lookup table
FDate – Feature Currency Date
FeatureCom – Reserved for future use
FeatureCla – Reserved for future use
FeatureDet – URL where detailed event entity data can be found
Flowdir – Flow direction is "WithDigitized" or "Uninitialized"
FromComID – The common identifier for a flowline in a flow relationship from which water flows (see ToComID)
FromNode – A unique number assigned to the implied node at the upstream end of an NHD Flowline
FType – NHD feature type
GNIS_ID – Geographic Names Information System ID for the value in GNIS_Name
GNIS_Name – Feature Name as found in the Geographic Names Information System
GOTBFI – Flag indicating BFI data (1) or no BFI data (2) for a stream gage
GOTQ – Flag indicating flow data (1) or no flow data (0) for a stream gage
Grid_code – Value stored in grid cells; a unique identification number for each catchment (compressed numbering system)
Grid_count – Number of cells with a particular value in the value field; equals the number of 30x30 meter grid cells in each catchment; catchment area can be computed from this field

HILC_1 – % of catchment area classified as Unclassified in NOAA C-CAP
HILC_2 – % of catchment area classified as High Intensity Developed in NOAA C-CAP
HILC_3 – % of catchment area classified as Low Intensity Developed in NOAA C-CAP
HILC_4 – % of catchment area classified as Cultivated Land in NOAA C-CAP
HILC_5 – % of catchment area classified as Grassland in NOAA C-CAP
HILC_6 – % of catchment area classified as Deciduous Forest in NOAA C-CAP
HILC_7 – % of catchment area classified as Evergreen Forest in NOAA C-CAP
HILC_8 – % of catchment area classified as Mixed Forest in NOAA C-CAP
HILC_9 – % of catchment area classified as Scrub/Shrub in NOAA C-CAP
HILC_10 – % of catchment area classified as Palustrine Forested Wetland in NOAA C-CAP
HILC_11 – % of catchment area classified as Palustrine Scrub/Shrub Wetland in NOAA C-CAP
HILC_12 – % of catchment area classified as Palustrine Emergent Wetland in NOAA C-CAP
HILC_13 – % of catchment area classified as Estuarine Forested Wetland in NOAA C-CAP
HILC_14 – % of catchment area classified as Estuarine Scrub/Shrub Wetland in NOAA C-CAP
HILC_15 – % of catchment area classified as Estuarine Emergent Wetland in NOAA C-CAP
HILC_16 – % of catchment area classified as Unconsolidated Shore in NOAA C-CAP
HILC_17 – % of catchment area classified as Bare Land in NOAA C-CAP
HILC_18 – % of catchment area classified as Water in NOAA C-CAP
HILC_19 – % of catchment area classified as Palustrine Aquatic Bed in NOAA C-CAP
HILC_20 – % of catchment area classified as Estuarine Aquatic Bed in NOAA C-CAP
HILC_21– % of catchment area classified as Tundra in NOAA C-CAP
HILC_22 – % of catchment area classified as Snow/Ice in NOAA C-CAP
HorizPosit – Metadata Horizontal Positional Accuracy
HU_8_Name –Text name of Subbasin
HUC – Hydrologic Cataloging Unit (8-digit HUC) of the gage
HUC_8 – 8-digit Hydrologic Unit Code, also known as Subbasin code (formerly known as catalog unit code)
HUC_REG – Hydrologic Region (2-digit HUC) of the gage
HwNodesqkm –Catchment area in square kilometers that drains to the headwater node of the flowline indicated by ComID
Hydrograph – hydrographic category, Intermittent or perennial
Hydroseq – Hydrologic sequence number
IncrFlowU – Incremental Flow (cfs) for Flowline as computed by the Unit Runoff Method
Inundation – Inundation Area Type
Lat_NHD – Latitude of the NHD location in decimal degrees, NAD83
Lat_Site – Latitude of the streamgage (site) location - gage house in decimal degrees, NAD83
LengthKM – Feature Length in kilometers
LevelPathi – Hydrologic sequence number of most downstream flowline in level path
LogicalCon – Metadata Logical Consistency
Lon_NHD – Longitude of the NHD location in decimal degrees, NAD83
Lon_Site – Longitude of the streamgage (site) location - gage house in decimal degrees, NAD83
MAFlowU – Mean Annual Flow (cfs) at bottom of flowline as computed by Unit Runoff Method
MAFlowV – Mean Annual Flow (cfs) at bottom of flowline as computed by Vogel Method
MAVelU – Mean Annual Velocity (fps) at bottom of flowline as computed by Unit Runoff Method
MAVelV – Mean Annual Velocity (fps) at bottom of flowline as computed by Vogel Method

MaxElevRaw – Maximum elevation (unsmoothed) in meters
MaxElevSmo – Maximum elevation (smoothed) in meters
Measure – Measure along reach where a point event is located, in percent from downstream end
Metadata_1 – Metadata Standard Version
Max_ – Maximum daily flow for the period of record for a stream gage
MetadataDa – Metadata Date
MetadataSt – Metadata Standard Name
Min_ – Minimum daily flow for the period of record for a stream gage
MinElevRaw – Minimum elevation (unsmoothed) in meters
MinElevSmo – Minimum elevation (smoothed) in meters
NewHUCode – Substr(NewReachCo,1,8)
NewReachCo –New Reach Code in a Reach cross reference entry
NewReachDa –New Reach date in a Reach cross reference entry
NewUPMI – not used
NDays – Number of days of flow data for a stream gage
NDaysGT0 – Number of days of non-zero flow for a stream gage
NHD2Gage_D – Distance between a Stream Gage and the NHD Reach to which it is linked
NLCD_11 – % of catchment area classified as Open Water in National Land Cover Dataset 1992 (NLCD)
NLCD_12 – % of catchment area classified as Perennial Ice/Snow in NLCD
NLCD_21 – % of catchment area classified as Low Intensity Residential in NLCD
NLCD_22 – % of catchment area classified as High Intensity Residential in NLCD
NLCD_23 – % of catchment area classified as Commercial/Industrial/Transportation in NLCD
NLCD_31 – % of catchment area classified as Bare Rock/Sand/Clay in NLCD
NLCD_32 – % of catchment area classified as Quarries/Strip Mines/Gravel Pits in NLCD
NLCD_33 – % of catchment area classified as Transitional in NLCD
NLCD_41 – % of catchment area classified as Deciduous Forest in NLCD
NLCD_42 – % of catchment area classified as Evergreen Forest in NLCD
NLCD_43 – % of catchment area classified as Mixed Forest in NLCD
NLCD_51 – % of catchment area classified as Shrubland in NLCD
NLCD_61 – % of catchment area classified as Orchards/Vineyards/Other in NLCD
NLCD_71 – % of catchment area classified as Grasslands/Herbaceous in NLCD
NLCD_81 – % of catchment area classified as Pasture/Hay in NLCD
NLCD_82 – % of catchment area classified as Row Crops in NLCD
NLCD_83 – % of catchment area classified as Small Grains in NLCD
NLCD_84 – % of catchment area classified as Fallow in NLCD
NLCD_85 – % of catchment area classified as Urban/Recreational Grasses in NLCD
NLCD_91 – % of catchment area classified as Woody Wetlands in NLCD
NLCD_92 – % of catchment area classified as Emergent Herbaceous Wetlands in NLCD
Offset – Display offset for an event
OID – Internal ESRI Table row ID
OldHUCode – Substr(OldReachCo,1,8)
OldReachCo – Old Reach Code in a reach cross reference entry
OldReachDa – Old Reach Date in a Reach cross reference entry
OldUpMI –Not used
Operationa – Operational status

Originator – Metadata Originator
P1 – 1st percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P5 – 5th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P10 – 10th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P20 – 20th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P25 – 25th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P30 – 30th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P40 – 40th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P50 –50th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P60 – 60th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P70 – 70th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P75 – 75th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P80 – 80th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P90 – 90th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P95 – 95th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
P99 – 99th percentile of daily flow for the period of record of a stream gage. Negative values indicate reverse flow; tidal or backwater
PathLength – Distance to terminal flowline
Pct_CN – % of catchment area in Canada and not classified in NLCD
Pct_MX – % of catchment area in Mexico and not classified in NLCD
PipelineTy – Pipeline type
Positional – Metadata Positional accuracy
PostalCode – Metadata Postal Code
Precip – Mean annual precipitation in mm
Process –In a Reach cross reference entry, the name of the process that created the Reach Code change
ProcessDes – Metadata Process Description
Prod_unit – Production unit identifier
ProssDat – Metadata Process Date
Publicatio – Metadata Publication Date
ReachCode – Reach Code assigned to feature or reach on which an event is located
ReachFileV – Reach file version in a Reach cross reference entry

ReachsmDat – Reach Version Date
ReachResol – Reach Resolution
Relationsh – Relationship to surface
ReservoirT – Reservoir type
Resolution – Always "Medium"
Reviewed – Flag to indicate review status - Y or N – of an event location.
Shape_Area – ESRI feature area in square decimal degrees
Shape_Leng – ESRI feature length in decimal degrees
SiteStatus – Active (A) or Inactive (I) where active StreamGageEvents have streamflow data in water year(s) 2003 and/or 2004
Slope – Slope of flowline (cm/cm)
Source – Source of boundary;, 0 = Watershed Boundary Dataset, 1 = NHD, 2 = Other
SourceCita – Metadata Source Citation Abbreviation
SourceCont – Metadata Source Contribution
SourceCurr – Metadata Source Currentness Reference
SourceScal – Metadata Source Scale Denominator
Source_Ori – Originator of an event
Source_Dat – Description of event entity
Source_Fea – Unique Identifier of event entity, link to external data about entity
SpecialUse – Special use category
Stage – Elevation stage
StartFlag – 0 if a flowline is not a headwater flowline, 1 if a flowline is a headwater flowline
State – 2 char. state postal abbreviation of the USGS Water Science Center maintaining the gage. Puerto Rico is listed as a state.
State_Cd – 2-digit state FIPS code of the WSC maintaining the gage. Puerto Rico is listed as a state.
Station_NM – Station name
StateorPro – Metadata State or Province
StDev – Standard deviation of daily flow for the period of record
StreamLeve –Stream level (dimensionless)
StreamOrde – Strahler stream order. Not populated. See NHDPlus data extension table SOSC.dbf.
SubRegion – Hydrologic sub-region (4-digit HUC)
Sum_pct – Sum of the % catchment areas
Temp –Mean annual temperature in degrees centigrade * 10
TerminalFl – 0 if a flowline is not a network terminus, 1 if a flowline is a network terminus
TerminalPa – Hydrologic sequence number of terminal flowline
ThinnerCod – Ordinal value used to display various network densities
Title – Metadata title of source data used as input for creating or updating NHD
ToComID – Common identifier for a flowline which is receiving flow in a flow relationship (see FromComID)
ToComIDMea – Not valued
ToNode – A unique number assigned to the implied node at the downstream end of a flowline
TypeofSour – Metadata type of Source Media
UpHydroSeq – Upstream mainstem hydrologic sequence number
UpLevelPat – Upstream mainstem level path identifier

UpMinHydro – Upstream minimum hydrologic sequence number
Value – The value stored in grid cells; also known as Grid_code in related tables
VertPositi – Metadata Vertical Positional Accuracy
WBAreaComI – ComID of an NHD polygonal water feature through which an NHD "Artificial Path" flowline flows

Appendix C.1 – NLCD Land Cover Classification System Key

Used for Continental US Only
(Rev. July 20, 1999)

Water
All areas of open water or permanent ice/snow cover.

11. **Open Water –** All areas of open water; typically at least 25 percent of pixel or cell is water.

12. **Perennial Ice/Snow –** All areas characterized by year-long cover of ice and/or snow.

Developed
Areas characterized by at least 30 percent of constructed materials (e.g., asphalt, concrete, buildings, etc).

21. **Low Intensity Residential –** Areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover; the remaining percentage is vegetation. These areas most commonly include single-family housing units. Population densities are lower than in the high intensity residential class.

22. **High Intensity Residential –** Highly developed areas where large numbers of people reside, such as apartment complexes and row houses. Vegetation occupies less than 20 percent of the area, and constructed materials cover 80 to100 percent.

23. **Commercial/Industrial/Transportation** – Includes infrastructure (e.g., roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

Barren
Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present, regardless of any inherent ability to support life. Vegetation, if present, is sparse and scrubby compared to other vegetated categories, and lichen may be extensive.

31. **Bare Rock/Sand/Clay –** Perennially barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. **Quarries/Strip Mines/Gravel Pits –** Areas of extractive mining activities with significant surface expression.

33. **Transitional –** Areas of sparse vegetative cover (less than 25 percent of area) that are dynamically changing from one land cover to another, often because of human activities. Examples include forest clearcuts, transition between forest and agricultural land, temporary removal of vegetation, and changes due to natural causes (e.g., fire, flood, etc.).

Forested Upland – Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall). The tree canopy accounts for 25-100 percent of the land cover.

41. **Deciduous Forest –** Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. **Evergreen Forest –** Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. **Mixed Forest –** Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the land cover.

Shrubland – Areas characterized by natural or semi-natural woody vegetation that is generally less than 6 meters tall. Individual shrubs or clumps may be isolated or interlocking. Shrubland includes evergreen and deciduous species of true shrubs, young trees, and small or stunted trees or shrubs.

51. **Shrubland –** Areas dominated by shrubs, with shrub canopy covering 25-100 percent of the land. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrubs may cover less than 25 percent where no other vegetation type has a greater percentage to establish a distinct classification.

Non-Natural Woody – Areas dominated by non-natural woody vegetation occupying 25-100 percent of the area. Classifying non-natural woody land cover depends upon the availability of ancillary data to differentiate non-natural from natural woody vegetation.

61. **Orchards/Vineyards/Other –** Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland – Upland areas characterized by natural or semi-natural herbaceous vegetation that accounts for 75-100 percent of the cover.

71. **Grasslands/Herbaceous –** Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, although they are often grazed.

Planted/Cultivated – Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. **Pasture/Hay** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. **Row Crops –** Areas used for the production of crops such as corn, soybeans, vegetables, tobacco, and cotton.

83. **Small Grains –** Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. **Fallow –** Areas used for the production of crops that are temporarily barren or with sparse vegetative cover due to land management that alternates between cropping and tillage.

85. **Urban/Recreational Grasses –** Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands – Areas where water covers or saturates the soil or substrate periodically, as defined by Cowardin et al.

91. **Woody Wetlands –** Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover, and the soil or substrate is periodically saturated with, or covered with, water.

92. **Emergent Herbaceous Wetlands –** Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover, and the soil or substrate is periodically saturated with, or covered with, water.

Appendix C.2 – NOAA C-CAP Land Cover Classification System Key

Used for Hawaii Only

0	Background
1	Unclassified
2	High Intensity Developed
3	Low Intensity Developed
4	Cultivated Land
5	Grassland
6	Deciduous Forest
7	Evergreen Forest
8	Mixed Forest
9	Scrub/Shrub
10	Palustrine Forested Wetland
11	Palustrine Scrub/Shrub Wetland
12	Palustrine Emergent Wetland
13	Estuarine Forested Wetland
14	Estuarine Scrub/Shrub Wetland
15	Estuarine Emergent Wetland
16	Unconsolidated Shore
17	Bare Land
18	Water
19	Palustrine Aquatic Bed
20	Estuarine Aquatic Bed
21	Tundra
22	Snow/Ice

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Footnotes

[1] All referenced placeholder shapefiles and dBase files are included to complete the official NHD data model and are empty in NHDPlus.
[2] The elev_cm grids have "Zunits 100" instead of "Zunits NO."
[3]Additional information about the NHD content and format can be found at the NHD Web site: http://nhd.usgs.gov. The NHD Schema is described at http://nhd.usgs.gov/NHD.pdf.
[4] Additional information about the NHD content and format are available on the NHD Web site at http://nhd.usgs.gov.
[5] In Hydrologic Regions 01, 02, and 03, USGS WRD field offices were able to specify NHD network updates that were based on local knowledge and/or the use of DRGs.
[6] Table 1 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.