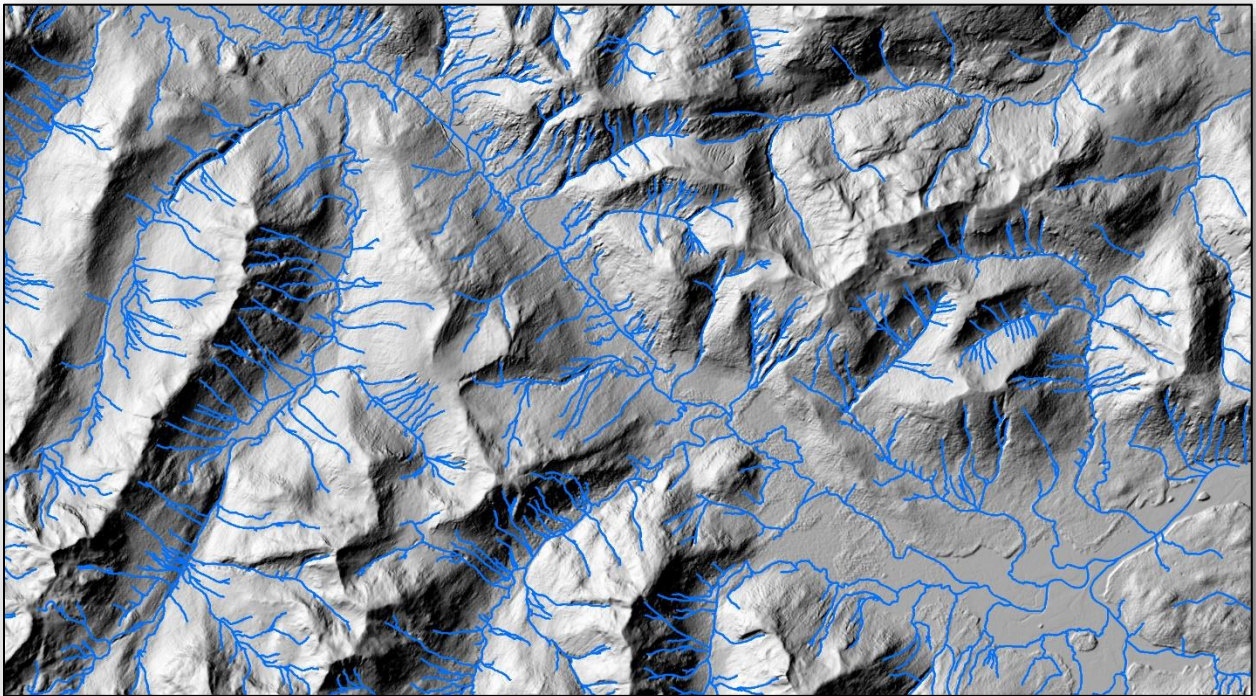




Bulk Updating the NHD with DEM-derived Flowlines





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Overview

The National Hydrography Dataset (NHD) is the most comprehensive collection of hydrography data in the United States, and it is used by scientists and government agencies in numerous capacities. The NHD consists of line features that represent the spatial geometry of streams and rivers, and area features that represent waterbodies like lakes and ponds, as well as wide rivers and streams. The majority of data that is currently in the NHD was manually digitized from 1:24,000 scale topographic maps. An increasing amount of the NHD, however, is comprised of high-resolution digital elevation model (DEM)-derived streamlines that are more spatially and geometrically accurate than the traditional 1:24,000 scale data.

As the U.S. Department of Agriculture, Forest Service (USFS) continues to collect lidar data for National Forests across the country, there is increasing availability of high-resolution (1 meter) digital elevation models that can be used to model very accurate stream networks. However, the process of bulk updating the NHD with lidar-derived stream networks, or flowlines, is often seen as a difficult, unintuitive process. To facilitate the incorporation of lidar-derived flowlines into the NHD, USFS Pacific Southwest Region (Region 5) cooperators partnered with the USFS Geospatial Technology and Applications Center (GTAC) for technical guidance on submitting relatively large amounts of data (thousands of new features) to the NHD in an efficient manner. To meet that objective, GTAC worked with subject matter experts to provide detailed information about the NHD update process and recommend ideal workflows for preparing DEM-derived flowlines for bulk updates to the NHD. The workflow detailed in this project is implemented prior to the standardized NHD update workflows, and it focuses on streamlining the update process by enacting key quality control measures that prepare flowline data for the US Geological Survey's standardized process.

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Introduction

The National Hydrography Dataset (NHD) is the authoritative national database for spatial information about surface water within the United States and is a component of U.S. Geological Survey's (USGS) The National Map (U.S. Geological Survey, 2018a). The NHD consists of vector-based geospatial data that represent the nation's drainage networks and related features, including rivers, streams, canals, lakes, ponds, glaciers, coastlines, dams, and stream-gages. The primary product within the NHD is the High Resolution dataset, which contains all hydrography data mapped at a scale of 1:24,000 or better.

Traditional applications of the NHD include resource management activities (e.g., fishery and forestry management plans), informing environmental regulation (e.g., mineral extraction activities), aiding in disaster response planning (e.g., flooding or chemical spills), and everyday mapping requirements for recreation or travel.

The majority of existing NHD data was derived from aerial or satellite image interpretation or GPS field survey. An increasing amount of the NHD, however, is comprised of streamlines derived from lidar or Interferometric Synthetic Aperture Radar (IfSAR) digital elevation models (DEM) that are more spatially and geometrically accurate than the traditional 1:24,000 scale data (Poppenga and others 2009; Poppenga and others 2013). Figures 1 and 2 illustrate the contrast between NHD flowlines captured through digitization of features from aerial imagery versus NHD flowlines derived from DEM.

As the U.S. continues to collect lidar data for National Forests across the country, there is increasing availability of high resolution (e.g., 1 meter) DEMs that can be used to model very accurate stream networks. Although this data has the potential to greatly improve the accuracy of the NHD, many see the process of updating the NHD as a difficult, unintuitive process. Moreover, many are unaware of the variety of tools and workflows available to facilitate the submission of large amounts (e.g., tens of thousands of features) of DEM-derived flowline data to the NHD.

To address the growing demand for transparent, easy-to-follow workflows for preparing and submitting flowlines to the NHD, this project sought to do two primary things: (1) build awareness of the resources and tools made available by the USGS for submitting newly-derived content to the NHD; and (2) detail a comprehensive workflow that informs users how to prepare flowline data for standardized NHD GeoConflation workflows. Accordingly, the USFS Geospatial Technology and Applications Center (GTAC), under direction from the Geospatial Technology and Applications Steering Committee (GeoTASC), partnered with cooperators from the Plumas National Forest in the Pacific Southwest Region (Region 5) to identify and document the appropriate steps for submitting bulk updates to the NHD. GTAC worked with subject matter experts to identify any potential inefficiencies in the existing bulk update workflow, and to clarify the available avenues for a given update effort. The resulting deliverables provide detailed information about the NHD stewardship model and the avenues available for submitting NHD updates. In addition, a set of step-by-step exercises were created that walk users through an ArcMap workflow that implements critical quality control (QC) measures prior to the use of the standardized USGS tool. This workflow effectively streamlines the update process by addressing metadata and geometric errors in the flowline data that would otherwise be flagged as errors by the USGS tool and require further iterations of the tool.

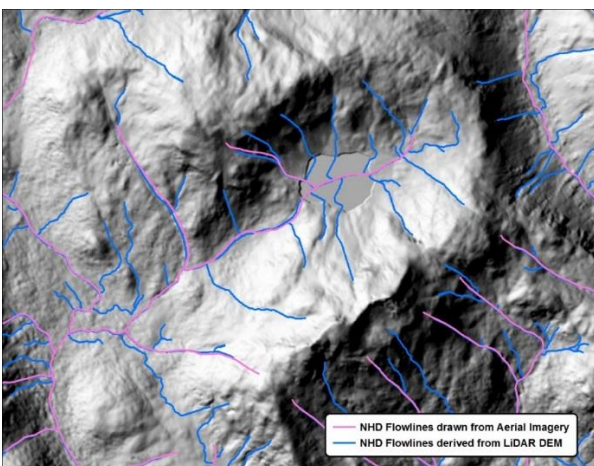


Figure 1: Comparison of flowlines derived from imagery (shown in purple) and flowlines derived from a DEM (shown in blue)

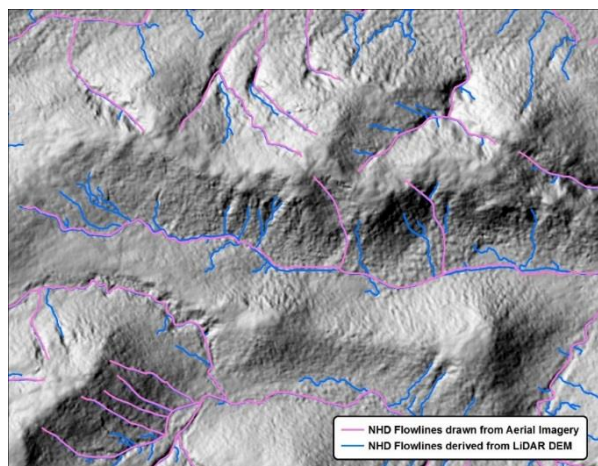


Figure 2: Comparison of flowlines derived from imagery (shown in purple) and flowlines derived from a DEM (shown in blue)

NHD Stewardship

The USGS administers and distributes the NHD, and although the USGS does undertake general maintenance activities on the data (i.e., the image integration and network improvement programs of work), states are generally responsible for conducting the bulk of NHD stewardship activities (e.g., feature updates). Stewardship of the NHD can be separated into two functional components: federal support and state stewardship. The federal component focuses on the provision of infrastructure and technical support, while the state component focuses on funding and the provision of resources to update the NHD. As a result, the NHD is administered and regulated at the federal level by the USGS, while stewardship of the data within the NHD is typically the responsibility of agencies at the individual state level. This enables NHD Stewards within each state to use a standardized operations platform at the federal level, while still relying on local knowledge about surface water characteristics within their area of interest.

To integrate new hydrography data into the NHD, the USGS works with qualified individuals from state, federal, and local agencies to conflate new data with the NHD. These stewards have access to the NHD Update tool and have the knowledge and skills to perform final QC checks for the new data that has passed through standardized NHD update workflows. Table 1 lists the NHD Stewards and key points of contact for Region 5, including a regional technical point of contact and the national contact for GeoConflation support and training.

Name	Role	Association
Jane Schafer-Kramer	California NHD Principal Steward	California Dept. of Water Resources
Greg Smith	California NHD Principal Steward	USGS NGTOC
David Anderson	GeoConflation Expert	USGS NGTOC
Bill Smith	West Coast Regional Technical POC	USGS NGTOC

Table 1: California NHD Stewards and Key Points of Contact

Although there are a variety of tools available (table 2) to qualified users interested in updating the NHD, it is not always clear what tools are appropriate for a given situation. This section is intended to elaborate on the role of each tool in the update process, as well as clarify what circumstances call for specific tools.

Tool	Purpose	Role/Type of Update
NHD Update Tool	This tool contains all of the core functionality required to submit updates to the production NHD. Typically used for manual feature-by-feature updates to the NHD.	Used to perform the required final step of submitting changes to the NHD for both manual and bulk updates.
GeoConflation Tool (GCT)	The NHD GCT is used to migrate/conflate reach codes, permanent identifiers and other attribute information from existing NHD content to new, higher resolution NHD content. This tool is typically used to facilitate bulk updates to the NHD.	Used to facilitate bulk updates to the NHD. The pre-conflation workflow developed during this project is implemented before this tool, while the NHD Utilities and NHD Update tools are implemented after the GCT.
NHD Utilities	Software suite of advanced tools for performing specialized tasks with the NHD data.	As it relates to GeoConflation, these tools are used to translate conflated data to an NHD checkout job.
Subset by Polygon Tool	This Esri Add-In tool ingests a user-defined polygon to define an area of interest from which to extract all intersecting hydrography data.	Used to select and prepare a subset of an NHD checkout extent for a GeoConflation update.
NHD Flowcheck Tool	This Esri Add-in tool performs a series of functions that validate the flow in the target data based on the digitized direction and assigned flow direction values.	This tool is used to assess the suitability of data for the GeoConflation workflow and to direct users to features that may have potential conflicts with the GeoConflation workflow.

Table 2: USGS Tools, Descriptions and Applications

Although the USGS provides extensive training and documentation for NHD update workflows and related toolsets, including workflows for bulk updates to the NHD, the information gap addressed by this project focused on the preparation of newly-derived hydrography content that meets NHD requirements. The preparation of NHD content from scratch has, to date, not been a standardized workflow within the USGS's administration purview. This is due to the numerous ways in which hydrography data can be collected or synthesized for NHD integration, and those differing collection methodologies being too broad in scope to capture as prescriptive documentation. As a result, the USGS focuses the bulk of its NHD training and documentation deliverables on how to proceed with updates once the data has been formatted to minimum NHD requirements. For example, the USGS focuses on

how to use the GeoConflation tool and related GeoConflation update workflow, rather than focusing on how to prepare data that is suitable for GeoConflation requirements.

This project addressed the data preparation information gap by documenting a prescriptive workflow for preparing DEM-derived hydrography to meet USGS formatting requirements for the NHD. The resulting information was designed to provide users with a sequential workflow for making DEM-derived streams suitable for use with the USGS's GeoConflation tool and workflow documentation.

Study Area

The study area used to demonstrate the workflow developed for this project (figure 3) is coincident with the extent of the Moonlight Fire, which burned over 65,000 acres on the Plumas National Forest in northern California in September 2007. The burned area became the focus of a restoration project aimed at rehabilitating and promoting healthy and resilient ecosystems. To that end, lidar data was collected in 2013 for a large portion of the fire's extent, with the intention of using that data to better assess physical landscape characteristics, including surface hydrography. The lidar assessment resulted in the production of newly-derived surface flowlines that could be used to update the NHD within the study area.

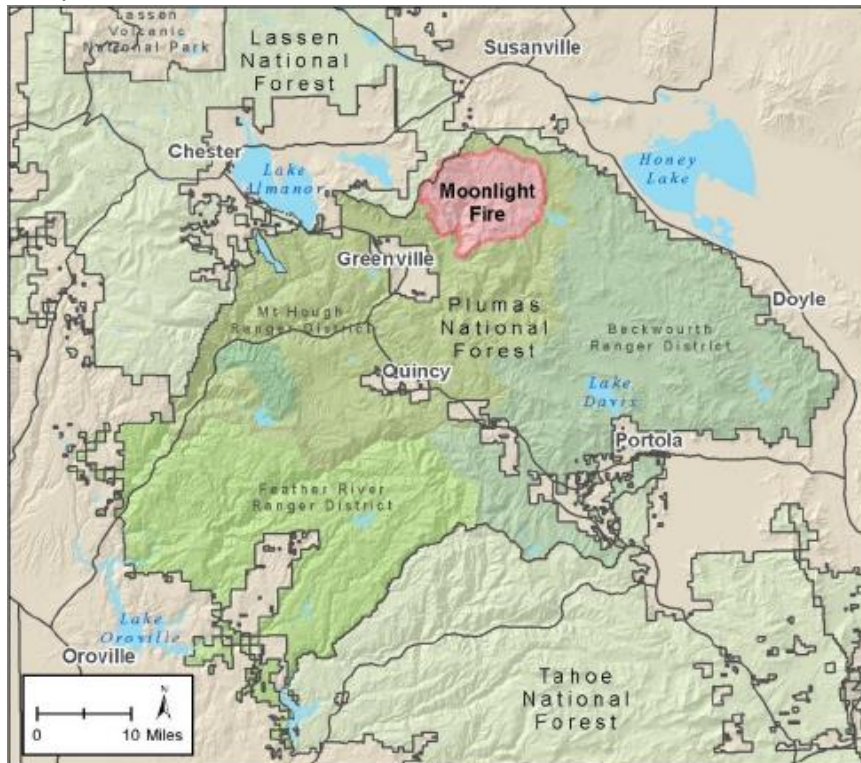


Figure 3: Moonlight Fire Location Map (Credit: Moonlight Fire Restoration Strategy, USDA FS)

The extent of the study area was contained within a subset of a single 8-digit Hydrologic Unit (HUC8) within the national Watershed Boundary Dataset (WBD) (U.S. Geological Survey, 2018b). HUC8s within the WBD serve as the frame of reference by which NHD updates are transacted (i.e., NHD data is

checked out and updated on the basis of individual HUC8s, and in some instances HU10s, so the study area included one single job checkout from the NHD).

Within the study area, the newly-compiled surface hydrography consisted of a mixture of DEM-derived and manually digitized stream flowlines. The new flowline data was based largely on lidar DEM-derived features where available and then infilled with manually-digitized features where lidar data was absent.

Bulk Update Workflow

The most efficient way to submit large amounts of data to the NHD is to use the USGS GeoConflation tool. This tool performs several key tasks, including transferring existing Reachcodes and GNIS Names to the new data, tracking transferred Reachcodes, and performing QC checks that ensure data submitted for NHD updates are in the correct NHD schema (Anderson 2017). Figure 4 outlines the general workflow of preparing a DEM for flowline generation, producing and attributing those flowlines, and finally conflating flowlines with the NHD. Each of the blue and green boxes in figure 4 describe processes that are well documented within the USFS and USGS. The preprocessing for GeoConflation step (red box), however, is not documented by either agency.

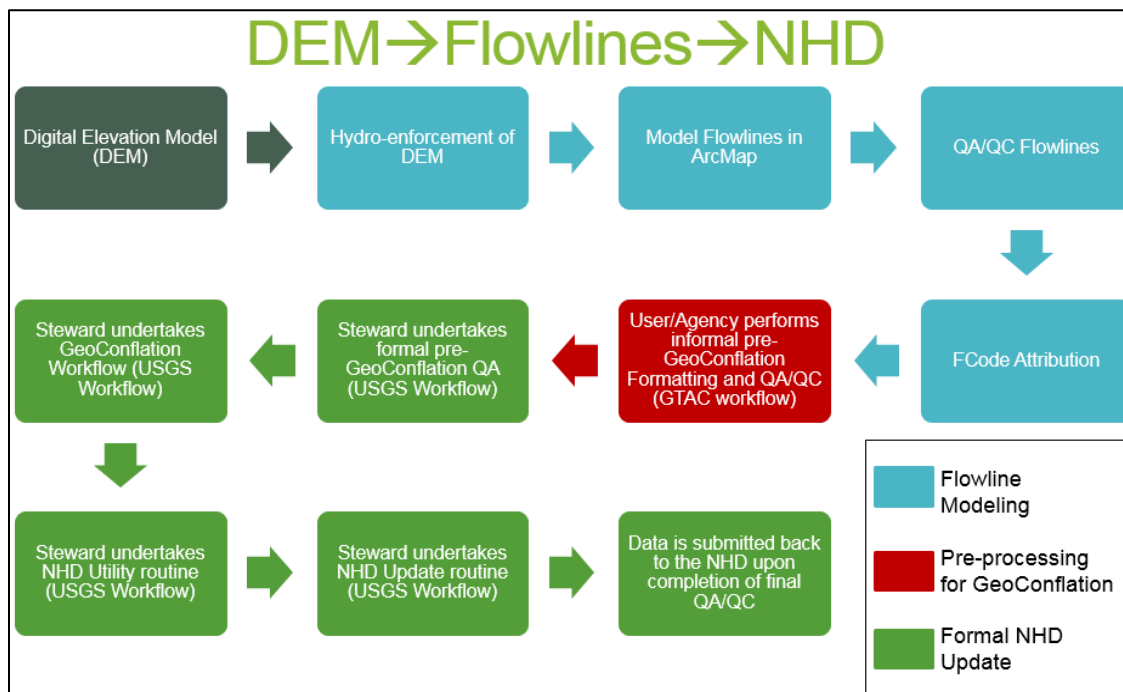


Figure 4: Generalized Workflow Diagram

The goal of the pre-GeoConflation workflow (red box in figure 4) is to perform QC processes that address typical issues with DEM-derived flowlines that would otherwise impede or completely prevent the flowline data from being useful within the standardized USGS GeoConflation workflow. Similarly, by addressing any and all formatting issues prior to beginning the standardized USGS workflow, the pre-GeoConflation workflow effectively saves time and money by eliminating the need to iterate the process whenever the tool encounters a formatting error.

Figure 5 denotes the sequential order in which a user would address QC tasks related to the preparation of DEM-derived flowlines for the NHD. Broken down into sub-steps, the pre-GeoConflation data processing workflow has eight parts to it. Each of the eight sub-processes have been documented in detail and are presented to users in the context of practice examples with accompanying data so that users can apply the workflow firsthand and replicate it using their own data.

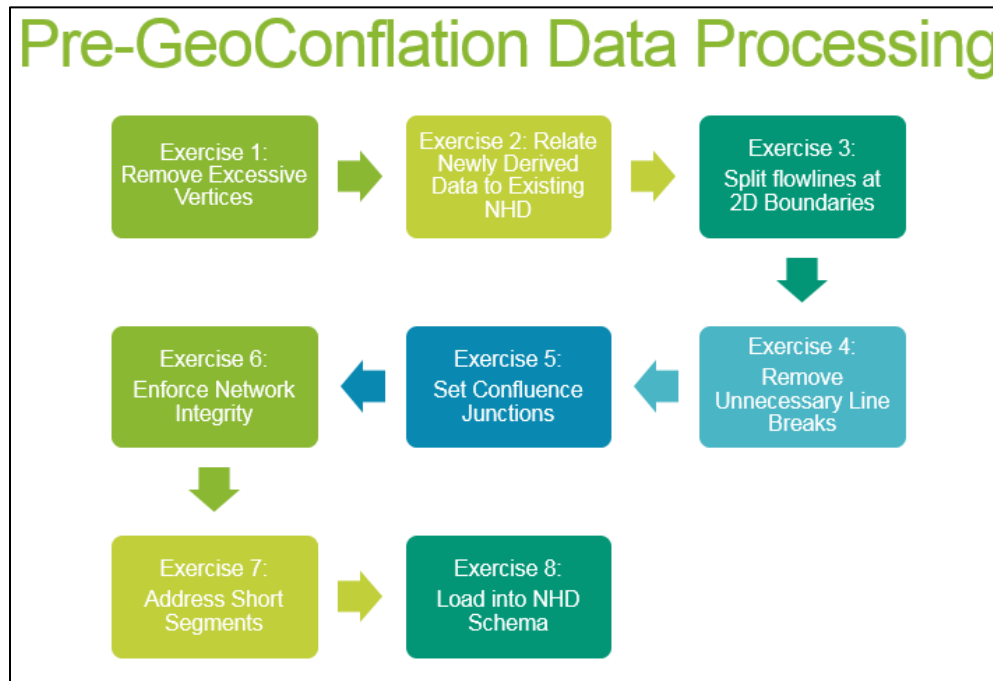


Figure 5: Pre-GeoConflation Workflow Diagram

The pre-GeoConflation data processing workflow involves minimal formatting requirements, as these requirements are addressed across each of the eight sub-processes within the pre-GeoConflation workflow. However, the one requirement that users must consider prior to attempting the workflow is the provision of an NHD FCode value for each unique feature that is intended to update the NHD. By and large, these eight sub-processes documented in this project employ standard GIS processes in ArcMap that are easily repeatable for users with varying levels of GIS experience.

Deliverables

There are two primary deliverables for this project that will be made available to the wider USFS community (accessible deliverables here: <https://bit.ly/37jmouL>), as well as two secondary deliverables that directly benefit stakeholders on the Plumas National Forest. For the broader USFS community, a user guide was developed that provides critical background information on the NHD, the NHD Stewardship model, NHD standardized tools, and a discussion of the overall workflow. It is intended that this document will serve the wider USFS community, particularly GIS users or hydrography stewards seeking information about methods for submitting bulk updates to the NHD.

This project also produced a series of eight step-by-step exercises that are prefaced by the aforementioned user guide. These exercises begin with basic DEM-derived flowlines, assuming only that FCodes have already been assigned by someone with local/expert knowledge of the study area. The eight exercises walk users through the process of preparing data to be entered later in the USGS GeoConflation Tool. The associated exercise data is provided in a way that a user can start from the beginning and continue to use the same dataset throughout the sequential exercises. Alternatively, an ArcMap Document (MXD file) with the appropriate data is provided for each exercise so that users can jump into the workflow at any point they see fit.

Specific to the Plumas National Forest, we prepared and submitted their flowline data to the NHD, which directly supports their restoration efforts within the extent of the Moonlight Fire. Similarly, geometric inconsistencies within the working dataset for the study area were identified and communicated to Plumas National Forest staff. This served to illustrate common areas of concern within DEM-derived flowlines so that subject matter experts on the Forest would be able to better identify those inconsistencies in the future. Finally, a meeting was held with NHD and GeoConflation experts from the USGS and interested USFS personnel from Region 5. The purpose of the meeting was to highlight this project, discuss the various avenues for updating the NHD, and to provide a platform for experts from the USGS to discuss the stewardship model and the GeoConflation tool more specifically. Meetings such as this provide a great opportunity to build synergy between the USFS and USGS, while also offering a platform for people with a range of experience with the NHD to learn and ask questions about data and the stewardship process.

Conclusion/Next Steps

The material developed for this project provides important information about the NHD that will serve to better inform NHD users about the USGS stewardship model and the available ways to update the NHD with hydrography data derived from lidar or IfSAR DEMs. The user guide and exercises can act as a point of reference for USFS personnel interested in preparing their DEM-derived flowlines for NHD conflation. USGS personnel who reviewed the deliverables remarked that the user guide and exercises provide a nice balance of introductory information on the NHD and more in depth information on the methods for preparing hydrography data for the NHD update process. They also recommended that users interested in NHD editing register for a free NHD 101 training course held by Bill Smith and Joel Skalet (contact Joel at jjskalet@usgs.gov to sign up). To gain access to production-level NHD tools, which includes the GeoConflation tool, contact David Anderson (danderson@usgs.gov) to schedule the required training.

To build awareness of these products, we plan to schedule meetings with different USFS Regions, in which the experts from the USGS and the authors of this report can share information with a broader USFS audience and respond to any pertinent questions or concerns.



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