

Stream Mapping of Western North Carolina Counties

Roger K. Cottrell, Jr., PMP, Joe Sewash, Scott Edelman, P.E.

Abstract

The Studies Act of 2004 (Senate Bill 1152) created by the 2003 North Carolina General Assembly directed the North Carolina Geographic Information Coordinating Council (GICC) and the North Carolina Department of Environment and Natural Resources (NC DENR) to develop an implementation plan for improving the mapping and digital representation of surface waters in North Carolina. The North Carolina Center for Geographic Information and Analysis (NC CGIA) as staff to the GICC and a division of NC DENR, facilitated meetings in Fall 2004 with the stakeholder community to document business requirements, consider production methods and costs, project returns on investment in terms of efficiencies and cost avoidance, and develop a comprehensive implementation plan for the statewide dataset. The plan was presented to the General Assembly through the Environmental Review Commission in January 2005. In the fall of 2004, Hurricanes Ivan and Frances battered significant portions of North Carolina leaving nineteen (19) counties in the region declared federal disaster areas. In response, the North Carolina General Assembly, through Senate Bill 7, developed the Hurricane Recovery Act. The act created several programs to support the response and recovery of this area. This package included support for the North Carolina Stream Mapping Project to implement the recommendations of implementation plan. Under the direction of CGIA, this local resolution stream mapping was completed in June of 2007, and included an accuracy study, development of a custom geodatabase and associated production tools, and the creation of high resolution stream and water body features in National Hydrographic Dataset (NHD) format. Streams and water body features were mapped to two hundred feet upstream of the six acre drainage area limit using high resolution aerial photography and Light Detection and Ranging (LiDAR)-derived terrain products, including hill shades and two foot contour vector files.

1.0 Introduction

The Streambed Mapping Project for the Western North Carolina Counties was a product of the “Implementation Plan to Improve the Digital Representation and Mapping of Surface Waters in North Carolina.” This technical report written in 2004 was drafted in response to the Studies Act of 2004 (Senate Bill 1152), which mandated a plan to improve the mapping of streams and surface waters in the State of North Carolina. It was established that current stream maps used by government agencies and the private sector were often outdated, inaccurate, and incomplete, which lead to significant inefficiencies in the development and management of projects and business processes dependent on hydrographic data.

To develop an effective implementation plan, the Geographic Information Coordinating Council (GICC) tasked the Statewide Mapping Advisory Committee (SMAC) with the creation of the Stream Mapping Working Group (SMWG), comprised of federal, state and local agencies. Through a series of meetings, the Stream Mapping Working Group established user requirements, mapping specifications, and implementation options for the plan. This group effort identified the need for a new statewide digital stream file to be referenced and maintained by federal, state and local government agencies, as well as the public. Upon completion, the new statewide digital stream file will be placed on the NCOneMap Web site (<http://www.nconemap.org/>) for public access.

The creation of this new digital surface waters file will provide financial and time-saving benefits to individual agencies. This file will benefit users’ standard business practices and improve the data quality produced by these agencies for analytic and/or regulatory purposes. Some of these benefits

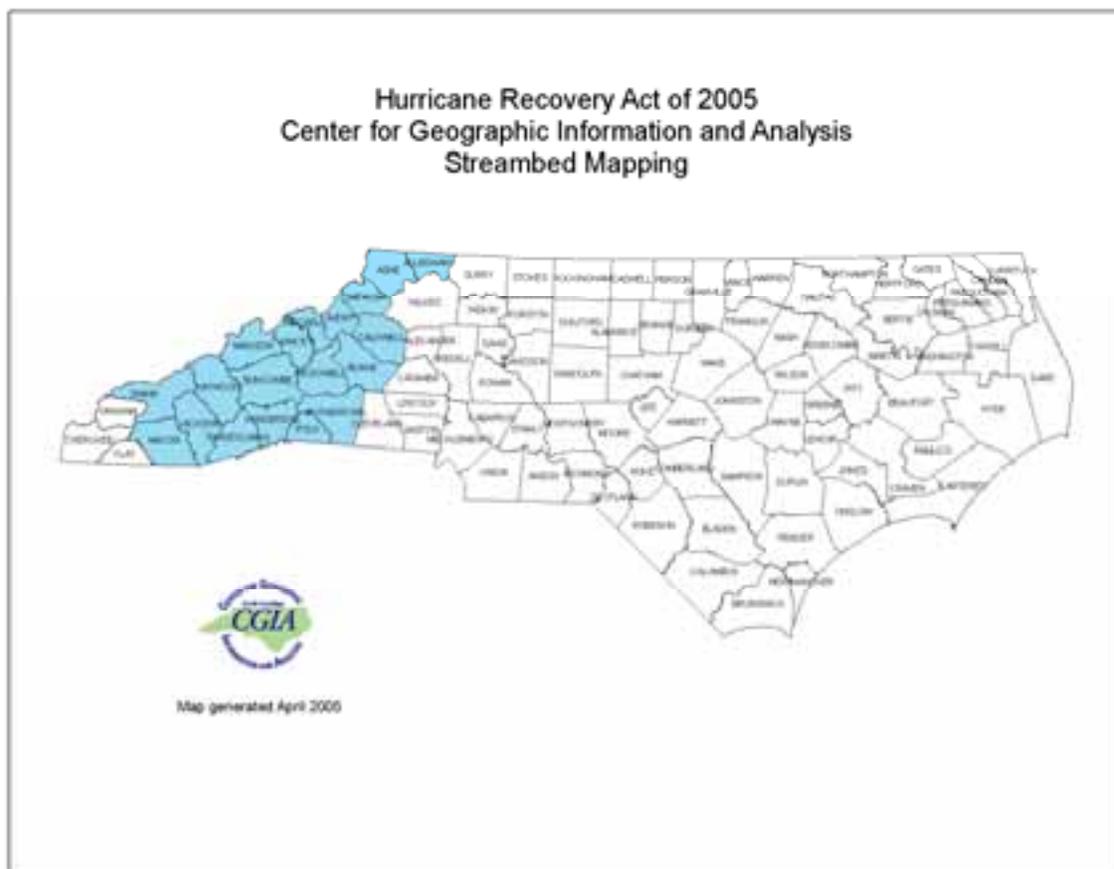
include more effective project planning, reduced field work/site visits, and the improvement of stream corridor monitoring and protection.

The vision of the study was one of interagency cooperation to facilitate data sharing and use. This shared vision, supported by common goals, ensured a product beneficial to all stakeholders. The insights and perspectives gathered through the creation of the “Implementation Plan to Improve the Digital Representation and Mapping of Surface Waters in North Carolina” provided a solid foundation for the next phase of the project: development of a process for creation and completion of a new statewide digital stream file.

The plan was adopted by the Geographic Information Coordinating Council January 5, 2005, and was presented to the Environmental Review Commission January 13, 2005. Both groups received the plan favorably. Senate Bill 1129 and House Bill 1387 have been introduced to fund the entire Streambed Mapping Project for Western North Carolina Counties on a statewide level.

The General Assembly appropriated funds to begin streambed mapping with Senate Bill 7, “Hurricane Recovery Act of 2005.” The Act allocates mapping funds for the nineteen counties in Western North Carolina that were declared disaster areas in the Hurricane Recovery Act. Figure 1 displays the 19 counties cited in Senate Bill 7.

Figure 1 Nineteen Counties Included in Study Area as Identified in Senate Bill 7



Map graphic created by CGIA

As discussed in Senate Bill 7, “streambed mapping” is defined as the mapping of all surface waters. This includes perennial streams, intermittent streams, ephemeral channels, lakes, and ponds.

CGIA created an Advisory Committee to accurately assess all user needs for the streambed mapping data set. The Advisory Committee contains members of the Stream Mapping Working Group established for the creation of the “Implementation Plan to Improve the Digital Representation of Surface Waters in North Carolina.” Some of these agencies include NC Department of Transportation (NC DOT), NC Division of Water Quality (NC DWQ), NC Ecosystem Enhancement Program (NC EEP), NC Geodetic Survey (NC GS), US Geological Survey (USGS), NC Floodplain Mapping Program (NC FMP), and NC Division of Water Resources (NC DWR). Individuals from the Advisory Committee provide unique perspectives and valuable insights concerning the user requirements of the project. The committee was involved in many tasks including, but not limited to:

- Geodatabase design
- Data maintenance plan design
- Standards modification
- New tools needed for the project
- Accuracy study for horizontal placement of the streamlines and water bodies review
- Final data set review

2.0 Project Planning

In addition to the formation of the Stream Mapping Working Group and Advisory Committee, planning for this project included the creation of a detailed project management plan. The project management plan included sections containing the project scope and schedule, project budget plan, communications plan, risk management plan, staffing plan, quality assurance plan and change management plan and communications plan. This plan was updated on a quarterly basis to ensure any changes or modifications were recorded and executed, and to ensure the project baselines were cataloged and adhered to by the entire project team. The project management plan was the blueprint for all project tasks.

The project was broken down into five, logical phases to allow for maximum creation of each work product.

1.0 – Project Management, which included execution of and modifications to the project management plan, Advisory Committee and other stakeholder meetings, project administration and management, and communication with all stakeholders

2.0 – Accuracy Study, which included the planning and execution of an accuracy study to determine the proper accuracy standards given available base data and technology to be used for creating hydrologic features

3.0 – Geodatabase and Custom Application Development, which included the planning, design, implementation and testing of a custom NHD geodatabase and associated custom ArcGIS 9.1 extension for data set production

4.0 – Horizontal Alignment and Attribution, which included the production and attribution of surface water features in the project area under the quality assurance plan

5.0 – Erosion Event Creation, which included the creation of an event table of associated erosion areas contained in the project area

The project management plan was approved by CGIA, and a project management web site was created in OnProject™ to allow for the efficient flow of information and project deliverables between CGIA and Watershed Concepts.

3.0 Project Execution

3.1 Base Data Compilation and Software Preparation

North Carolina has a rich history in the planning and development of high quality mapping products for the protection of its natural resources, personal property and the lives of its citizens. North Carolina has developed a statewide LiDAR data set to support the efforts of state floodplain mapping and the updating of digital flood insurance rate maps (DFIRM). This was in direct support of the Federal Emergency Management Agency (FEMA) map modernization project. Hillshades were created from this LiDAR to be used as a three-dimensional representation of the ground. Included in this effort was the acquisition of ADS40 imagery, which is specified at one half foot resolution. Additionally, three vector data sets were used as base data. Six acre breaklines, or streamlines were generated from the raw LiDAR points using Watershed Concepts' Watershed Information System (WISE™) software. These breaklines were used as a guide for the GIS operators when performing horizontal alignment of the streambed lines. Two foot contours were generated in the vicinity of the breaklines to provide better decision making for the GIS Operators tasked with generating new surface water features. Additionally, the existing 1:24,000 NHD blue line streams and water bodies were used as a guide for recognizing surface water features and providing legacy attribution for the newly created water features.

The software of choice for horizontal alignment activities for this project was Environmental Systems Research Institute (ESRI) ArcGIS 9.1 and ArcSDE 9.1. ArcGIS 9.1 offered many features needed for successful placement of surface water features, including the support of all base data layers for analysis and display, heads-up digitizing capabilities, geodatabase editing and support, custom tool development and support, and geoprocessing support. ArcSDE 9.1 was set up for multi-user data production and editing in conjunction with a Microsoft SQLServer relational database. The production team worked both locally and over through the Citrix environment.

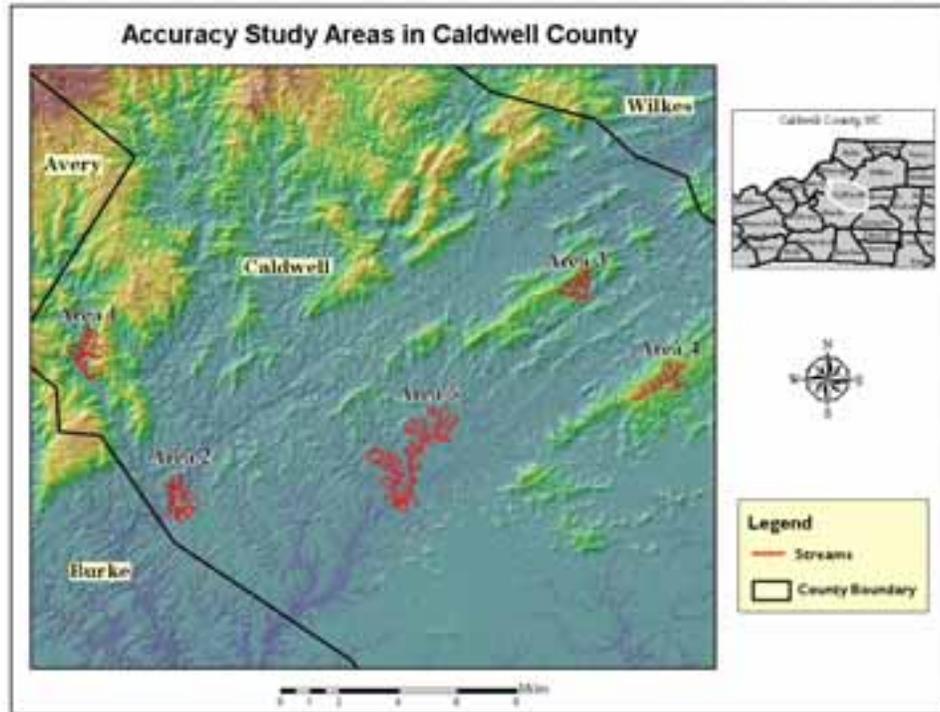
3.2 Accuracy Study

One of the most important activities performed on this project was the accuracy study to determine optimal horizontal accuracy targets, software requirements and methodology. The accuracy study consisted of the choosing of five disparate locations with differing land use and land cover classifications, and the "heads-up" digitizing of streamlines and waterbodies two hundred feet past the six acre drainage area limit. Additionally, the study included the production of streamlines using the current, industry standard automated processes for creating this type of hydrologic work product in order to have a comparison between manual and automated alignment methods. The automated processes included

The Advisory Committee agreed that the creation of accuracy standards for the project were essential to create the most value to local, state, and federal agencies; non-profit organizations; private organizations; and the general public. Accuracy standards allow users to understand the limitations of

the data set for various applications related to modeling, development and regulatory activities. Furthermore, accuracy standards allow for measurable, repeatable results using the most up-to-date technology available during mapping operations. Five areas of varying terrain located in Caldwell County, North Carolina were selected for the accuracy study. These areas are shown in Figure 2 below.

Figure 2 Accuracy Study Areas in Caldwell County, NC



Map graphic created by Watershed Concepts

Five separate areas were identified in Caldwell County, North Carolina to be used as individual representations of various land covers, terrain characteristics and drainage area sizes. Areas 1 and 2 contain a mix of open areas and heavily forested areas. Area 5 contains a portion of the City of Lenoir, which is an urban area. Areas 3 and 4 were chosen because the NC DWQ is performing some projects in these areas and may be able to provide some information for future analysis. These areas encompass approximately one hundred miles of stream and were approved by CGIA.

The accuracy study resulted in a report describing the methodology and results of the study to allow users to understand the limitations of the resulting data based upon the current technology, time and fiscal restraints for which this project was performed.

3.3 Geodatabase Development

The existing NHD database contains tables to support all necessary feature classes and associated feature attributes. However, the North Carolina database required the project team to add additional tables to the geodatabase model to support additional attribution, track the conflation of attribution from the 1:24,000-scale to the new, high resolution data set, and support the flow direction and metadata attribution. The creation of these additional, custom geodatabase tables required the input

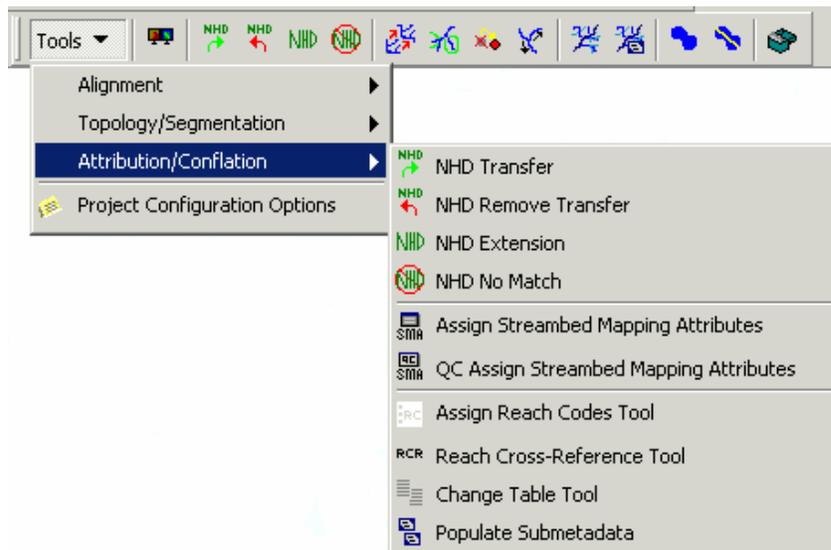
of all stakeholders residing on the Advisory Committee. It was agreed upon early in project planning that these tables would aid in tracking old and new attribution, and provide a link to the legacy 1:24,000-scale NHD data. Additionally, these tables would allow the user community to understand the metadata associated with the data set, which would empower them to know the value and limitations of using this data for their specific application needs.

In order to maintain a good planning process, a proven geodatabase development process outlined by ESRI was used for this project. The process included the development of conceptual, logical and physical geodatabase models with an iterative approach to development. The North Carolina NHD database was implemented on an enterprise-wide, Microsoft SQLServer system utilizing ArcSDE 9.1 used by CGIA to house and manages all of their spatial data sets.

3.4 Custom Application Development

The support of the production of features and the population of existing and custom tables in the NHD database required a set of custom tools specific to this project. The Streambed Analyst Toolset was created to support this effort, and included a conglomerate of custom utilities specific to the newly-created custom NHD database. Watershed Concepts used the traditional Waterfall Method for its software development life cycle. This approach ensured the software development followed a systematic approach resulting in good application development practices, a quality work product and comprehensive software documentation. The Streambed Analyst Toolset was developed as an extension to ArcGIS 9.1 capable of running from the ArcMap module. As mentioned in the previous section, the NC NHD database was implemented on an enterprise-wide system that included ArcSDE running on a SQLServer database to allow for editing and production by multiple GIS operators. This required the Streambed Analyst Toolset to handle transactional attribution, commonly referred to as “versioning”. The Streambed Mapping Analyst Toolset extension included twenty utilities specific to the production of surface water features for the North Carolina NHD geodatabase.

Figure 3 Streambed Mapping Analyst Toolset toolbar



Graphic created by Watershed Concepts

3.5 Horizontal Alignment

Horizontal alignment included the digitization of water body, streamlines and artificial paths contained in the project area. Water bodies were defined by the Advisory Committee as any lake or pond greater than or equal to one quarter acre. Streamlines were captured two hundred feet past, or upstream of the six acre drainage area upstream limit. This specific requirement ensured that a consistent data set was created across the nineteen-county area. GIS Operators used hillshades representing the terrain, two foot contours, WISE-generated breaklines extending to the six acre drainage area limit, and local, high resolution aerial photography for the “heads up” horizontal alignment of these surface water features. Some of this data required preprocessing to extract the upstream limits of the six acre streams, create specific terrain products such as the hillshades and contours, and acquire and configure aerial photography. Most of the aerial products were acquired from the local communities to ensure the operators were using the most recent base data.

Unlike traditional digitizing methodology, this project required the operators to negotiate several base data sets to ensure the proper placement of surface water features. Urban areas created the most challenging environment due to development, stream rerouting and storm water system development. These areas required close evaluation of current aerial photography to ensure placement of streams was correct near developed areas. Figure 4 below illustrates the complexity posed by negotiating urban areas and the main reason an update of this hydrologic data set was of great importance to North Carolina. Urban areas often required “connectors” to illustrate streamlines that go underground and are indeterminate based upon the terrain and photography.

Figure 4 NHD “blue line streams” are shown in yellow dashed lines, and the new six acres streams are shown in blue.



Graphic created by Watershed Concepts

The production environment utilized the Citrix™ environment to ensure all operators had remote access to the database, GIS software licenses and base data. This environment ensured that the production data was housed on remote, secure servers that were backed up on a daily basis, and that system administration was centralized.

3.6 Conflation and Attribution

All pertinent attribution contained in the 1:24,000 NHD data set was “conflated”, or transferred onto the new data set. Additionally, new reach codes and other important attributes were created and placed into the new data set based upon allotments accessible through a web site created by the USGS. The custom NHD geodatabase contained numerous attributes, most of which had predefined domain tables to ensure consistency. The Streambed Mapping Analyst Toolset processed most of the attribution automatically, including tools to conflate the existing NHD attributes from the existing 1:24,000 NHD streamlines to the newly created data set. In addition to specific attribution, the Watershed Concepts production team incorporated the population of drainage areas in acre units for each water feature segment. These drainage areas were extracted from the company’s proprietary WISE™ software to the six acre breaklines and then conflated to the newly created data set using the Streambed Mapping Analyst Toolset. All attribution was quality controlled by Watershed Concepts and CGIA to ensure a consistent, complete data set.

3.7 Erosion Event Creation

Networks allow for the modeling and analysis of linear features for transportation, hydrology, pipelines, and other modal applications. They are built upon the concept of dynamic segmentation, which allows for the creation of linear routes from simple line features connected together by nodes. A route is created by combining multiple linear features together to create either one route, or a series of routes in a network. For example, a simple linear feature such as a road centerline has a series of line segments with unique identifiers for each line segment. These line segments are joined together by a node feature. A route feature is made up on one or more of these line segments and contains one unique identifier that relates back to multiple line segments. This dynamic segmentation allows for the creation of a linear feature capable of supporting attributes associated with measures along the route and associated events. Measures are georeferenced unit measurements at any given point along the route. The units of measure for these locations are determined using the coordinate system and user-defined linear units, which can be feet, miles, meters, etc. Events are a point or line feature or concept associated to the route. For example, car accidents are events along a highway route that are usually represented as point events. An example of a linear event is the species type of salmon living along a stretch of river in a northwestern section of the United States. In this case, an entire linear section of a route can be represented as a linear event.

This project required the association of point erosion events caused by excessive flooding during and after by hurricane occurrences. Erosion point locations were provided to Watershed Concepts by CGIA. These erosion events were represented by a point feature with associated coordinate pairs and other non –spatial attributes such as date, time, size of event, soil types, etc. These point events were associated to the streamlines by first creating routes from the linear features using ArcCatalog™, Once the routes were created, the points were associated to the routes using the out of the box functionality for creating point events in ArcCatalog™. The result was the creation of an event table in the database containing all of the erosion features with their associated attributes.

3.8 Quality Assurance and Quality Control (QA/QC)

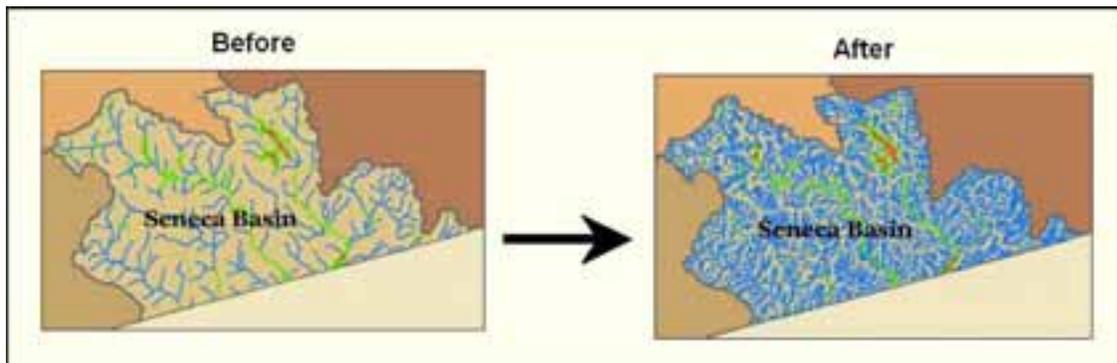
A comprehensive QA/QC process was designed and reviewed by the Advisory Committee to ensure a topologically correct, fully attributed surface water data set was created for this project. This included both manual and automated processes for checking data integrity.

As mentioned a previous section, horizontal alignment, or digitization required a very high amount of operator scrutiny; therefore, a large amount of QA/QC was required for both horizontal alignment and attribution. The project team implemented standard ArcGIS project or (MXD file) parameters that included the proper snapping distance, fuzzy tolerance, coordinate system, and other important parameters. This ensured that all operators were working within the same environment. Horizontal alignment was broken down into logical units that were peer reviewed after completion. Once they passed peer review, they were sent to CGIA for additional QC. All comments by CGIA were addressed by the consultant, thus ensuring a solid QC process. Attribution was handled in the same manner. Additionally, the Streambed Mapping Analyst extension contained several utilities for checking topology and attribution.

3.9 Resultant Data Set

The resulting data set was a seamless, fully-attributed, topologically correct NHD surface water feature geodatabase, complete with domain, metadata and transactional attribute and event tables. Figure 5 illustrates the increased density of surface water features produced in a small basin located in the project area.

Figure 5 Seneca Basin in western North Carolina



Graphic created by Watershed Concepts

3.10 Potential Data Set Applications

As with all spatially-enabled data, the applications are numerous; therefore, we only included a few of the following examples of using this data for the protection of life, property, infrastructure and the natural resources of North Carolina.

- *Individual Project Planning* – Public and private industries will be able to use this revised data set for a multitude of projects during the planning stages of their particular endeavor. For example, developers will be able to use this data for site planning, transportation planning, and environmental agencies will be able to use this data set to meet a range of business requirements.

- *Flow Modeling / Navigation* – The final data set is topologically correct in terms of connectivity and flow direction. Additionally, the data set is attributed with a FlowTable containing logical segment flow direction. This will allow for navigation upstream and downstream, or tracing of the stream network. Applications for this functionality are numerous; however, one important application that may be of interest to local governments is spill response analysis. Users can use this data to create a geometric network to understand which direction and to what extent a toxic spill would reach based upon the characteristics of the spilled material.

4.0 Author Information

Roger K. Cottrell, Jr., PMP
Watershed Concepts (a division of HSMM, an AECOM Operating Company)
4905 Koger Blvd., Suite 270
Greensboro, NC 27407
rcottrell@watershedconcepts.com

Joe Sewash
North Carolina Center for Geographic Information and Analysis
20322 Mail Service Center
Raleigh, NC 27699
joe.sewash@ncmail.net

Scott Edelman, P.E.
Watershed Concepts (a division of HSMM, an AECOM Operating Company)
4905 Koger Blvd., Suite 270
Greensboro, NC 27407
sedelman@watershedconcept.com