Issue 19: Handling of Surface-Water Features for the Printed Digital Flood Insurance Rate Map (FIRM) and the Digital FIRM Database

Background

The mapping of surface waters should be comprehensive and accurate. The surface-water mapping should also complement the other data layers that are part of the North Carolina Flood Mapping Program. The decision by North Carolina officials to use digital FIRM map scales of 1″=500′ and 1″=1,000′ for printed panels is an important determination for this issue.

Sources of data available as a component of the printed digital FIRM and spatial database include:

1. Statewide geographic database at 1:24,000 scale, by River Basin. This layer of the statewide geographic database contains surface-water features at 1:24,000 scale derived from USGS topographic maps. Approximately 24 attributes are contained in the Geographic Information System (GIS) tables that describe each feature, including stream name, index number, stream classification, and other characteristics. The names used in this data layer are derived from the USGS 7.5-minute series topographic maps. The data layer has been developed cooperatively between the Center for Geographic Information and Analysis (CGIA), the United States Geological Survey (USGS), North Carolina Department of Transportation, and the North Carolina Department of Environment and Natural Resources, Division of Water Quality. This layer is complete and maintained for changes in the attribute tables.
2. Statewide geographic database, National Hydrographic Data (NHD), at 1:24,000 scale, by Cataloging Unit. The layer described above in item #1 is currently being transformed by CGIA into a new layer that is based on the NHD Model. The work is in progress, and the core components are expected to be built for entire cataloging units that are wholly or partially in the state. The core NHD is expected to be completed during the next 2 years. The program to maintain NHD will also include a large-scale pilot component at a scale of 1:4,800.
3. North Carolina Flood Mapping Program breaklines at a scale of 1:12,000. As part of the North Carolina Flood Mapping Program, surface-water features are being mapped by contractors to augment the derivation of hydrologically corrected Digital Elevation Models and as part of the analytical and engineering work within the studied floodplains. USGS Digital Orthophotographs and aerial imagery from locally derived sources are used as a basis for the determination of the surface-water features outside of the floodplain boundaries. At minimum, these surface-water features are derived from a map scale of 1:12,000 and in many cases from map scales at 1:4,800. Content of this mapping includes surface-water feature delineation where the watershed is 1 square mile in area or larger. See "Methods for Surface-Water/Breakline Delineation" section of this issue paper for more details. Surface-water features mapped within the studied floodplains are derived from available imagery, Airborne Light Detection and Ranging (LIDAR) data, and possibly field surveys.

4. Data layers of locally derived surface-water mapping exist for some communities and were mapped using base photography equivalent to 1:4,800 and 1:2,400 scale. Surface-water names may be a component of base maps produced by each community.

5. The U.S. Geographic Names Information System (GNIS) http://mapping.usgs.gov/www/gnis/ is the official name source for maps produced by Federal agencies. The primary source of names in the GNIS is the USGS 7.5-minute series topographic maps.
6. Existing Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) contain surface-water feature names.

Methods for Surface-Water/Breakline Delineation

Method One (White-Oak, Tar-Pamlico, Neuse, and Pasquotank River Basins)

As part of the terrain coverage being created for the North Carolina Flood Mapping Program, the mapping contractor is also creating topologically corrected, 3-dimensional hydrology coverage. The primary function of the dataset is to supplement and contain the Triangulated Irregular Networks (TINs) being created from the LIDAR data. However, the data are being created to provide additional uses to the engineering community.

Because LIDAR data contain only points, the ability of a LIDAR-only terrain model to capture detailed linear features in their precise 3-dimensional location is limited. In a traditional photogrammetric DTM, this is addressed using breaklines. To be most effective, LIDAR data need their own "breaklines." Various parties have investigated using existing hydrology datasets for this application, with limited success. Typical problems are that the existing linework is out of date, incomplete, inaccurate, and, in most cases, 2-dimensional. The mapping contractor investigated using existing hydrology at a scale of 1:24,000 for the NC Flood Mapping Program and found many of these same shortcomings.

An additional problem with using existing linework is the functional differences between the existing data and the current needs. Most mapping data were created for mapping, not engineering. Data for a braided stream will include all (or as many as possible) of the various water paths. While this is laudable in mapping, such data is not well suited for hydrologic and hydraulic modeling. Engineers need a topologically corrected model of the drainage network, simplified to conform to a basic dendritic pattern. In areas of braided streams, only the primary channel, or flow path, needs to be included. Existing hydrology datasets usually must undergo extensive manual editing to make them usable for engineering applications.

For the NC Flood Mapping Program, the mapping contractor is creating a completely new hydrology dataset specifically tailored to meet the needs of engineers. Using the 1:24,000-scale data as a starting reference, new linework is to be digitized from the 1:12,000-scale DOQs depicting water bodies greater than 50 feet in width. Approximate centerlines also will be added, taking care to preserve the direction of flow. Single-line streams will be added in a later stage of processing. The water bodies and centerlines will be processed in ArcINFO to ensure correct topological structure. The water bodies will be converted into polygons and used to delete stray LIDAR points within them.

After the LIDAR data have been processed to bare-earth, single-line streams will be digitized using both the 1:12,000-scale Digital Orthophoto Quadrangles (DOQs) and a TIN of the bare-earth LIDAR. This ensures that the streamline, when used as a "breakline" in the final TIN construction, will augment rather than conflict with the natural channel location. It also ensures that significant differences between the LIDAR and image data can be noted.

The single-line streams will be added to the centerline/bankline data, and again processed in ArcINFO to ensure proper connectivity, continuous flow, and a fully dendritic network structure. The lines then will be processed using ArcView to assign Z values to each line vertex, using the LIDAR points (not the TIN). Final Quality Control will ensure that the downhill flow of the network pattern is supported by the vertex elevations. The profiles then will be smoothed vertically.

The final product differs from traditional hydrology sources, such as the 1:24,000-scale data, in five significant respects:

1. The final product is 3-dimensional (ArcVIEW PolylineZ shapefile format).
2. The final product does not contain all of the same linework (for example, braided streams are simplified).
3. The final product is more detailed (1:12,000).
4. The final product is hydrologically corrected (dendritic network, flowing downhill).
5. The final product is topologically corrected (no dangles, except at network inputs and outfalls).

While not a "mapping" product in the traditional sense, this dataset is far better suited for engineering applications and provides an excellent source of "breakline" data to refine the LIDAR-based TINs.

Method Two (Lumber and Cape Fear River Basins)

All breaklines are extracted in 3 dimensions to ensure accurate portrayal of stream edges and banks.

Features to be Extracted

All streams in rural areas having a 1-square mile or larger drainage basin will be extracted as a breakline. All streams in urban areas having a 0.5-square mile or larger drainage basin will be extracted as a breakline. All bodies of water, including swamps and marshes, that are located along the extracted streams will be extracted as polygons. All bodies of water, including swamps and marshes, not located on the extracted streams that are considered to be of a significantly large size will be extracted as polygons. All dams, causeways, weirs, levees, dikes, road fills, and other linear features that are inside the floodplain and are capable of deflecting a 5-foot contour will be extracted as a breakline. Centerlines of streams will be extracted when required to show the drainage path through a particular feature.

Single-Line Streams

All streams less than 30 feet wide at the lower bank (water edge) and having at least a 1-square mile drainage basin in rural areas or 0.5-square mile basin in urban areas will be extracted using a single line down the center of the stream. These streams will be extracted as high as possible (highest elevation) inside this small drainage basin. At confluences of streams, the more significant stream should be followed to the top of the basin. The more significant stream may be the one with more water, the one that is wider or deeper, the one that is longer, the one that has the more direct course to the top, or the one that contains lakes and swamps along its route. The branch that will have the greatest effect on the drainage in the area will be extracted.

Double-Line Streams

All streams that are greater than 30 feet wide at the lower bank (water edge) and have at least a 1-square mile drainage basin in rural areas and 0.5-square mile drainage basin in urban areas will be extracted using a line along each side at the lower bank (water edge) and a centerline down the middle of the stream. In cross sections, these three lines will have approximately the same Z value.

These lower bank lines will be tapered where the stream becomes narrow enough to change to a single-line stream.

These streams will stop at the boundaries of standing water, such as lakes, ponds, and other bodies of water. These lower bank lines will share coincident line work with swamps/marshes and bodies of water where needed. The centerline will stop when it reaches a standing body of water. The lower bank line work will be a closed polygon.

Double line streams will be extracted through swamp/marsh areas when they are identifiable. The lower bank linework will be coincident with the swamp/marsh boundary, as needed.

The upper bank of double line streams will be extracted when it is high enough to deflect a 5-foot contour line (approximately 3 feet) and when and where it is identifiable. Due to the forest along many of the riverbanks, the upper banks will not be identifiable, or only portions of them will be identifiable. Therefore, the extraction of the upper banks may be in broken linework on one or both sides of the stream. The upper bank linework should stop at standing bodies of water in the same way as the lower bank linework. The Z values of upper banks are not constant and will be collected where they appear.

Lakes, Ponds, Reservoirs, and Coastline

All bodies of water that are located along the extracted streams will be extracted as closed polygons. This includes all bodies of water that are identifiable as being a separate standing body of water, as opposed to being just a pool in the normal stream flow. These bodies of water should be extracted as closed polygons.

Bodies of water not located on the extracted streams will only be extracted if they are considered to be of a significant size. This size is approximately 0.5-inch diameter on a 1:24,000 map sheet, or approximately 0.1 square mile ground area.

Islands inside the body of water body will be extracted only if they are considered to be of a significant size. This size is approximately 0.5-inch diameter on a 1:24,000 map sheet, or approximately 0.1 square mile ground area. All islands, regardless of size, will be collected if they are inhabited or contain man-made structures.

The coastline will be extracted using the same linework as other bodies of water.

Swamps and Marshes

Only the portions of swamps and marshes that contain standing water will be extracted. Swamps and marshes will be collected at the edge of the standing water, or as close to this edge as possible. There is an exception to this is — all tidal swamps and marshes will be collected, regardless of the water level shown in the imagery.

All swamps and marshes that are located along the extracted streams will be extracted as a closed polygon.

Swamps or marshes not located on the extracted streams will be extracted only if they are considered to be of a significant size. This size is approximately 0.5-inch diameter on a 1:24,000 map sheet, or approximately 0.1 square mile ground area.

Swamps and marshes require a centerline or a double-line stream to show flow through them. If there is a double line stream through the swamp or marsh, extract it and its associated centerline; otherwise, follow the existing main channel where possible for a centerline. If there is not a main channel to follow, place a centerline in a logical flow path.

Swamps or marshes that adjoin lakes or other bodies of water, including double-line streams, require coincident linework along this border. Swamps and marshes that have a double-line stream through them, or border on a double-line stream, also require coincident linework along these borders.

Single-line streams through a swamp or marsh will be shown as a centerline inside the swamp or marsh boundary.

Islands or dry land (holes in the polygon) inside the swamp or marsh boundary will be collected only if they are inhabited or contain man-made structures. In some areas, islands will contain swamps/marshes, so the swamp/marsh linework may be coincident with part of the island linework.

Dams, Causeways, Levees, Weirs, and Other Linear Features

All dams, causeways, weirs, levees, dikes, road fills, and other linear features that are inside the floodplain and are capable of deflecting a 5-foot contour will be extracted as a breakline. If a linear feature is going to affect the flow of water in the area, portray it as a breakline.

These features will be portrayed using the same extraction tool as used to portray the upper banks on double-line streams.

Place a single-line along the crest of dams. This line will have a natural space between the body of water and the crest of the dam, and another natural space between the crest of the dam and any stream that exits the dam. Natural space means that features are collected where they are seen and that there is not a preset distance placed between these features.

Place a single line along the center of the other linear features. If the feature is wide enough, portray it by placing a line along its edge. As a general rule, if the feature is less than 30 feet wide, just place a line along the center.

If a single-line stream crosses under a road fill or other feature, and that feature requires a breakline, portray the portion of the stream under the road as a centerline. As an example, when a stream passes through a culvert and the road above would require a breakline, portray the portion of the stream inside the culvert as a centerline.

Stream centerlines will be checked against the surveyed cross sections for accurate portrayal. Inaccurate portrayal will be flagged, and the analyst will be required to assess the imagery in that location to determine whether the stream was obscured in the area of the discrepancy. When the stream is obscured, the analyst will move the centerline to match the survey portrayal. If the stream is clearly visible in the area of the discrepancy, a warning will be sent to the engineer group responsible for the modeling and the GIS group responsible for the map finishing phase. The assumption is that this stream has moved since the photography was acquired, and adjustments will be required to match the photograph base at the time of digital FIRM mapping.

Issue

Current digital FIRM spatial database specifications for surface water data include three attribute tables: a water area table, a water line table, and a stream centerline table.

The current (as of June 4, 2001) draft North Carolina Flood Mapping Program specifications for attributes and tables are:

Water Area Table	
1. Wtr_ar_id	Unique system ID
2. Water_type	Feature type for line symbology
3. Wtr_name	Feature name if available
4. Norm_pool	Normal pool elevation (discussion ongoing)
5. Shore_yr	Year the shoreline represents (if known)
6. Meta_id	Relational item to metadata tables

Water Lines Table	
7. Wtr_ln_id	Unique system ID
8. Water_type	Feature type for line symbology
9. Wtr_name	Feature name if available
10. Meta_id	Relational item to metadata tables

Stream Centerlines Table	
11. Stream_id	Unique system ID
12. Stream_name	Feature name if available
13. Ds_wtr_name	Downstream feature name
14. Ds_rivid	River ID of downstream stream centerline
15. Rch_code	NHD reach code (place holder for later use)
16. Meta_id	Relational item to metadata tables

The primary issues that need to be resolved are:

1. Feature content of the digital FIRM database data layer(s).
2. Cartographic content of digital FIRM graphic. Example: Whether to map centerlines, double lines, or both on digital FIRM and/or as part of the spatial database.
3. Adaptability of the North Carolina Flood Mapping Program surface-water data layer to the *work-in-progress* on the NHD layer for the statewide corporate geographic database.
4. Determination of the accepted name for each feature and the process used to reconcile name conflicts.

Recommendations

1. Features to be mapped as part of the digital FIRM database and the printed digital FIRM should include streams, rivers, lakes, shorelines, ponds, swamps, marshes, pocosins, reservoirs, coastlines, and other hydrographic features required for FIRM production.

2. Drainage features within drainage basins of 1-square mile in rural areas and 0.5-square mile in urban areas should be included in the digital FIRM database and the printed digital FIRM.
3. All features should be delineated using map scale of 1:12,000 or larger; therefore, data sources A and B would not be acceptable for mapping.
4. The digital FIRM database should include feature representation as 1-dimensional (single line) and 2-dimensional (double line) elements.
5. Tidal coastal shoreline should be mapped as the waterline depicted on the orthophoto imagery used for the digital FIRM, assuming that the water is within its normal parameters.
6. 1-dimensional representation (single line) in the digital FIRM database should include single lines for streams, artificial paths (approximate centerlines within 2-dimensional elements) in water bodies, and connectors (example: culverts).
7. 2-dimensional representation (double lines) in the digital FIRM database should be used to depict water bodies that are a minimum of 50 feet wide (*narrower widths would be acceptable*) and should also include centerlines as described above.
8. Good photogrammetric judgment should be used to taper double lines to single lines.
9. 3-dimensional representation as elevation vertex values in the digital FIRM database should be further explored by the North Carolina Flood Mapping Program digital FIRM database team.
10. The digital FIRM database data should be topologically correct.
11. The digital FIRM database data should reflect downstream flow.
12. Attribute table content and format for the digital FIRM database should be finalized through recommendation of the DFRIM database team to the North Carolina Flood Mapping Program core team.
13. Metadata should be associated with each data layer in the digital FIRM database.
14. The printed digital FIRM should show surface waters using 1-dimensional (single line) and 2-dimensional (double line) coverage. The printed digital FIRM should show double lines for features that are 50 feet wide or wider without the centerline or artificial path. The printed digital FIRM should show a single line for features less than 50 feet wide (*narrower widths are acceptable*).
15. Features should be shown according to existing surface water FEMA specifications for line weight, leader, line symbology, and name font/size/style(s). Additionally, hydrographic names should be shown using upper and lower case (Ex: Walnut Creek); however, dominant features will be shown using all upper case characters (Ex: ATLANTIC OCEAN).
16. For features that require names per digital FIRM specifications, the following priorities apply: first, names that are currently used for the existing FIRM will be used in the spatial database; second, names from the Statewide 24k data layer will be used; third, the FEMA practice to use name/numbering conventions (Trib1, Trib2) will apply. A log should be created to show inconsistencies between the FIRM and the Statewide 24k data layer

17. Whether or not water body names are required for the graphic, all known names from the existing FIRM and the statewide 24k data layer should be included in the spatial database.
18. digital FIRM specifications for names in the study areas on the printed graphic should be applied. Additional names outside of the floodplain areas can be shown on the printed graphic, as these names are considered lower on the hierarchy of importance for annotation.
19. River mile markers should not be part of the digital FIRM graphic or database.
20. No distinction should be made between natural and man-made channels.

Discussion Summary

Date Discussed: 06/20/2001

Discussion Attendees: Rodger Durham, North Carolina Flood Mapping Program (FMP); Abdul Rahmani, North Carolina FMP; Ken Shaffer, North Carolina Center for Geographic Information and Analysis (CGIA); David Giordano, North Carolina CGIA; Eric Simmons, Dewberry & Davis LLC (D&D); Zsolt Nagy, NC CGIA; John Dorman, North Carolina Office of State Budget, Planning and Management; Ed Curtis, North Carolina Division of Emergency Management; Laura Algeo, FEMA; Tim Johnson, North Carolina CGIA; Ted Cassidy, D&D

Summary of Discussion

Recommendation Number 5 (tidal shoreline to be the mean high tide) was identified as a potential high-cost item and, therefore, was further discussed. Durham/Nagy/Rahmani agreed that providing an instruction to the contractors to map one consistent shoreline derived from a survey and engineering perspective would be problematic because of the variability in the orthophotography and the LIDAR collection schedule. Altogether there are seven potential shorelines that could be specified in the instruction to the contractor, all with high cost ramifications. The State, therefore, explored the purpose of the tidal shoreline on the ditigal FIRM and concluded that there is not a survey, flood study, or engineering purpose that requires high-accuracy mapping of the shoreline. The State determined that cartographic appeal on the digital FIRM printed graphic and spatial database is the function served by the mapped shoreline. The State agreed to the following instruction:

"Tidal coastal shoreline will be mapped as the waterline depicted on the orthophoto imagery used for the digital FIRM, presuming that the water is within its normal parameters"

Final Guidelines

The recommendations were adopted, with the amendment to Guideline Number 5 discussed above.