High-Resolution Hydrographic Mapping
Using Lidar-Derived Digital Elevation Models

A concept paper:
Developed by U.S. Geological Survey
Earth Resources Observation and Science Center
and the
South Dakota Water Science Center

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Background

For many decades, U.S. Geological Survey (USGS) 1:24,000-scale topographic maps have been widely used as a primary basis for hydrographic mapping. However, capabilities for higher-resolution hydrographic mapping are improving rapidly with advances in availability of high-resolution geospatially-referenced datasets and capabilities for processing these datasets. High-resolution hydrographic mapping would be especially beneficial in many parts of eastern South Dakota, where accurate definition of drainage features can be very difficult, especially in areas with low relief or numerous depressions. Numerous water resource and watershed management applications would exist, especially with mounting drainage issues related to widespread installation of drain tiling.

Light Detection and Ranging (lidar) datasets are become increasingly prevalent as source data for generating high-resolution topographic coverages and have immense potential for refinement to achieve high-resolution hydrographic mapping. The Earth Resources Observation and Science (EROS) Center and the South Dakota Water Science Center (SDWSC) of the USGS are interested in partnering with other agencies to develop high-resolution hydrographic mapping in parts of South Dakota where lidar data already are available or might soon be forthcoming.

An example of high-resolution hydrographic mapping is provided by a recent pilot project that was conducted by EROS and SDWSC. Figure 1 shows a comparison among several levels of hydrographic mapping from the pilot area in Roberts County. The red polygon in figure 1A is a 12-digit Hydrologic Unit (HU) from the Watershed Boundary Dataset (WBD) for South Dakota (http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd). This HU was delineated using the USGS 1:24,000-scale topographic base maps as the source dataset. The black polygon in figure 1A was automatically delineated from a 30-meter digital elevation model (DEM) from the USGS National Elevation Dataset (NED), which is a primary elevation product of the USGS (Gesch *et al.*, 2002; Gesch, 2007). The drainage channels that are shown in figure 1A also are derived from the 30-meter DEM, which is a different topographic coverage than what was mandated for use in development of the 12-digit WBD. Substantial differences in drainage networks between the two source datasets are apparent from the substantial differences in the two watershed delineations, especially in the southern, southeastern, and northwestern areas where the red polygon crosses the blue drainage channels (see yellow arrows).

Figure 1B shows the additional improvement in watershed delineation (brown polygon) that is achieved through incorporation of a 3-meter lidar-derived DEM for the area. Figure 1B also shows the additional ground-surface detail that is visible on the 3-meter shaded relief image, which is especially evidenced by roads that appear as thin straight lines on this figure. Substantial improvements in the depiction of drainage channels also are apparent, especially in the southern, southeastern, and northern parts of the watershed.

Figure 1C shows the redefined 12-digit HU subdivided into 14-digit HUs. Figure 1C also shows a densification of the drainage channel network that is achieved by specifying a different density threshold.

Generalized Concept for High-Resolution Hydrographic Mapping

High-resolution hydrographic mapping probably would be justifiable only for areas where lidar data are available. Figure 2 shows the 12-digit WBD delineations for South Dakota and areas where lidar data currently are available. Lidar data also have been recently acquired for Brown County and for a relatively small area in extreme eastern South Dakota that is within the Minnesota River Basin; however, these data are not yet available in the USGS NED.

One proposed product of high-resolution hydrographic mapping would be an improved and "densified" WBD. A new version of WBD Federal Standards (http://pubs.usgs.gov/tm/tm11a3/) has been released that provides options and guidelines for additional densification of HUs to the 14- and 16-digit levels. A preferred option for densification features 14-digit HUs nested within a 12-digit HU and having a typical size range of 3,000 to 10,000 acres. This compares with a typical size range of 10,000 to 40,000 acres for the 12-digit HUs. The 16-digit HUs nest within a 14-digit HU and have a typical size range of 100 to 3,000 acres. These standardized watershed delineations would have many useful applications. An example is demonstrated by an interface between Google Earth and the 12-digit HUs which provides a public-access viewing tool that can be easily used without GIS software or experience. This interface can be accessed at: http://sd.water.usgs.gov/projects/GoogleHuc/GoogleHUC.html.

High-resolution hydrographic mapping also would result in a variety of lidar DEM derivative products that are necessary for development of the densified WBDs, but that would also be useful as stand-alone products. For any given area, the derivatives would include grids for hydro-enforced flow direction, flow accumulation, slope, shaded relief, and hydro-enforced drainage channels. Development of a hydro-enforced flow direction grid is a key step prior to delineation of WBDs. This step involves a semi-automated hydro-enforcement method that involves digital "removal" of elevated surfaces (such as roads or railroad grades) in locations of culverts) from the lidar DEM so that the flow direction grid follows the next steepest down slope path (Poppenga *et al.*, 2010, 2011). This method has the capability to create a list of digitally-derived culvert locations, which can be checked for accuracy or field surveyed in critical locations where flow directions may be substantially affected by such "conduit" locations. A side benefit of the high-resolution flow direction grid is the capability for delineating hydro-enforced drainage channels at different drainage density thresholds (fig. 1C).

Funding Arrangements and Potential Partners

USGS work activities would be performed as a collaborative arrangement between EROS and SDWSC. It is anticipated that costs for USGS work activities would be highly variable and would depend on (1) the size and hydrologic/topographic complexity of any given area of interest and (2) details regarding specific activities that would need to be conducted. For example, locations of selected critical conduits were determined by field visits conducted by USGS staff as part of the pilot project in Roberts County, which adds to overall project costs but strengthens the accuracy of the end product. USGS will gladly develop costs estimates for any area of interest and generally would expect to be able to provide at least some amount of cost share. USGS also will gladly assist in seeking other potential funding partners.

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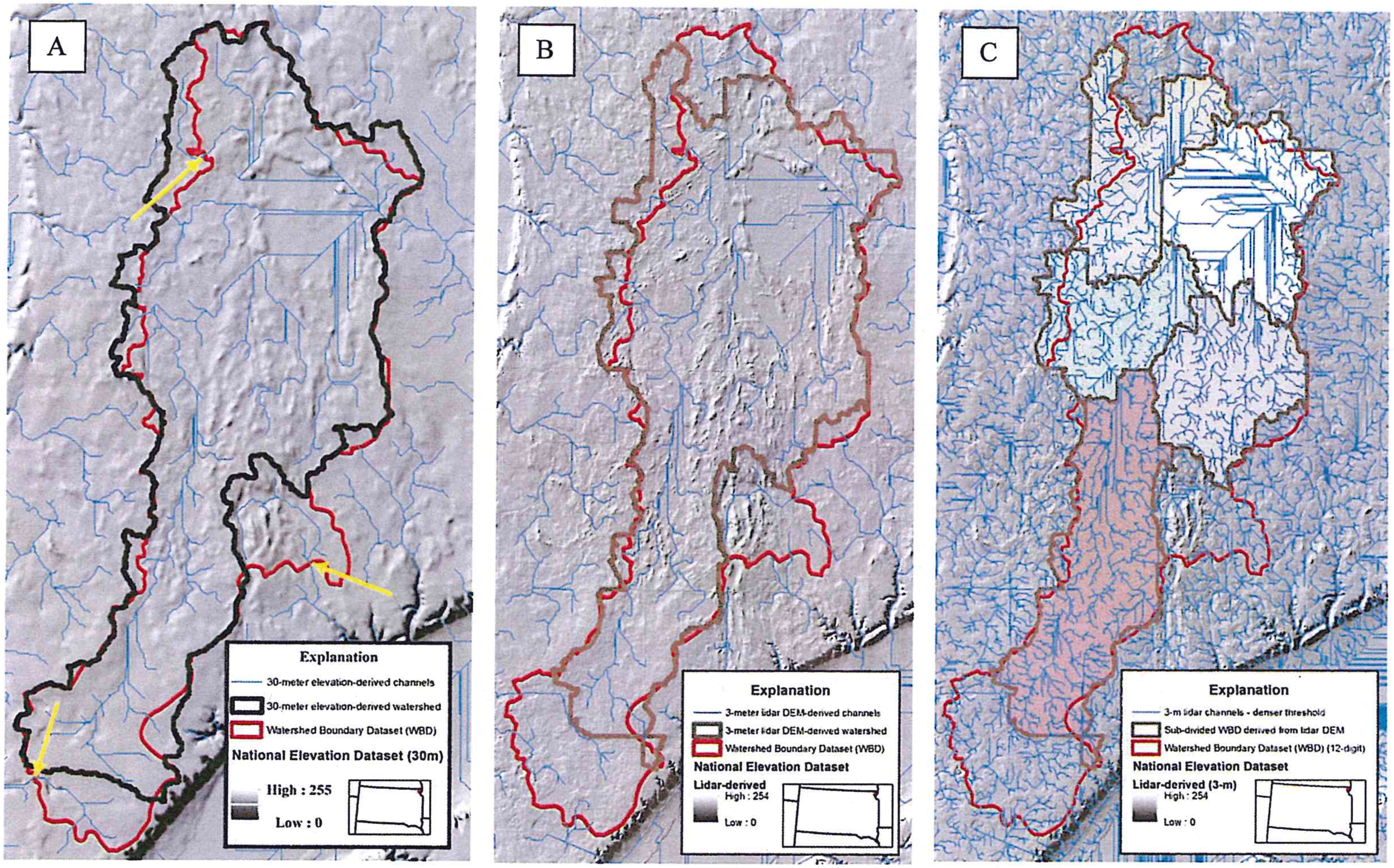

Figure 1. Example of hydrographic mapping at various levels of resolution. (A) Comparison of WBD 12-digit HU (red polygon) and NED 30-meter elevation-derived watershed boundary (black polygon) overlain on 30-meter shaded relief. (B) Comparison of WBD 12-digit HU (red polygon) and NED 3-meter lidar DEM-derived watershed boundary overlain on NED 3-meter lidar DEM shaded relief. (C) Same as (B), but with densification of WBD and drainage channels.

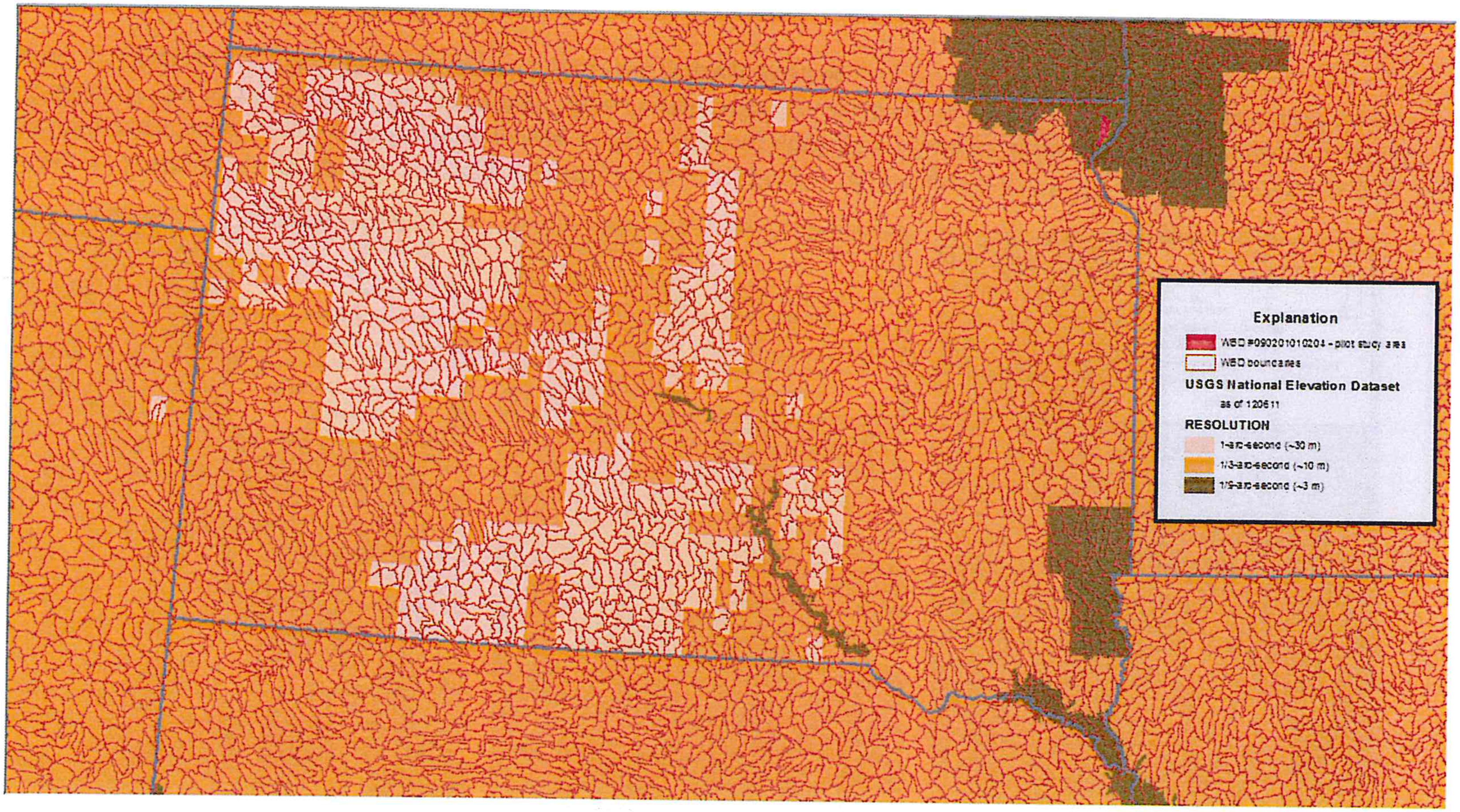

Figure 2. 12-digit watershed boundary dataset (WBD) delineations for South Dakota and USGS National Elevation Dataset.