DIGITAL MAPPING TECHNIQUES 2014

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US Topo Maps 2014: Program Updates and Research

By Kristin A. Fishburn

U.S. Geological Survey
National Geospatial Technical Operations Center
Denver Federal Center, Box 25046, MS 510
Denver, CO 80225
Telephone: (303) 202-4405
email: kafishburn@usgs.gov

ABSTRACT

The U. S. Geological Survey (USGS) US Topo map program is now in year two of its second three-year update cycle. Since the program was launched in 2009, the product and the production system tools and processes have undergone enhancements that have made the US Topo maps a popular success story. Research and development continues with structural and content product enhancements, streamlined and more fully automated workflows, and the evaluation of a GIS-friendly US Topo GIS Packet. In addition, change detection methodologies are under evaluation to further streamline product maintenance and minimize resource expenditures for production in the future. The US Topo map program will continue to evolve in the years to come, providing traditional map users and Geographic Information System (GIS) analysts alike with a convenient, freely available product incorporating nationally consistent data that are quality assured to high standards.

INTRODUCTION

The National Geospatial Technical Operations Center (NGTOC) - part of the National Geospatial Program (NGP) of the USGS - produces US Topo maps, georeferenced digital maps that provide on-screen, modern technological advantages to map use. The US Topo maps also provide traditional paper map users with a product that can be printed and has a traditional USGS topographic map look and feel (Carswell, 2013). These maps are designed as a successor to the 7.5-minute (1:24,000-scale) topographic map series produced between approximately 1947 and 1992. The US Topo maps are published in Adobe Systems Inc. Portable Document Format (PDF) with a geospatial extension (GeoPDF) patented by TerraGo Technologies. An orthorectified image, shaded relief, and vector data layers (transportation, geographic names, hydrography, structures, boundaries, topographic contours, and woodland areas) are incorporated into these products. The maps have been published at three different scales (1:25,000 for Alaska, 1:20,000 for Puerto Rico, and 1:24,000 for the conterminous 48 states and Hawaii) and are updated every three years (Cooley et al., 2011) (see Figure 1). The total number of maps is over 65,000 covering all 50 U.S. states and territories, and over 18,000 maps are revised or newly published every year. Full coverage of Alaska and the territories is not yet available, but is anticipated by the end of 2017.

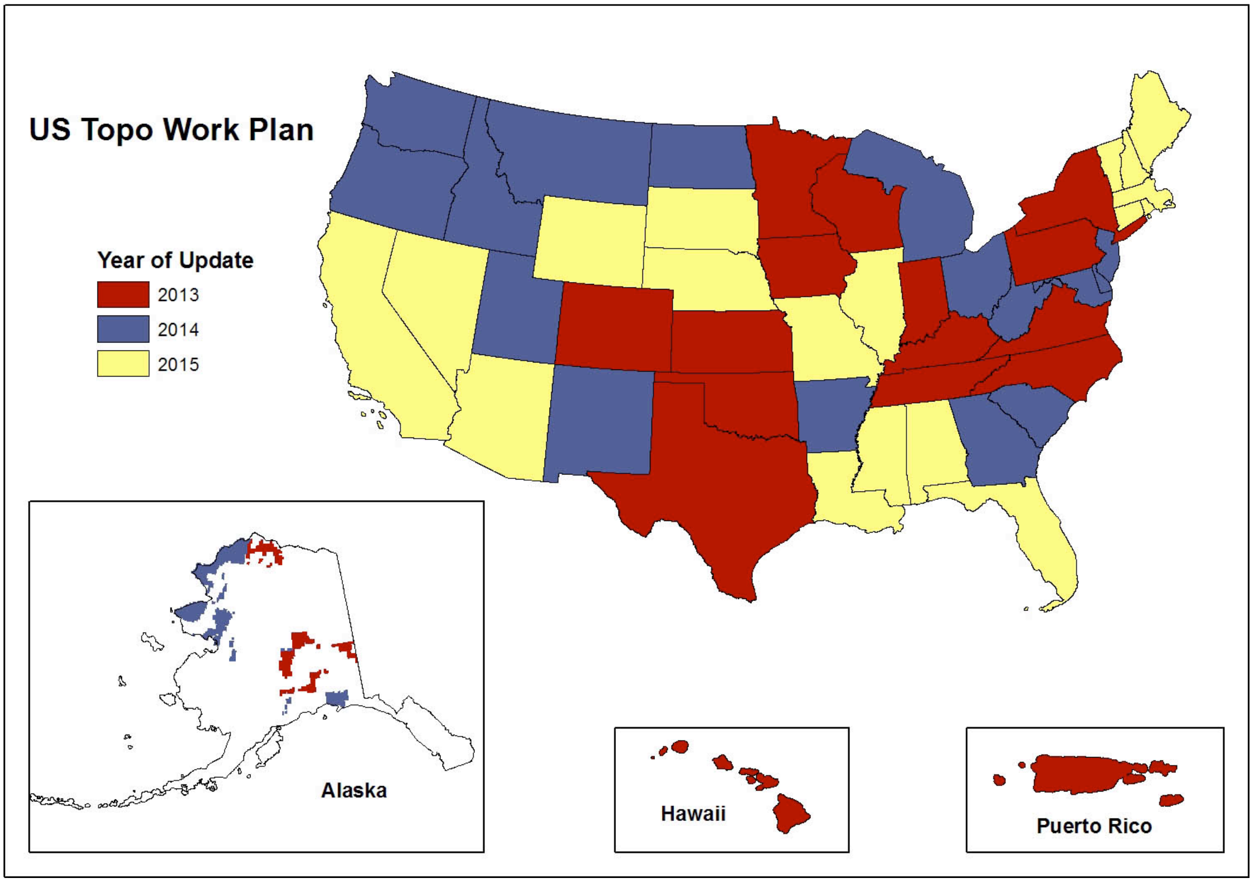

Figure 1. US Topo Map Work Plan.

US TOPO MAP CONTENT

In 2009, the USGS began publishing maps called "Digital Map – Beta", the precursor to the US Topo map. About 13,000 Digital Map-Beta maps were produced and they consisted of a map collar, projection line and grids, orthoimage and a limited number of roads, geographic names and annotation. Late in 2009 the product was rebranded as "US Topo" and by the end of October 2010, over 32,000 maps had been published with added layers of topographic contours and hydrography (Cooley et al., 2011). The content has continued to expand over the years (see Figure 2). In 2010, State, County, and U.S. Forest Service (USFS) boundaries were added to the maps. Airport runways and woodland polygons were added in 2011, and in 2012 Public Land Survey System (PLSS) (for western states), railroads, fire stations, hospitals, and schools were added. Military boundaries, cemeteries, post offices and state capitals were added in 2013 as was a new shaded relief raster layer. This year (2014) trails, U.S. Fish and Wildlife Service (FWS) boundaries, police stations and correctional facilities were added.

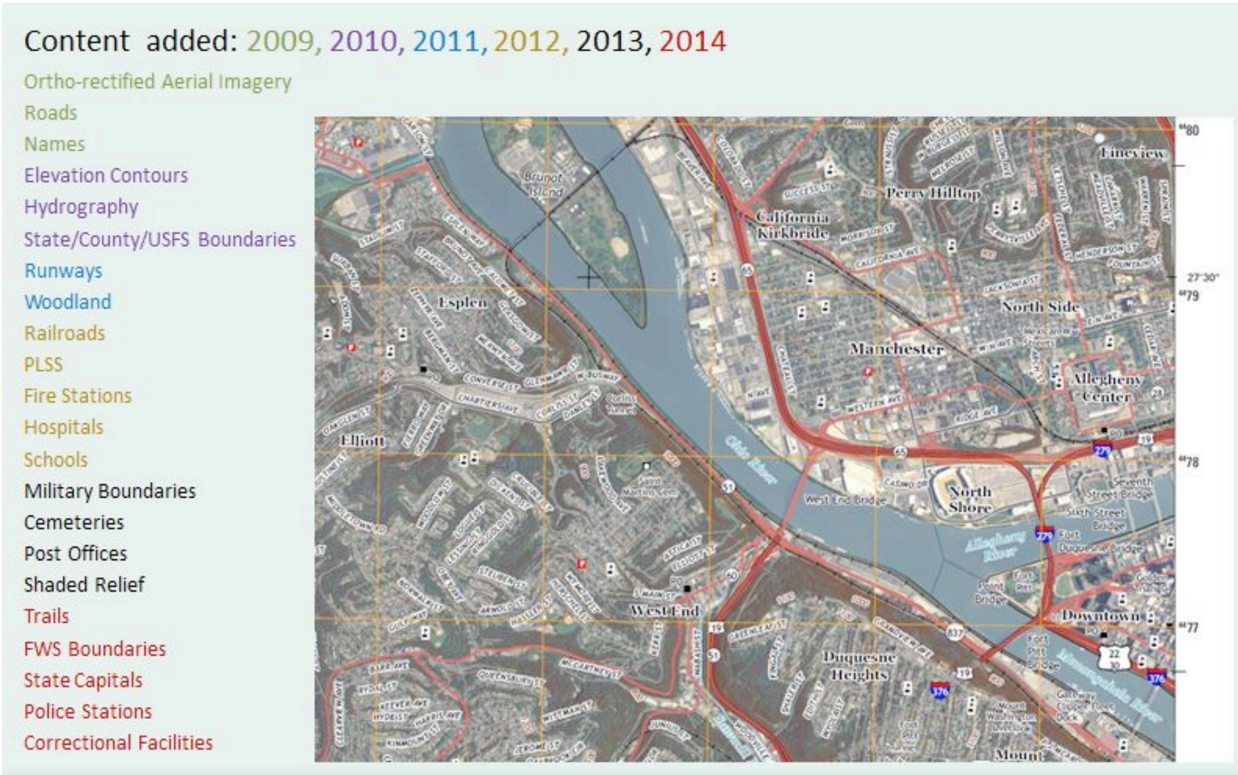

Figure 2. US Topo Map Content Changes from 2009 through 2014.

The USGS is continually evaluating new data types and sources for inclusion on the US Topo maps. Currently the maps are produced with USFS roads in National Forests and Alaska Department of Transportation (AKDOT) roads for Alaskan US Topo maps produced in 2014. All other areas have been produced with a commercial source for roads, including TomTom (formerly Tele Atlas), and HERE (a Nokia company). The commercial data source for roads will be replaced with U.S. Census Bureau TIGER roads beginning in late 2015. Ambulance services; wetlands; U.S. National Park Service (NPS), U.S. Bureau of Land Management (BLM), and U.S. Bureau of Indian Affairs (BIA) boundaries; national cemetery polygons; bathymetry; and elevation control points are currently under consideration for addition to the product (in 2015 and 2016). An additional land cover raster layer is also being considered that could contain woodland canopy, impervious surface, agriculture, barren land, grassland, and water.

When evaluating any feature addition, the USGS must consider whether authoritative data sources are available to support coverage over the entire U.S. and territories. It is also important to contemplate other potential impacts such as increased file size, which can negatively impact how easily and quickly the file can be downloaded and opened. Cartographic design and production processes must also be considered. In 2013 the USGS updated the US Topo map design with the support of Pennsylvania State University (PSU), funded through the USGS Center of Excellence for Geospatial Information Science (CEGIS) (http://cegis.usgs.gov). All of the content additions had resulted in map complexity that required a new design to ensure map legibility and clarity. Each new layer prompted consideration of an update to both map design and the production system. All factors must be weighed and balanced prior to implementing new content, including potential impacts to customers; authoritative data source

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availability; and the availability of NGTOC resources required to make content changes. See Figures 3 and 4 for a comparison of maps produced in 2010 and 2013, respectively.

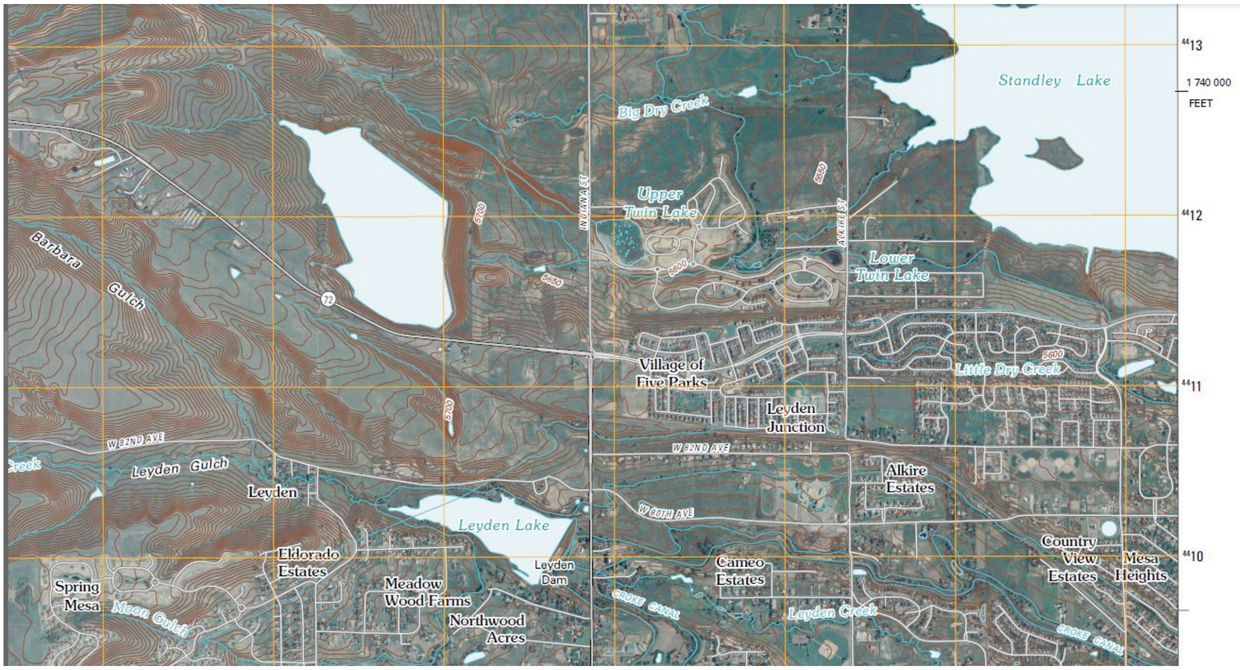

Figure 3. Golden, GO US Topo Map Published in 2010.

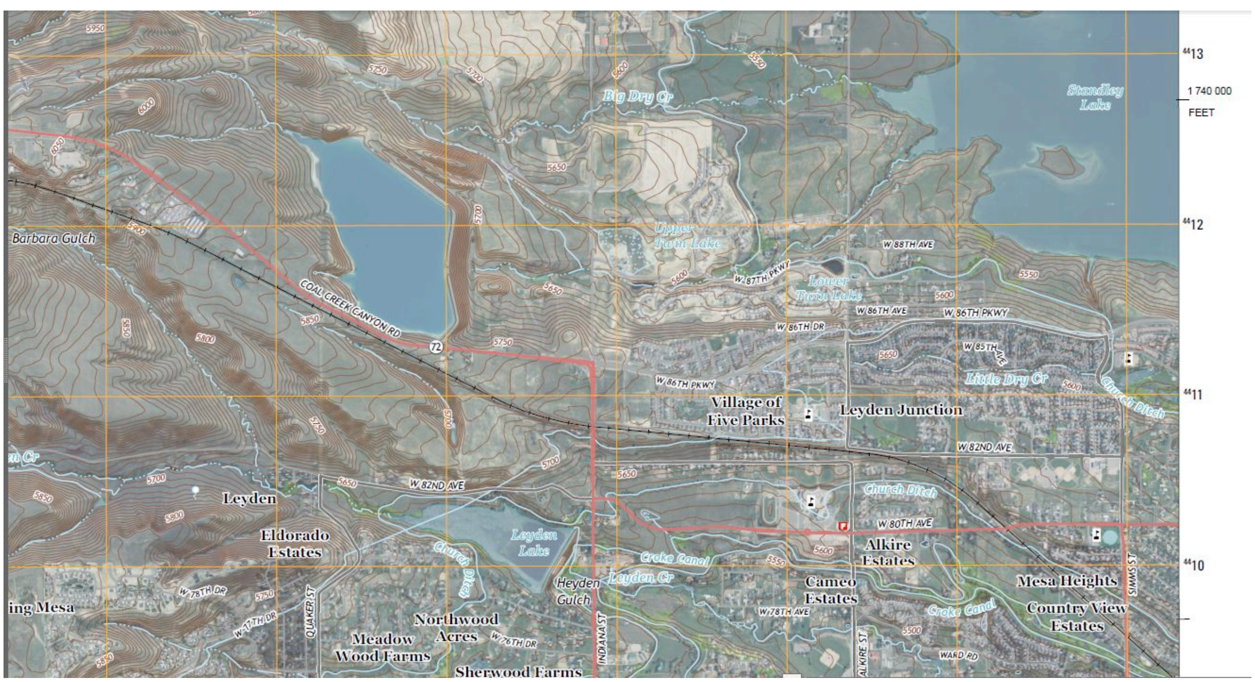

Figure 4. Golden, CO US Topo Map Published in 2013.

US TOPO MAP PRODUCT AND WORKFLOW ENHANCEMENTS

The USGS continues to enhance US Topo maps in ways other than through the addition of cartographic content. Products for the conterminous U.S. states have been in production since 2009. US Topo maps for Puerto Rico and Hawaii have now been completed and production of maps for Alaska began in 2013. In 2015 and 2016, US Topo production will begin for the US Pacific Island Territories. The NGTOC Applied Research and Technology Branch, in conjunction with the NGTOC Operations Office, is currently researching a number of additional improvements and extensions to US Topo maps. A 1:100,000-scale product will be evaluated for feasibility in 2015. We are investigating the practicality of extending the production system to customizable map extents and data layers, as well as delivery in formats other than the current GeoPDF (other options being considered include georeferenced Tagged Image File Format (geoTIFF), Joint Photographic Experts Group (JPEG) 2000, GIS (Geographic Information System) packets, and others).

NGTOC is also continually working to enhance and improve the map compilation systems as described in the following paragraphs. The objectives are to continue to improve product quality while lowering unit production cost, and (eventually) to create a fully automated online system for tailored, real-time map creation. Change detection research (described in the next section) may also help meet these long-term goals.

NGTOC uses two core systems for map compilation: 1) a series of customized Esri Workflow Manager (WMX) workflows that support semi-automated grid and interior annotation generation and edit, as well as map quality assurance; and 2) Maps On Demand (MOD), a fully automated system that uses Esri and TerraGo software in combination with customized code to assemble the GeoPDF maps. NGTOC begins the map compilation process by creating grids and interior map annotation. ArcGIS core tools and WMX are used to generate and edit map grids and annotation, which are stored in ArcGIS SDE (Spatial Database Engine) feature classes. The interior map labels are created with a complex ArcGIS map document (*.mxd) that uses Maplex for ArcGIS software to label transportation, geographic names, hydrography, structures, boundaries, and topographic contours. The interior labels are converted to annotation and also stored in SDE annotation feature classes. Currently operators edit the interior annotation as well as the grids and grid annotation prior to submitting a list of map cell identifiers (cell IDs) to the MOD web interface. MOD automatically assembles the maps and creates several ancillary files in addition to the GeoPDF. MOD produces an Extensible Markup Language (XML) Federal Geographic Data Committee (FGDC, 1998) metadata file (also a direct attachment to the final product GeoPDF), a JPEG thumbnail that can be used for previewing the maps at the USGS online store (http://store.usgs.gov, the Map Locator and Downloader application), and an ArcMap document set to the given map extents for internal NGTOC use. Once the maps have been generated, WMX workflows are used for quality assurance and to correct any errors found with the grid and interior annotation. After final edits are complete, maps are re-submitted to the MOD system for final assembly. The final maps are then published to the USGS online store.

Several research and development projects are in progress to improve upon MOD and on the WMX workflows. Figure 5 demonstrates the results of the improvements to the production system since 2009. The stability and efficiency of the system, as well as the increased expertise of the analysts who assemble and provide quality assurance, can be seen in each of the annual production lines in the graph as compared to the 18,000 per year pace. The first several years

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show that map production was consistently behind schedule, although the production goals were met. The past two years, and in particular 2014, demonstrate a pace that is consistently ahead of the 18,000 per year objective. In moving towards full automation, NGTOC is currently evaluating fully dynamic grid and grid labeling within the MOD system that would completely replace the more manual grid generation and editing that is currently done with core ArcGIS tools and WMX workflows. Substantial improvements have already been made in map labeling results with the support of PSU. The first major enhancement in 2012 was to update the label template so that all feature layers are labeled concurrently. Originally each data theme was labeled separately, resulting in many overprinted labels that required manual editing to correct. In 2013 polygon buffers were added to structure point features with a weight that Maplex can incorporate to prevent labels from being placed on top of point symbols. These two enhancements further improved label placement results, which has decreased manual editing time. In 2014 and 2015 NGTOC continues to research how Maplex can be extended and results improved with the use of multiple label templates and incorporation of polygon masks to help prevent overprints between labels. In addition, tools are being developed to convert landform names to linear and polygon features. These features can be used in the Maplex templates to automatically label landforms so that the extent of the landform can be represented in a more traditional cartographic fashion (for example, summits, canyons, and valleys). Obtaining labeling results that require little to no manual editing will help enable a fully automated MOD system for real-time generation of tailored maps.

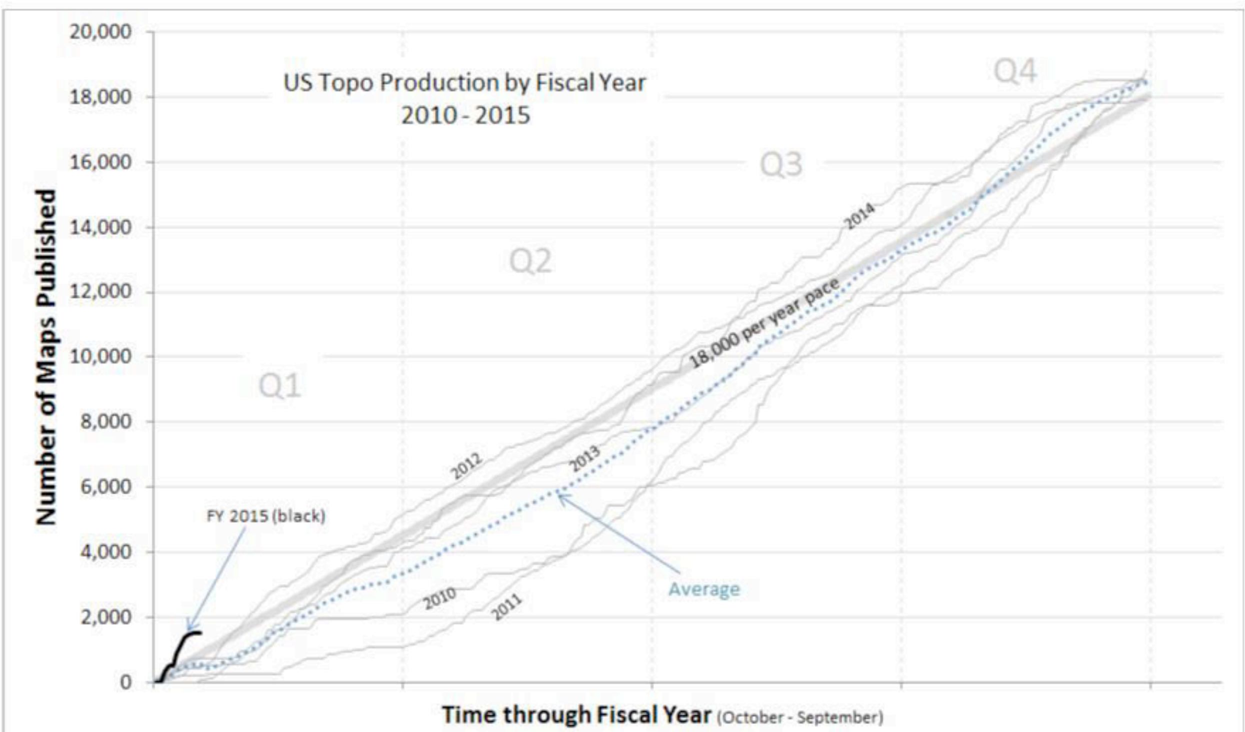

Figure 5. US Topo Map Production by Fiscal Year 2009 - 2014.

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CHANGE DETECTION RESEARCH

NGTOC manages and maintains The National Map (TNM) (http://nationalmap.gov/), providing a vast amount of raster and vector data, including national coverage for the data themes of Hydrography, Transportation, Boundaries, Structures, Geographic Names, Orthoimagery, and Elevation. These data are maintained and integrated through internal production processes and through a variety of contracts, partnerships and agreements with private, academic, and public federal, state, and local organizations. The National Map Corps initiative (http://nationalmap.gov/TheNationalMapCorps/) also provides volunteered geographic information (VGI) through crowdsourcing. From these core data themes, NGTOC produces and distributes the US Topo maps (Sugarbaker and Carswell, 2011). The focus of the change detection research is on reducing the resources required to update and re-publish the maps. To minimize resource expenditures, NGTOC proposes to use change detection methodologies for identification of change that occurs within the core high resolution national vector datasets. This type of change detection can help NGTOC quickly identify which maps require maintenance, based on several parameters, including when the product was last updated; what type of change occurred (geometry and/or attribution); magnitude of change (i.e., offset distance); and total (aggregate) change across all layers in the map. These parameters are evaluated against program requirements that specify what types of changes in the data trigger a product update.

Figure 6 includes a diagram of the high level Concept of Operations addressed by this research project, which addresses vector change detection only. Raster change detection is not within the scope of this project. Existing processes for maintaining and integrating core TNM vector data themes remain unchanged and are identified in the dashed box at the top. Historical instances of TNM datasets are compared to current instances using vector-based change detection tools (green box). Methodologies used to create the maps (discussed in the previous section) are unchanged by the change detection research, and are represented in the blue box. Information about where change is occurring in the database may also support data acquisition processes, noted in the left portion of the figure.

The vector change detection tools (green box in Figure 6) evaluate the type of change (attribution and/or geometry); the magnitude of change (e.g., did the change in a single feature exceed National Map Accuracy Standards (NMAS) (U.S. Bureau of the Budget, 1947)); and the location in the real world where the change occurred. This information is subsequently evaluated against the programmatic requirements that determine whether a map needs to be updated. For example, consider a change in a road segment's attribution for a US Topo map. A change in the Name attribute is more important than a change in the One Way Direction attribute because the Name attribute drives a change in the road label, while the One Way Direction attribute is not used either for label placement or for symbolization. Similarly, a geometric change in a National Hydrography Dataset (NHD) flowline that is greater than NMAS is considered substantial, but not if that is the only change that occurred in the entire map for all data layers. If 90 percent of NHD flowlines in a US Topo map have been edited beyond NMAS, the map would certainly require an update. Similarly, if the Name attribute of 50 percent of all major roads were to change, that would also indicate that the map requires refresh. An example of an aggregate change across feature classes follows: 25 percent of NHD flowlines change beyond NMAS and 10 percent of major road Names change. In this case the change to each feature class may not drive an update to the map by itself, but the combined changes do indicate that the map should be refreshed. These examples demonstrate the types of programmatic requirements that must be defined as NGTOC moves ahead with the change detection research.

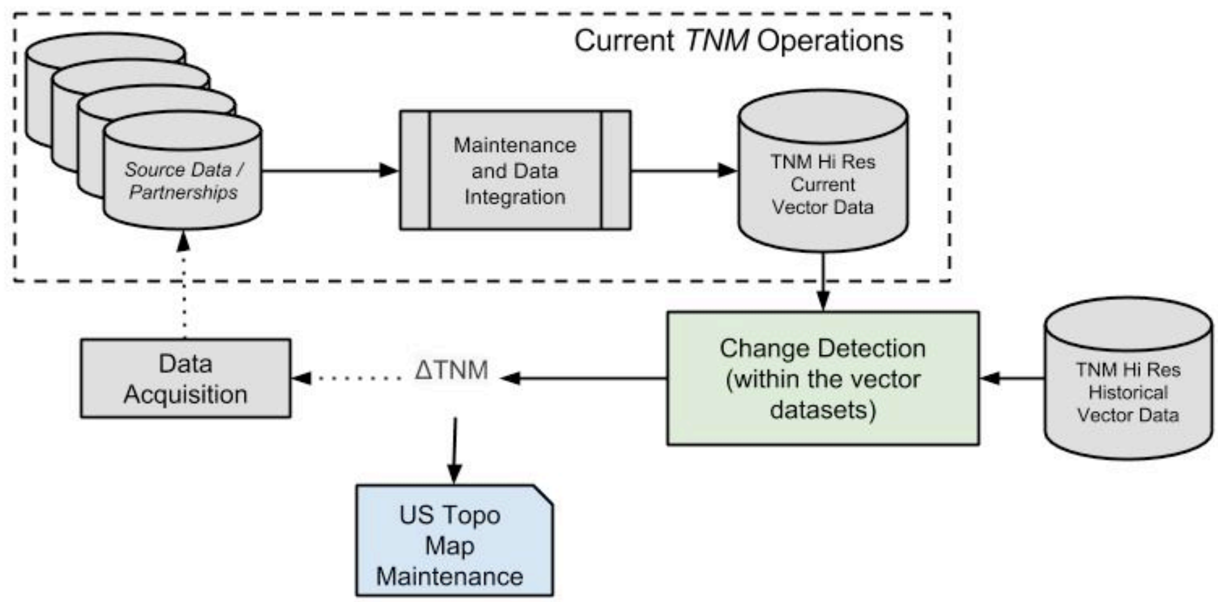

Figure 6. NGTOC Change Detection Proposed Concept of Operations.

US TOPO GIS PACKETS

Geologic mapping activities have historically used USGS topographic maps as their base maps. To provide geologists with the most current base map information from *The National Map*, the National Geospatial Program (NGP) has been working with the geologic community of users (GeoCOU) to develop a product that contains symbolized feature content identical to US Topo maps, but packaged in a way that can be more easily used in common GIS software. Through research and development activities in the past two years, NGTOC has created a prototype that is currently being evaluated both by the GeoCOU and by NGP. The product is called a US Topo GIS Packet with the intent that it would be an optional delivery format for US Topo maps.

The GIS Packet is in an Esri map packet file format (.mpk) and an ArcGIS license is required to use the product. The map packet is a single packed file that when unpacked, extracts an Esri file geodatabase containing feature data that are clipped to the extents of the map. TNM services (http://viewer.nationalmap.gov/example/services/serviceList.html) have been incorporated into the prototype, providing access to orthoimagery and shaded relief for display. ArcMap opens with a fully formatted map layout at 1:24,000-scale including map collar information and a table of contents containing data that is symbolized the same way the GeoPDF maps are symbolized (Figure 7). Map labels in the form of annotation features and vector feature data (boundaries, contours, hydrography, structures, woodland polygons, and transportation) are included in the file geodatabase. Having symbolized feature data and labels incorporated into a standard layout provides advanced capability for the geologist (or other user) to create, modify, and stylize their own maps with additional geologic (or other) data layers.

Metadata will be included with the packet in an Extensible Markup Language (XML) format just as it currently is provided with the GeoPDF maps. Additionally, alternative data formats are being evaluated to provide along with the packets (for example, Keyhole Markup Language (KML) files). This would provide for extensibility to users that do not have ArcGIS.

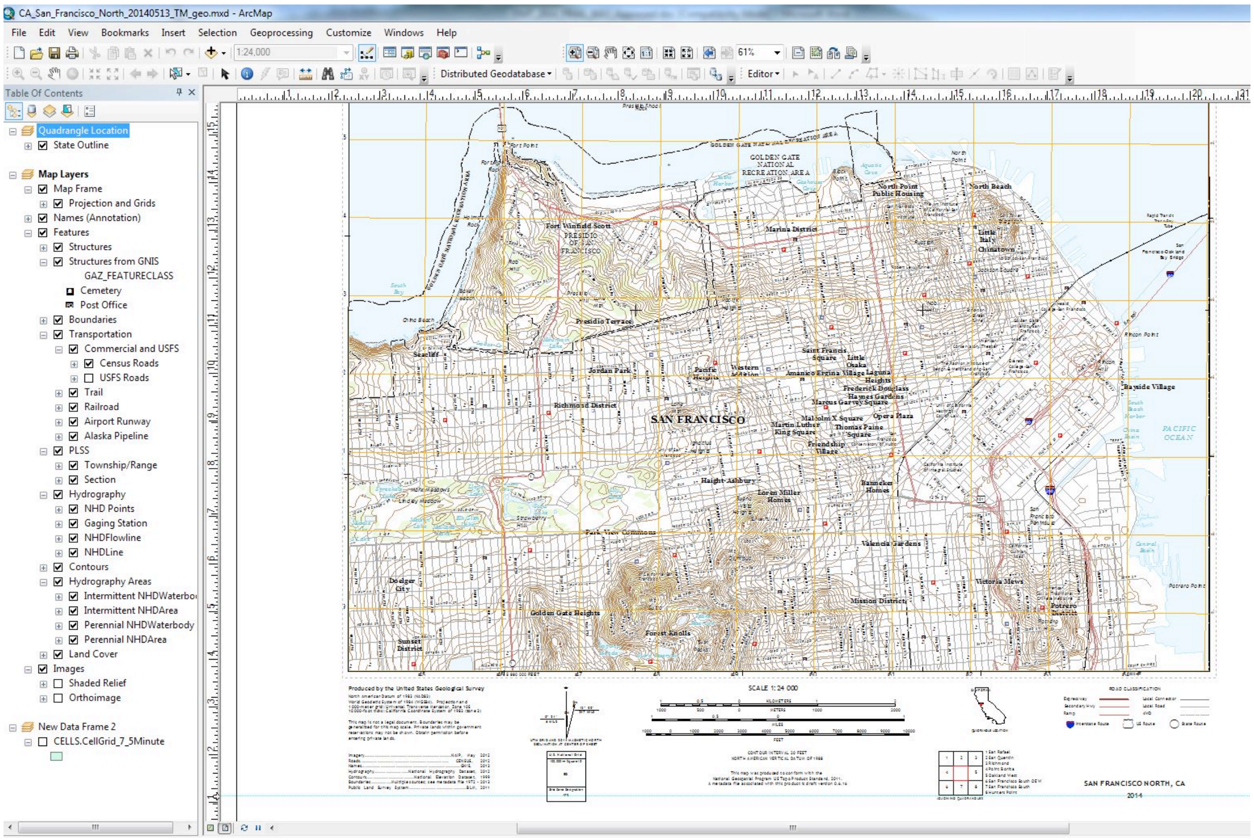

Figure 7. Sample US Topo GIS Packet (San Francisco, CA).

NGTOC is currently evaluating another option to assist GIS users with access to US Topo map content. This additional option includes a pre-staged “Combined Vector” product to be delivered in ArcGIS geodatabase format over various geographic footprints, including a 7.5-minute cells, 1 degree cells, Watershed Boundary units, and counties. The NGTOC is evaluating whether the Combined Vector product could be delivered in conjunction with one or more ancillary files instead of using the Esri map packet (.mpk) format. After unpacking, the map packet includes a file geodatabase (containing map and annotation features) and ArcMap (.mxd) template (including the map layout, collar and feature symbology). The Combined Vector product plus ancillary file option would provide almost the same data and information. It would include the file geodatabase containing all of the map feature data, but would not include the annotation features. The ancillary file could be an ArcMap template (.mxd) containing the map collar, map layout, and feature symbology just as with the map packet. In this case, however, the ArcMap template would also contain feature labeling rules, given that annotation features are not included in the Combined Vector product file geodatabase. The advantage to the map packet option is that it includes all necessary data and information packaged in a single file, which

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makes distribution and sharing very easy. It also includes annotation features that may be edited and manipulated by the GIS user. The disadvantage to the .mpk format is that it may not be as versatile as the Combined Vector product option given that, in testing the map packet, there appear to be dependencies on ArcGIS versions and operating system configurations that may not allow every user to open every map packet. The Combined Vector product plus ancillary file option provides all of the same data and information and could be packaged in a single zip file. Providing labeling rules rather than annotation gives the end user the option to generate their own annotation features as well as to adjust labeling rules as necessary. Finally, the Combined Vector product option is more versatile than the map packet because the file geodatabases will be delivered as multiple ArcGIS versions, eliminating the problems found with unpacking map packets using various system configurations.

SUMMARY

The US Topo map program has been very successful and well received, and continues to grow in popularity as demonstrated in Figure 8. The overall average daily download is 2,900 maps. Note that in Fiscal Year 2014, that number is 6,300, and the total number of downloads over the life of the program is 6.6 million. Enhancements in map content and in the map compilation system are important contributors to the success of the program. NGTOC research and development will continue to pursue product enhancements, process improvements, and technological advancements in the future. NGTOC goals are to continue research and development towards attaining more fully automated and efficient production processes, minimizing the cost of production and at the same time maximizing the convenience and usefulness of the maps for customers.

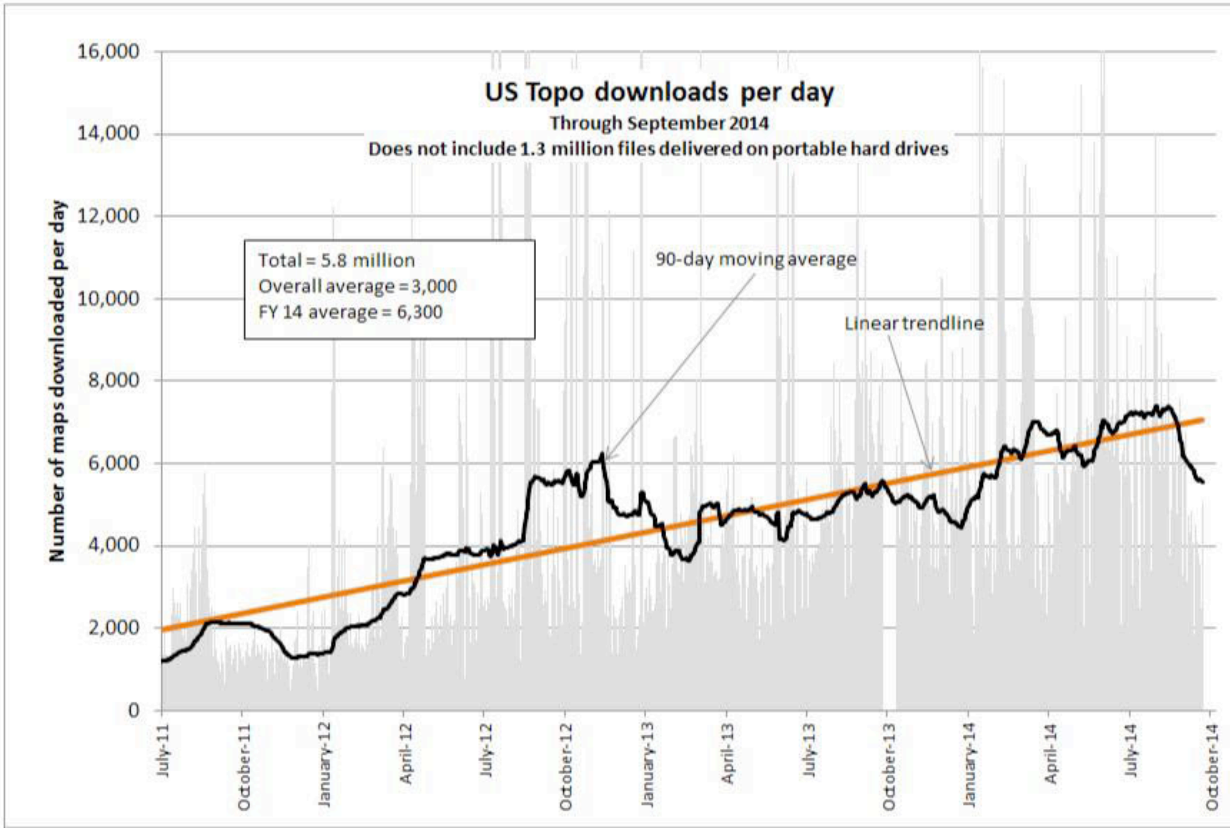

Figure 8. US Topo Map Downloads Per Day.

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