

GIS-Based Plan and Profile Mapping

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ABSTRACT

The plan and profile sheet is a type of engineering drawing, traditionally prepared in CAD, that combines a plan view, a map that targets a linear feature such as a levee, road, or channel, with a profile view, an XY plot of the elevation of the targeted linear feature. Plan and profile sheets provide engineers and project managers with valuable information for preparing construction drawings and planning improvements.

The New Orleans District of the U.S. Army Corps of Engineers has developed a work flow to create GIS-based plan and profile maps using the new charting library in ArcGIS 9.2 and data from its Levees GIS database. The ESRI Developer Samples Map Book program has been modified to accommodate plan and profile mapping, resulting in a system that has demonstrated significant cost-savings and has yielded valuable mapping products in support of levee reconstruction and emergency operations.

Introduction

The plan and profile sheet is a tool used in the discipline of civil engineering to communicate between engineers designing projects and the builders constructing projects. Designers produce “plans and specifications”, which include drawings of how to build the project (plans) together with written instructions, design criteria, and other guidelines (specifications). Conversely, builders typically provide the designers with “as-built” drawings that show how the project was actually built, since field conditions not anticipated by the engineer could result in alterations to the original design by the construction crew. Both types of products may include plan and profile sheets, as shown in Figure 1, which combine a plan view of the project area with a profile view of the project features within the extents of the plan view. These sheets are especially useful on linear project features, such as roads, levees, or canals. The plan view is a map of the project area with background imagery, annotations, and the linear project feature. The profile view is an xy plot, typically used to represent the existing elevation of the project feature. Additional lines may be plotted on the graph to represent design elevations. Based on the comparison of the lines on the plot, users can see the change in elevation required for the project’s linear feature. A numbering system, such as one based on the

surveyed baseline of the distance along the linear feature, is used to visually tie points from the linear feature in the plan to its x value in the profile plot. Multiple sheets are created at a fixed scale along the path of the linear feature.

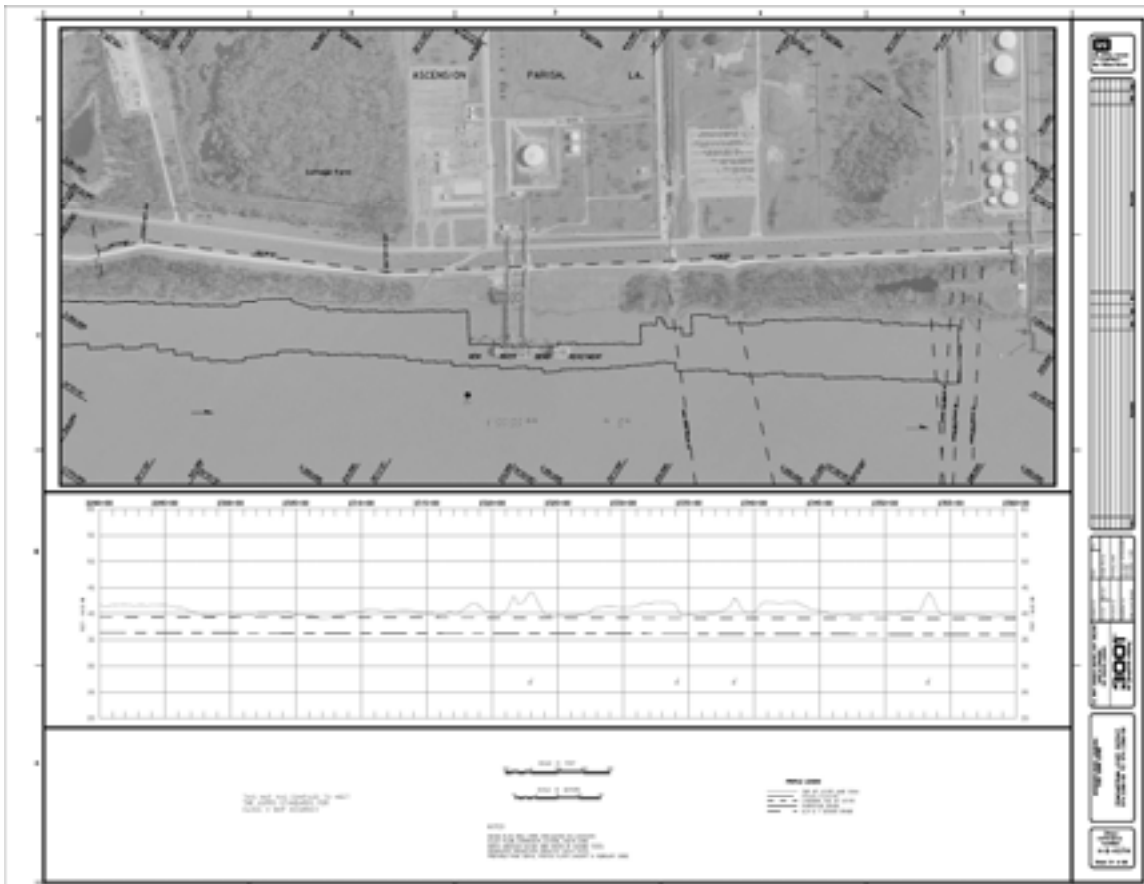


Figure 1 Typical plan and profile sheet as created by CAD software. Plan view with black and white imagery and a stationing centerline is shown on top half of the page. A profile plot with the existing levee crown elevation and design grades is shown on the lower half of the page.

Plan and profile sheets are created by CAD software, which is primarily used to create precise free-form drawings for scientific and engineering purpose. However, the creation of plan and profile sheets can be viewed as more of a mapping effort than a drawing one. If a GIS product could create plan and profile maps, it would be able to take advantage of many of the features inherent in GIS software, such as attribute and scale-based labeling, on-the-fly projection, and integration with a geospatial database. Based on this premise, the New Orleans District of the U.S. Army Corps of Engineers (CEMVA) developed the JAMB (Just Another Map Book) software.

JAMB Development

ESRI publishes the source code to a collection of developers' sample programs, including an ArcGIS extension to create map books with the ArcGIS software. This extension is generally referred to as DS Map Book. This software allows a user to create a series of maps from a single map document (mxd file). Map books work by creating a set of pages. Each page contains the same data with the same layout, but with a different bounding extent. The page extents are generated from features in a polygon feature class that also serves as the index layer. A user can switch pages in the Table of Contents to view different map book pages. DS Map Book includes utilities to batch print and batch export map book pages to create atlases.

Using DS Map Book extension improves the efficiency of creating map series. The alternative to map book is to have a user to create an individual map document for each page of the series. Copying the mxd file and panning to different areas repeatedly is not overly labor-intensive. However, once the maps are created, difficulties arise if the series requires cartographic modifications such as changing the text in the map legend or adding a new layer. The user then incurs an incremental cost for each change, as he must open each map, make the change and move on to the next, hoping he is consistent on each map. Once the maps number in the dozens, the incremental cost becomes expensive. In contrast, map books scale well with such modifications. A change in one page is applied to all others. The user makes a single change and reruns the batch export or print process.

Since the source code was freely available, CEMVN decided to exploit the existing DS Map Book code base and add the features that are needed to support plan and profile mapping. For a map book to work as a plan and profile map book, two key requirements have to be addressed. First, the profile plot has to change the range of its x axis to match the visible portion of the linear feature in the plan view whenever the user or the export/print process changes the page. Second, for practical reasons, the map book needs to be able to include graphic elements that only appear on specific pages.

To dynamically set the profile range of the x axis, CEMVN took inspiration from another existing feature of map book: tagged elements. In the original DS Map Book, a user can tag elements through the user interface, such that the text of a graphic element is dynamically set to a column value from the index feature class. The current page uses the column value of the associated grid index feature. This built-in functionality can be used to perform tasks such as adding titles and page numbers. In a similar fashion, CEMVN has added a tagging option for ArcMap charts. Charts that are tagged in this fashion are associated to starting and ending station columns in the index feature class. When the event fires that changes the current page, the tagged chart changes its range to the station range of the new page's index feature.

With the graph-tagging capability in place, the next key component is the ability to generate a polygonal index dataset with starting and ending station columns. DS Map Book already included functions to generate the index feature class from a linear feature by using circular arcs to find a point on the line segment a certain distance away from the

starting point. These two points become the starting point and ending point of the grid feature. The ending point of one grid feature becomes the starting point of the next grid feature, and the process is repeated until all of the grid features are created. The starting point or “From point” is centered on the left edge of the grid feature, while the end point or “To point” is centered on the right edge of the grid feature.

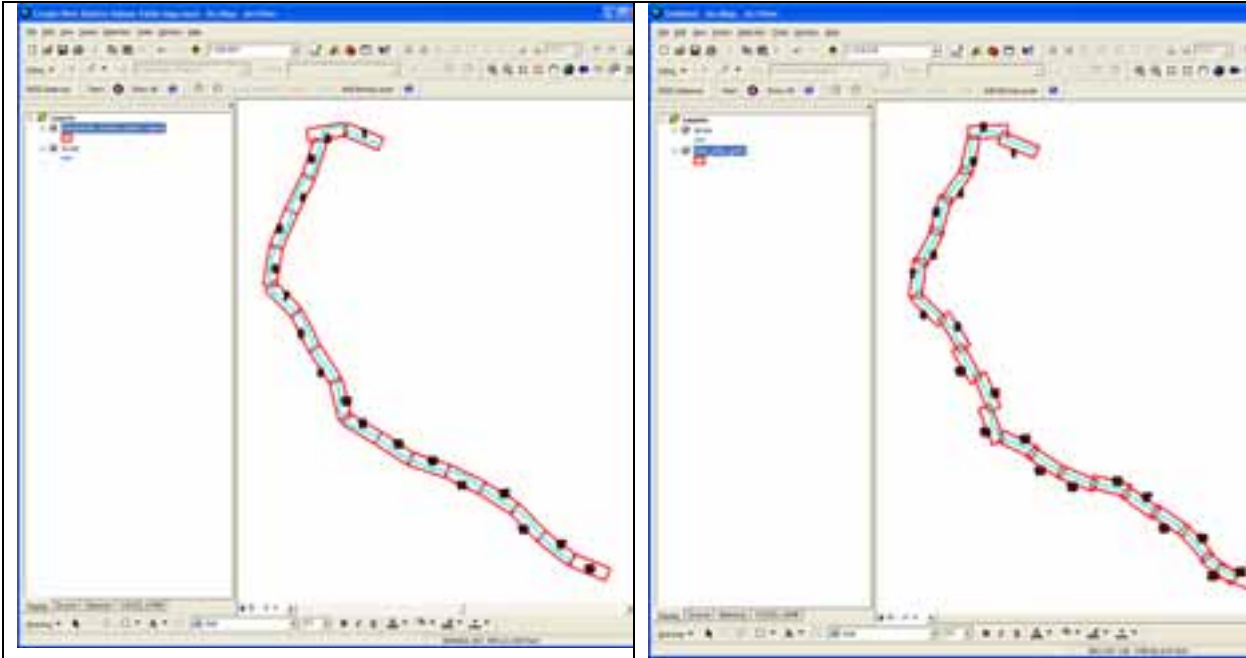


Figure 2 Comparison of the index grids generated from a linear project feature. The figure on the left shows the result of using the original DS Map Book generator. The figure on the right shows the index grid generated by the station range algorithm in JAMB.

For plan and profile methods, the objective is to ensure an equal amount of stationing appears on each page with the exception of the last page. To break the line feature according to stationing, the feature must have M values. With this method, each grid feature will contain a segment of line starting and ending with specific station values. The slope of a straight line between the starting and ending station points along the linear feature determines the angle of the grid feature. An offset is calculated for each vertex in the linear feature between the starting and ending station points perpendicular to the straight line. The grid feature is translated perpendicular to the straight line based on the average offset.

Depending on the scale and data frame size chosen, the grid feature will also contain a certain amount of buffer space. Part of the line before the starting station point (“From Point”) and part of the line after the ending point (“To Point”) will be visible on the page. Because of this, there will be some overlap between neighboring grid features. The amount of overlap can be modified by changing the scale. Each polygon grid cell inherits attributes for its start station and end station values.

The buffer space will give the consumer of the map page a visual context to associate adjacent maps in the same series. A comparison of the index grid generated by the

original DS Map Book algorithm and by the stationing algorithm in JAMB is shown in Figure 2. The start of each page of the DS Map Book index begins at the exact end of the preceding page, providing no overlap. Each page of the JAMB index provides overlap with both the preceding and subsequent pages, resulting in a product better suited for plan and profile mapping.

Profile plot generation is accomplished by using ArcMap's built-in graph functionality. CEMVN already manages its profile data by storing both station and elevation for each vertex in topographic centerlines[1]. The station value in the point feature class matches the m-value of the corresponding vertex in the topographic centerline feature class. The station column serves as the value on the x axis, while the elevation serves as the value on the y axis for plotting existing elevations. Design elevation datasets are also managed with station and elevation columns and a foreign key reference to a topographic centerline.

The implementation of page-specific graphic elements was added to support labeling of the profile plot. For instance, a user can label a spike in the graph as a pipeline or highlight the extents of a planned construction project. Use of this feature does increase incremental cost much the same way that the addition of annotations and graphic elements increase incremental cost in the plan view.

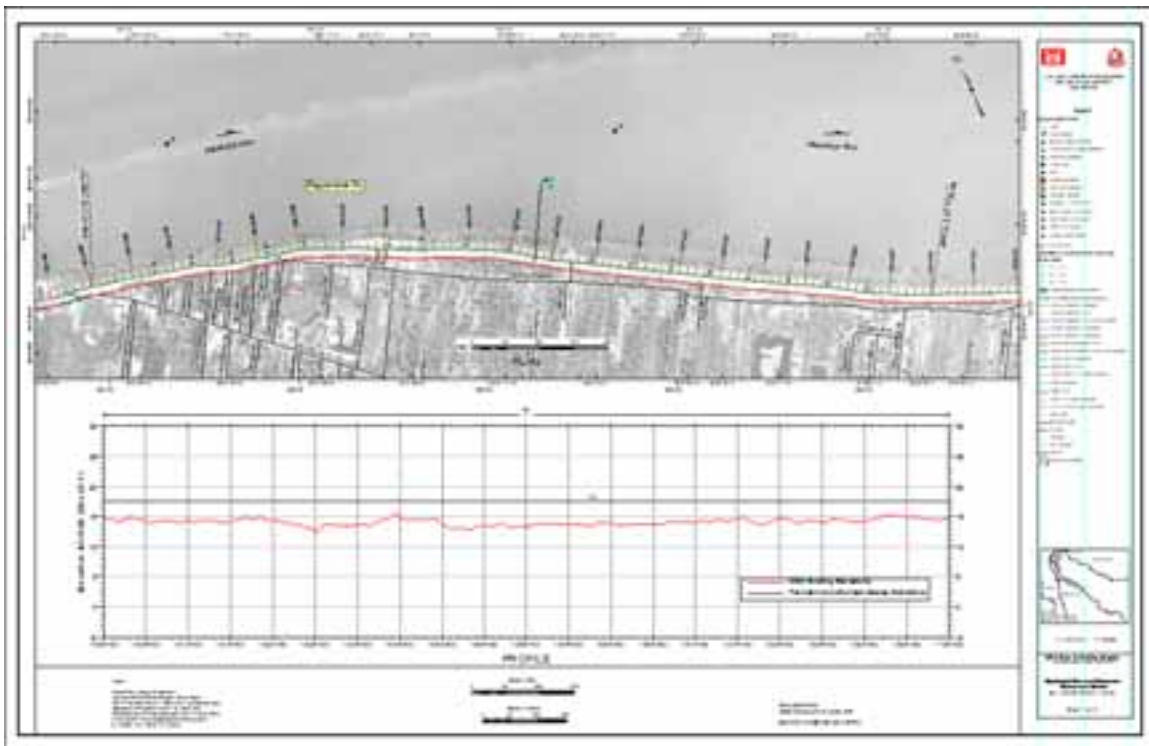


Figure 3 Sample plan and profile map created by JAMB.

Application: Atchafalaya Basin Project

CEMVN first used JAMB in 2009 to create a set of updated base maps for the Atchafalaya Basin Flood Control Project, which consists of 455 miles of levees and floodwalls in the largest freshwater swamp in the United States. The base maps were to be used for analysis in determining locations of deficiencies, and, if found, to help prioritize work in the basin. As the basin is huge and project funds were limited, the Atchafalaya Basin team needed a way to quickly develop base maps for analysis and it needed a cost-effective way to maintain data on these base maps. CEMVN conducted a new profile survey of the Atchafalaya Basin System and used JAMB to map the thirteen historic centerlines of the basin. By using JAMB, CEMVN was able to create 247 plan and profile maps such as the one shown in Figure 3 using 14 map documents. The project was completed 28 weeks from the time the new surveys were received. In contrast, the last time that comprehensive plan and profile sheets were produced in 1998, the production process took approximately 47 week from the time the surveys were completed to produce the final set of maps. However the true improvement does not necessarily lie in the initial creation of the maps, but rather in the maintenance. Since CEMVN already has a business process by which centerlines and designs elevation series are updated, most plan and profile map updates are realized by reopening and printing or exporting the map documents, instead of recreating or modifying line work as is typical with CAD drawings.

Conclusion

As a result of the success of JAMB, CEMVN project managers realized how quickly they could obtain plan and profile maps of their project areas. JAMB has since been applied to other projects such as determining the river mile on the Mississippi River levees where hurricane storm surge poses a greater risk than riverine. JAMB is also currently being used by New Orleans, Vicksburg, and Memphis district of the U.S. Army Corps of Engineers in analysis for FEMA's Levee Certification Process for the Mississippi River Levee south of Cairo, Illinois.

As of this writing, JAMB plan and profile maps are only used for planning and analysis. Organizational mandates require CEMVN to use Bentley Microstation for creating maps for formal plans and specifications and as-built drawings are submitted to CEMVN primarily through hard-copies of drawings. However, due to its short turnaround time and its access to the CEMVN Enterprise database, plan and profile maps have and will continue to be an indispensable tool for planning projects at CEMVN for the foreseeable future.

Works Cited

[1] McDaniel, David, Flanagan, Maik, and Aurand, Michele. "Rebuilding the Levees with GIS". *Proceedings of the 27th Annual ESRI User Conference*. San Diego, California. 2007. http://proceedings.esri.com/library/userconf/proc07/papers/papers/pap_1385.pdf