



CHARTING WATERWAY CHANGES

Coast Survey nautical charts, piloting tools used by skippers of coastal vessels include fine examples of Nineteenth Century cartography. Unfortunately, when compiling source maps of the land and water features for this historical geography series, the authors were unable to acquire nautical charts covering the entire study area.

The Coast Survey carefully preserved “compilation smooth sheets,” the final working draft source maps — both hydrographic (water) “H-sheets” and topographic (land) “T-sheets” — which provided the baseline information for portraying bathymetric, shoreline, and land conditions on the charts. (In Volume 1, “Charting Sarasota Bay” described the fieldwork and cartographic processes in the creation of nautical charts.) The H-sheets portrayed soundings and depth contours derived from them. The T-sheets provided information on shore features of interest to navigators, generally showing terrain and landmarks to the inland extent visible from vessels. Therefore, for parts of our coast where the published pre-development era nautical charts are no longer readily obtainable, the archived H- and T-sheets are an invaluable resource. This is the case for Southwest Florida.

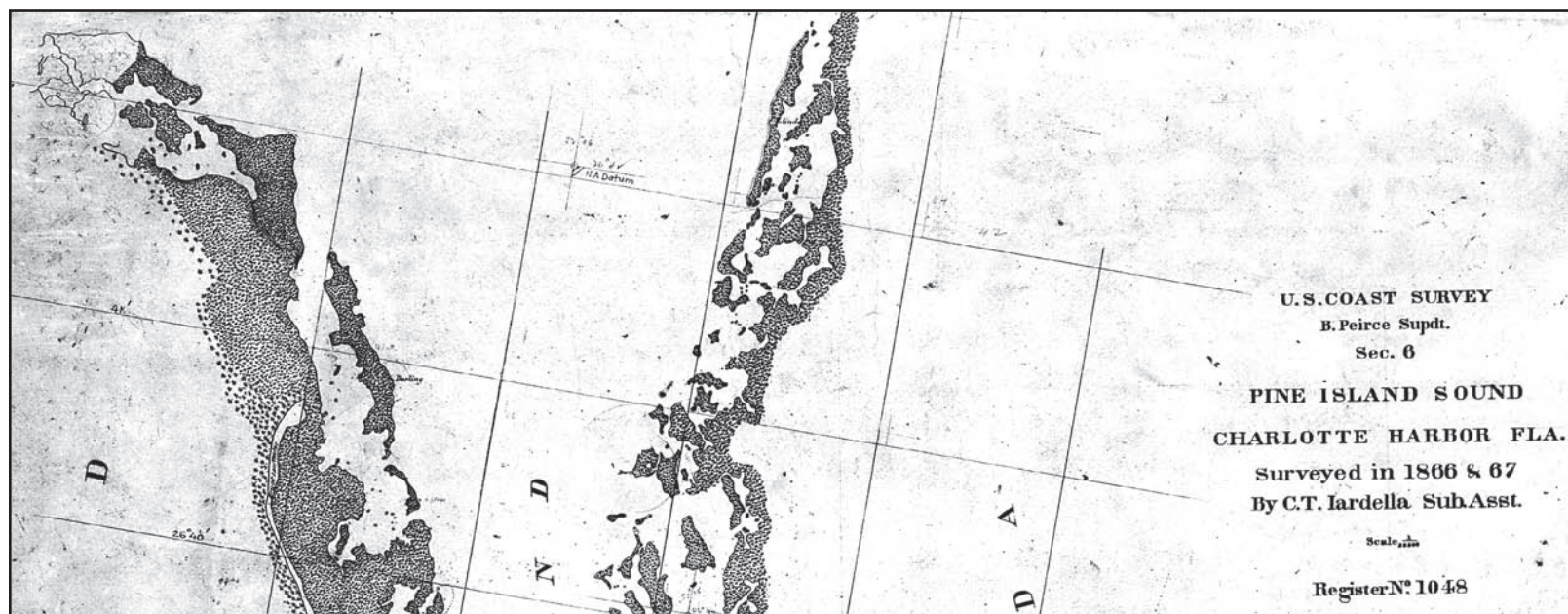
Figure 1 is a T-sheet, with an enlarged inset showing the amount of detail drawn to indicate land cover, here mostly mangrove forest. This map shows what is today known as Matlacha Pass, between Pine Island and the mainland near Cape Coral; the T-sheet, dated 1886-87, labels the pass “Pine Island Sound.”

In every bay, estuary, and navigable river along Florida’s Gulf of Mexico coast, the hydrographic surveys produced thousands of individual depths, each carefully measured by a sounding pole or a lead line heaved from a boat. Surveying techniques, based on sextant or transit sightings to or from shore stations, established a location for each sounding. Recording tide gauges allowed correction for the tidal variations. Shore parties performed the topographic surveys, mapping shorelines and other natural features, as well as roads, homesteads, farms, townships, and prominent buildings. Boundaries between land cover communities (mangrove, scrub, brushland, fresh and salt-water marshes, other wetlands, upland forests, etc.) were carefully drawn. The H- and T-sheets preserve abundant data on the state of water and land.

Today, Geographic Information System (GIS) computer programs facilitate quantitative analysis of change in shorelines, bathymetry, land use, etc., both among earlier eras and from historic to modern times. A printed historic map may be used as a data source, when input into a GIS via a file made by scanning either the paper map or a photograph of it. The GIS also needs the geographic coordinates of at least a few identifiable mapped features in order to relate all parts of the map to the coordinate system. Otherwise, the file is simply a picture or graphic, not a *georeferenced* map.

In low-energy coastal areas, away from inlets or other features subject to significant change due to storm events, scour, sedimentation, etc., it is often possible to identify presently existing natural or manmade features on historic maps. They can serve as *ground control points* (GCPs) for georeferencing. However, in Southwest Florida, especially near the barrier island passes, few natural or manmade features have survived unchanged since the mid-to late -1800s. The distinctive shoreline shapes and many small islands visible on historic maps, which might serve as GCPs if identifiable on modern maps or aerial photographs, usually reflect mangrove forest boundaries, which may have changed substantially in the intervening years.

Fortunately, historic T-sheets were drawn with accurate geographic grids, the familiar lines of latitude and longitude. Using visible grid intersections with known geographic coordinates as control points, georeferencing map scans is straightforward. Once the coordinates of selected grid intersections (or other ground control points) are associated with the corresponding pixel coordinates in the image file, the GIS then transforms all pixel coordinates to geographic ones. In addition, this process can *rectify* the image, correcting source map inaccuracies, as well as removing distortions induced in the paper maps over decades of storage and handling or introduced in the scanning process. Sophisticated mathematical operations (algorithms) start with the map coordinates of the GCPs and interpolate new positions for all other pixels in the image.



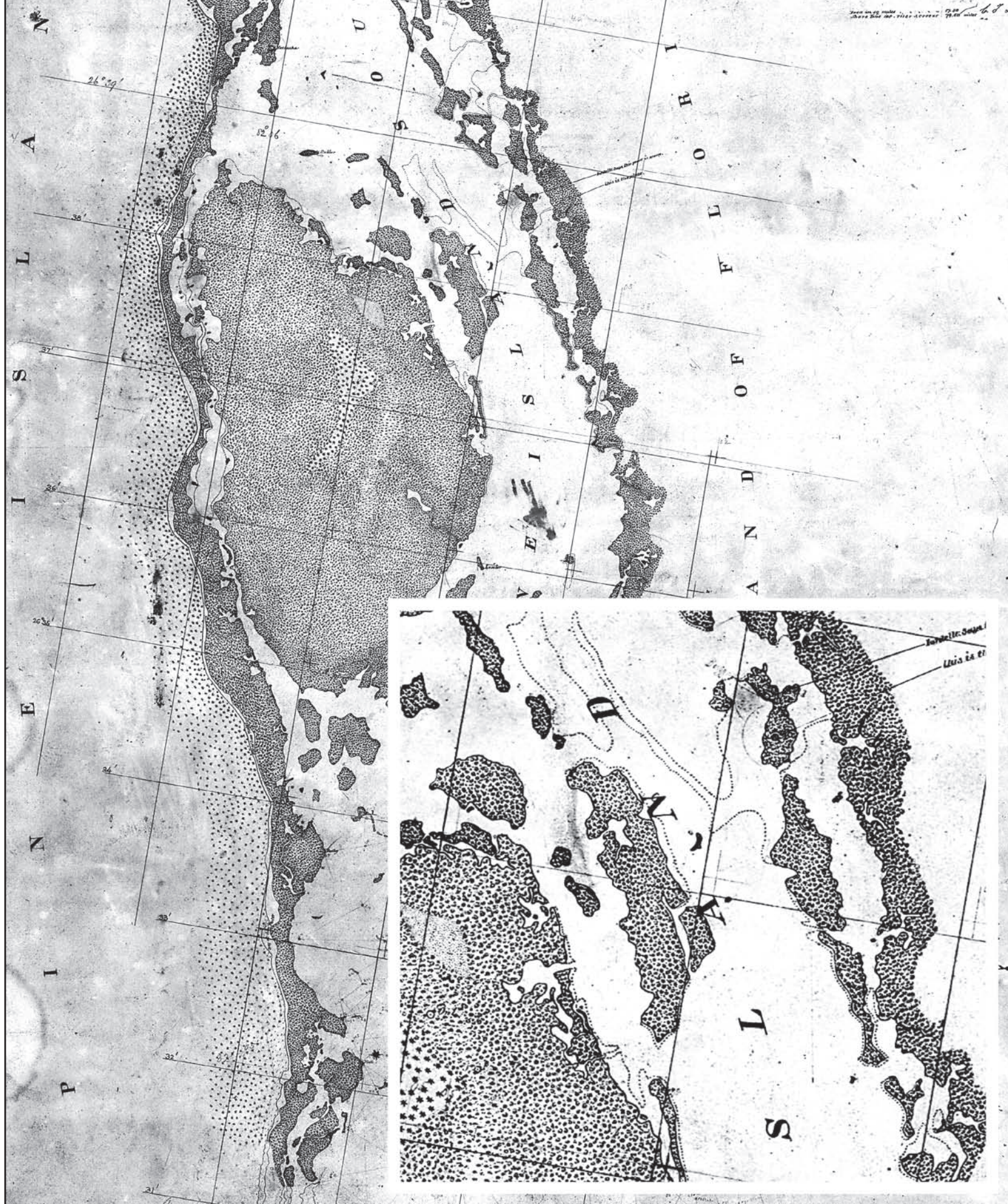


Figure 1. Example terrestrial smooth sheet (T-Sheet).

Many of the H-sheet scans do not show geographic grids, which may have been drawn so lightly that the scan process failed to capture them. Also, the cartographers often drew H-sheet shorelines in a simplified fashion, omitting small, distinctive features. However, H-sheets (and the T-sheets) show the shoreline *triangulation stations*, used for position determination in both the topographic and hydrographic surveys. Figure 2 is a small portion of an H-sheet scan, showing station "Annie," near the south end of Captiva Island. The scan shows no trace of a geographic grid, but the triangulation stations are visible, if only barely, as are parts of colored depth contours. The green line is the 6-foot contour.

Triangulation stations were points of precisely known location, distributed along the barrier island and mainland shorelines, often on prominent points. A few occupied small bay islands or oyster reefs. The survey crews selected sites that maximized views of the open water, performed careful surveys to determine their positions, and thoroughly documented each station's important characteristics.

The National Ocean Service provided the T-sheets as high-quality photographic negatives; thus, Figure 1 retains most of the detail visible on the original map. For the H-sheets, obtained as scans of much lower resolution, we plotted the scans onto paper at full size and then *digitized* depth contours, either tracing the original contours or interpolating between the point soundings. This process requires an operator to trace each contour with an electronic "puck" on a special table, following rigid rules of contour construction. Of the 95 control points used in the shoreline and depth contour mapping, 52 were triangulation stations. (The T-sheets and some bet-

ter quality H-sheets also served as sources for land use/land cover interpretation. The operator did "heads up" digitizing on a computer screen, rather than moving a puck over a paper plot.)

Two source documents provide the coordinates of the triangulation stations in our study area. The *Report to the Superintendent of the United States Coast Survey, Showing the Progress of the Survey during the Year 1868*, tabulates some of them. These positions used the *Bessel ellipsoid*. An ellipsoid is a representation of the Earth's shape; improved knowledge of the true shape of the planet allows definition and adoption of more accurate ellipsoids (also called *spheroids*).

Another document, *Triangulation along the West Coast of Florida*, by Clarence H Swick, provided most of the station positions and descriptions. Station coordinates were based on the "Old North American" *datum* (mathematical model that fits the earth to an ellipsoid or spheroid); this datum used the Clarke 1866 spheroid, which succeeded the Bessel ellipsoid. Swick also discusses the Old North American Datum. In 1901, the Coast Survey adopted a single datum, the *United States Standard Datum*. This was made possible by analysis ("a very heavy piece of work") of data from the transcontinental triangulation of the United States, completed in 1899. Canada and Mexico adopted the new datum in 1913, and its name became the North American Datum. Later, the *North American Datum of 1927* (NAD27) became the standard, and the previous datum came to be referred to as the "Old North American Datum."

To summarize, converting historic source maps into forms usable for Geographic Information System analyses required transforming map coordinates of ground control points from the Old North American Datum (based on either of two obsolete spheroids) to the NAD27 Datum. The next step was conversion of the coordinates from NAD27 latitude and longitude degrees into modern *projected* systems that use meters or feet for units and yet other spheroids. (Projection displays the Earth's curved surface as a flat representation, such as a paper map. Unprojected coordinates are satisfactory for a globe, but not good for flat maps.)

The National Geodetic Survey generously supplied the triangulation station reference documents and provided formulas to transform coordinates from Bessel ellipsoid to Clarke 1866 spheroid-based coordinates, as well as from the "Old North American Datum" to NAD27. These transformations all vary from place to place; *Datum Differences: Gulf and Pacific Coasts*, published by the Coast and Geodetic Survey in 1936, specifies the corrections needed for the NAD27 transformation in Southwest Florida.

Table 1 is an example of the coordinate transformation steps. Transforming the Bessel-ellipsoid coordinates of station "Annie" to the Clarke 1866 spheroid required subtracting 3.32 arc-seconds from the original latitude (26 30 58.09 became 26 30 54.77) and adding 10.65 to the longitude (82 10 42.07 became 82 10 52.72). Then, to convert the Old NA coordinates to NAD27, latitude decreased by another 0.250 arc-second, and longitude increased by 0.039. The projection changed the degree-minute-second lat/lon coordinates to Annie's X-Y Albers coordinates: 580951.343/280297.497meters. Not shown is the conversion of degrees-minutes-seconds to decimal degrees, required for the projection operation. Each of the 95 ground control points required careful execution of these steps.

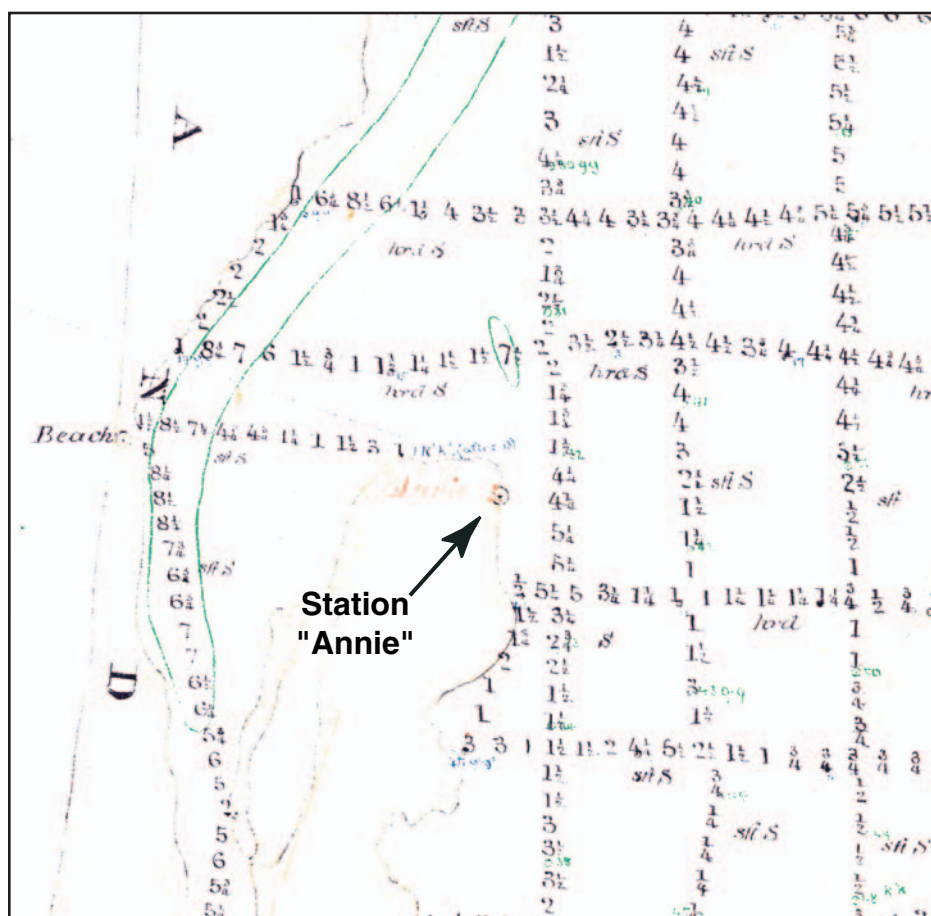


Figure 2. Detail of hydrographic smooth sheet (H-Sheet) scan.

Example of geographic coordinate transformations.

Example Map Triangulation Station	Geographic Coordinates						Albers Projection	
	NA Datum		NA Datum		NAD27		NAD83	
	(Bessel Ellipsoid)		(Clarke 1866 Spheroid)		(Clarke 1866 Spheroid)		(GRS80 Spheroid)	
Lat (DMS)	Lon (DMS)	Lat (DMS)	Lon (DMS)	Lat (DMS)	Lon (DMS)	X (m)	Y (m)	
Mistake			26 37 43.030	82 10 44.200	26 37 42.780	82 10 44.239	581000.298	292887.974
Boca Captiva			26 36 40.539	82 13 28.750	26 36 40.289	82 13 28.789	576486.397	290895.047
Oyster Shell	26 32 46.57	82 07 23.10	26 32 43.25	82 07 33.75	26 32 43.000	82 07 33.789	586398.834	283724.254
Annie	26 30 58.09	82 10 42.07	26 30 54.77	82 10 52.72	26 30 54.520	82 10 52.759	580951.343	280297.497
Havelock			26 30 05.720	82 06 10.078	26 30 05.470	82 06 10.117	588784.823	278902.973
New Year	26 28 4.61	82 07 39.09	26 28 1.29	82 07 49.74	26 28 1.040	82 07 49.779	586089.004	275024.823

<p>← Bessel Ellipsoid to</p> <p>Clarke 1866 Spheroid: lat -3.32” lon +10.65”</p>	<p>← NA Datum to</p> <p>NAD27: lat -0.250” lon + 0.039”</p>	<p>← Geographic Coordinates to</p> <p>Albers Conic Equal-Area Projection</p>
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Table 1.

How well did the process work? Figure 3 shows the pre-development bathymetry map of Matlacha Pass, with depth contours interpreted from an H-sheet, displayed in the GIS program. A recent (1999) georeferenced aerial photograph overlies the map. In places, the shoreline neatly continues from the photograph onto the map, indicating little change from the late 1800s to 1999. Other parts of the shoreline do not line up as well, suggesting change has occurred, either from natural processes, such as variation in mangrove coverage, or by the influence of man. At the upper and lower edges of the photograph, changes in the water depth — indicated by color variation, mostly due to sea grass beds — correlate well with the depth contours visible on the

map. Matlacha Pass is a relatively low-energy waterway, not subject to the dramatic changes wrought by storm events at the barrier island Gulf passes, so the lack of major variation is not surprising.

Geographic Information System computer programs allow researchers to compare old and new maps, in a common reference frame, in order to visualize and quantify changes that occur over time. Many of the maps in this book required this capability in their creation. Traditional methods could have produced similar maps and even allowed simplified change analyses, but the time, expense, and limitations associated with those older techniques would have precluded our embarking on the task.

References

Published Reports

“Datum Differences: Gulf and Pacific Coasts,” 1936. U. S. Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

Swick, Clarence H., 1913. “Triangulation along the West Coast of Florida,” Special Publication No. 16, U.S. Government Printing Office, Washington, D.C.

U.S. Government Printing Office, 1871 “Report to the Superintendent of the United States Coast Survey, Showing the Progress of the Survey during the Year 1868,” Washington, D.C.

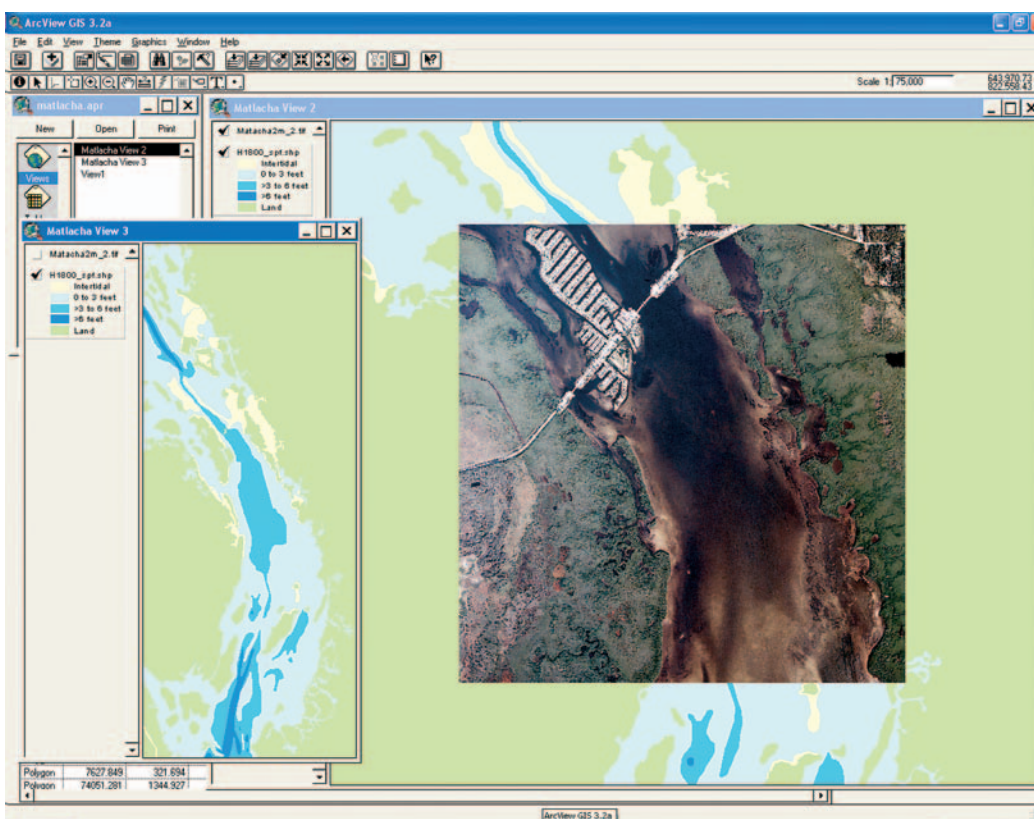


Figure 3. Map of pre-development era bathymetry with modern aerial photograph.