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Regional Morphology Analysis Package (RMAP), Version 3: User's Guide and Tutorial

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PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) serves as a user's guide for the Regional Morphology Analysis Package (RMAP) Version 3, a modernized version of the Beach Morphology and Analysis Package (BMAP). A revised interface facilitates assembly, quality control, manipulation, analysis, visualization, and archiving of geospatial shoreline positions, beach profiles, and channel cross-sections. The interface, options, data import and export, and data analysis routines are described within this CHETN. A step-by-step tutorial is also provided to familiarize the user with selected features of RMAP Version 3.

BACKGROUND: RMAP evolved from the BMAP software (Sommerfeld et al. 1993, 1994), which was devised to simplify analysis of beach profile data and results of computations from the Storm-induced BEAch CHange model (SBEACH) (Larson and Kraus 1989; Larson et al. 1990). Although BMAP provided robust tools for profile analysis, it was limited to two-dimensional data (in distance-elevation space) and in interface capability. Access to geospatial aspects of profile data was unavailable, which can be essential for data assembly, quality control, and establishing relationships to other data. Regional analysis of geomorphology typically involves manipulation of another type of geospatial data, shoreline position.

Typically, analysis of beach profile and shoreline position data requires several software packages. RMAP contains analysis and visualization tools in support of complete project workflow, from the import of raw data and coordinate conversion through analysis of various types, to report-quality graphics. RMAP supports the analysis of beach profile, channel or river cross-sectional data, and shoreline position data for engineering and science applications. Capabilities extend from generation of spatially referenced shoreline change maps to a suite of beach profile analysis tools. Data can be examined in both cross-sectional and map views to simplify data assembly, quality control and assurance, data analysis, and generation of report figures. The map viewer supports the display of profiles, shorelines, aerial imagery, and ArcMap® shapefiles in a geospatial environment. Data options allow storage, organization, and analysis of data, with support for a variety of import/export formats. In addition, RMAP supports calculation of geographic coordinates from reduced distance-elevation data pairs. Chart options allow export of images and direct copy-and-paste into word processing software. Metadata can be stored at project, group, or individual data item levels. RMAP Version 3 contains numerous interface and application framework upgrades principally aimed at supporting large data sets as encountered in regional studies.

In addition, RMAP supports calculation of geographic coordinates from reduced distance-elevation data pairs. Chart options allow export of images and direct copy-and-paste into word processing software. Metadata can be stored at project, group, or individual data item levels.

RMAP Version 3 contains numerous interface upgrades principally aimed at supporting large data sets, as encountered in regional studies. Additionally, RMAP Version 3 operates through a database to store the data rather than a single flat file as in past versions and BMAP. A database requires only those data being edited, visualized, or accessed in a computation to be loaded into the computer's memory. By minimizing the amount of data held in memory at one time, RMAP can process much larger data sets without degrading performance. Architecture extensions were made as a prerequisite for analyzing and visualizing three-dimensional data in anticipation of future RMAP capabilities. Two technical notes describe the theory and operation of previous versions of RMAP (Batten and Kraus 2004, 2005), including some capabilities not discussed here.

RMAP INTERFACE:[1] RMAP runs in the Microsoft Windows® environment on typical personal computers with the XP operating system. The RMAP Version 3 interface consists of four main elements (Figure 1).

- **File Menu and Toolbar.** Data import/export, analysis functions, and viewer controls are accessed through the file menu and toolbar.
- **Data Tree.** The data tree displays data items present in the software package and allows selection of multiple items for batch conversion or analysis.
- **Graph/Map Viewer.** The graph/map view window supports visualization of data by cross-section in graph mode and plan view in map mode.
- **Data Table.** The data table allows the user to view and edit data for each item in the data tree. This area also stores the time stamp of the data entry and allows the user to store comments on each item in the data tree.
- **Profile Properties.** Information on the plot in the Graph/Map Viewer, such as survey date and time.

FILE MENU AND TOOLBAR: The RMAP file menu provides access to functions common in Windows applications (such as Save, Open, etc.). Functions unique to RMAP, such as graph controls, data grid functions, and profile and shoreline analysis tools can be accessed from the RMAP toolbar, where they are grouped by functionality (Figure 2). These functions are discussed below.

File Menu. Items under the *File* menu support import/export of project data from ASCII text files or the RMAP free format. The RMAP free-format allows users to import entire datasets at once or archive RMAP projects into an ASCII text file that can be accessed by spreadsheet applications or text viewers.

[1] In this CHETN, selectable commands or menu items which are specific to RMAP are denoted by italic font. Text or values that a user enters are shown in quotation marks.

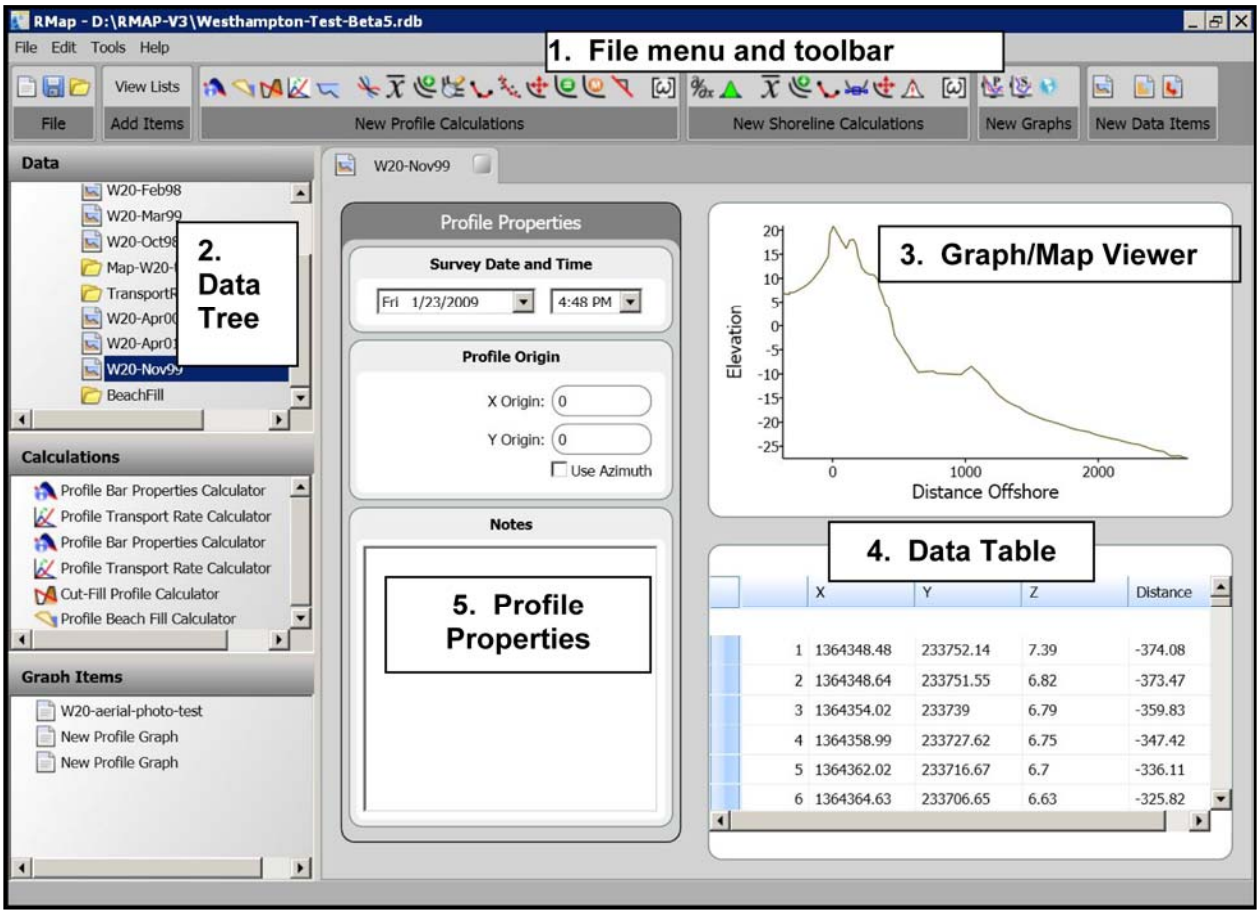

Figure 1. RMAP Version 3 interface is organized as: (1) file menu and toolbar, (2) data tree, (3) graph/map viewer, (4) data table, and (5) profile properties.

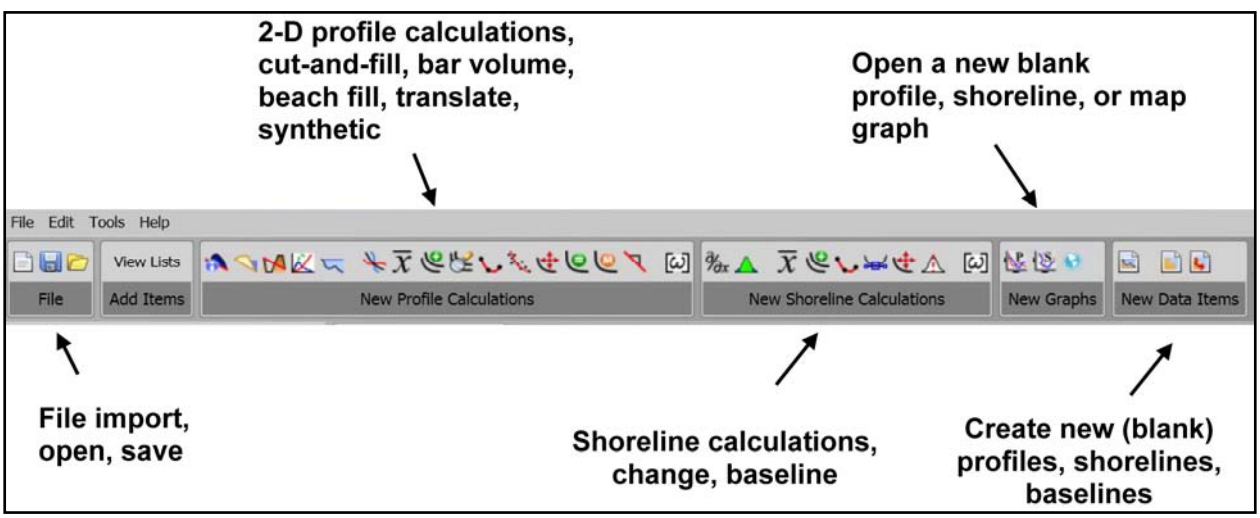

Figure 2. RMAP Version 3 toolbar.

Toolbar. The RMAP toolbar provides quick access to analysis routines. The toolbar is organized by file options, profile calculations, shoreline calculations, graph functions, and data items (Figure 2). To view the function of a button, place the mouse pointer over the icon in the RMAP window and a mouse-over description will appear. Table 1 lists individual commands.

Table 1. Tool bar commands.

File Options
New project
Open project
Save project
Profile Calculations
Bar properties
Beach fill calculations
Cut and fill calculations
Transport rate
Profile volume
Align profiles
Compute average profile
Compare profiles
Combine two or more profiles
Interpolate profiles
Least squares fit
Translate profile
Create equilibrium profile
Create modified equilibrium profile
Create plane slope
Eigenfunction calculations
Shoreline Calculations
Shoreline change rate
Calculate statistics
Draw average shoreline
Combine two or more shorelines
Interpolate shorelines
Smooth a shoreline
Translate shoreline
Mean shoreline
Eigenfunction calculations
New Graph Creation
New graph to display profiles
New graph to display shorelines
New map to display georeferenced aerial photographs, shorelines, and profiles
New Data Items
Create and open a new profile
Create and open a new shoreline
Create and open a new baseline

Data Tree. The data tree has been expanded in RMAP Version 3 and now contains three main categories:

1. *Data organizer*. Organizes project data into three categories: beach profiles, shorelines, and baselines, each identified by an icon (Figure 3). Monument locations (X-Y location) are included in the baseline category. Items can be arranged into folders and subfolders, and data items can be sorted manually by the user by dragging and dropping in the desired order or folder. It is usually convenient to create separate folders for each type of data. For example, one would create a folder titled "Profiles," then create subfolders for each separate profile location (such as Transects 38, 40, 42, etc., in Figure 3).

2. *Calculation organizer*. Calculations can be uniquely named and saved. Then, at a later session, they can be reopened and modified as needed. This utility can save time as compared to reentering all of the parameters or on-off data limits from the beginning. In addition, the *Calculation organizer* provides a convenient archive of the calculations.

3. *Graph items*. After a graph is created, it can be assigned a unique name and saved. It can be reopened later and modified as needed (e.g., to remove or add data items). Modification of an existing graph can save time, compared to redrawing a new graph.

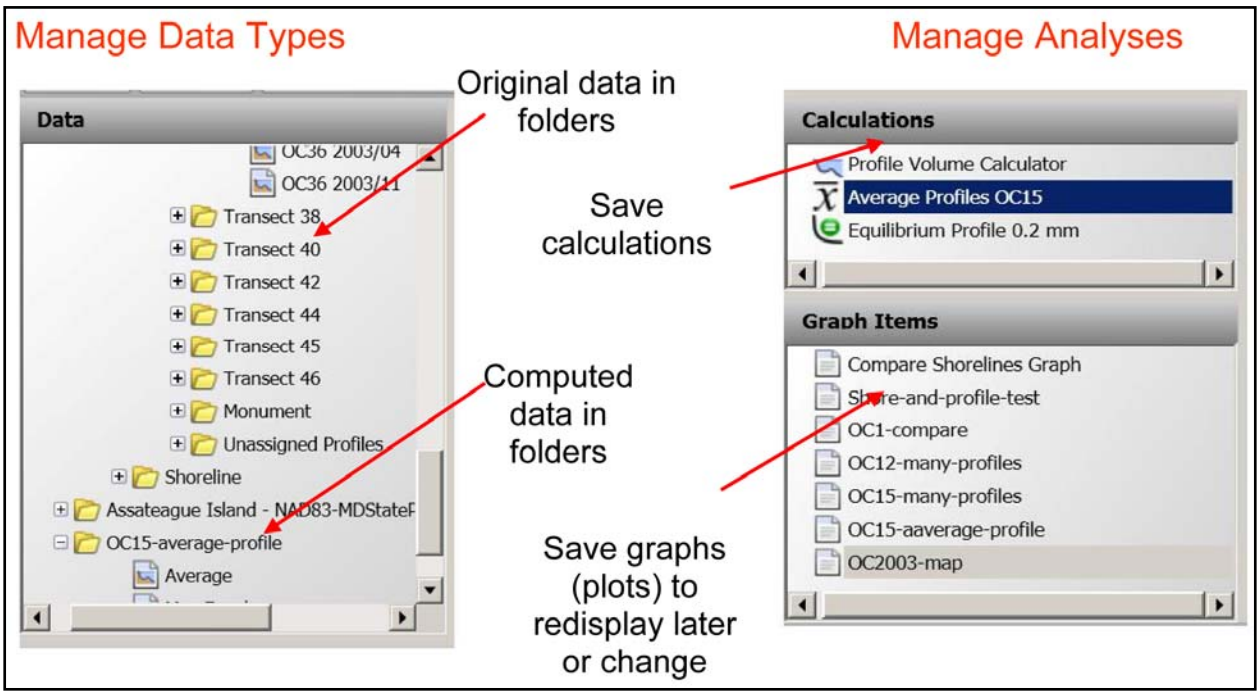

Figure 3. RMAP Version 3 data tree and options to store calculations and graphs.

Graph/Map Viewer. The Graph/Map Viewer occupies the right side of the RMAP screen and allows the user to display both profile and shoreline data in graph (cross-section) or map (plan) views (Figure 1). The window can be opened via several methods:

1. Single profile. If a profile (or shoreline) in the data tree is double-clicked, a typical cross-section plot is generated in the viewer. Plot axes adjust to the full extent of plotted data. If the data table is edited, the plot automatically refreshes.

2. New graphs. A new blank graph can be opened by clicking one of the buttons in *New Graphs*. This graph can be populated then with data from the tree via drag-and-drop (Figure 4). The plot legend is automatically generated on the plot as data are added. Once the graph has been populated, it can be saved with its own (unique) name. The user has control over graph appearance and titles.

3. Redisplay older graph. A previously created graph can be reopened by clicking its name in the *Graph Items* list.

Numerous graphs or maps can be open simultaneously. Each unique graph can be selected with tabs along the top of the graph/map viewer region (Figure 4).

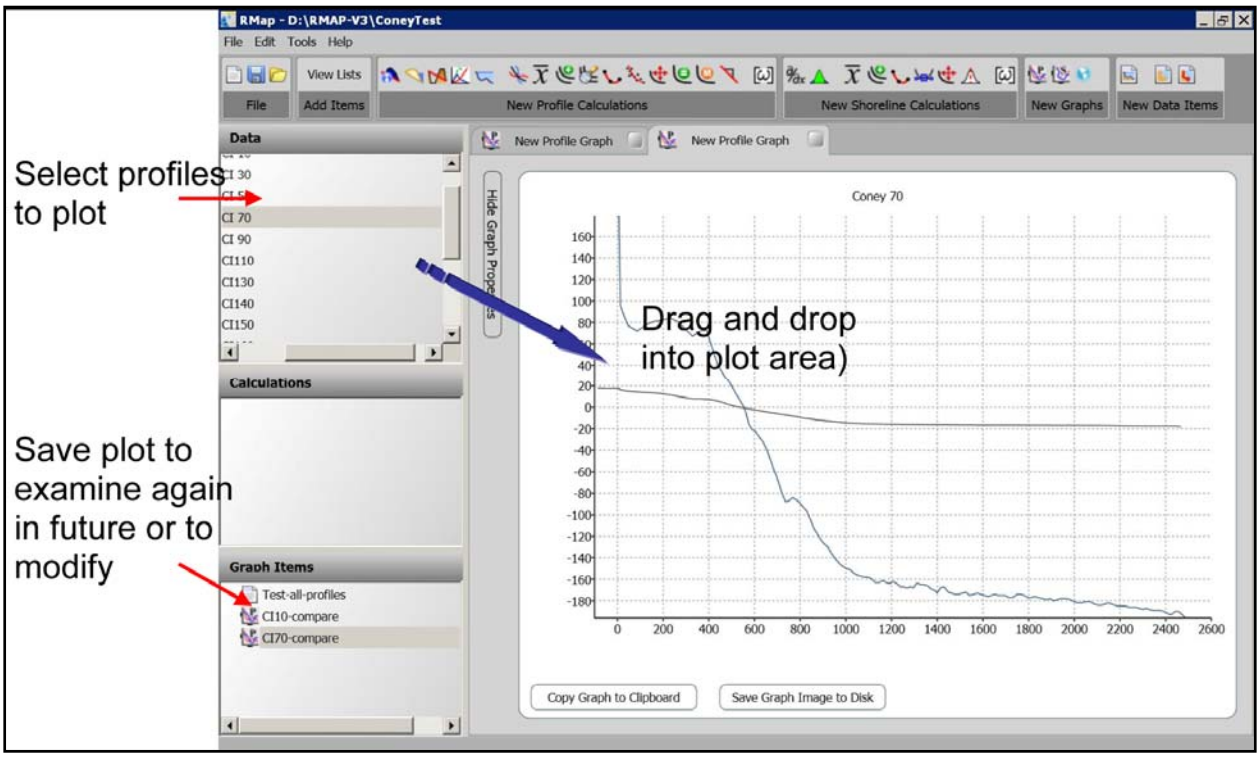

Figure 4. Dragging and dropping data into a graph.

Data Table. Once a single profile is opened in the graph/map viewer, a data table opens below the graph (Figure 1). The table allows the user to view and edit the coordinate, elevation, and distance values (Figure 5). Numbers in the table can be edited in a fashion similar to standard spreadsheet applications. A Notes window to the left allows storing metadata for individual items.

For beach profile survey data, the table contains four columns: geographic horizontal coordinates (X and Y), elevation (Z), and distance (D). Tools are provided in the data grid to calculate distances along the transect based on geographic coordinates, in addition to calculating geographic coordinates from distance elevation pairs given profile origin coordinates and transect azimuth. Consideration was given for accommodating 2D BMAP project files in implementing RMAP coordinate capabilities (three-dimensional with X, Y, and Z values). BMAP data columns (distance/elevation pairs) are automatically assigned to the Z and D columns upon opening. In addition, data are assigned to different columns depending on the number of columns present: for example, pasting two columns places data in the D and Z columns; pasting three columns places data in the X, Y, and Z columns; or pasting four columns places data X, Y, Z, and D columns. Shoreline data has three data columns: geographic horizontal coordinates (X and Y) and elevation (Z), whereas a baseline is defined by X and Y only.

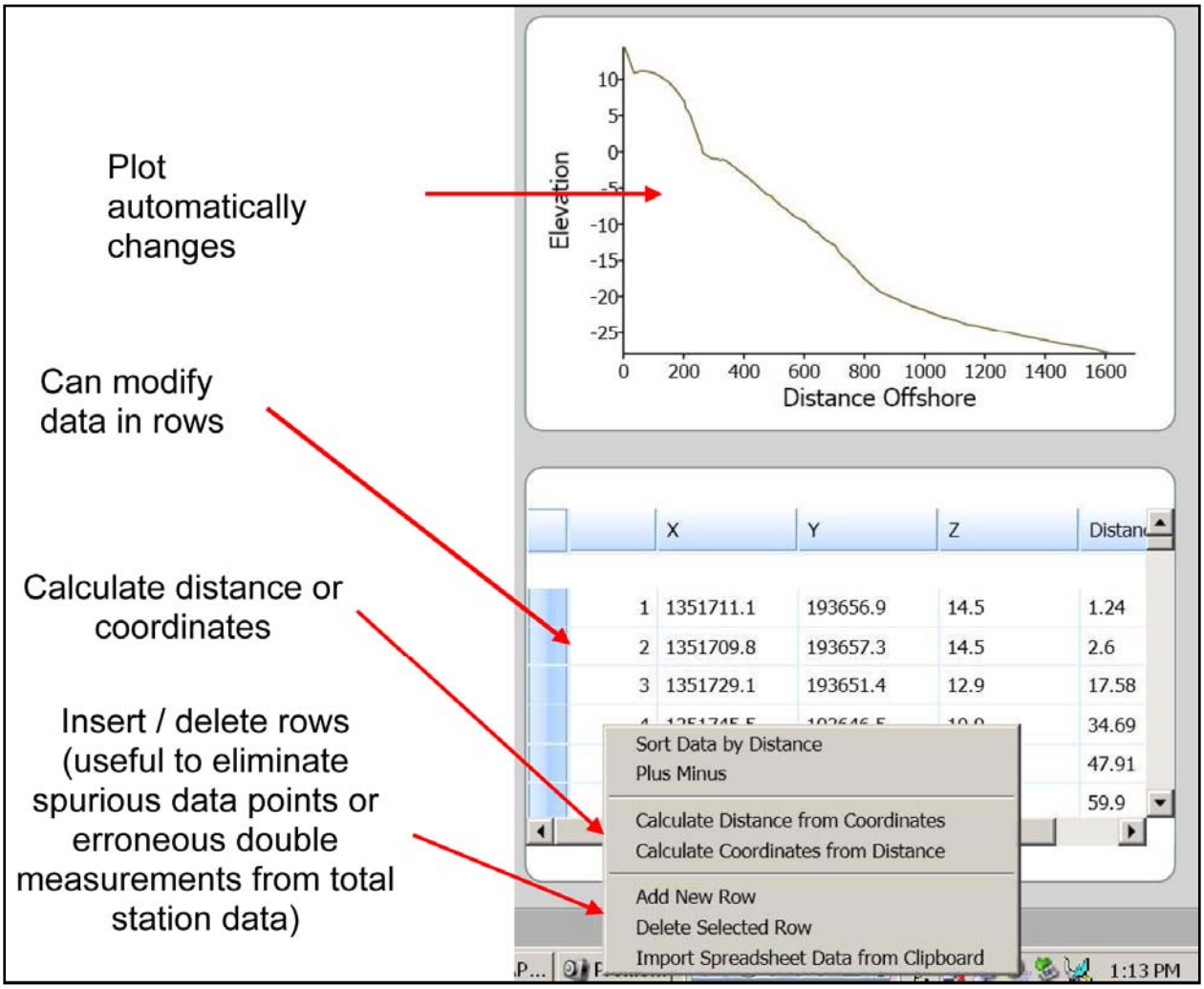

Figure 5. RMAP data table contains point attributes in spreadsheet format, displayed below the graph view pane. Tool options are opened by right-clicking the mouse.

IMPORTING DATA: RMAP can treat three general kinds of data: cross-sections (beach profile or channel), shorelines, and baselines. These data can be imported into RMAP from ASCII files, BMAP, previous versions of RMAP, and older ISRP (Interactive Survey Reduction Program) data files, copying and pasting from spreadsheet applications, or by entering points into the data table manually. Baselines are reference lines usually used for shoreline change measurements and are normally located landward of all the shorelines.

Importing ASCII files. This procedure can be used to import cross-shore or channel profiles (ZD, XYZ or XYZD), shorelines, and baselines.

To begin, first add folders under the main project folder. Each subfolder will be the name of a profile survey location (for example, OC 01, OC 02, etc., the prefix "OC" referring to a location such as Ocean City, MD). Click to highlight the folder into which the first profile will be imported.

Next, go to the file menu and click *File*, then *Import*. The following window gives the user the choice of importing RMAP free format files, ASCII text, BMAP files, and ISRP files (Figure 6). Select *ASCII Text* (default) and click *Next*. The user will then be prompted for a file type. RMAP supports three data types, shorelines, profiles (or channel cross sections), and baselines. Select *Profile* from the menu and click *Finish*. When prompted for the file location, click *Browse* and navigate to the directory containing the RMAP tutorial files, locate the desired profile, then click *Next* at the bottom of the window.

The *Data Organization* window (Figure 6) provides a preview of the first twenty lines of the file, and allows the user to specify column delimiters and remove header rows. Header rows often cause problems when importing text files as they are not delimited in the same manner as numerical data. The example in Figure 6 has two header rows. Here, the user can enter "2" under *Number of Header Rows*. Then, the header rows are removed and only the following data rows are displayed. Select *White Space Delimited* under import format. RMAP also allows a user to specify the delimiter if it is not present in the menu by selecting *Other Delimited* -> and entering the delimiter in the provided space. Click *Next* to proceed.

The *Import Information* window allows the user to tailor the data column order. RMAP imports data in the order of X, Y, Z, and D. If data columns in the imported file are not in this order, the user can select the boxes next to X, Y, and Z and select the appropriate column. Click *OK* to proceed.

RMAP will now prompt for the date of the data in YYYY/MM/DD format and the user can enter the appropriate date. Metadata or other notes may also be added to the data item at this time by entering text into the *Notes* form.

To view the imported data item, expand the data tree by clicking the + symbol beside the Project group (profile location). The newly-imported data item will now appear in the data tree. Select the item by double-clicking it. The plot will appear in the graph/map window on the right side of the screen and the X, Y, Z data will be listed in the data table below it (Figure 1).

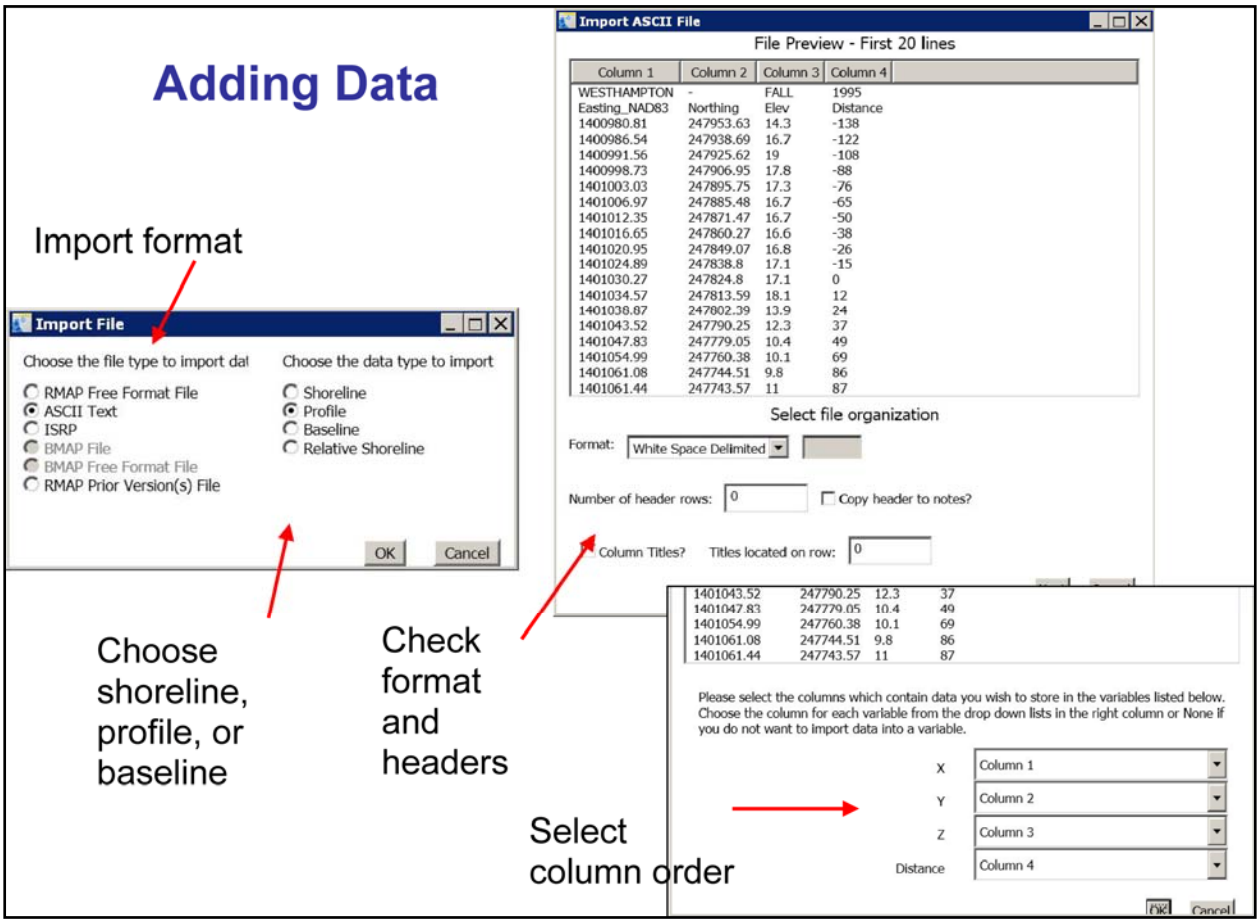

Figure 6. RMAP has the ability to import several formats of ASCII files.

Copying and Pasting Data into RMAP. Spreadsheets are a common method for storing profile, shoreline, and baseline data. Data may be copied and pasted directly into RMAP from spreadsheet applications.

Entering Data in the Data Grid. Data may also be entered directly into the data grid. Direct entry is helpful in establishing a baseline, editing profiles or shorelines, and adding a datum reference line. Rows can be added or removed by clicking the right mouse button and then selecting *Add New Row* or *Delete Selected Row* (Figure 5).

Importing Georeferenced Imagery and Shapefiles. RMAP supports the display of georeferenced background images in JPEG (.jpg), bitmap (.bmp), and TIFF (.tif) formats. For RMAP to position the image in geographic space, the images must be georeferenced to the project coordinate system. If images are not in the project coordinate system, they must be converted by means of an image analysis software package; or, the Corpscon software can be used to convert the coordinates in the image world file (.jpgw or .tifw).[1]

[1] The U.S. Army Corps of Engineers Topographic Engineering Center distributes Corpscon at *http://crunch.tec.army.mil/software/corpscon5/corpscon5.html*, accessed 16 June 2009.

Georeferenced images are imported by first creating and opening a new map (the globe symbol in the toolbar). In the column labeled *Map Files*, the user can import background images or ESRI® shapefiles. These will display in the image area to the right (Figure 7). In addition, profiles, shorelines, and baselines can be displayed superimposed on the aerial photographs. To add these elements, they are dragged-and-dropped from the data tree to the left into the appropriate box underneath *Map Files*. The user can check that profiles are in the correct location or orientation (for example, if X and Y were transposed) or can compare historical shorelines with a contemporary photograph. Note that profiles must have complete X, Y, Z attributes. Two-dimensional profiles (ZD-only) will not plot in the geospatial display.

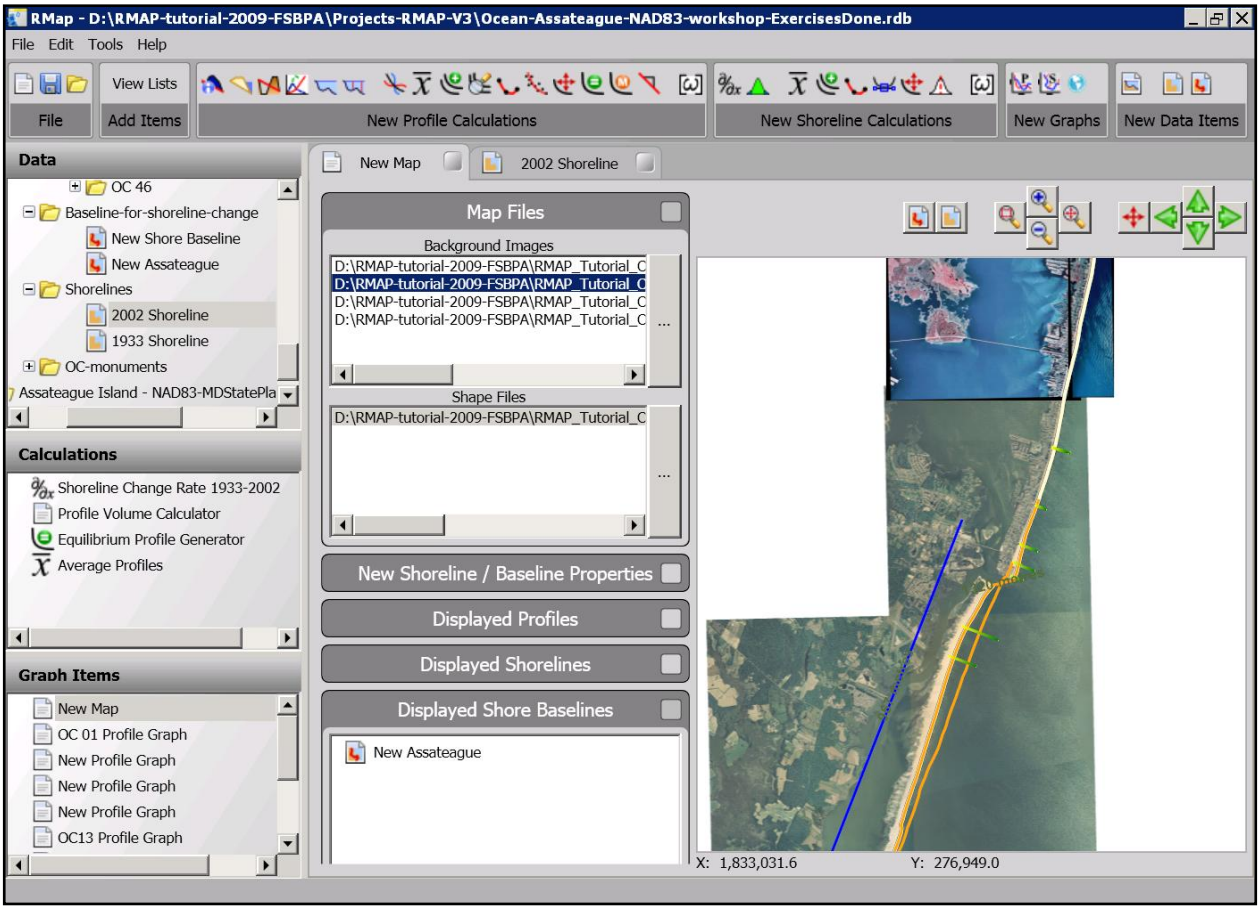

Figure 7. Example of import options in map view. The orange shorelines are shapefiles from 1933 and 2002. The blue line is a baseline.

TUTORIAL: The following is a step-by-step tutorial to familiarize the user with project setup, organization, and data analysis within RMAP Version 3. To begin the tutorial, the user should copy the demonstration files to the computer hard drive. Next, launch RMAP, select *File* and then *Open* when prompted. Browse to the RMAP Tutorial folder and select the file "Ocean-Assateague-NAD83-workshop.rdb."

Setting Project Units and Coordinate System. Before starting any project and or importing data into RMAP, the user should complete three organizing tasks:

1. Organize the project data into convenient folders. To reduce the likelihood of errors, it is recommended that all project data be in the same coordinate system; and vertical datum, or at least that data with different coordinate systems not be filed in the same folders.

2. Decide what project units and project datum will be used in the analysis. These will be based on the input data or on the specific requirements of the customer. Table 2 lists coordinate systems appearing in many U.S. Army Corps of Engineers survey programs.

3. Design a naming convention for profiles and, if needed, shorelines. We recommend a format in the form of "location-date-note" (for example, "OC15-080309" or "OC15-020429 - DO NOT USE" or "OC12-020429 - TRANSLATE+45").

Table 2. Commonly used coordinate systems and datums for USACE survey programs.

	System	Notes	Datum
Horizontal Coordinate System			
Common for recent projects in continental USA	State plane	Depends on state where project is located. Units usually feet, sometimes meters	North American Datum 1983 (NAD 83)
Often used for mid-20th century projects	State plane	Depends on state, units in feet	North American Datum 1927 (NAD 27)
Alternate horizontal	Universal Transverse Mercator (UTM)	Zone depends on location, units meters	NAD 83
Vertical Datum			
Common for recent projects			North American Vertical Datum of 1988 (NAVD 1988)
Alternate, common for mid-20th cent. projects		Still used in some projects to maintain continuity with older datasets	National Geodetic Vertical Datum of 1929 (NGVD 1929)

Notes:
- List is not comprehensive.
- NOAA provides a useful list of frequently asked questions about datums: *http://www.ngs.noaa.gov/faq.shtml* (accessed 21 May 2009).
- The following interactive map shows State Plane boundaries and lists the UTM zones in which they are located: *http://home.comcast.net/~rickking04/gis/spc.htm* (accessed 21 May 2009).

Creating a New Map View.

1. Open the project named "Ocean-Assateague-NAD83-workshop.rdb."
2. Select map button (blue globe). Go to the aerial photography directory and find JPEG file "2007NAIP_mos.jpg."
3. Under "Map Files," "Background Images," click the "…" button on the right. Go to the aerial photography directory and find JPEG file "2007NAIP_mos.jpg." and import it into map.
4. Open the directory containing aerial photographs with TIFF files in coordinate system NAD83.
5. Click files Assaw 417, 317, 217, and 117 and import.
6. To be sure of proper location, check coordinates. At the inlet, x ≈ 1,860,000 (Figure 7).

Display Profiles on the Map.

1. Click the plus (+) symbol next to "Ocean City and Assateague Island" in the *Data* box (upper left side of screen).
2. Double-click "Ocean City – NAD83-MDStatePlane" or click the plus (+) symbol.
3. Double-click "Profiles" or click the plus (+) symbol.
4. Click "OC 01."
5. Drag any 2004, 2005, or 2008 profile into the *Displayed Profiles* box. The profiles should plot north of the inlet (Figure 7).

Import a Baseline.

1. Go to the *Data* box and click "Ocean City – NAD83-MDStatePlane."
2. Right-click *Create Folder*.
3. After the new folder appears, click it, right-click, and rename it "OC-Monuments."
4. Then, go to *File* and *Import* – ASCII – baseline.
5. Go to *Monuments* and select the text file "OC-monuments_NAD83-MDStatePlane.txt."
6. Open the file and enter 1 for header rows.
7. Select the X to be column 2, Y to be column 1.
8. The file will have the name "New Shore Baseline," but it can be renamed "OC Monuments Baseline" for easier identification.
9. Double-click to plot the file and verify correct shape and orientation (Figure 8).
10. Open the map view (click tab), then drag the file into the map into the box labeled *Displayed Shore Baselines*.
11. Check the map display on the right. Zooming into the map can be performed to see more detail.

Import Shorelines (ASCII Point Files).

1. Click the folder "Shorelines" under "Ocean City." (This informs RMAP where to place a newly-imported piece of data.)
2. Go to *File* and *Import*.
3. Choose *ASCII* and *Shoreline*.
4. Find "OC-shorelines-ASCII-MDSP."
5. Select "2002_NAD83MDSPft.txt."
6. Enter 1 for the number of header rows, X is Column 1, Y is Column 2.
7. Reopen the *Data* menu tree and find the newly-imported shoreline. Right-click and rename it "2002 Shoreline."
8. Drag the 2002 entry into *Displayed Shorelines* in the map view and verify that it displays in the correct location. If not, X and Y may have been transposed.
9. Import "1933_NAD83MDSPft.txt" in the same way and plot it in the map to check its location.
10. Pan the map to the north to see how far Assateague Island has migrated landward since 1933 (Figure 7).

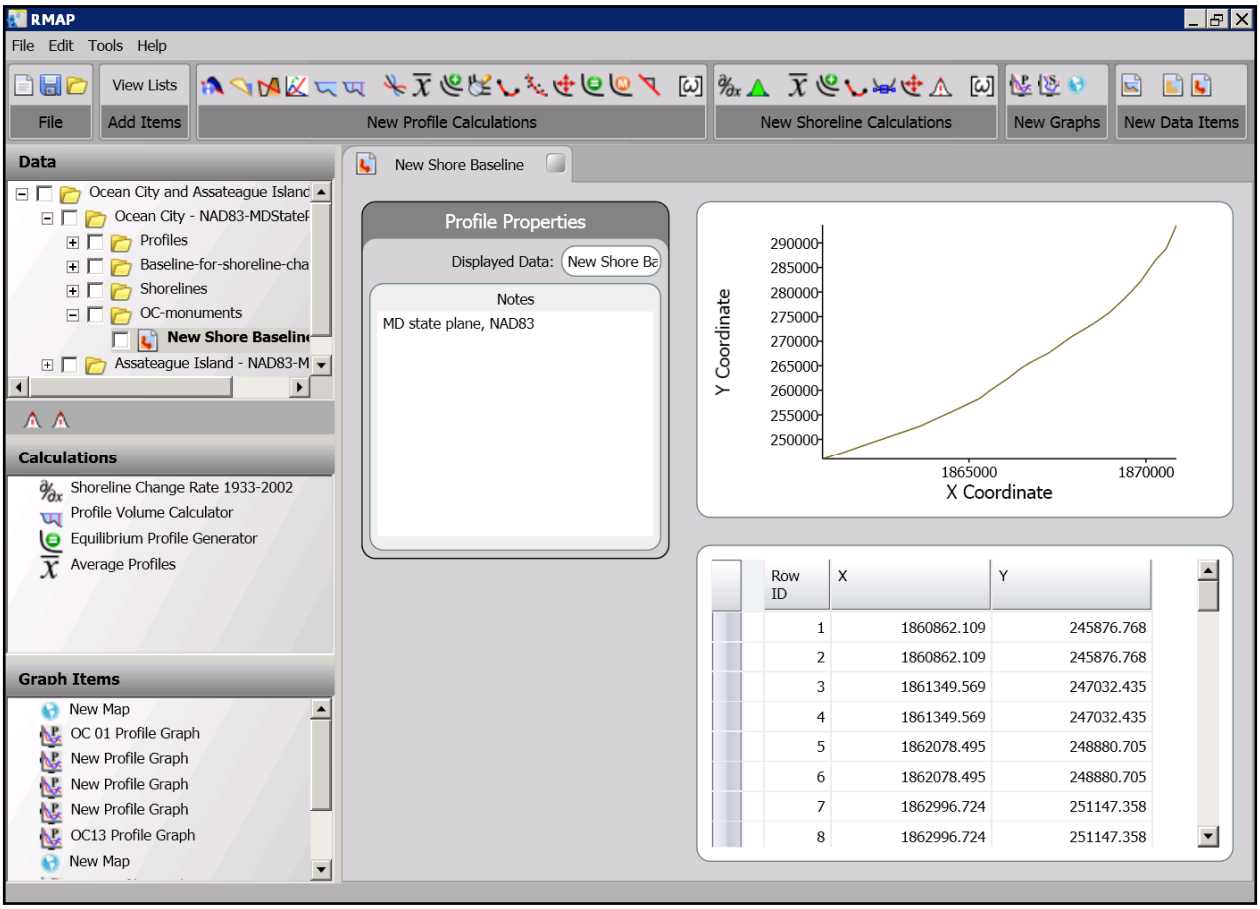

Figure 8. Display of monuments baseline. The table below the graph lists each monument.

Import Shorelines (ESRI® Shapefiles).

1. Open the map view and click the box *Shape Files*.
2. Find the directory "Shorelines," then "2002-MDStatePlane-NAD27-and-83," and click "shr_15June2002_NAD83MDSP_ft.shp."
3. Check the map to view the shoreline. Click the "Zoom Extents" button (magnifying glass with a red +) to see the full coast of Maryland and Delaware (Figure 9).

ANALYSIS OF SHORELINES: RMAP supports end-point shoreline change rate analysis between two shorelines. Transects are established perpendicular to the baseline at a user-defined interval; the distance of each shoreline is measured at each transect. The difference between the two measurements is then divided by the time interval to determine the shoreline change rate at each transect. The analysis is limited to the common spatial extent of the two shorelines, and a summary report is generated for the analysis reach. Kraus and Rosati (1998) reviewed the backgrounds of different possible definitions of shoreline position. Shoreline data must have a consistent definition.

Before the shoreline change analysis can be conducted, a baseline must be established on the landward side of the shoreline dataset. A baseline can be imported from a text file or drawn in the map viewer (demonstrated earlier).

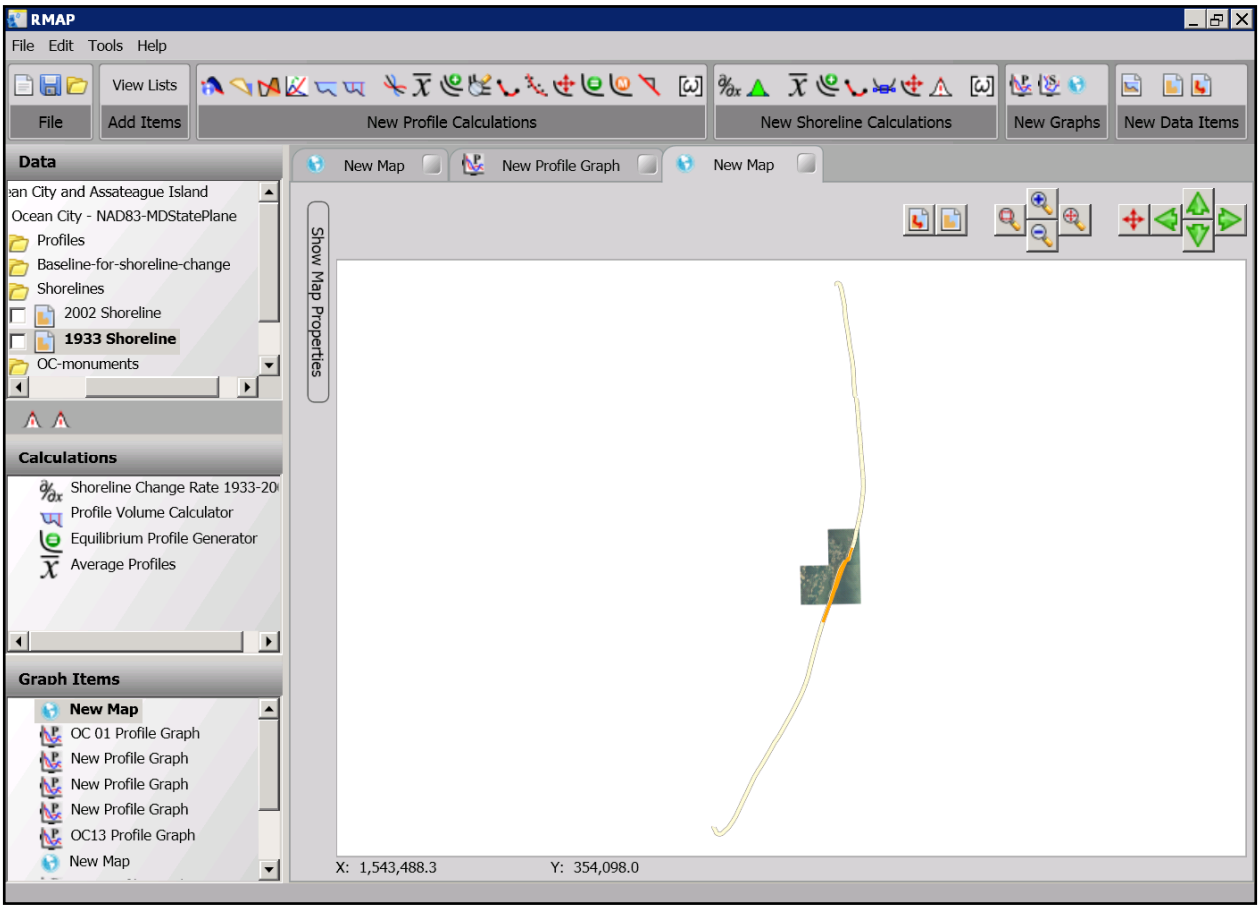

Figure 9. Shoreline shapefile of Maryland and Deleware. Rectangles are the Ocean City aerial photographs imported earlier.

Draw a Baseline by Hand.

1. Zoom in or out or pan the map to see the full extent of the aerial photographs imported earlier.
2. Drag the folder "Baseline-for-shoreline-change" into the box *Destination Folder*, located under the label *New Shoreline / Baseline Properties*.
3. Under *New Item Name*, type "New Assateague."
4. Click the button *Draw a Baseline* ( ) (left of the zoom and pan buttons above the map).
5. Draw a baseline approximately parallel to the existing baseline (the blue line in Figure 7).
6. Note that a straight baseline can also be imported from an ASCII points file instead of drawn in RMAP.

Shoreline Change.

1. Open the 1933 shoreline (display by double-clicking). Enter the date as 6/1/1933 at 12:00. Type "NOS T-sheets" in the notes area. Note: the date must be correct because RMAP uses it in its calculations. If the time is unknown, enter 12:00.
2. Next, open the 2002 shoreline. Enter 10/1/2002 and 12:00. Type "On-ground differential GPS survey" in the notes area.

3. Open Shoreline Change Calculation Page (the button) $^{\partial}/_{\partial x}$.
4. Drag 1933 into Initial Shoreline and 2002 into Final Shoreline (Figure 10).
5. Drag one of the baselines into the box *Baseline*.
6. Drag the folder OC-shoreline-calculations into the box *Destination Folder*.
7. Click the *Calculate* button on the bottom.
8. In the Data catalog under the specified output folder; find the report called *Rate of Change* (Figure 11).

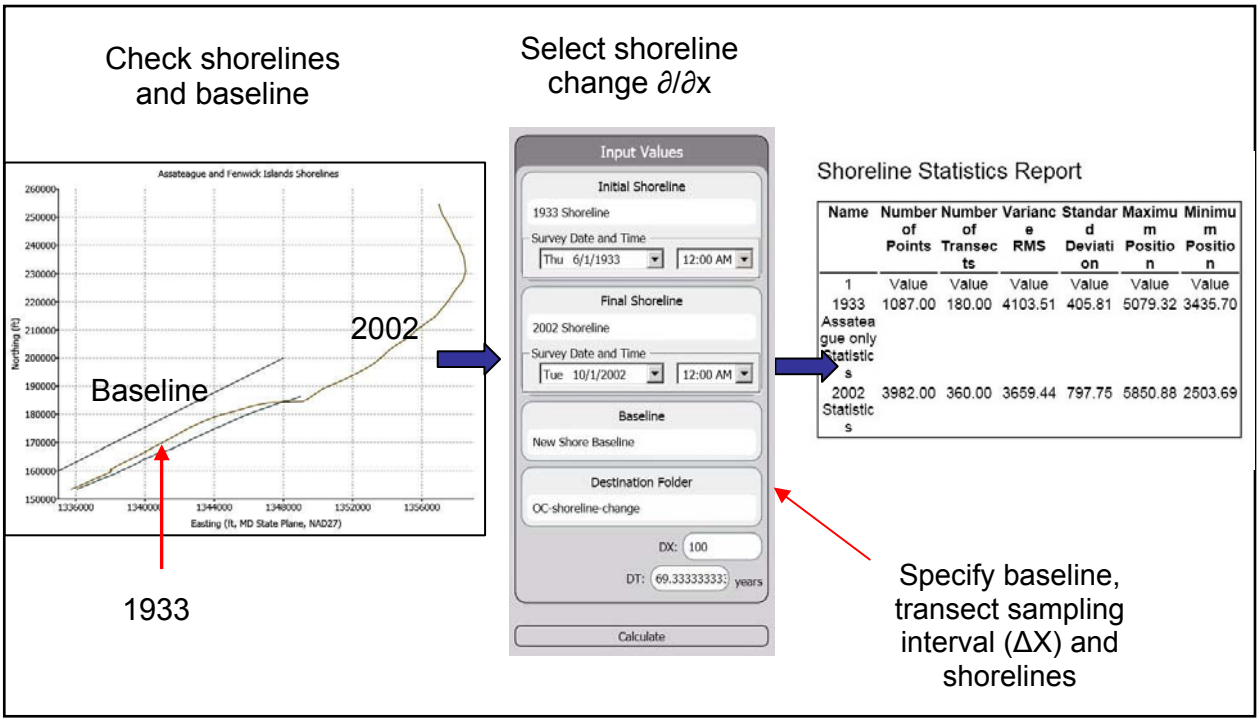

Figure 10. Computing shoreline change statistics from two shorelines and a baseline at 100 ft intervals.

PROFILE ANALYSES AND SYNTHETIC PROFILES: RMAP provides numerous analysis tools to examine profiles and river or channel cross-sections. A report is generated for each analysis, which can be exported as text, printed, or copied and pasted into spreadsheet applications.

Synthetic Profiles. RMAP allows the user to generate several types of synthetic profiles, including equilibrium (Dean 1991) and modified equilibrium (Larson 1991), interpolated, and plane sloping profiles.

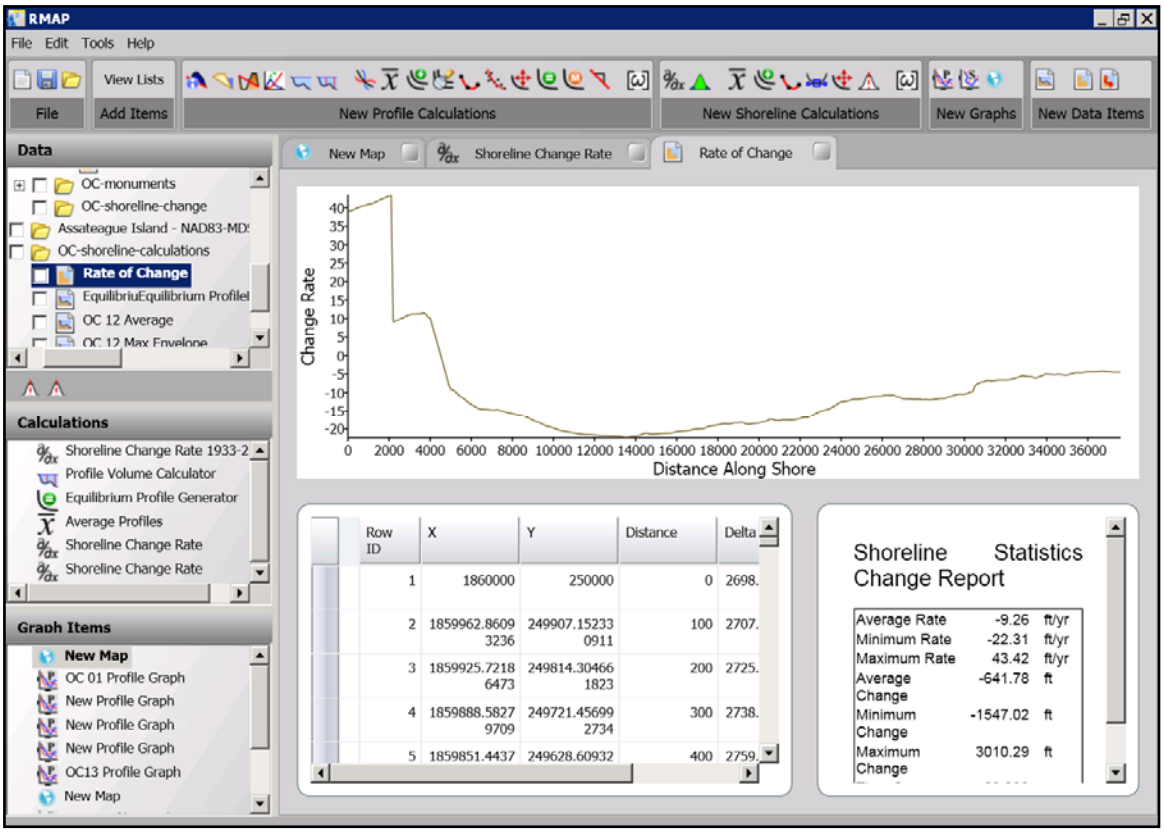

Figure 11. Shoreline change rate plotted in graph viewer.

Equilibrium Profile. The Dean equilibrium profile is a concave up monotonic curve given by the power-law relation $h = Ax^{2/3}$, where h is water depth, A is the shape parameter, and x is the distance offshore from the shoreline. The shoreline is defined as $h = 0$ and $x = 0$. The parameter, A, is a function of median grain size d_{50}. The user is required to enter *Xon*, *Xoff*, the calculation interval (*dx*), and either the median grain size (mm) or the A-parameter ($ft^{1/3}$ or $m^{1/3}$).

1. Click the button for Equilibrium Profile .
2. For X_{on} use 100, for X_{off} use 1000, $\delta x = 10$, grain size = 0.20 mm.
3. Destination folder: use "OC-shoreline-calculations."
4. Press *Create Profile*. The resulting curve can be plotted by double-clicking (Figure 12).
5. Reopen the OC 12 Profile Graph and drag-and-drop in the new equilibrium profile to compare with the natural profiles. Note how the upper shoreface is steeper than the equilibrium profile based on 0.2 mm sand.

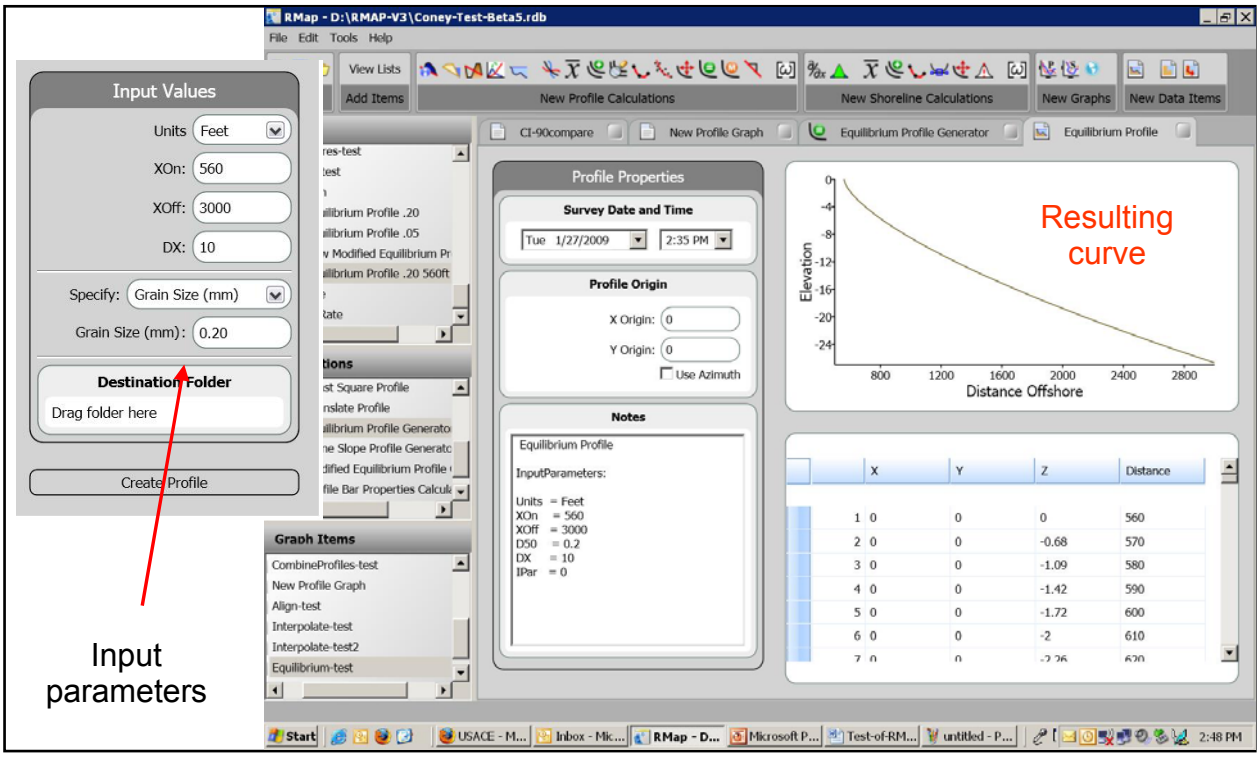

Figure 12. Equilibrium beach profile generated in RMAP for a d_{50} of 0.2 mm.

Modified Equilibrium Profile. The modified equilibrium profile is a concave monotonic profile shape developed to describe beaches that may be steeper near to shore than in the offshore, corresponding to a decrease in grain size from coarser near the shoreline to finer in the offshore. This profile depends on two additional parameters, the energy dissipation ratio, d_{Ratio}, and the decay coefficient (Λ), which controls change in grain size from coarser to finer. These parameters allow fitting of the profile to the shape of the native profile. The user is required to input X_{on}, X_{off}, the calculation interval (dX), either the native grain size (d_{50}) or the A-parameter, the *dRatio*, and the decay coefficient. Values of d_{Ratio} typically lie between 1 and 5; lambda between 0.005 and 0.03 1/m (Larson 1991).

To generate a modified equilibrium beach profile, select the modified equilibrium profile button on the toolbar . The input data box is shown in (Figure 13).

Plane Sloping Profile. This function generates a plane sloping profile, which has been the initial profile type in physical models studies and is often used for testing in numerical modeling studies. The user is required to input X_{on}, X_{off}, dx, and the elevations at X_{on} and X_{off} to determine the slope of the profile.

To generate a planar profile, select the plane sloping profile button and enter the appropriate values (Figure 13).

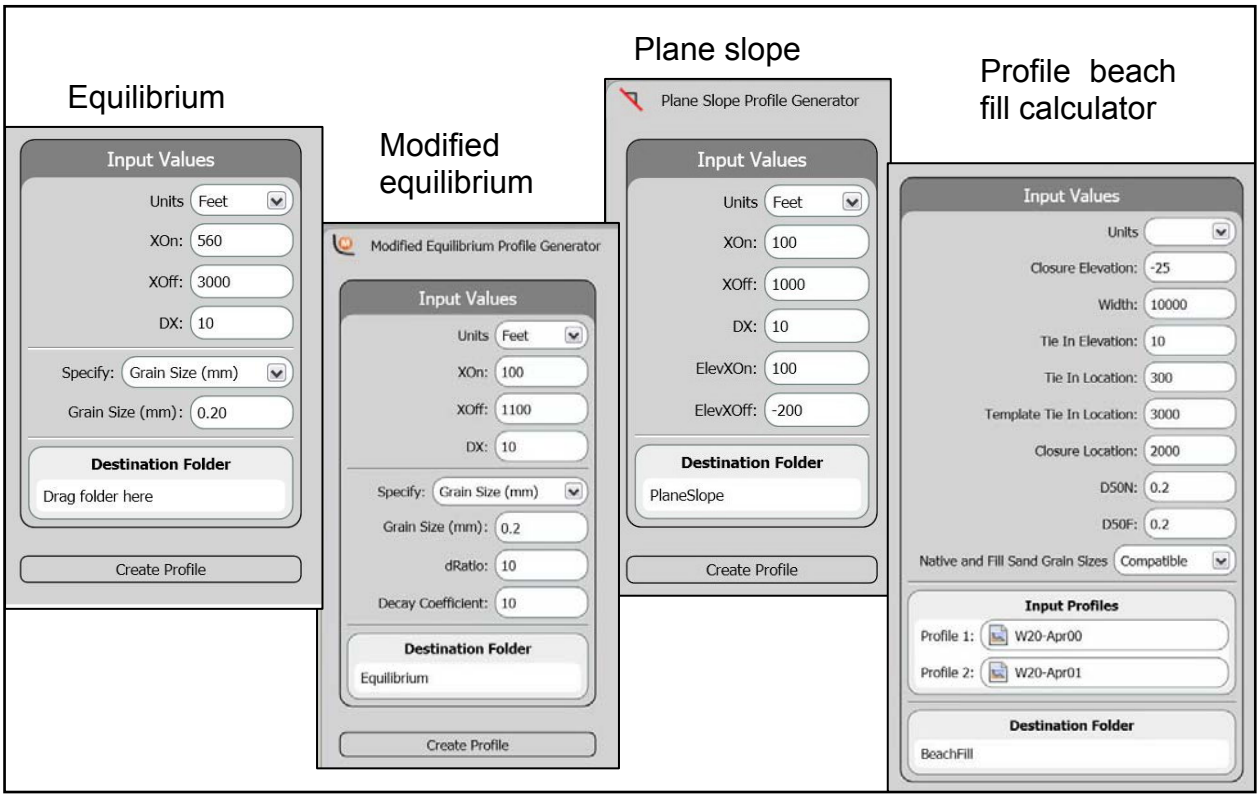

Figure 13. Input data boxes for RMAP synthetic profiles.

Bar Properties. Bar properties are analyzed in RMAP by selecting X_{start} and X_{end} limits. Bar volume, length, center of mass, minimum depth and location, and maximum depth and location are calculated from a reference or base surface, which is usually an equilibrium profile. To perform the calculation, select the bar properties symbol , enter the limits, and drag the appropriate reference surface and profile into *Input Profiles* (Figure 14).

Profile Comparison. The profile comparison routine calculates the volume and contour location change for two profiles within a user-defined area (X_{on}, X_{off}, *Zero Elevation*). The zero elevation should be deeper than the lowest elevation on the profiles or cross-sections. The example in Figure 15 is based on two profiles from Coney Island, NY. Here X_{on} was 100 ft, X_{off} was 1,400 ft, and *Zero Elevation* was -20 ft. The output shows the volume change between profile 1 and 2, and plots the changes in elevation from X_{on} to X_{off}.

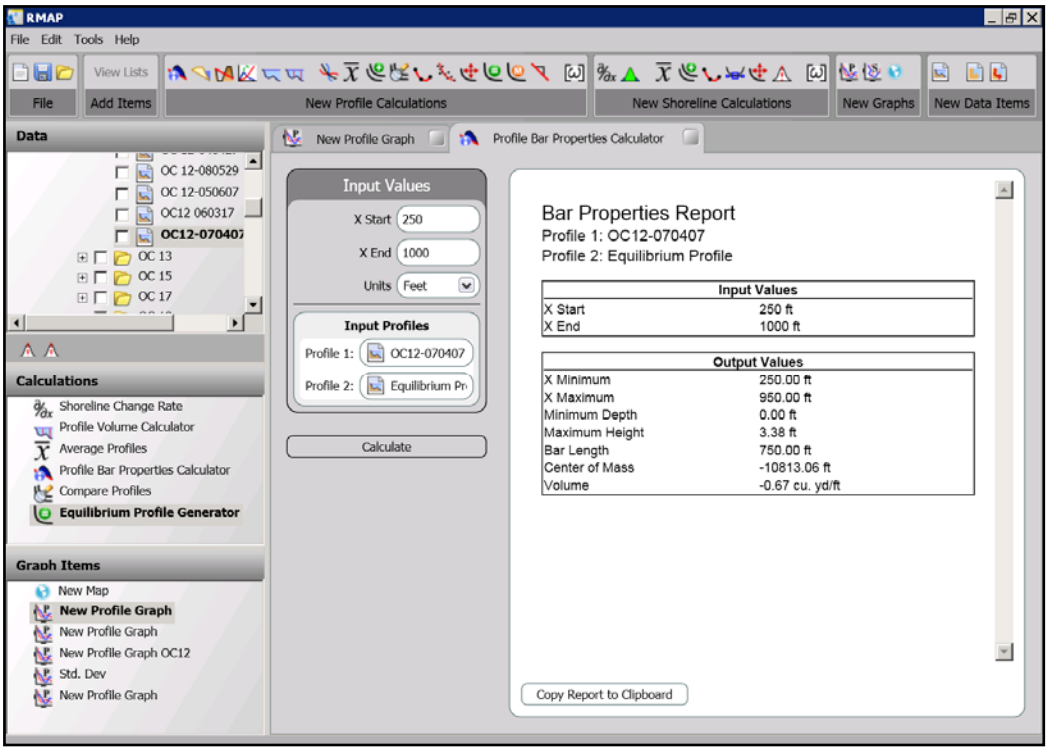

Figure 14. Bar properties report based on an OC 12 profile and an equilibrium synthetic profile as a base level.

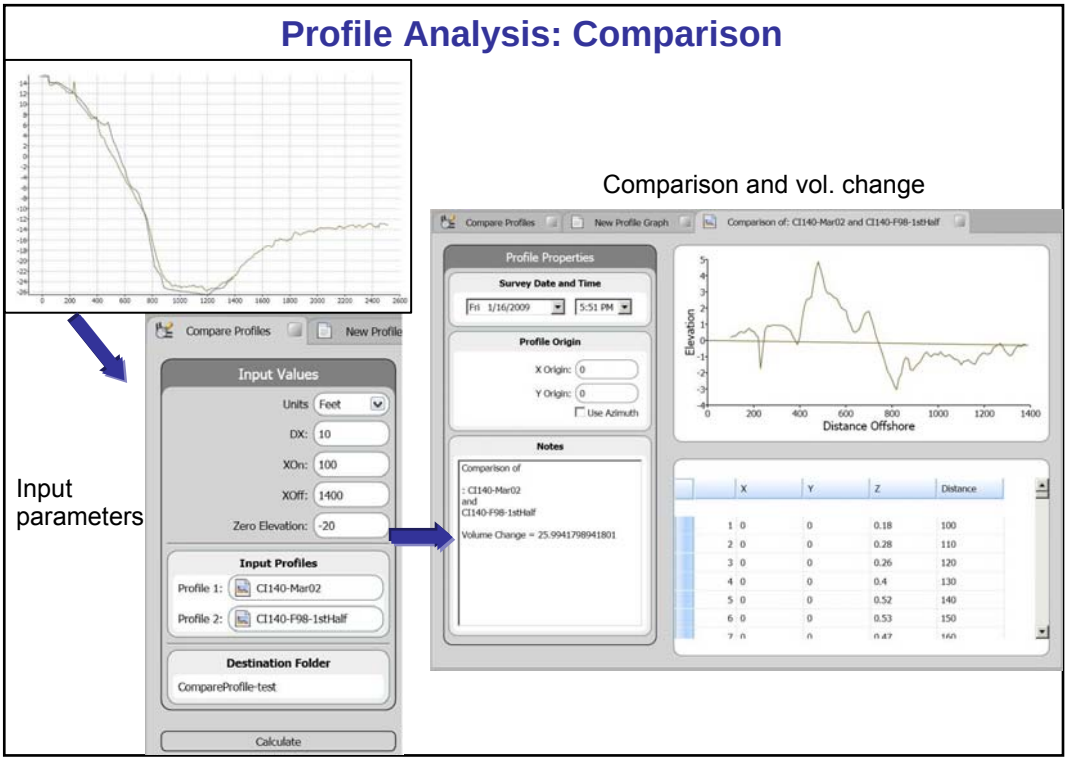

Figure 15. Comparison between two profiles from Coney Island, NY.

Cut and Fill. The cut and fill routine compares two profiles and defines cells from intersections between the two profiles. The analysis report gives the distance and elevation boundaries of each cell, in addition to volume change within the cell. Total volume change, volume change above and below the vertical datum, and shoreline change at the datum are also calculated.

1. Expand the tree to show the OC 12 profiles.
2. Select Cut and Fill from the toolbar .
3. Drag profiles OC 12-060317 and OC 12-070407 into the Input Values box (Figure 16).
4. Press Calculate and review results in the report (Figure 16).

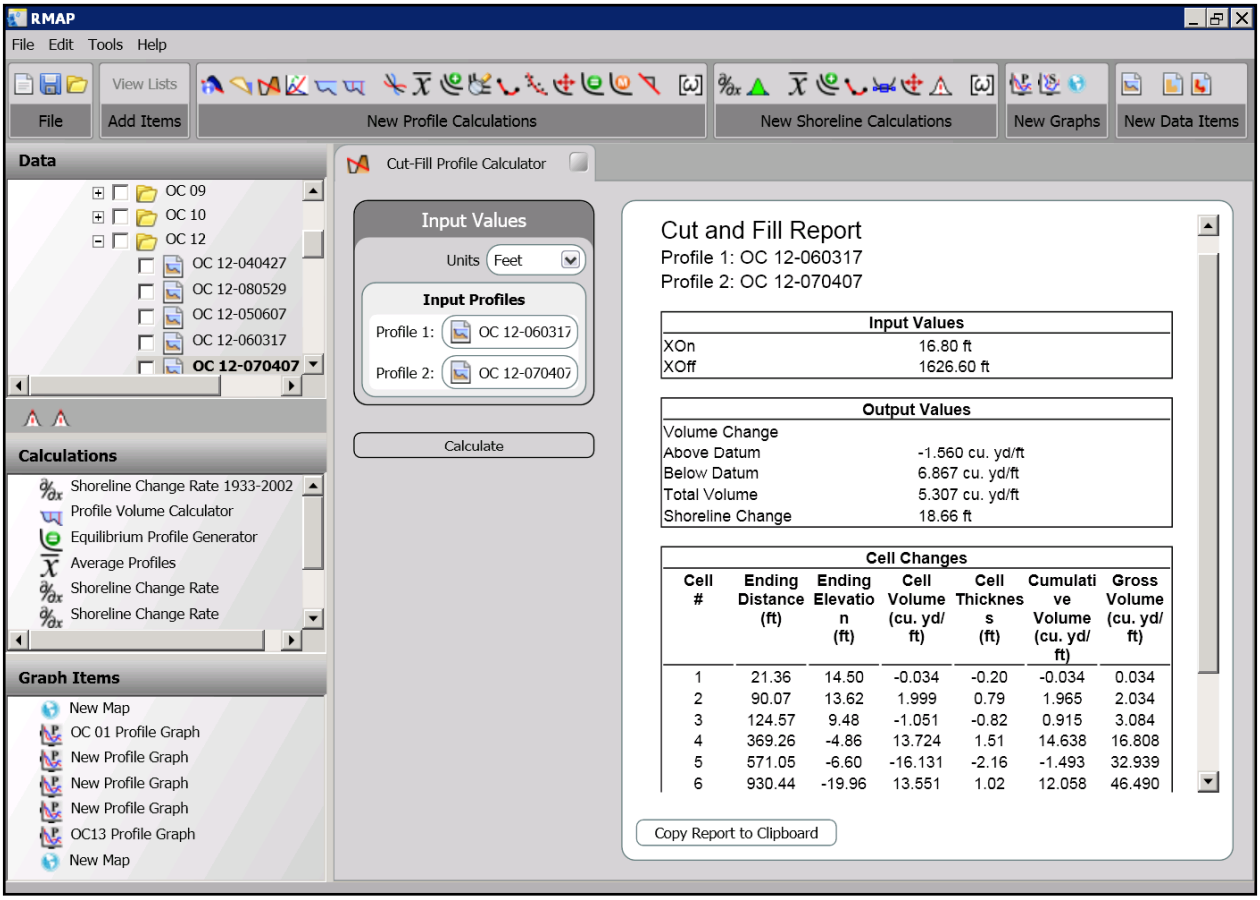

Figure 16. Cut and fill for two Ocean City profiles.

Sectional Volume. The volume function calculates the volume of the profile above a user-specified elevation for any number of profiles or cross-sections between user-specified limits (X_{on} and X_{off}). Analysis reports include volume and contour location. The algorithm will interpolate profiles or modify analysis bounds if profile extent does not meet the analysis extent. The volume of the profile is determined by extrapolating the area under the curve for one unit length of shoreline (cubic yard per linear foot or cubic meter per linear meter of shoreline).

1. Click the Profile Volume button .
2. Enter a *Zero Elevation* of -22 ft.
3. For X_{on} use 100, for X_{off} use 2800.

4. Drag seven Assateague Island AI 06 profiles into the profiles box (Figure 17).
5. Press *calculate*.
6. In the report, notice the volume is close for these profiles.

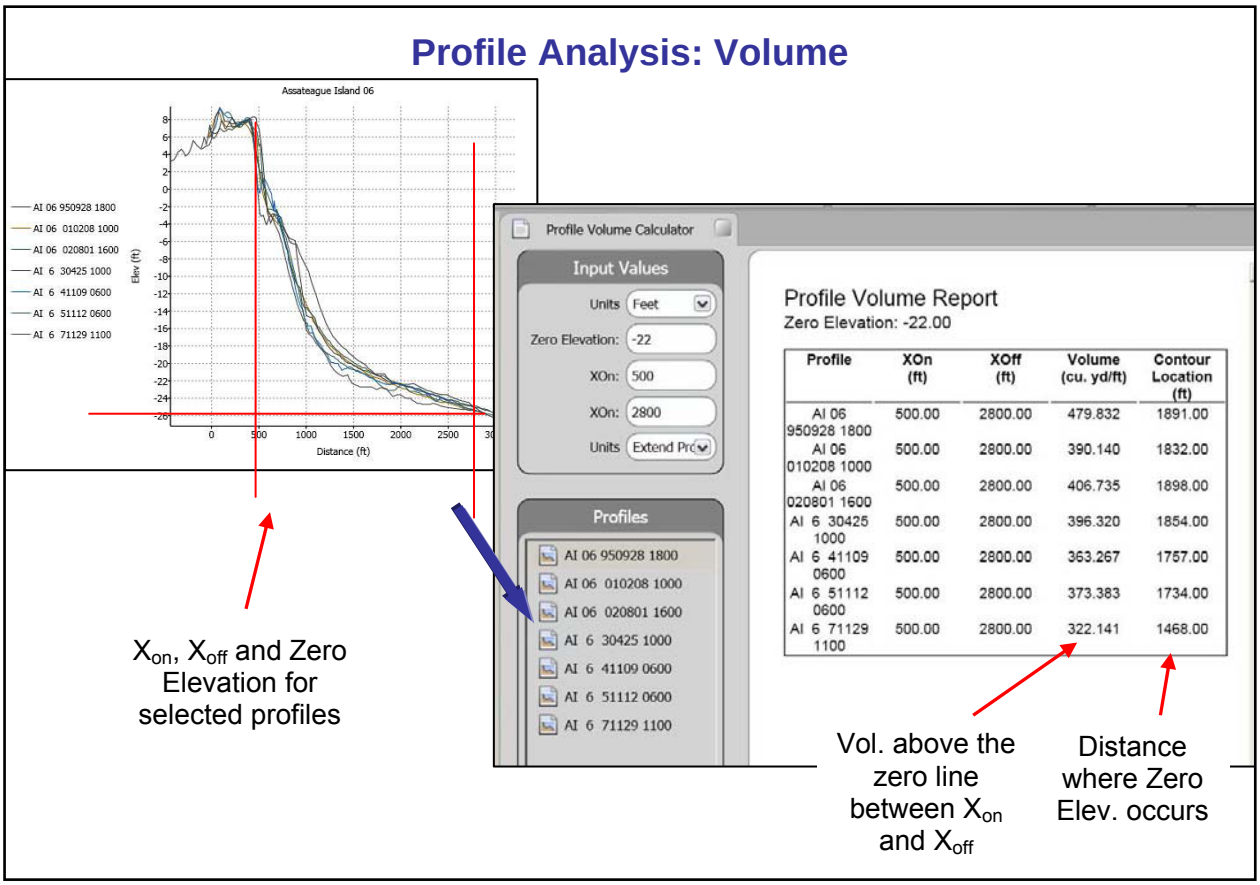

Figure 17. Profile (or channel cross-section) volume analysis. The report table can be exported.

Average. This function is commonly used to determine the depth of the shoreface active zone (depth of closure; Kraus et al. 1998) at a station. The average, maximum, and minimum profiles (profile envelope), in addition to the standard deviation, are calculated, plotted, and generated as data items.

1. Open OC 15 in the data tree.
2. Open the *Average Profile* calculation page $\overline{X}$.
3. For δX use 10, X_{Start} = 200, X_{End} = 2000.
4. Destination folder: use "OC-shoreline-calculations."
5. Drag ten OC 12 profiles into the *Profiles* box (Figure 18).
6. Press *Calculate*.
7. Find Average, Standard Deviation, Max Envelope, Min Envelope. The user can rename by adding "OC 12" before each name for record keeping.
8. Reopen the OC 15 Profile Graph and bring in the profiles to compare with the natural profiles. The Average Profile may be hard to see. The Standard Deviation minimum occurs at about 950 ft offshore, or in about 23 ft water depth (Figure 18).

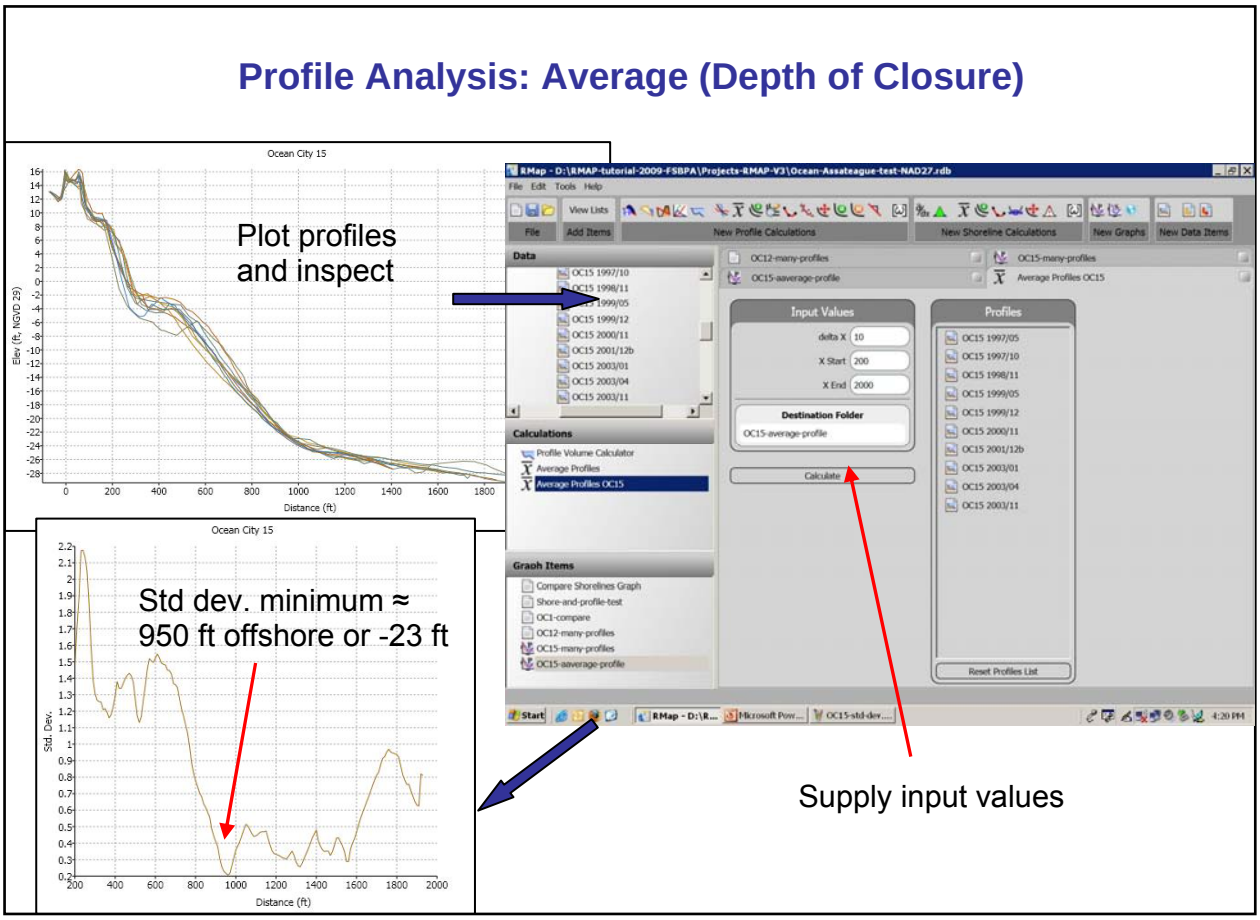

Figure 18. Depth of closure can be estimated from the location where the standard deviation drops to a minimum value.

Beach Fill Template. This option allows a user-defined beach fill template to be attached to an existing profile, or allows the addition of beach width to an existing profile for estimation of beach fill volume requirements. A new profile and volume report are generated upon completion.

To add a beach width to an existing profile for estimation of nourishment volume requirements, select the *beach fill template button* from the toolbar. The *Input Values* window allows the user to specify the fill *Width*, the *Tie In Elevation* (where the template begins, the profile seaward of this elevation will be translated by the *width*), and the *Closure Location* (where the translation of the profile ends). If fill material is incompatible, the *non-compatible* option is available to estimate the additional volume required (Figure 19).

Eigenfunction Analysis. Eigenvector or empirical orthogonal function (EOF) techniques encompass the mapping of the observed data onto a set of shape functions (the EOFs) that have been extracted from the data set itself (Connell and Larson 2007). In RMAP, the function $[\omega]$ opens a data box for the user to input profiles and calculation limits. The reader is referred to Connell and Larson (2007) for background theory and RMAP operation.

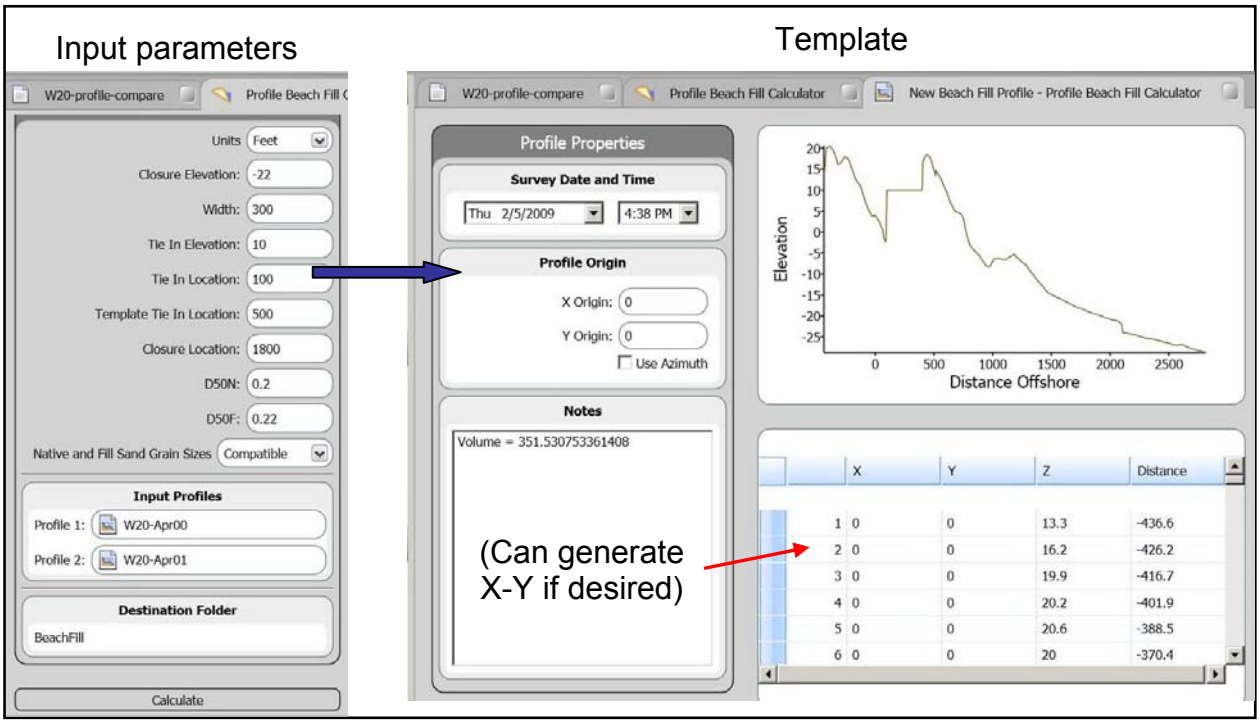

Figure 19. The beach fill calculator is used to design a template. Example based on Long Island profiles.

PRODUCT DEVELOPMENT AND AVAILABILITY: U.S. Army Corps of Engineers research and development programs develop products to support engineers in the workforce. Improvements or additions to RMAP are dependent upon user comments. Please forward comments and suggestions to the appropriate program manager or RMAP point-of-contact listed below.

ADDITIONAL INFORMATION: This Technical Note was prepared by Dr. Andrew Morang, Research Physical Scientist and Dr. Nicholas C. Kraus, Senior Scientist, Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center; Dr. Brian K. Batten and Kenneth J. Connell, formerly of CHL; Dr. Magnus Larson, of the University of Lund, Sweden; and Wayne Tanner, Applied Research Associates. The document was based on an earlier tutorial by Drs. Batten and Kraus, and additional work done by Mr. Connell and Dr. Larson. The study was conducted as an activity of the System-Wide Water Resources Program (SWWRP) and the Coastal Inlets Research Program (CIRP). For information on the SWWRP, please consult *https://swwrp.usace.army.mil/DesktopDefault.aspx* or contact the Program Manager, Dr. Steven L. Ashby, at *Steven.L.Ashby@usace.army.mil*. For questions about the CIRP, please consult *http://cirp.wes.army.mil/cirp/* or contact the Program Manager, Dr. Nicholas C. Kraus, at *Nicholas.C.Kraus@usace.army.mil*. Questions about this CHETN can be addressed to Dr. Morang (601-634-2064; *Andrew.Morang@usace.army.mil*).

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