UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Digital Shoreline Analysis System (DSAS) User's Guide
Version 1.0

by

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and

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Open-File Report

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TABLE OF CONTENTS

INTRODUCTION

As shoreline mapping has come into increased use as both a scientific and management tool, a critical need has developed among coastal researchers and policy-makers for a standardized method to obtain accurate shoreline position data, as well as a means to quantify changes in shoreline position over time. A number of methods exist to do the both of the above, and vary greatly in their application and approach (e.g., Dolan and others, 1978; McBride 1989; Leatherman, 1984; Leatherman and Clow, 1983; Stafford and Langfelder, 1971). Danforth and Thieler (1992) present a method for obtaining shoreline position data from digitized maps and aerial photographs that is compatible with the directory structure and file formats required by the Digital Shoreline Analysis System (DSAS) described here.

The most common method of obtaining shoreline rate-of-change data from a time series of shoreline positions is to employ a measurement baseline approach. In this method, a baseline is established adjacent to (and usually landward of) the historical shoreline positions (we will refer to "shorelines" or "each shoreline" from herein which indicates different historical shoreline positions). The distance from the baseline to each shoreline in the series is measured along an orthogonal (also called a transect) to the baseline at a specific alongshore interval (*e.g.*, Dolan and others, 1978; Leatherman and Clow, 1983). For the simple case of two shorelines, a rate of change for a given transect can then be computed by dividing the distance between each shoreline relative to the baseline by the elapsed time between the shoreline measurements.

Consider the following hypothetical example for two measured shoreline positions, one representing the shoreline position in 1960, the other in 1990. If the shoreline position in those 30 years has moved (retreated or eroded) landward (toward the baseline) a distance of 15 meters, then the rate of change is

$$15 \text{ meters} \div 30 \text{ years} = 0.50 \text{ m/yr}$$

Landward movement (retreat or erosion) of the shoreline is expressed as a negative number in DSAS, thus giving the rate of change as -0.50 m/yr. Dolan and others (1991) discuss four different methods (end-point rate, average of rates, linear regression, and jackknife) that can be used to calculate rates of shoreline change, each of which is calculated in DSAS v1.0.

This report summarizes the capabilities of the DSAS and explains the procedures for generating shoreline rate-of-change data from digital shoreline change maps.

DESCRIPTION

The DSAS employs a measurement baseline approach (*e.g.*, Leatherman and Clow, 1983) to calculate shoreline rates-of-change at a user-specified interval along the shoreline. DSAS v1.0 performs the four rate-of-change calculations reviewed by Dolan and others (1991) (end-point rate, average of rates, linear regression and jackknifing). The programs run on UNIX-based systems, and utilize standard ASCII files for input and output. DSAS v1.0 requires ASCII files in a format generated by MapGrafix™, an Apple Macintosh®–based GIS, and that all data are in meters (*e.g.*, UTM coordinates). Future releases will support output from a variety of GIS software (*e.g.*, Arc/Info, Atlas Pro, etc.). It is important to note that any shoreline position data that is input to DSAS must be spacially correct with respect to each shoreline, otherwise erroneous rates will be calculated. The shoreline data used as examples here has been digitized from aerial photographs and subsequently rectified using a three dimensional space resection technique described by Danforth and Thieler (1992).

Two separate programs are used to generate rate-of-change data. The first, called *transect*, is used to specify the longshore spacing of transects along the measurement baseline (described later), determine the X-Y coordinates of each shoreline that lies along each transect, and input the dates associated with each shoreline position. An additional option allows the specification of a "tolerance distance" to be used to exclude data that lie more than the tolerance distance away from the baseline. The algorithm also includes a solution whereby transects are measured where there is a change in angle of the baseline, as occurs around tidal inlets, headlands, etc. where data are desired.

The second program, *rates*, computes the rate-of-change for each transect using the shoreline points and dates output from *transect.* The output from *rates* consists of tab-delimited ASCII files that can be used in spreadsheet and statistical software (*e.g.*, Excel, Lotus 1-2-3, MATLAB, SAS, Wingz) for presentation and further data analysis.

An example data set from the north coast of Puerto Rico is used periodically throughout this paper to illustrate the various stages in the mapping and rate calculation process, and the graphical appearance of map elements. Input and output files used with this data set are given in Appendixes A-G.

PROCEDURE FOR THE PRODUCTION OF RATE-OF-CHANGE DATA

The steps required for producing shoreline rate-of-change data from a digital shoreline change map are shown in Figure 1. For purposes of this discussion, we assume that MapGrafix™ (MapGrafix™ v2.2.1 was used in this application) is the GIS being used for compiling, editing, establishing the measurement baseline, and exporting and importing the various files required in DSAS execution. Technical terms (*e.g.*, "overlay") are used as they apply to MapGrafix™. It is important to note, however, that most GIS software is similar in structure and use.

Compile and edit shoreline data

The first step in using the DSAS is making sure that the shoreline data have been properly compiled and edited. Essentially, this means that all of the shoreline data for a given date should be in the same overlay (Figure 2), and that extraneous points, gaps, etc., have been edited using a text editor of your choice. Shoreline data overlays in MapGrafix™ can have any valid number assigned to them. A shoreline change map depicting part of the north coast of Puerto Rico is shown in Figure 3.

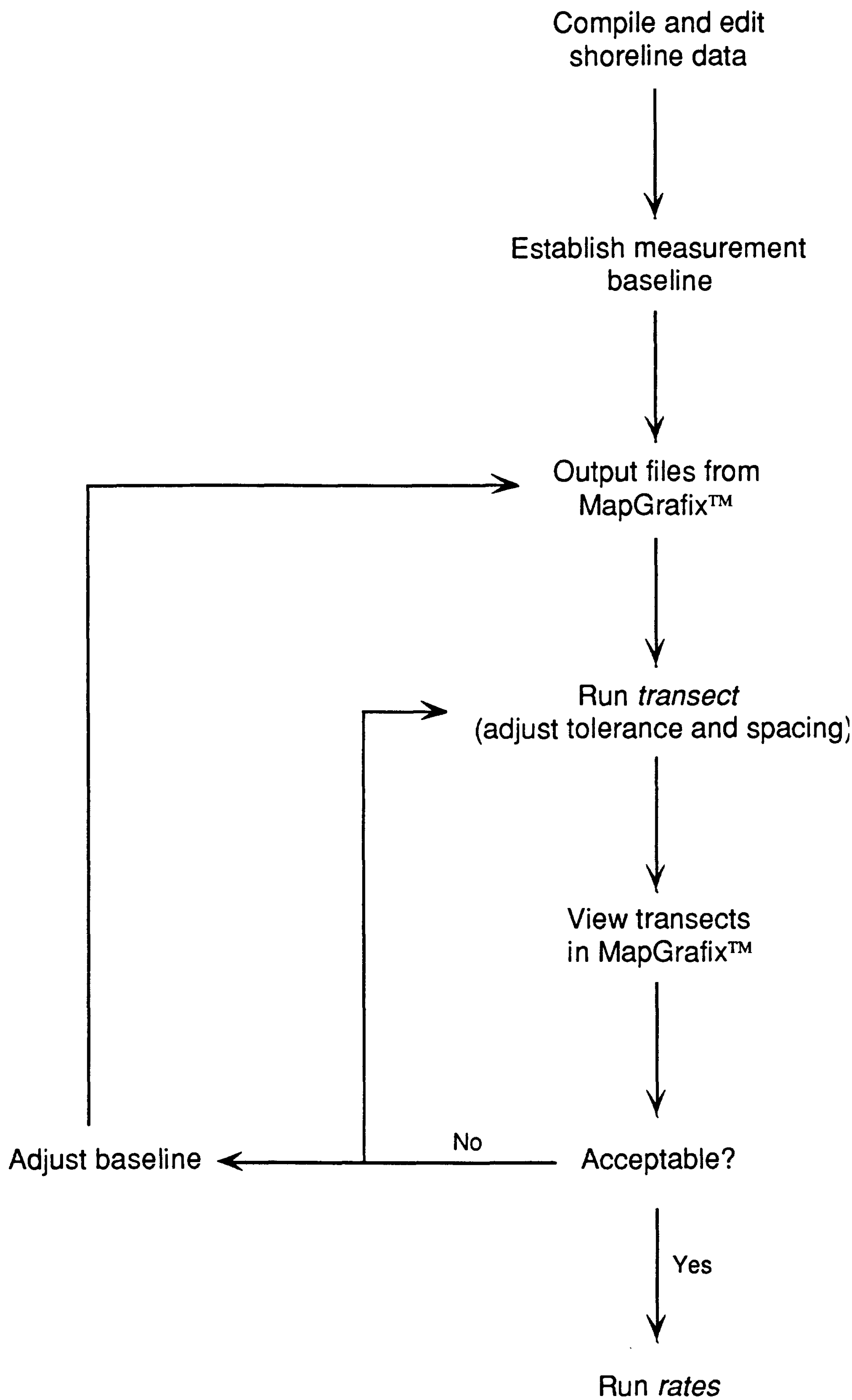


Figure 1. Flow chart of steps in data preparation and DSAS execution.

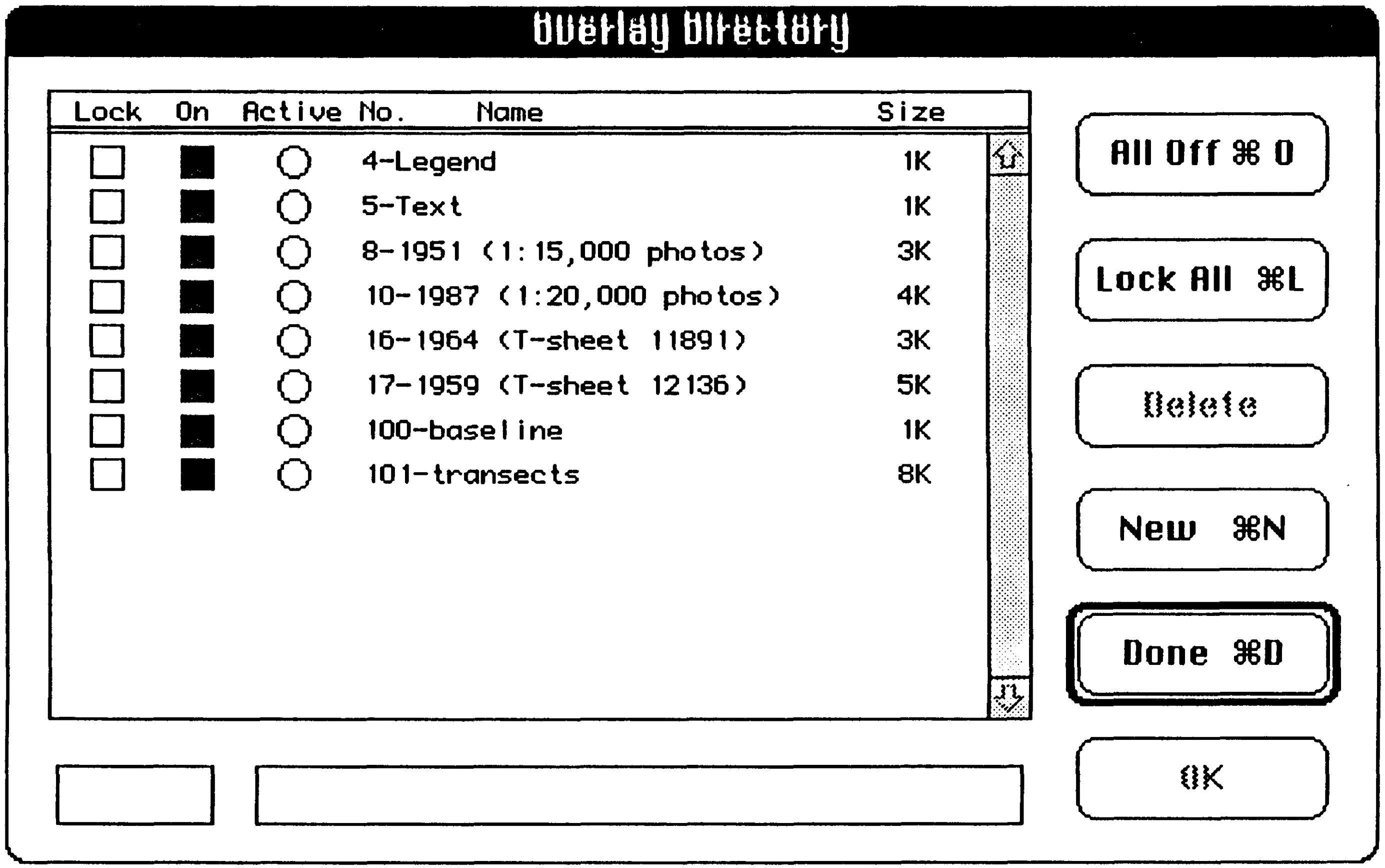


Figure 2. Overlay directory dialog for the MapGrafix file *uvero.demo* used in this paper. Each overlay contains the data for one date or shoreline position (in this example, each date corresponds to a year). The overlays containing shoreline position data can have any number, but the baseline MUST be in overlay number 100.

Figure 3. Compiled and edited shoreline change map for part of the north coast of Puerto Rico near Punta Uvero.

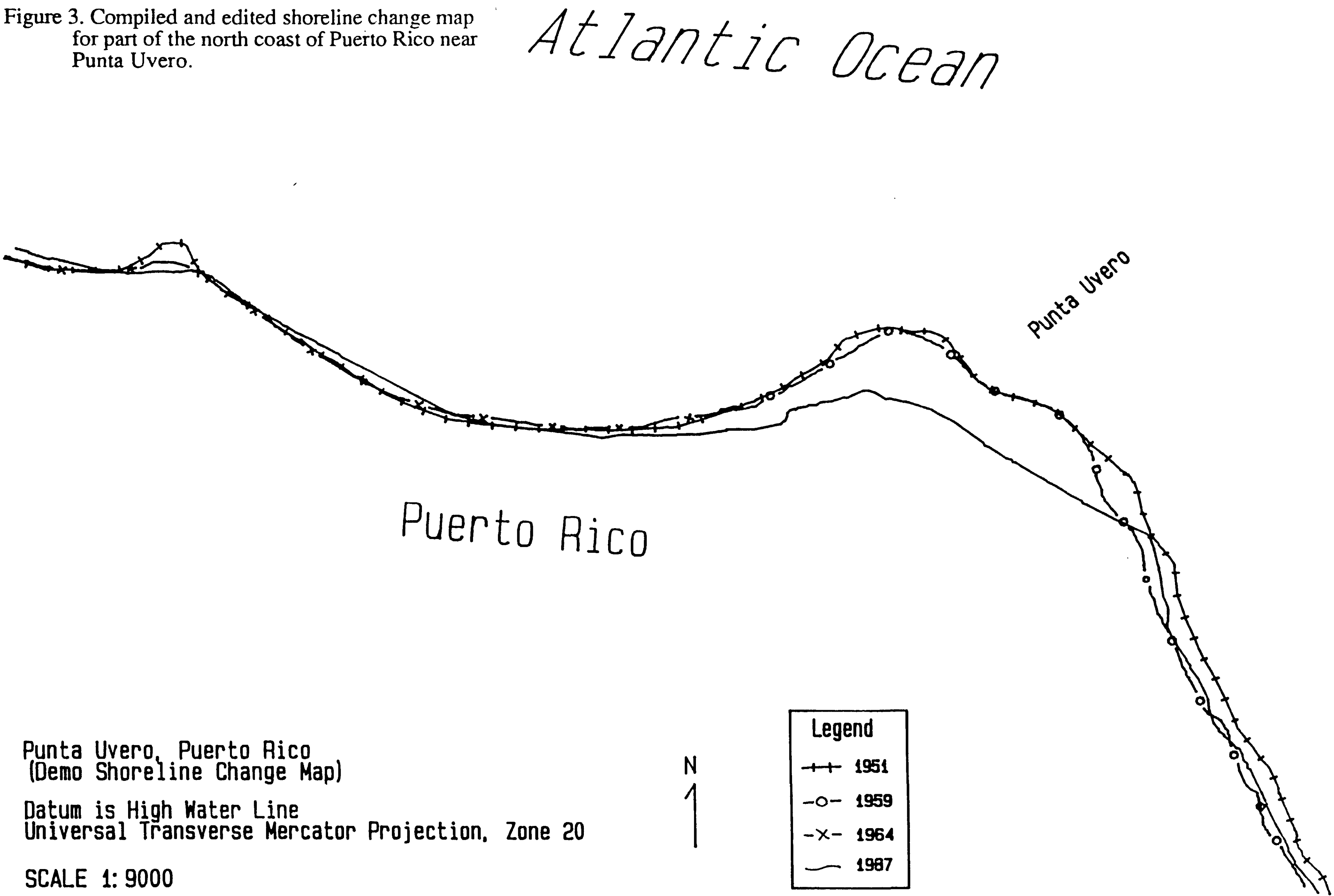


Figure 4. The baseline has been drawn in the "baseline" overlay in MapGrafix™ as an open polygon. The baseline approximates the mean shoreline position, and is placed landward of the shorelines.

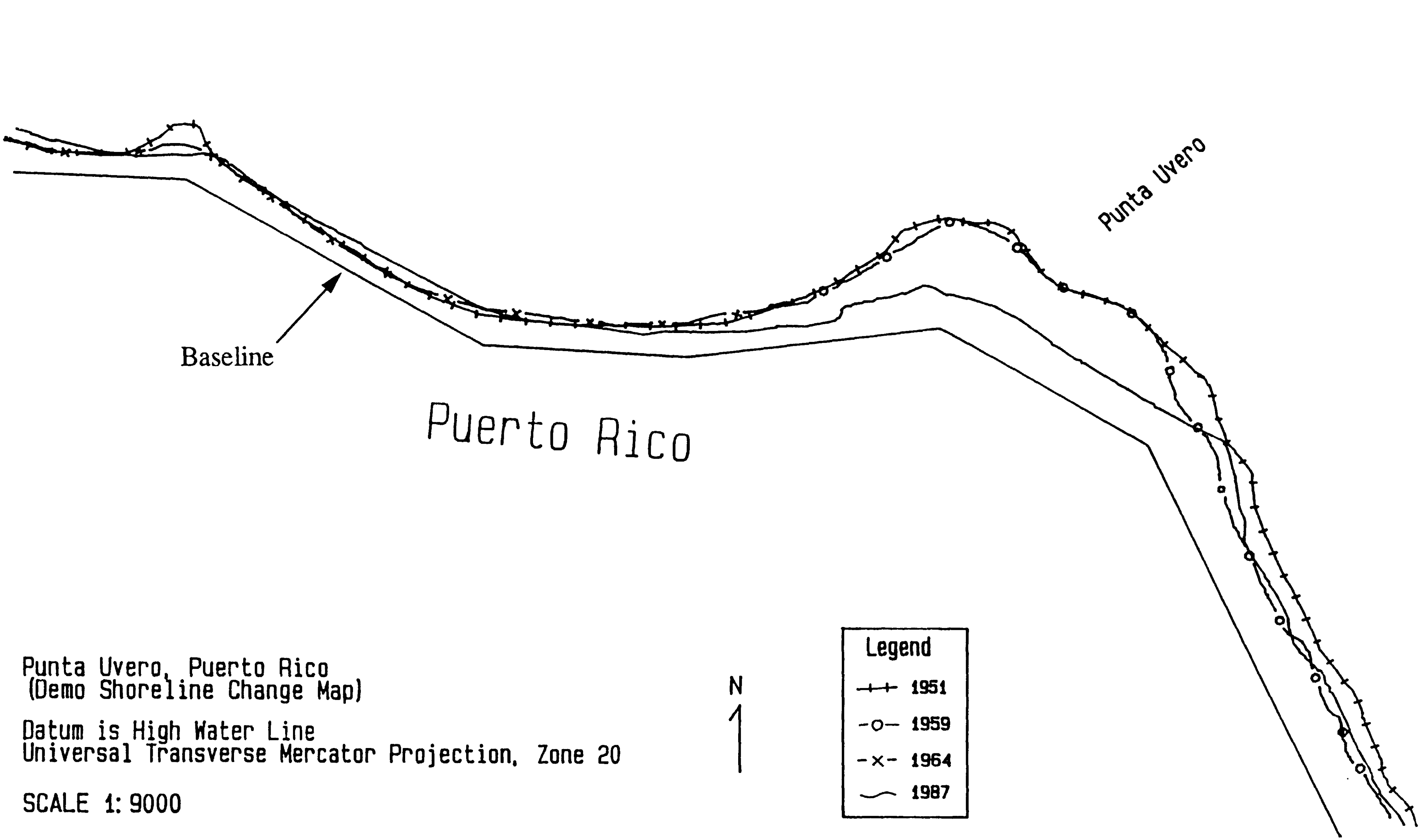
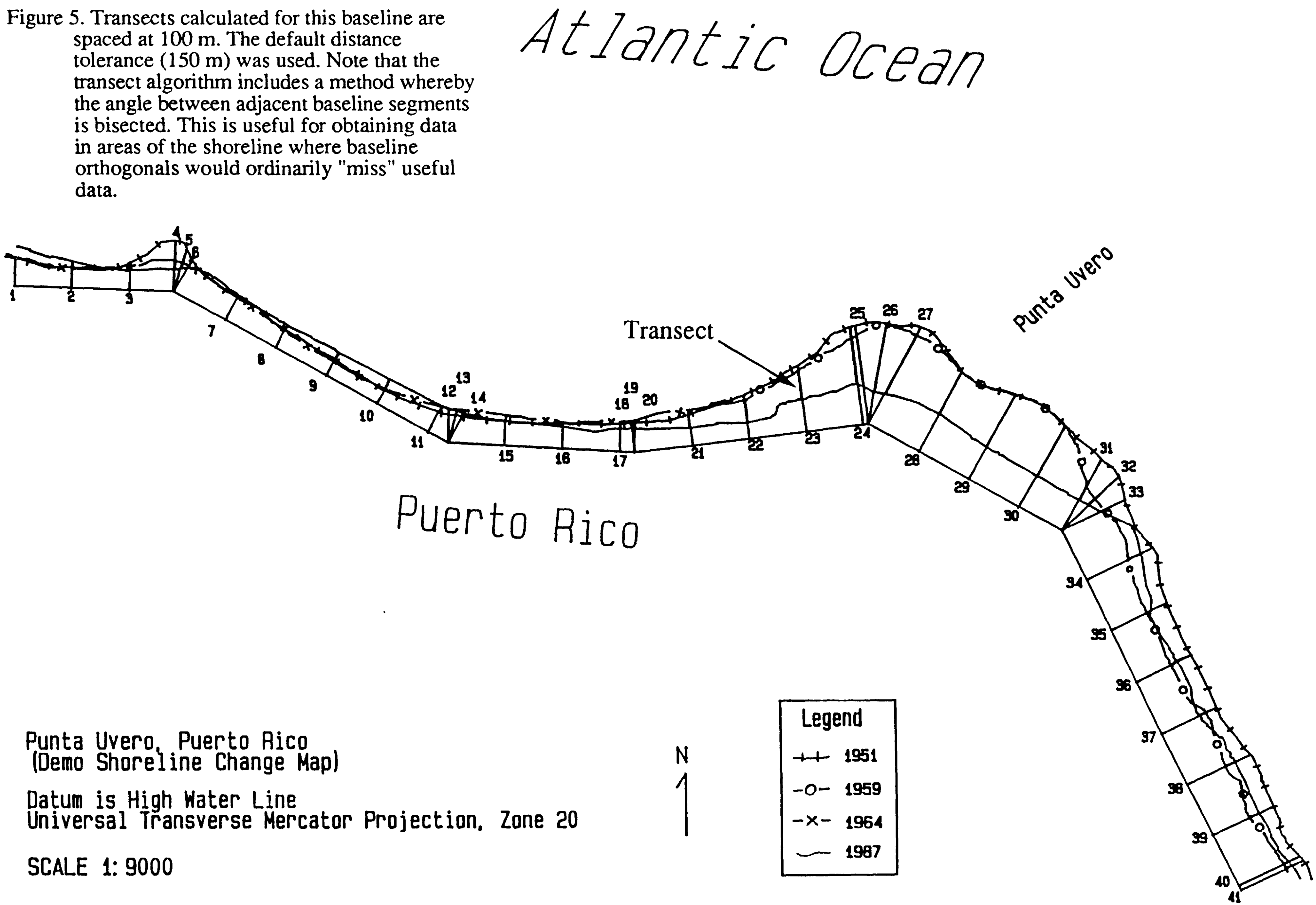


Figure 5. Transects calculated for this baseline are spaced at 100 m. The default distance tolerance (150 m) was used. Note that the transect algorithm includes a method whereby the angle between adjacent baseline segments is bisected. This is useful for obtaining data in areas of the shoreline where baseline orthogonals would ordinarily "miss" useful data.



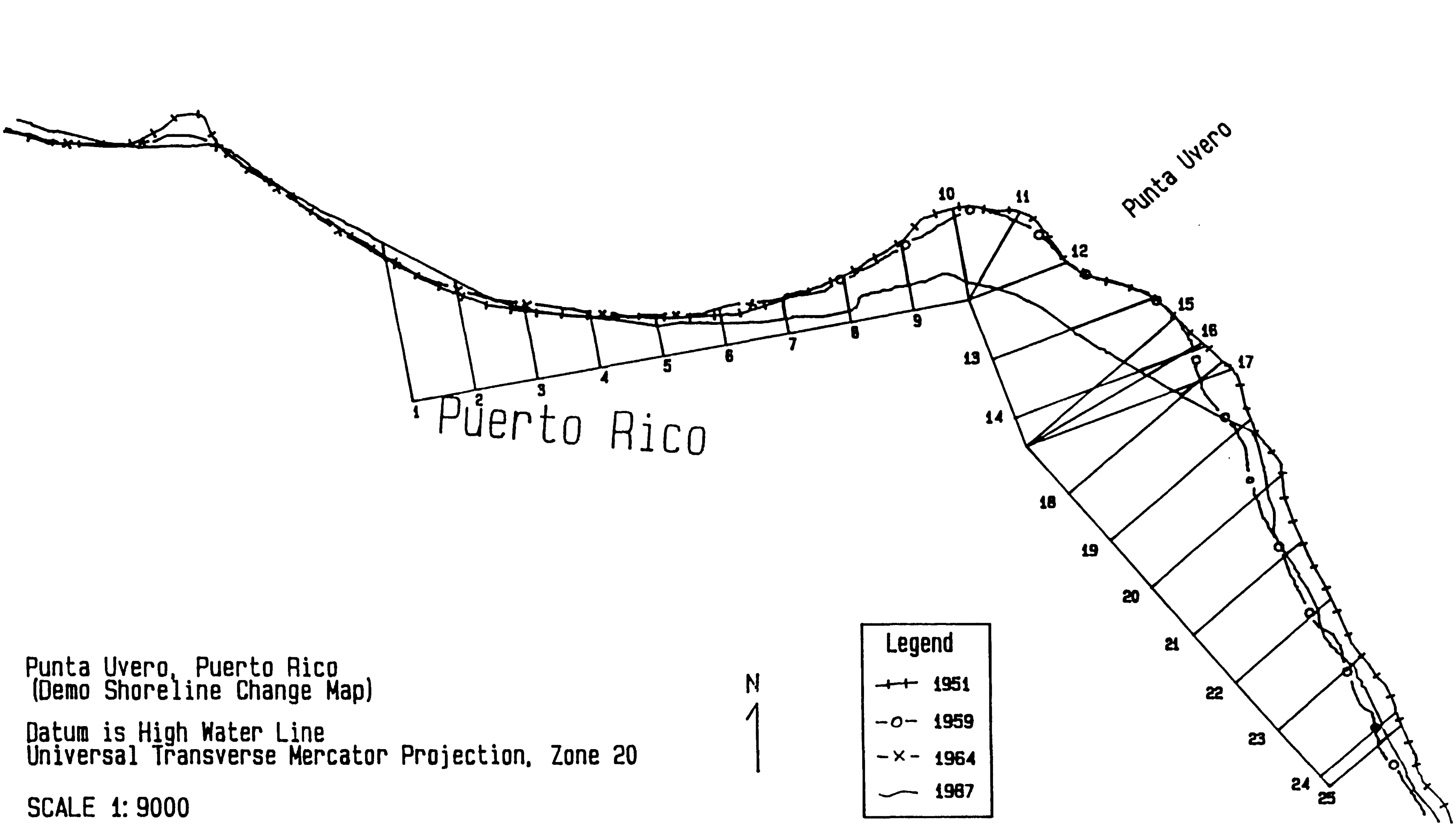
Establish measurement baseline

The most important step in the mapping process is choosing an appropriate baseline from which to make the shoreline change measurements, placing it on the appropriate "side" of the shoreline data, and ensuring that it represents the desired level of detail in terms of conforming to changes in shoreline orientation. Typically, a drawing tool from the GIS is used to draw the baseline as an open polygon (in this case the "Polygon" tool in MapGraphix™, see Figure 4). The baseline often consists of several segments of differing orientation. The number, orientation, and distance from the shorelines of individual segments depends on the nature of the shoreline and the interpreter's judgement as to what combination best meets the requirements of the particular study.

The algorithm used by the measurement program *transect* expects the baseline to be landward of the shoreline data (Figure 4). To calculate the location of the transects, which are perpendicular to the baseline, the *transect* algorithm moves along the baseline (by either default or user specified increments) in the order in which the baseline coordinates are output from MapGrafix™ correpsonding to the direction in which it is drawn (*e.g.*, North to South; East to West). This convention ensures that the measured transects proceed in an orderly fashion that is easily read and interpreted on the map. Figure 5 shows the transects used in the Punta Uvero case study. Note that the transect algorithm includes a method whereby the angle between adjacent baseline segments is bisected. This is useful for obtaining data in areas of the shoreline where baseline orthogonals would ordinarily "miss" useful data.

Considerable attention should be devoted to ensuring that the baseline is as near to and parallels the general shoreline trend as closely as possible. The transect program determines the shoreline coordinates that lie along an orthogonal (the transect) to the baseline. Thus, if the baseline is at a considerable angle to the general shoreline trend, the shoreline coordinates selected by the transect program will not be located immediately seaward of the baseline. Rather, they will be offset some distance alongshore. This effect also increases as the baseline

Figure 6. Because the baseline used in this example does not closely parallel the mean shoreline trend, the erosion rates determined for each transect may not reflect the desired erosion rate trend for a given point along the shoreline.



is moved further back from the shoreline and as the sense of shoreline trend (*e.g.*, curvature) changes. A graphical example of this problem is shown in Figure 6. Clearly, the rate-of-change data generated by this set of transects will not accurately reflect the desired information. In other words, the rate of shoreline change determined for these transects does not reflect what is most often desired: a rate of change immediately seaward of potentially threatened buildings. Varying the baseline position and orientation, however, can also be used to experiment with the data if proper techniques are employed.

Output files from MapGrafix™

Once an acceptable baseline has been established, the overlays containing shoreline data and the baseline are ready for export. Exporting files from MapGrafix™ for use in DSAS requires selecting the overlays to be used and exporting according to the conventions outlined below.

1) The overlays must be properly numbered in MapGrafix™. Overlays containing shoreline data can have any valid number. The DSAS v1.0, however, requires that the baseline be number 100 (see Figure 2).

2) All the overlays that are NOT to be used for analysis using the DSAS must be turned off in the MapGrafix™ "Overlay Directory" dialog. This permits overlays with text or other data to exist in the same file as the shoreline data, and more importantly, permits the user to export various combinations of shorelines for analysis.

3) The file is exported using the "Output Map File" feature (Figure 7), with ONLY the "On Overlays," "Overlay Number," and "Coordinates" options selected.

4) Output file names should follow the format *file.pts*, where *.pts* is an extension used in the DSAS to designate a file containing shoreline coordinate and baseline data. A complete list of filenames used in the DSAS is shown in Table 1. Appendix F shows the contents of the *uvero.pts* file used in the figures and examples in this paper.5) The *file.pts* file is

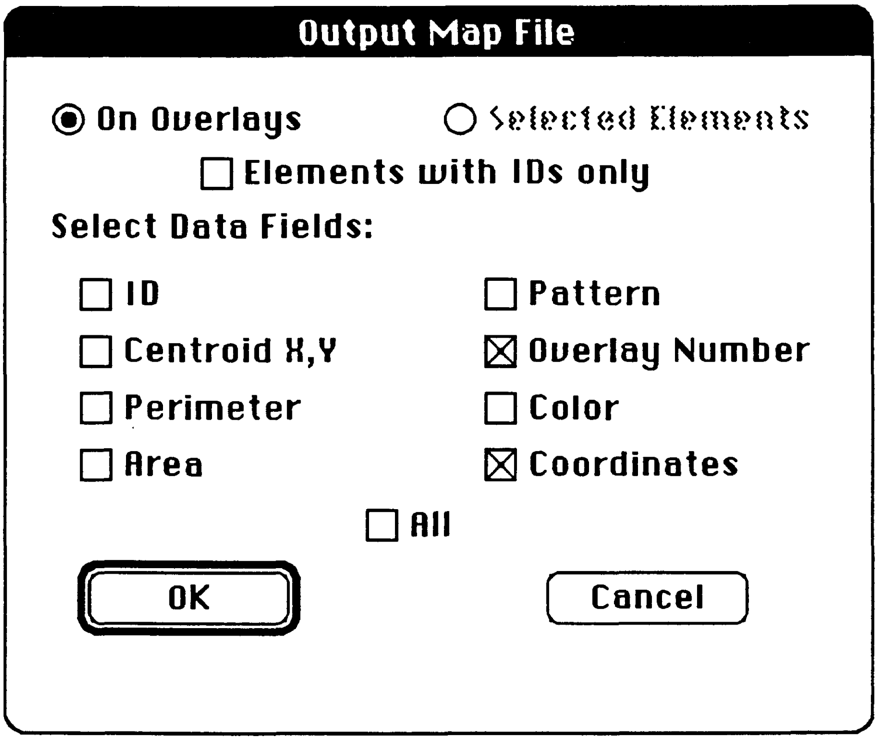


Figure 7. The "Output Map File" dialog from MapGrafix™, showing the options that should be selected for file export to DSAS.

Table 1. Extension names and contents of files used in the DSAS. All files should reside in the **points** subdirectory of the basemap-level directory (Figure 8).

File extension	Created by Program	File Contents
.dates	(text editor)	Calendar date (mm/dd/yyyy) for each shoreline, in order of ascending overlay number.
.dist	*rates*	Transect numbers and distances between shorelines by calendar date. (Appendix A)
.jul	*transect*	UTM coordinates for transect origins, shoreline coordinates and julian date for each coordinate pair. (Appendix B)
.loc	*transect*	UTM location and number of each transect along the baseline. (Appendix C)
.log	*runtransect*	Logged output of *rates*. Includes shoreline and baseline coordinates used to calculate rates along each transect; and points used in calculating each of the different rates-of-change. (Appendix D)
.mapg	*transect*	CGDEF file for display in MapGrafix™. (Appendix E)
.pts	MapGrafix™	UTM coordinates and overlay numbers for shorelines and baseline. (Appendix F)
.rates	*rates*	Transect numbers and rates-of-change as determined by each of the four calculations performed. (Appendix G)

transferred (*e.g.*, using the UNIX file transfer protocol *ftp* or some similiar network file transfer tool) to the computer on which the DSAS programs reside, and placed in the appropriate directory. The recommended directory structure is one that conforms to the conventions set out in Danforth and Thieler (1992). These conventions are based on the "basemap" concept, where all data (*e.g.*, aerial photograph data, ground control data, etc.) are referenced to each basemap used in the mapping project, such as a 7.5' U.S. Geological Survey topographic quadrangle. The DSAS expects the *file.pts* file and other needed files to reside in a subdirectory of the basemap directory called **points** (Figure 8).

```
% ls
clon.ref          14-262/           points/
for002.dat        14-263/           riogrande.gcp
for003.dat        15-367/           riogrande.latlon
for004.dat        15-368/           riogrande.proj
for008.dat        lr12-80/          riogrande.utm
k12-1300/         lr12-86/
k14-1364/         lr12-88/
k15-1425/         lr12-90/
14-258/           lr12-92/
14-260/
```

Figure 8. Example directory structure for a basemap directory named **riogrande**. The files needed for DSAS execution should all reside in the **points** subdirectory.

Run *transect*

The program *transect* can be run from any directory. For most purposes, it is convenient to keep all necessary files in the **points** subdirectory of the basemap-level directory.

Two important *transect* options are the tolerance and transect spacing. "Tolerance" refers to a distance (in meters) from the transect origin beyond which shoreline coordinates are not determined for a given transect. The default tolerance is 150 meters. The alongshore spacing of transects (in meters) can also be specified. The default distance is 100 meters.

A file containing the calendar dates associated with each shoreline in the *file.pts* file can also be used to provide date input to *transect*, and should reside in the **points** directory. The dates should be of the form mm/dd/yyyy, with one entry per line, and the entries in the order of increasing MapGrafix™ overlay number. The file should be named *file.dates*, where *file* is the same name given to the *file.pts* file. A typical *file.dates* file is shown in Figure 9. These dates can also be input by the user on screen, if desired.

```
% more uvero.dates
02/01/1951
02/01/1987
02/01/1964
04/01/1959
```

Figure 9. The contents of the file *uvero.dates*. Each line contains the date associated with each shoreline in the *file.pts* file generated by MapGrafix™. The date format is mm/dd/yyyy. The dates are arranged in order of increasing overlay number (see Figure 2).

The algorithm used in *transect* executes in the following manner:

1) the first transect is measured at the origin of the first baseline segment;
2) the following transects are measured at the specified increment (*e.g.*, 100 m) along the baseline segment until the end of the segment is reached;
3) a transect is measured at the end of a baseline segment;
4) a transect is measured between consecutive baseline segments such that the transect bisects the angle made by the segments;
5) a transect is measured at the origin of the next baseline segment; and
6) steps 2-5 are repeated until the end of the baseline data is reached.

View transects in MapGrafix™

Transect produces three files as output, including a file called *file.mapg* (Appendix E). This file contains data that can be used to graphically display each transect in MapGrafix™. The file is in the MapGrafix™ "ComGrafix Data Exchange Format" (CGDEF) and can be imported directly into MapGrafix™ using the "Import File" command.

Typically, an overlay called "transects" is created in MapGrafix™ to hold the transect data. Be sure that the "transects" overlay is active (the overlay into which the *file.mapg* file will be imported) before importing the transects. Otherwise, the transects may be imported into an undesired overlay where they may be difficult to remove. It is also possible to have multiple transect overlays. These can be used to view different solutions of the transect program if tolerances and transect spacings are varied in different runs.

Two other files are produced by *transect*. *File.jul* (Appendix B) contains the X-Y coordinates and julian date for each shoreline coordinate on a given transect. Although it is an ASCII file, it is largely unreadable in form. It is used by *rates* to generate shoreline rate-of-change data. *File.loc* (Appendix C) contains the X-Y coordinates of each transect origin, and the transect number. This ASCII file can be used to post transect labels in the *Mapgen* program (Evenden and Botbol, 1985).

If the transects as viewed in MapGrafix™ are acceptable (see Figure 5), then the program *rates* can be run to calculate the various rate-of-change measurements. If the transects are not acceptable, however, (*e.g.*, longshore spacing too sparse/dense, tolerance value too high/low, or the baseline is unacceptable), then two options exist:

1) run *transect* again, adjusting the tolerance and/or transect spacing; and/or
2) adjust the baseline, and/or tolerance and/or transect spacing.

It is important to note that the first option DOES NOT require that a new *file.pts* file be exported. The second option, however, DOES require that a new *file.pts* file be generated, and transferred to the computer on which the DSAS resides.

Run *rates*

When an acceptable set of transects has been achieved, the program *rates* can be run to calculate the rates-of-change for each transect. *Rates* calculates four measures of shoreline change simultaneously: 1) end-point rate; 2) average of rates (including the standard deviation and variance for each transect); 3) linear regression; and 4) jackknife. Dolan and others (1991) provide an extensive discussion of the applications and implications of these measures of shoreline change. *Rates* generates two files: *file.rates* (Appendix G) and *file.dist* (Appendix A). A log of the shoreline coordinates and dates used, as well as the calculations made for each transect, is provided as *stdout*, and can be piped to a file (see Appendix D).

The file *file.rates* can be exported to any spreadsheet, presentation graphics, statistical analysis or other software (*e.g.*, Excel, Lotus 1-2-3, MATLAB, SAS, Wingz) capable of reading tab-delimited ASCII files. Two examples of graphs produced from the data in file *uvero.rates* are shown in Figures 10 and 11.

ENVIRONMENT AND AVAILABILITY

The Digital Shoreline Analysis System (DSAS) was developed on a Digital Equipment Corporation DECStation 5000 running version 4.1 of the Ultrix operating system. Source code for the programs is available (as a UNIX *tar* file) from the authors. The authors will also provide periodic upgrades as new features become available.

MapGrafix™ v2.2.1, running on an Apple Mac IIci under versions 6.0.7 and 7.0.1 of the Macintosh operating system, was used in DSAS development. Further information about MapGrafix™ can be obtained from:

ComGrafix, Inc.
620 E Street
Clearwater, FL 34616
Tel: (813) 443-6807

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APPENDIX A
Contents of file *uvero.dist*
(Notes in **bold**)

tr #	date-date	distance	date-date	distance
1	02/1951-02/1964	2.37		
2	02/1951-02/1964	-1.42	02/1964-02/1987	13.35
3	02/1951-02/1964	-7.11	02/1964-02/1987	-7.41
4	02/1951-02/1964	-36.76	02/1964-02/1987	-14.54
5	02/1951-02/1964	-26.55	02/1964-02/1987	-9.61
6	02/1951-02/1964	-11.70	02/1964-02/1987	-2.65
7	02/1951-02/1964	-0.49	02/1964-02/1987	3.96
8	02/1951-02/1964	-1.68	02/1964-02/1987	10.08
9	02/1951-02/1964	-3.74	02/1964-02/1987	19.13
10	02/1951-02/1964	2.40	02/1964-02/1987	18.37
11	02/1951-02/1964	10.70	02/1964-02/1987	1.74
12	02/1951-02/1964	13.09	02/1964-02/1987	-5.44
13	02/1951-02/1964	11.71	02/1964-02/1987	-2.35
14	02/1951-02/1964	10.26	02/1964-02/1987	1.24
15	02/1951-02/1964	9.79	02/1964-02/1987	-10.70
16	02/1951-02/1964	0.68	02/1964-02/1987	-8.01
17	02/1951-02/1964	2.37	02/1964-02/1987	-12.98
18	02/1951-02/1964	3.97	02/1964-02/1987	-14.86
19	02/1951-02/1964	2.96	02/1964-02/1987	-13.09
20	02/1951-02/1964	2.01	02/1964-02/1987	-12.56
21	02/1951-02/1964	8.10	02/1964-02/1987	-31.27
22	02/1951-04/1959	-8.27	04/1959-02/1987	-38.39
23	02/1951-04/1959	-9.74	04/1959-02/1987	-49.24
24	02/1951-04/1959	-21.40	04/1959-02/1987	-80.49
25	02/1951-04/1959	-17.58	04/1959-02/1987	-89.90
26	02/1951-04/1959	-1.26	04/1959-02/1987	-123.02
27	02/1951-04/1959	-16.39	04/1959-02/1987	-117.79
28	02/1951-04/1959	-0.15	04/1959-02/1987	-84.59
29	02/1951-04/1959	-0.29	04/1959-02/1987	-104.92
30	02/1951-04/1959	-1.76	04/1959-02/1987	-99.71
31	02/1951-04/1959	-52.74	04/1959-02/1987	-29.42
32	02/1951-04/1959	-58.94	04/1959-02/1987	-15.02
33	02/1951-04/1959	-41.66	04/1959-02/1987	-8.80
34	02/1951-04/1959	-49.75	04/1959-02/1987	25.54
35	02/1951-04/1959	-39.63	04/1959-02/1987	10.19
36	02/1951-04/1959	-40.46	04/1959-02/1987	11.97
37	02/1951-04/1959	-21.40	04/1959-02/1987	-12.42
38	02/1951-04/1959	-47.38	04/1959-02/1987	18.32
39	02/1951-04/1959	-43.67	04/1959-02/1987	17.92
40	02/1951-04/1959	-31.40	04/1959-02/1987	9.86
41	02/1951-04/1959	-32.87	04/1959-02/1987	11.52

APPENDIX B

Contents of file *uvero.jul*

(Notes in **bold**)

tr	base x	base y	shore x	shore y	jul date	shore x	shore y	jul date	shore x	shore y	jul date
1	198803.82	2040602.86	198805.93	2040650.63	2433680	198806.03	2040653.00	2438428			
2	198903.72	2040598.45	198905.30	2040634.26	2433680	198905.83	2040646.19	2446829	198905.24	2040632.85	2438428
3	199003.62	2040594.03	199005.81	2040643.52	2433680	199005.17	2040629.01	2446829	199005.49	2040636.41	2438428
4	199079.77	2040590.66	199083.83	2040682.43	2433680	199081.57	2040631.18	2446829	199082.21	2040645.71	2438428
5	199079.77	2040590.66	199101.77	2040667.47	2433680	199091.82	2040632.71	2446829	199094.46	2040641.95	2438428
6	199079.77	2040590.66	199111.60	2040647.06	2433680	199104.54	2040634.55	2446829	199105.85	2040636.87	2438428
7	199166.87	2040541.52	199189.18	2040581.07	2433680	199190.89	2040584.09	2446829	199188.94	2040580.64	2438428
8	199253.96	2040492.38	199271.76	2040523.92	2433680	199275.89	2040531.24	2446829	199270.93	2040522.46	2438428
9	199341.06	2040443.24	199356.23	2040470.14	2433680	199363.80	2040483.54	2446829	199354.39	2040466.88	2438428
10	199428.15	2040394.10	199441.66	2040418.04	2433680	199451.86	2040436.13	2446829	199442.84	2040420.14	2438428
11	199515.24	2040344.96	199534.36	2040378.84	2433680	199540.47	2040389.67	2446829	199539.62	2040388.16	2438428
12	199548.81	2040326.02	199574.15	2040370.94	2433680	199577.91	2040377.59	2446829	199580.58	2040382.34	2438428
13	199548.81	2040326.02	199562.45	2040372.75	2433680	199565.07	2040381.74	2446829	199565.73	2040383.99	2438428
14	199548.81	2040326.02	199551.44	2040374.45	2433680	199552.06	2040385.93	2446829	199551.99	2040384.69	2438428
15	199648.66	2040320.61	199650.99	2040363.47	2433680	199650.94	2040362.56	2446829	199651.52	2040373.25	2438428
16	199748.52	2040315.20	199750.96	2040360.35	2433680	199750.57	2040353.03	2446829	199751.00	2040361.03	2438428
17	199848.37	2040309.79	199851.13	2040360.72	2433680	199850.56	2040350.13	2446829	199851.26	2040363.09	2438428
18	199875.05	2040308.34	199877.93	2040361.51	2433680	199877.34	2040350.63	2446829	199878.14	2040365.47	2438428
19	199875.05	2040308.34	199873.29	2040361.47	2433680	199873.62	2040351.34	2446829	199873.19	2040364.43	2438428
20	199875.05	2040308.34	199868.63	2040361.43	2433680	199869.90	2040350.96	2446829	199868.39	2040363.43	2438428
21	199974.32	2040320.33	199967.85	2040373.95	2433680	199970.63	2040350.95	2446829	199966.88	2040382.00	2438428
22	200073.60	2040332.32	200064.44	2040408.17	2433680	200070.04	2040361.85	2446829	200065.43	2040399.96	2436661
23	200172.88	2040344.31	200158.95	2040459.70	2433680	200166.02	2040401.14	2446829	200160.11	2040450.03	2436661
24	200272.16	2040356.30	200251.45	2040527.80	2433680	200263.67	2040426.64	2446829	200254.01	2040506.55	2436661
25	200281.40	2040357.42	200260.56	2040530.00	2433680	200273.44	2040423.30	2446829	200262.67	2040512.55	2436661
26	200281.40	2040357.42	200316.07	2040532.02	2433680	200291.87	2040410.13	2446829	200315.83	2040530.79	2436661
27	200281.40	2040357.42	200375.92	2040525.52	2433680	200310.16	2040408.56	2446829	200367.89	2040511.23	2436661
28	200368.57	2040308.41	200446.69	2040447.33	2433680	200405.15	2040373.47	2446829	200446.61	2040447.20	2436661
29	200455.73	2040259.39	200538.98	2040407.45	2433680	200487.42	2040315.74	2446829	200538.84	2040407.19	2436661
30	200542.90	2040210.38	200623.13	2040353.07	2433680	200573.40	2040264.63	2446829	200622.27	2040351.54	2436661

31	200616.43	2040169.03	200686.44	2040293.54	2433680	200646.17	2040221.93	2446829	200660.59	2040247.57	2436661
32	200616.43	2040169.03	200716.95	2040263.74	2433680	200663.11	2040213.02	2446829	200674.05	2040223.32	2436661
33	200616.43	2040169.03	200728.38	2040223.48	2433680	200683.00	2040201.41	2446829	200690.92	2040205.26	2436661
34	200660.16	2040079.10	200778.17	2040136.49	2433680	200756.40	2040125.91	2446829	200733.43	2040114.74	2436661
35	200703.90	2039989.18	200802.08	2040036.93	2433680	200775.62	2040024.05	2446829	200766.45	2040019.60	2436661
36	200747.63	2039899.25	200844.73	2039946.47	2433680	200819.10	2039934.00	2446829	200808.34	2039928.77	2436661
37	200791.37	2039809.32	200887.08	2039855.86	2433680	200856.67	2039841.08	2446829	200867.83	2039846.51	2436661
38	200835.10	2039719.39	200943.61	2039772.16	2433680	200917.47	2039759.45	2446829	200901.00	2039751.44	2436661
39	200878.83	2039629.46	200980.93	2039679.11	2433680	200957.78	2039667.85	2446829	200941.66	2039660.01	2436661
40	200922.57	2039539.53	201027.38	2039590.50	2433680	201008.02	2039581.08	2446829	200999.15	2039576.77	2436661
41	200926.69	2039531.04	201033.59	2039583.03	2433680	201014.39	2039573.69	2446829	201004.03	2039568.66	2436661

APPENDIX C
Contents of file *uvero.loc*
(Notes in **bold**)

baseline x coordinate of transect origin	**baseline y coordinate of transect origin**	**transect #**
198803.815300	2040602.864400	1
198903.717609	2040598.445271	2
199003.619918	2040594.026142	3
199079.774100	2040590.657500	4
199079.774100	2040590.657500	5
199079.774100	2040590.657500	6
199166.867894	2040541.518198	7
199253.961689	2040492.378896	8
199341.055483	2040443.239595	9
199428.149278	2040394.100293	10
199515.243072	2040344.960991	11
199548.810800	2040326.021700	12
199548.810800	2040326.021700	13
199548.810800	2040326.021700	14
199648.664284	2040320.610443	15
199748.517768	2040315.199187	16
199848.371253	2040309.787930	17
199875.045500	2040308.342400	18
199875.045500	2040308.342400	19
199875.045500	2040308.342400	20
199974.324078	2040320.332564	21
200073.602655	2040332.322727	22
200172.881233	2040344.312891	23
200272.159811	2040356.303054	24
200281.401500	2040357.419200	25
200281.401500	2040357.419200	26
200281.401500	2040357.419200	27
200368.566556	2040308.406416	28
200455.731612	2040259.393632	29
200542.896668	2040210.380848	30
200616.427800	2040169.034400	31
200616.427800	2040169.034400	32
200616.427800	2040169.034400	33
200660.162140	2040079.104941	34
200703.896479	2039989.175483	35
200747.630819	2039899.246024	36
200791.365159	2039809.316565	37
200835.099499	2039719.387107	38
200878.833838	2039629.457648	39
200922.568178	2039539.528190	40
200926.694000	2039531.044400	41

APPENDIX D
Abridged contents of file *uvero.log*

```
Sat Apr 18 09:56:59 EDT 1992
transect_output_filename = uvero.jul
mapgraphics_output_filename = uvero.mapg
4 shoreline files detected
baseline # 1:
x[0] = 198803.815300, y[0] = 2040602.864400
x[1] = 199079.774100, y[1] = 2040590.657500
baseline # 2:
x[0] = 199079.774100, y[0] = 2040590.657500
x[1] = 199548.810800, y[1] = 2040326.021700
baseline # 3:
x[0] = 199548.810800, y[0] = 2040326.021700
x[1] = 199875.045500, y[1] = 2040308.342400
baseline # 4:
x[0] = 199875.045500, y[0] = 2040308.342400
x[1] = 200281.401500, y[1] = 2040357.419200
baseline # 5:
x[0] = 200281.401500, y[0] = 2040357.419200
x[1] = 200616.427800, y[1] = 2040169.034400
baseline # 6:
x[0] = 200616.427800, y[0] = 2040169.034400
x[1] = 200926.694000, y[1] = 2039531.044400
baseline # 7:
x[0] = 200926.694000, y[0] = 2039531.044400
x[1] = 200926.694000, y[1] = 2039531.044400
epr file = uvero.rates
distance file = uvero.dist

TRANSECT #: 1
      points from .jul file:
      x[0] =  198805.928193, y[0] = 2040650.630130, jul = 2433680.000000
      x[1] =  198806.033023, y[1] = 2040653.000000, jul = 2438428.000000
      base x = 198803.815300  base y = 2040602.864400

      sorted by julian day:
      x[0] =  198805.928193, y[0] = 2040650.630130, jul = 2433680.000000
      x[1] =  198806.033023, y[1] = 2040653.000000, jul = 2438428.000000

      distances:
      x[0],y[0]->x[1],y[1] = 2.372187


      epr results:
      dist from base x[0],y[0] = 47.812439
      dist from base x[1],y[1] = 50.184626
      epr = 0.182486

      aor results:
      tmin = 61.997828
      dist from base x[0],y[0] = 47.812439
      dist from base x[1],y[1] = 50.184626
      epr for this pair = 0.182486
      difference in years = 12.999316
```

```
      regression results:
      decimal years elapsed since shorel:
      x[0],y[0] = 0.000000
      x[1],y[1] = 12.999316
      regression slope =   0.18

      jacknife results:
      excluding point 0:
      regression slope[0] = NaN
      excluding point 1:
      regression slope[1] = NaN
      jkavg = NaN


TRANSECT #: 2
      points from .jul file:
      x[0] =  198905.302072, y[0] = 2040634.264904, jul = 2433680.000000
      x[1] =  198905.829528, y[1] = 2040646.188979, jul = 2446829.000000
      x[2] =  198905.239537, y[2] = 2040632.851171, jul = 2438428.000000
      base x = 198903.717609  base y = 2040598.445271

      sorted by julian day:
      x[0] =  198905.302072, y[0] = 2040634.264904, jul = 2433680.000000
      x[1] =  198905.239537, y[1] = 2040632.851171, jul = 2438428.000000
      x[2] =  198905.829528, y[2] = 2040646.188979, jul = 2446829.000000

      distances:
      x[0],y[0]->x[1],y[1] = -1.415115
      x[1],y[1]->x[2],y[2] = 13.350851


      epr results:
      dist from base x[0],y[0] = 35.854660
      dist from base x[2],y[2] = 47.790395
      epr = 0.331548

      aor results:
      tmin = 34.123873
      dist from base x[0],y[0] = 35.854660
      dist from base x[1],y[1] = 34.439544
      epr for this pair = -0.108861
      difference in years = 12.999316
      dist from base x[0],y[0] = 35.854660
      dist from base x[2],y[2] = 47.790395
      epr for this pair = 0.331548
      difference in years = 36.000000
      *** used this pair ... ***
      dist from base x[1],y[1] = 34.439544
      dist from base x[2],y[2] = 47.790395
      epr for this pair = 0.580454
      difference in years = 23.000684
      arate =  0.331548 std_dev = 0.444444      var =  1.885618
      regression results:
      decimal years elapsed since shorel:
      x[0],y[0] = 0.000000
      x[1],y[1] = 12.999316
      x[2],y[2] = 36.000000
      regression slope =   0.36
```

```
jacknife results:
excluding point 0:
regression slope[0] = 0.580454
excluding point 1:
regression slope[1] = 0.331548
excluding point 2:
regression slope[2] = -0.108861
jkavg = 0.267714


TRANSECT #: 3
     points from .jul file:
     x[0] =  199005.809035, y[0] = 2040643.515047, jul = 2433680.000000
     x[1] =  199005.167322, y[1] = 2040629.007992, jul = 2446829.000000
     x[2] =  199005.494950, y[2] = 2040636.414612, jul = 2438428.000000
     base x = 199003.619918  base y = 2040594.026142

     sorted by julian day:
     x[0] =  199005.809035, y[0] = 2040643.515047, jul = 2433680.000000
     x[1] =  199005.494950, y[1] = 2040636.414612, jul = 2438428.000000
     x[2] =  199005.167322, y[2] = 2040629.007992, jul = 2446829.000000

     distances:
     x[0],y[0]->x[1],y[1] = -7.107378
     x[1],y[1]->x[2],y[2] = -7.413863


     epr results:
     dist from base x[0],y[0] = 49.537299
     dist from base x[2],y[2] = 35.016058
     epr = -0.403368

     aor results:
     tmin = 28.048120
     dist from base x[0],y[0] = 49.537299
     dist from base x[1],y[1] = 42.429920
     epr for this pair = -0.546750
     difference in years = 12.999316
     dist from base x[0],y[0] = 49.537299
     dist from base x[2],y[2] = 35.016058
     epr for this pair = -0.403368
     difference in years = 36.000000
     *** used this pair ... ***
     dist from base x[1],y[1] = 42.429920
     dist from base x[2],y[2] = 35.016058
     epr for this pair = -0.322332
     difference in years = 23.000684
     arate = -0.403368 std_dev = 0.444444      var =  1.885618

     regression results:
     decimal years elapsed since shorel:
     x[0],y[0] = 0.000000
     x[1],y[1] = 12.999316
     x[2],y[2] = 36.000000
     regression slope =  -0.39
```

```
jacknife results:
excluding point 0:
regression slope[0] = -0.322332
excluding point 1:
regression slope[1] = -0.403368
excluding point 2:
regression slope[2] = -0.546750
jkavg = -0.424150


TRANSECT #: 4
      points from .jul file:
      x[0] =  199083.833570, y[0] = 2040682.429080, jul = 2433680.000000
      x[1] =  199081.566462, y[1] = 2040631.177058, jul = 2446829.000000
      x[2] =  199082.209132, y[2] = 2040645.705760, jul = 2438428.000000
      base x = 199079.774100  base y = 2040590.657500

      sorted by julian day:
      x[0] =  199083.833570, y[0] = 2040682.429080, jul = 2433680.000000
      x[1] =  199082.209132, y[1] = 2040645.705760, jul = 2438428.000000
      x[2] =  199081.566462, y[2] = 2040631.177058, jul = 2446829.000000

      distances:
      x[0],y[0]->x[1],y[1] = -36.759231
      x[1],y[1]->x[2],y[2] = -14.542909


      epr results:
      dist from base x[0],y[0] = 91.861320
      dist from base x[2],y[2] = 40.559181
      epr = -1.425059

      aor results:
      tmin = 7.939113
      dist from base x[0],y[0] = 91.861320
      dist from base x[1],y[1] = 55.102090
      epr for this pair = -2.827782
      difference in years = 12.999316
      *** used this pair ... ***
      dist from base x[0],y[0] = 91.861320
      dist from base x[2],y[2] = 40.559181
      epr for this pair = -1.425059
      difference in years = 36.000000
      *** used this pair ... ***
      dist from base x[1],y[1] = 55.102090
      dist from base x[2],y[2] = 40.559181
      epr for this pair = -0.632282
      difference in years = 23.000684
      *** used this pair ... ***
      arate = -1.628374 std_dev = 0.790303      var =  1.451715

      regression results:
      decimal years elapsed since shorel:
      x[0],y[0] = 0.000000
      x[1],y[1] = 12.999316
      x[2],y[2] = 36.000000
      regression slope =  -1.33
```

```
jacknife results:
excluding point 0:
regression slope[0] = -0.632282
excluding point 1:
regression slope[1] = -1.425059
excluding point 2:
regression slope[2] = -2.827782
jkavg = -1.628374


TRANSECT #: 5
     points from .jul file:
     x[0] =  199101.773107, y[0] = 2040667.465735, jul = 2433680.000000
     x[1] =  199091.817133, y[1] = 2040632.705040, jul = 2446829.000000
     x[2] =  199094.463953, y[2] = 2040641.946257, jul = 2438428.000000
     base x = 199079.774100  base y = 2040590.657500

     sorted by julian day:
     x[0] =  199101.773107, y[0] = 2040667.465735, jul = 2433680.000000
     x[1] =  199094.463953, y[1] = 2040641.946257, jul = 2438428.000000
     x[2] =  199091.817133, y[2] = 2040632.705040, jul = 2446829.000000

     distances:
     x[0],y[0]->x[1],y[1] = -26.545574
     x[1],y[1]->x[2],y[2] = -9.612791


     epr results:
     dist from base x[0],y[0] = 79.896566
     dist from base x[2],y[2] = 43.738201
     epr = -1.004399

     aor results:
     tmin = 11.264157
     dist from base x[0],y[0] = 79.896566
     dist from base x[1],y[1] = 53.350992
     epr for this pair = -2.042075
     difference in years = 12.999316
     *** used this pair ... ***
     dist from base x[0],y[0] = 79.896566
     dist from base x[2],y[2] = 43.738201
     epr for this pair = -1.004399
     difference in years = 36.000000
     *** used this pair ... ***
     dist from base x[1],y[1] = 53.350992
     dist from base x[2],y[2] = 43.738201
     epr for this pair = -0.417935
     difference in years = 23.000684
     *** used this pair ... ***
     arate = -1.154803 std_dev = 0.790303      var =  1.451715

     regression results:
     decimal years elapsed since shorel:
     x[0],y[0] = 0.000000
     x[1],y[1] = 12.999316
     x[2],y[2] = 36.000000
     regression slope =  -0.94
```

```
jacknife results:
excluding point 0:
regression slope[0] = -0.417935
excluding point 1:
regression slope[1] = -1.004399
excluding point 2:
regression slope[2] = -2.042075
jkavg = -1.154803

TRANSECT #: 41
points from .jul file:
x[0] =  201033.593722, y[0] = 2039583.031689, jul = 2433680.000000
x[1] =  201014.394343, y[1] = 2039573.694680, jul = 2446829.000000
x[2] =  201004.034963, y[2] = 2039568.656724, jul = 2436661.000000
base x = 200926.694000  base y = 2039531.044400

sorted by julian day:
x[0] =  201033.593722, y[0] = 2039583.031689, jul = 2433680.000000
x[1] =  201004.034963, y[1] = 2039568.656724, jul = 2436661.000000
x[2] =  201014.394343, y[2] = 2039573.694680, jul = 2446829.000000

distances:
x[0],y[0]->x[1],y[1] = -32.868828
x[1],y[1]->x[2],y[2] = 11.519451


epr results:
dist from base x[0],y[0] = 118.870639
dist from base x[2],y[2] = 97.521262
epr = -0.593038

aor results:
tmin = 19.077536
dist from base x[0],y[0] = 118.870639
dist from base x[1],y[1] = 86.001811
epr for this pair = -4.027286
difference in years = 8.161533
dist from base x[0],y[0] = 118.870639
dist from base x[2],y[2] = 97.521262
epr for this pair = -0.593038
difference in years = 36.000000
*** used this pair ... ***
dist from base x[1],y[1] = 86.001811
dist from base x[2],y[2] = 97.521262
epr for this pair = 0.413796
difference in years = 27.838467
*** used this pair ... ***
arate = -0.089621 std_dev = 0.509594      var =  1.427718


regression results:
decimal years elapsed since shorel:
x[0],y[0] = 0.000000
x[1],y[1] = 8.161533
x[2],y[2] = 36.000000
regression slope =  -0.34
```

```
jacknife results:
excluding point 0:
regression slope[0] = 0.413796
excluding point 1:
regression slope[1] = -0.593038
excluding point 2:
regression slope[2] = -4.027286
jkavg = -1.402176
```

APPENDIX E
Contents of file *uvero.mapg*
(Notes in **bold**)

TEXT	198802.815300	2040601.864400	125	0.0	1	**transect label (includes utm x-y, point size offset, and number for label)**
POLY						**line type**
198803.815300	2040602.864400					**shoreline point**
198805.928193	2040650.630130					**shoreline point**
198806.033023	2040653.000000					**shoreline point**
TEXT	198902.717609	2040597.445271	125	0.0	2	
POLY						
198903.717609	2040598.445271					
198905.302072	2040634.264904					
198905.829528	2040646.188979					
198905.239537	2040632.851171					
TEXT	199002.619918	2040593.026142	125	0.0	3	
POLY						
199003.619918	2040594.026142					
199005.809035	2040643.515047					
199005.167322	2040629.007992					
199005.494950	2040636.414612					
TEXT	199078.774100	2040589.657500	125	0.0	4	
POLY						
199079.774100	2040590.657500					
199083.833570	2040682.429080					
199081.566462	2040631.177058					
199082.209132	2040645.705760					
TEXT	199078.774100	2040589.657500	125	0.0	5	
POLY						
199079.774100	2040590.657500					
199101.773107	2040667.465735					
199091.817133	2040632.705040					
199094.463953	2040641.946257					
TEXT	199078.774100	2040589.657500	125	0.0	6	
POLY						
199079.774100	2040590.657500					
199111.596654	2040647.059339					
199104.540904	2040634.553828					
199105.845421	2040636.865936					
TEXT	199165.867894	2040540.518198	125	0.0	7	
POLY						
199166.867894	2040541.518198					
199189.182597	2040581.068457					
199190.889102	2040584.093042					
199188.941740	2040580.641565					
TEXT	199252.961689	2040491.378896	125	0.0	8	
POLY						
199253.961689	2040492.378896					
199271.758186	2040523.921153					
199275.889740	2040531.243861					
199270.934484	2040522.461235					

```
TEXT  199340.055483     2040442.239595    125    0.0    9
POLY
199341.055483     2040443.239595
199356.231304     2040470.137003
199363.795215     2040483.543169
199354.394745     2040466.881912
TEXT  199427.149278     2040393.100293    125    0.0    10
POLY
199428.149278     2040394.100293
199441.659139     2040418.044978
199451.864615     2040436.133017
199442.840173     2040420.138225
TEXT  199514.243072     2040343.960991    125    0.0    11
POLY
199515.243072     2040344.960991
199534.359346     2040378.842401
199540.469570     2040389.672074
199539.616229     2040388.159626
TEXT  199547.810800     2040325.021700    125    0.0    12
POLY
199548.810800     2040326.021700
199574.152971     2040370.937801
199577.908955     2040377.594853
199580.583452     2040382.335094
TEXT  199547.810800     2040325.021700    125    0.0    13
POLY
199548.810800     2040326.021700
199562.445607     2040372.748814
199565.068326     2040381.736992
199565.726437     2040383.992366
TEXT  199547.810800     2040325.021700    125    0.0    14
POLY
199548.810800     2040326.021700
199551.435333     2040374.451993
199552.057566     2040385.934011
199551.990329     2040384.693284
TEXT  199647.664284     2040319.610443    125    0.0    15
POLY
199648.664284     2040320.610443
199650.987073     2040363.472684
199650.937710     2040362.561784
199651.516925     2040373.250000
TEXT  199747.517768     2040314.199187    125    0.0    16
POLY
199748.517768     2040315.199187
199750.964520     2040360.348892
199750.568051     2040353.032896
199751.001397     2040361.029395
TEXT  199847.371253     2040308.787930    125    0.0    17
POLY
199848.371253     2040309.787930
199851.131462     2040360.721850
199850.557594     2040350.132307
199851.259922     2040363.092307
```

```
TEXT  199874.045500      2040307.342400    125    0.0    18
POLY
199875.045500      2040308.342400
199877.926564      2040361.506444
199877.337038      2040350.627961
199878.141242      2040365.467880
TEXT  199874.045500      2040307.342400    125    0.0    19
POLY
199875.045500      2040308.342400
199873.290278      2040361.469903
199873.624813      2040351.344125
199873.192433      2040364.431525
TEXT  199874.045500      2040307.342400    125    0.0    20
POLY
199875.045500      2040308.342400
199868.633569      2040361.433200
199869.898807      2040350.957026
199868.392842      2040363.426419
TEXT  199973.324078      2040319.332564    125    0.0    21
POLY
199974.324078      2040320.332564
199967.848448      2040373.950787
199970.625773      2040350.954533
199966.876658      2040381.997216
TEXT  200072.602655      2040331.322727    125    0.0    22
POLY
200073.602655      2040332.322727
200064.442206      2040408.171266
200070.036802      2040361.847996
200065.433970      2040399.959460
TEXT  200171.881233      2040343.312891    125    0.0    23
POLY
200172.881233      2040344.312891
200158.945689      2040459.699225
200166.017626      2040401.143572
200160.113143      2040450.032702
TEXT  200271.159811      2040355.303054    125    0.0    24
POLY
200272.159811      2040356.303054
200251.447580      2040527.800363
200263.665039      2040426.639775
200254.013928      2040506.550998
TEXT  200280.401500      2040356.419200    125    0.0    25
POLY
200281.401500      2040357.419200
200260.558309      2040530.000858
200273.444407      2040423.303943
200262.665727      2040512.551439
TEXT  200280.401500      2040356.419200    125    0.0    26
POLY
200281.401500      2040357.419200
200316.073217      2040532.023830
200291.868209      2040410.128903
200315.828182      2040530.789850
```

```
TEXT   200280.401500      2040356.419200     125    0.0    27
POLY
200281.401500       2040357.419200
200375.924817       2040525.520858
200310.157557       2040408.559395
200367.890141       2040511.231871TEXT       200367.566556
       2040307.406416     125    0.0    28
POLY
200368.566556       2040308.406416
200446.685825       2040447.334873
200405.151649       2040373.469883
200446.612529       2040447.204522
TEXT   200454.731612      2040258.393632     125    0.0    29
POLY
200455.731612       2040259.393632
200538.981425       2040407.446324
200487.415712       2040315.741101
200538.838599       2040407.192320
TEXT   200541.896668      2040209.380848     125    0.0    30
POLY
200542.896668       2040210.380848
200623.133303       2040353.074859
200573.400694       2040264.629656
200622.272691       2040351.544335
TEXT   200615.427800      2040168.034400     125    0.0    31
POLY
200616.427800       2040169.034400
200686.439045       2040293.543429
200646.172142       2040221.932175
200660.591049       2040247.574972
TEXT   200615.427800      2040168.034400     125    0.0    32
POLY
200616.427800       2040169.034400
200716.950887       2040263.738581
200663.113358       2040213.017506
200674.048946       2040223.320074
TEXT   200615.427800      2040168.034400     125    0.0    33
POLY
200616.427800       2040169.034400
200728.379531       2040223.478574
200683.000410       2040201.409877
200690.916493       2040205.259613
TEXT   200659.162140      2040078.104941     125    0.0    34
POLY
200660.162140       2040079.104941
200778.169956       2040136.494300
200756.401341       2040125.907824
200733.432450       2040114.737633
TEXT   200702.896479      2039988.175483     125    0.0    35
POLY
200703.896479       2039989.175483
200802.084728       2040036.926223
200775.617118       2040024.054540
200766.450004       2040019.596405
```

```
TEXT  200746.630819      2039898.246024     125     0.0     36
POLY
200747.630819      2039899.246024
200844.725961      2039946.465167
200819.102862      2039934.004185
200808.336517      2039928.768315
TEXT  200790.365159      2039808.316565     125     0.0     37
POLY
200791.365159      2039809.316565
200887.076776      2039855.862875
200856.669493      2039841.075257
200867.834521      2039846.505014
TEXT  200834.099499      2039718.387107     125     0.0     38
POLY
200835.099499      2039719.387107
200943.611566      2039772.158509
200917.474013      2039759.447339
200901.003296      2039751.437328
TEXT  200877.833838      2039628.457648     125     0.0     39
POLY
200878.833838      2039629.457648
200980.930271      2039679.109010
200957.777444      2039667.849367
200941.658059      2039660.010215
TEXT  200921.568178      2039538.528190     125     0.0     40
POLY
200922.568178      2039539.528190
201027.381953      2039590.501044
201008.015002      2039581.082542
200999.145669      2039576.769223
TEXT  200925.694000      2039530.044400     125     0.0     41
POLY
200926.694000      2039531.044400
201033.593722      2039583.031689
201014.394343      2039573.694680
201004.034963      2039568.656724
```

APPENDIX F

Abridged contents of file *uvero.pts*
(Notes in **bold**)

Poly **line type**
155 **# points to follow**
198788.4222 2040655.3683
198840.1384 2040641.3708
.
.
.
201043.3752 2039570.3922
201049.5942 2039548.6422
8 **overlay # for preceding data**
Poly
188
198810.0160 2040672.6250
198809.4840 2040672.6250
.
.
.
201020.3910 2039566.7500
201028.3750 2039551.0000
10
Poly
159
198789.6090 2040659.0000
198797.2660 2040657.0000
.
.
.
199997.9530 2040386.6250
199999.9268 2040386.3458
16
Poly
306
200000.0368 2040386.7637
200004.5780 2040386.8750
.
.
.
201010.4530 2039557.1250
201011.2340 2039552.3750
17
Poly
7
198803.8153 2040602.8644
199079.7741 2040590.6575
199548.8108 2040326.0217
199875.0455 2040308.3424
200281.4015 2040357.4192
200616.4278 2040169.0344
200926.6940 2039531.0444
100 **overlay # for baseline**

APPENDIX G
Contents of file *uvero.rates.*

Transect	epr*	aor**	aor std dev	aor var	lr***	jk****
1	0.18	*	*	*	0.18	*
2	0.33	0.33	0.44	1.89	0.36	0.27
3	-0.40	-0.40	0.44	1.89	-0.39	-0.42
4	-1.43	-1.63	0.79	1.45	-1.33	-1.63
5	-1.00	-1.15	0.79	1.45	-0.94	-1.15
6	-0.40	-0.40	0.44	1.89	-0.37	-0.47
7	0.10	*	*	*	0.11	0.08
8	0.23	*	*	*	0.26	0.18
9	0.43	0.43	0.44	1.89	0.47	0.32
10	0.58	0.69	0.57	1.51	0.60	0.52
11	0.35	0.35	0.44	1.89	0.31	0.41
12	0.21	*	*	*	0.16	0.33
13	0.26	*	*	*	0.22	0.35
14	0.32	0.32	0.44	1.89	0.29	0.39
15	-0.03	*	*	*	-0.08	0.09
16	-0.20	*	*	*	-0.22	-0.17
17	-0.29	*	*	*	-0.33	-0.23
18	-0.30	*	*	*	-0.34	-0.21
19	-0.28	*	*	*	-0.31	-0.21
20	-0.29	*	*	*	-0.32	-0.23
21	-0.64	-1.00	0.57	1.51	-0.73	-0.46
22	-1.30	-1.34	0.51	1.43	-1.32	-1.23
23	-1.64	-1.53	0.99	1.63	-1.67	-1.53
24	-2.83	-2.78	0.99	1.63	-2.85	-2.78
25	-2.99	-2.79	0.99	1.63	-3.05	-2.79
26	-3.45	-2.68	0.99	1.63	-3.70	-2.68
27	-3.73	-3.32	0.99	1.63	-3.86	-3.32
28	-2.35	-1.80	0.99	1.63	-2.53	-1.80
29	-2.92	-2.24	0.99	1.63	-3.14	-2.24
30	-2.82	-2.21	0.99	1.63	-3.01	-2.21
31	-2.28	-3.27	0.99	1.63	-1.97	-3.27
32	-2.05	-3.27	0.99	1.63	-1.67	-3.27
33	-1.40	-2.27	0.99	1.63	-1.12	-2.27
34	-0.67	0.12	0.51	1.43	-0.26	-1.95
35	-0.82	-0.23	0.51	1.43	-0.51	-1.77
36	-0.79	-0.18	0.51	1.43	-0.48	-1.77
37	-0.94	-0.69	0.51	1.43	-0.81	-1.34
38	-0.81	-0.07	0.51	1.43	-0.43	-1.98
39	-0.72	-0.04	0.51	1.43	-0.37	-1.81
40	-0.60	-0.12	0.51	1.43	-0.35	-1.36
41	-0.59	-0.09	0.51	1.43	-0.34	-1.40

* end-point rate.
** average of rates.
*** linear regression.
**** jacknife.

APPENDIX H

UNIX Man Pages

NAME

rates - calculate shoreline rates-of-change for shoreline transects

SYNTAX

rates -f file

DESCRIPTION

Rates is a C program used in the Digital Shoreline Analysis System (DSAS) that calculates rates of change for shoreline transects created by *transect*.

The only option is:

-f *file* This option specifies the file containing the shoreline coordinates and julian dates generated by *transect*.

Rates calculates four measures of shoreline change simultaneously: 1) end-point rate; 2) average of rates (including the standard deviation and variance for each transect); 3) linear regression; and 4) jackknife. Dolan and others (1991) provide a discussion of the applications and implications of these measures of change. A value of eight (8) meters is used in the t_{min} test for the average of rates calculation.

Output from rates includes two files: 1) tab-delimited shoreline dates and distances for each transect (*file.dist*); and 2) tab-delimited rate-of-change calculations (*file.rates*).

A log of the shoreline coordinates and dates used, as well as the calculations made for each transect, is provided as *stdout*, and can be piped to a file.

FILES

Shoreline coordinates and julian dates for each transect (*file.jul*).

SEE ALSO

transect

Dolan, R., Fenster, M.S., and Holme, S. J., 1991, Temporal analysis of shoreline recession and accretion: Journal of Coastal Research, v. 7, no. 3, p. 723-744.

NAME

runtransect - calculate transects and rates-of-change for shoreline data

SYNTAX

runtransect

DESCRIPTION

Runtransect is a Csh script used to run the Digital Shoreline Analysis System (DSAS). The script is used to interactively execute *transect* and *rates*. Options available for *transect* are set interactively by screen prompts. Filename extensions used by both *transect* and *rates* are automatically appended to needed files once the basemap directory and map name have been specified. The *stdout* from *rates* is piped to a file named *file.log*.

See Danforth and Thieler (1992) for a description of a recommended directory structure.

FILES

Shoreline coordinates and julian dates for each transect (*file.jul*).
Shoreline and baseline coordinates (*file.pts*).
Optional shoreline dates file (*file.dates*).

SEE ALSO

rates
transect
Danforth, W. W., and Thieler, E. R., 1992. Digital Shoreline Mapping System (DSMS) User's Guide, Version 1.0: Reston, Virginia, U.S. Geological Survey Open-File Report No. 92-240, 33 p.

NAME

transect - measure distances between shorelines along shore-perpendicular transects

SYNTAX

transect -f file [-t tolerance -d spacing -s input dates from file or pipe]

DESCRIPTION

Transect is a C program used in the Digital Shoreline Analysis System (DSAS) that employs a measurement baseline approach to calculate the X-Y coordinates of a time series of shorelines that lie along an orthogonal (also called a transect) to a specified baseline.

The following options can appear in any order:

-f *file* This option specifies the file containing the shoreline and baseline coordinates.

-t *m* *M* sets the tolerance distance (in meters) from the transect origin beyond which shoreline coordinates are not determined for a given transect. The default tolerance is 150 meters.

-d *m* *M* sets the alongshore distance (in meters) between transects. The default distance is 100 meters.

-s This option specifies that date input will come from *stdin*. A file containing the calendar dates associated with each shoreline in the *file.pts* file can also be used to provide date input to *transect*. The dates should be of the form mm/dd/yyyy, with one entry per line, and the entries in the order of increasing MapGrafix overlay number. The file should be named *file.dates*, where *file* is the same name given to the *file.pts* file.

Transect is used to specify the longshore spacing of transects along the measurement baseline, determine the X-Y coordinates of each shoreline that lies along each transect, and input the dates of each shoreline. An additional option allows the specification of a "tolerance distance" to be used to exclude data that lie more than the tolerance distance away from the baseline.

The measurement baseline must be landward of the shoreline data as viewed in the GIS file that contains the data.

Transect expects ASCII output in a format generated by MapGrafix, an Apple Macintosh-based GIS, and that all data are in meters (*e.g*., UTM coordinates).

The algorithm used in *transect* executes in the following manner:

1) the first transect is measured at the origin of the first baseline segment;
2) the following transects are measured at the specified increment (*e.g*., 100 m) along the baseline segment until the end of the segment is reached;
3) a transect is measured at the end of a baseline segment;
4) a transect is measured between consecutive baseline segments such that the transect bisects the angle made by the segments;
5) a transect is measured at the origin of the next baseline segment; and
6) steps 2-5 are repeated until the end of the baseline data is reached.

Three output files are produced by transect: *File.jul* contains the X-Y coordinates and julian date for each shoreline coordinate on a given transect. Although it is an ASCII file, it is largely unreadable in form. It is used by *rates* to generate shoreline rate-of-change data. *File.loc* contains the X-Y coordinates of each transect origin, and the transect number. This ASCII file can be used to post transect labels in the *Mapgen* program (Evenden and Botbol, 1985). *File.mapg* contains data for graphical display of transect locations and numbers in MapGrafix. This file is in import-ready MapGrafix "CGDEF" format.

FILES

Shoreline and baseline coordinates (*file.pts*).
Optional shoreline dates file (*file.dates*).

SEE ALSO

rates