Digital Shoreline Analysis System (DSAS) Version 5.1 User Guide

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U.S. Department of the Interior
U.S. Geological Survey

Cover. Barrier beach at Joseph Sylvia State Beach and Caroline Tuthill Wildlife Preserve, Edgartown, Massachusetts. Photograph by Karen Morgan, U.S. Geological Survey.

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By Emily A. Himmelstoss, Rachel E. Henderson, Meredith G. Kratzmann, and Amy S. Farris

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Acknowledgments

Rob Thieler and Bill Danforth developed the original Digital Shoreline Analysis System (DSAS) software in the early 1990s, and DSAS has undergone numerous updates and refinements over the past 25 years. DSAS version 5 is a culmination of many years of collaborative effort to refine the functionality of the software to meet the needs of a global user base. The authors wish to thank Rob Thieler for the idea that started it all, Amy Farris for converting all of the original MATLAB code to Python, Jessica Zichichi, Ayhan Ergul, and Ouya Zhang from Corona Environmental for making versions 5.0 and 5.1 a reality, and the diverse user community for providing feedback, questions, and inspiration for ways to improve the DSAS workflow.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per year (ft/yr)	0.3048	meter per year (m/yr)

International System of Units to U.S. customary units

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
meter per year (m/yr)	3.281	foot per year ft/yr)

Abbreviations

CSDGM	Content Standard for Digital Geospatial Metadata
DSAS	Digital Shoreline Analysis System
EOV	edge of vegetation line
EPR	end point rate
EPRunc	uncertainty of the end point rate
FGDC	Federal Geographic Data Committee
HWL	high-water line
ID	identifier
ISO	International Organization for Standardization
LCI	confidence interval of linear regression
lidar	light detection and ranging
LR2	R-squared of linear regression
LRR	linear regression rate
LSE	standard error of linear regression
LWI	land-water interface
MHW	mean high water
NB	nonbias
NOAA	National Oceanic and Atmospheric Administration
NSM	net shoreline movement
PDB	proxy-datum bias
SCE	shoreline change envelope
TCD	total cumulative distance
USGS	U.S. Geological Survey

WCI	confidence interval of weighted linear regression
WDL	wet-dry line
WIS	Wave Information Studies
WLR	weighted linear regression rate
WR2	R-squared of weighted linear regression
WSE	standard error of weighted linear regression
XML	Extensible Markup Language

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By Emily A. Himmelstoss,[1] Rachel E. Henderson,[2] Meredith G. Kratzmann,[2] and Amy S. Farris[1]

Abstract

The Digital Shoreline Analysis System version 5 software is an add-in to Esri ArcGIS Desktop version 10.4–10.7 that enables a user to calculate rate-of-change statistics from a time series of vector shoreline positions. The Digital Shoreline Analysis System provides an automated method for establishing measurement locations, performs rate calculations, provides the statistical data necessary to assess the reliability of the rates, and includes a beta model for forecasting shoreline position. The Digital Shoreline Analysis System version 5.1 includes updates to the interface and the application of proxy-datum bias. This in-depth user guide provides comprehensive instruction on the installation and use of the program, including how to create a reference baseline for measurements, steps needed to generate measurement transects and metadata, guidelines on how to manually add or edit existing transects, and an explanation of the visualization options to display calculated rates of shoreline change.

1. Introduction

1.1 Overview

The Digital Shoreline Analysis System (DSAS) is a freely available software application that works within the Esri Geographic Information System (ArcGIS) software. DSAS computes rate-of-change statistics for a time series of shoreline vector data. DSAS version 5.1 (v5.1) was released in October 2021, has been tested for compatibility with ArcGIS versions 10.4–10.7, and is supported on Windows 7 and Windows 10 operating systems. See table 1 for system and software compatibility. Please note DSAS v5.1 is not compatible with Arc Pro. If you use DSAS, please cite it as follows and make note of the current version:

Himmelstoss, E.A., Farris, A.S., Henderson, R.E., Kratzmann, M.G., Ergul, Ayhan, Zhang, Ouya, Zichichi, J.L., and Thieler, E.R., 2021, Digital Shoreline Analysis System version 5.1: U.S. Geological Survey software release, https://code.usgs.gov/cch/dsas.

This user guide builds upon the previously published version, DSAS version 5.0 (v5.0) (Himmelstoss and others, 2018), and describes the system requirements, installation procedures, and inputs necessary to establish measurement locations with DSAS-generated transects and compute rate-of-change calculations. Although the nomenclature for this software utility is based on use in a coastal environment, the DSAS application can be used to compute rates of change for any boundary-change problem that incorporates a clearly identified feature position at discrete times, such as glacier limits, river banks, or land use/cover boundaries.

Work completed for this project by Rachel Henderson and Meredith Kratzmann was done through Cherokee Nation Business, Catoosa, Oklahoma, under contract to the U.S. Geological Survey (USGS).

1.2 System Requirements

Before installing the DSAS v5.1 application, ensure that your system meets the following requirements (installation of new applications will require administrative rights).

1. Windows 7 or Windows 10 operating system

[1]U.S. Geological Survey.

[2]Cherokee Nation Businesses, Catoosa, Oklahoma; under contract to the U.S. Geological Survey.

2. ArcGIS Desktop 10.4–10.7. *(Please note: At this time, DSAS is not compatible with ArcPro)*
    - ArcGIS .NET support feature (installed by default)
    - Microsoft .NET framework of 4.5.2 or later (installed by default)
3. The computer's date format must be set to English (USA), mm/dd/yyyy

To check your operating system, Click the Start button, enter "Computer" in the search box, right-click "Computer," and then click "Properties." Look under "Windows edition" for the version and edition of Windows that your computer is running.

To check the ArcMap version from ArcMap or ArcCatalog, select "Help," and then click "About ArcMap" to see the ArcGIS version number.

To verify the date format, go to the Control Panel menu and choose the option for Region and Language. Select "English (United States)" for the format, and make sure the date format is set to "mm/dd/yyyy."

1.3 What's New in DSAS v5.0

- **Help popups**: Wherever the icon is shown, descriptive help is available.
- **Advanced baseline placement options**: onshore, offshore, or midshore (**section 5.3.1**).
- **Attribute Automator**: a tool for adding required and optional fields to shoreline data (**section 6.1**).
- **Landward/seaward setting**: to orient rates of change in all new baseline configurations (**section 6.2.1**).
- **Baseline Search Distance**: to customize the transect length based on the spacing of shoreline data (**section 6.2.1**).
- **New options for Cast Transects window**: includes search distance, transect spacing and smoothing options, and an Upgrade Transects tool (**sections 6.3–6.5**).
- **Rates returned as feature class**: transects are returned with rate information spatially joined (**section 6.7.3**).
- **Data visualization**: rates of change are returned with symbology (**section 6.8**).
- **Beta shoreline forecasting**: displays the likely future shoreline position with uncertainty (**section 8**).
- **Summary report**: a summary of all chosen settings; data used for analysis; automatically generated stats and averages (**section 9**).

1.4 What's New in DSAS v5.1

This update builds on the capabilities of the previous version—DSAS v5.0 (Himmelstoss and others, 2018). Updates from the original in version 5.1 include the following:

- **Bias Feature:** The proxy-datum bias information (if applied) will no longer be stored as a table but stored and accessed by DSAS through a polyline feature class (see **sections 5.4** and **13**).
- **Update to location of land relative to baseline data:** In the Default Parameters window, Baseline Settings tab, there is a new visualization symbol to assist users in identifying the orientation of land relative to baseline data, left (L) or right (R) (see **section 6.2.1**).

1.5 Where to find help

There are many help resources available for DSAS. Within this document there are numerous workflows and detailed information about each DSAS setting, input, and output. The appendix sections provide a quick reference for troubleshooting (**section 12**, app. 1), advanced settings (**section 13**, app. 2), summary report information (**section 14**, app. 3) and detailed workflows for basic and advanced sample datasets (section 15, app. 4). Prior to installation, please consult table 1, which identifies DSAS compatibility with Windows and ArcMap versions. The DSAS project page (https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas) provides access to the current DSAS version, user guide, and other resources including a video describing the system requirements and installation, and a tutorial demonstrating the DSAS workflow using sample data. In addition, the DSAS project page provides access to all previous DSAS publications.

Table 1. Digital Shoreline Analysis System (DSAS) version compatibility with ArcGIS and Windows

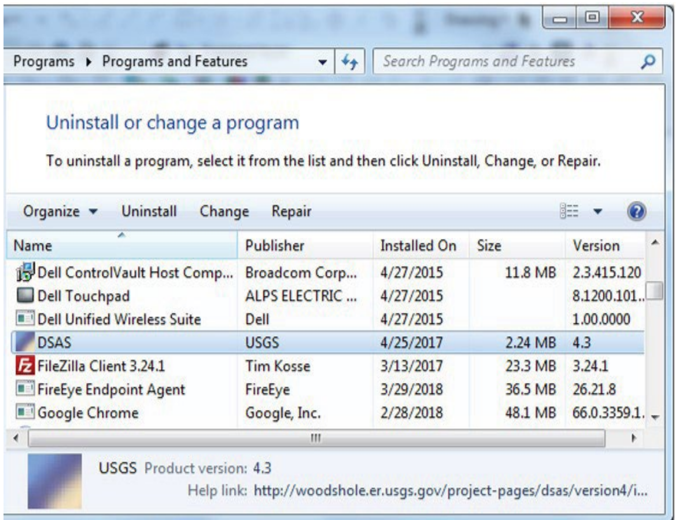
DSAS version	Arc compatible	Windows version compatible
v5.1	v10.4 to v10.7+	Windows 7, Windows 10
v5.0	v10.4 and 10.5	Windows 7, Windows 10
v4.4	v10.4 and 10.5	Windows XP, Vista and Windows 7
v4.3	v10.0 to v10.3	Windows XP, Vista and Windows 7
v4.2	v9.2 and 9.3.x	Windows XP, Vista

2. Installation Steps

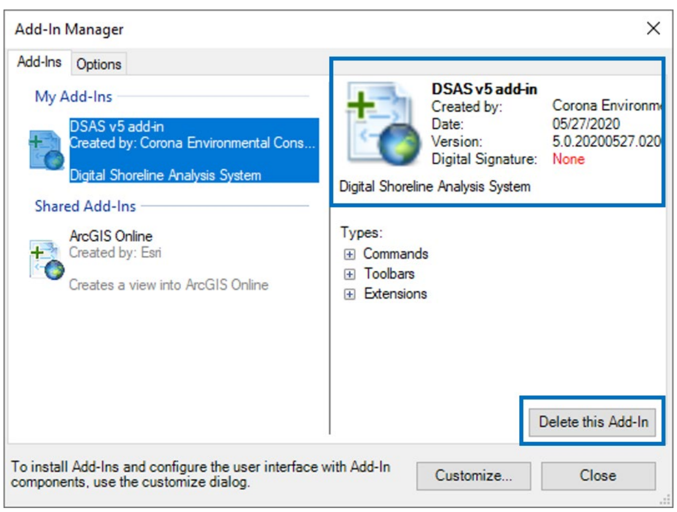
The ArcGIS add-in is available in compressed format for download at https://code.usgs.gov/cch/dsas, as DSASAddin_v5.1.zip. See the DSAS project page (see **section 1.5**) for a tutorial video describing system requirements and installation. The following steps outline how to download and install the latest version of DSAS.

1. Uninstall any prior version of the Digital Shoreline Analysis System software.

   A. For DSAS version 4.3 and prior: Go to Control Panel >> Programs >> Programs and Features >> Uninstall a Program.



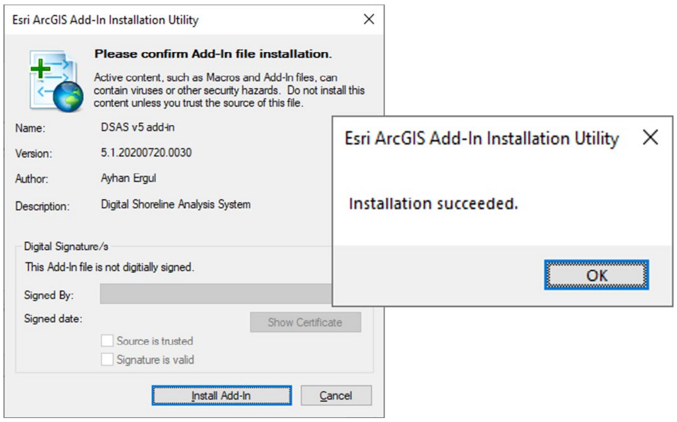
   B. For DSAS 4.4 and later: Go to ArcMap >> Customize >> Add-in Manager >> select the appropriate add-in. Then click "Delete Add-in." Close and reopen ArcMap to ensure the add-in/toolbar has been removed.



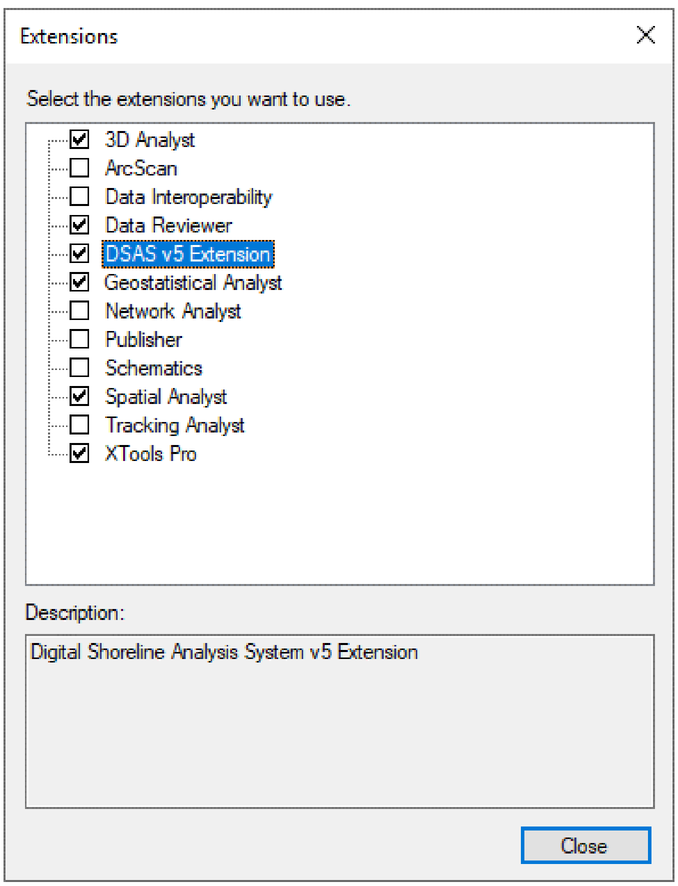
2. Download DSASAddin_v5.1.zip from the website https://code.usgs.gov/cch/dsas.

3. Uncompress then double-click “DSASAddin” to launch the Esri ArcGIS Add-In Installation Utility.

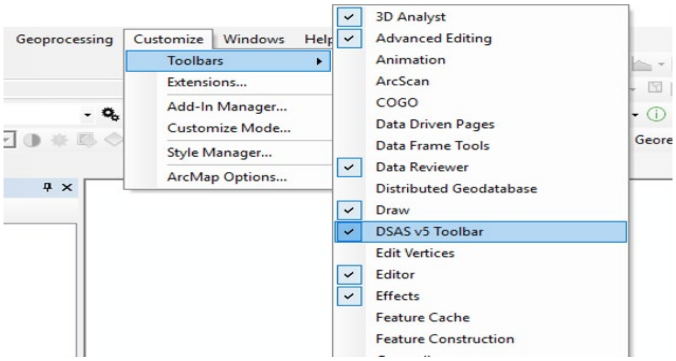
4. The Esri ArcGIS Add-In Installation Utility window will open. Click “Install Add-In.” A success message will appear once the add-in has installed properly.



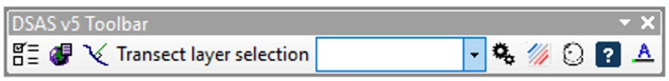
5. Open ArcMap and enable the DSAS v5 extension by going to Customize >> Extensions and checking the box next to the DSAS v5 Extension. You may need to close and reopen ArcMap after doing this to proceed to the next step.



6. Open ArcMap. If the DSAS v5 toolbar application is not automatically added, you can add it by clicking “Customize” on the main ArcMap menu, pointing to “Toolbars,” and then selecting the DSAS v5toolbar.



7. Once selected, the DSAS v5 toolbar should appear in ArcMap.



3. Sample Data

The sample datasets made available for the DSAS v5.0 release have been updated to include the proxy-datum bias (PDB) as a polyline shapefile bias feature as required in DSAS v5.1, while still including the PDB table for use in DSAS v5.0. The basic sample dataset is provided to illustrate the primary functions of DSAS. The advanced sample dataset is provided to illustrate the use of complex data with the bias feature in DSAS v5.1. Both datasets are available for download on the DSAS website (https://code.usgs.gov/cch/dsas). For step by step workflows using the basic and advanced sample datasets, see **sections 15.1** and **15.2**, respectively (app. 4).

3.1 Basic Sample Data

The basic sample data include four shoreline positions for a section of the North Carolina coast near Rodanthe along the Outer Banks and a reference baseline from which the DSAS transects are cast. These shoreline data are a subset of data from Miller and others (2005) and are available through the USGS Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/). The basic sample dataset (DSAS_v5_Basic_SampleData.mdb) is distributed as an ArcGIS (version 10) geodatabase (fig. 1*A*) that meets the attribute requirements for DSAS v5 shorelines (see **section 5.2.3**) and baselines (**see section 5.3.6**). For a complete guide to using the basic sample data, see **section 15.1** (app. 4).

3.2 Advanced Sample Data

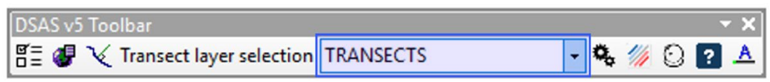
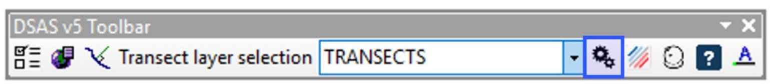
The advanced sample data include seven shoreline positions for a section of the Cape Cod Bay coast near Barnstable, Massachusetts, and a reference baseline from which the DSAS transects are cast. These shoreline data are a subset of data from the USGS Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/) and Massachusetts Coastal Zone Management shoreline change update (Smith and others, 2013) and are available through the USGS Coastal Change Hazards Portal. The advanced sample dataset (DSAS_v5_Advanced_SampleData.mdb) is distributed as an ArcGIS (version 10) geodatabase (fig. 1*B*) that meets the attribute requirements for DSAS v5 shorelines and baselines and includes advanced options (such as the Baseline Search Distance Field and application of proxy-datum bias). The uncertainty table (Shorelines_adv_uncertainty.dbf) must be used in DSAS v.5.0, and the new bias feature (Bias_Feature), must be used in DSAS v5.1; they are not interchangeable. For a guide to using the advanced sample data see **section 15.2** (app. 4).

Figure 1. Files within the two Digital Shoreline Analysis System (DSAS) sample geodatabases for basic and advanced workflows. *A*, The basic dataset with baseline and shoreline feature classes. *B*, The advanced sample data containing baseline and shoreline feature classes along with a proxy-datum bias uncertainty table (DSAS v5.0) and a proxy-datum bias feature (DSAS v5.1).

4. DSAS Toolbar

Table 2 provides a quick reference and explanation for each button (highlighted in blue) on the DSAS v5 toolbar interface.

Table 2. Explanation of functions in the Digital Shoreline Analysis System (DSAS) version 5 toolbar.

DSAS tool	Toolbar image and explanation
Attribute Automator	 The **Attribute Automator** tool allows the user to add required and optional fields to one or more selected shoreline and (or) baseline feature classes within a geodatabase.
Set Default Parameters	 The **Set Default Parameters** window specifies filenames for the baseline and shoreline inputs and includes other settings, such as basic metadata inputs.
Cast Transects	 **Cast Transects** generates a new (or overwrites an existing) transect feature class by using the user-specified settings in Default Parameters. Legacy transects (DSAS v4.x) can be upgraded by using the “Upgrade Transect Layer” tab.
Transect Layer	 The **Transect Layer** selection drop-down menu lists all recognized transect files added to the active ArcMap project.
Calculate Rates	 The **Calculate Rates** tool launches a dialog box populated with a selectable list of change-rate statistics to be calculated.
Data Visualization	 The **Data Visualization** tool includes options to alter the change-rate color options or generate a copy of the specified transect file that is clipped to the shoreline change envelope (SCE).
Shoreline Forecasting	 **Shoreline Forecasting** applies a statistically based model called the Kalman filter, which combines observed shoreline positions and model-derived shoreline positions to predict future shoreline position with an associated uncertainty.
DSAS Help	 Launches a link to DSAS v5 help resources.
About DSAS	 **About DSAS** provides information about the software, including the version number.

5. Required Inputs

Data requirements are presented in this section, including file format and field attributes that are necessary for DSAS to properly recognize and compute rate-of-change statistics. Instructions for producing the required files and field elements are also described.

5.1 Geodatabase

All DSAS input data must be imported and managed within a personal geodatabase, which also serves as the storage location for the DSAS-generated feature-class output files. DSAS requires data to be in meter units and in a projected coordinate system (such as Universal Transverse Mercator or State Plane). Finally, all shorelines and baseline files used in analysis must reside in the same geodatabase, or rates will not calculate, and a warning message will appear.

5.1.1 Creating a New Geodatabase

Follow the steps below to create a new personal geodatabase. Once a geodatabase has been created, existing data can be imported as individual feature classes into the geodatabase within ArcCatalog. More information can be found by using the keywords “importing data geodatabase” in ArcGIS Desktop Help.

1. Open ArcCatalog and navigate to the desired data storage location in the file tree.
2. Right-click on the folder where the geodatabase will be stored.
3. Navigate to New >> Personal Geodatabase in the popup menu.

5.1.2 Upgrading a Preexisting Geodatabase

DSAS v5.1 has been tested for compatibility with ArcGIS 10.4, 10.5, 10.6, and 10.7. Each ArcGIS version includes updates and improved geodatabase capabilities. Geodatabases created in earlier versions of ArcGIS must be upgraded to the current version.

For example, the user must upgrade a geodatabase in ArcGIS 9.3 before the data can be used in ArcGIS 10. This can be done in ArcCatalog by right-clicking on the geodatabase, selecting “Properties” from the popup menu, and clicking on the Upgrade Geodatabase button, as illustrated in figure 2 (this will also inform you of version status of the geodatabase). You may also choose to create a new geodatabase in the current version of ArcGIS and copy existing features from the preexisting geodatabase. Keep in mind, transects generated in prior versions (DSAS v4.x) must be upgraded before being used in DSAS v5 (see **section 6.5**).

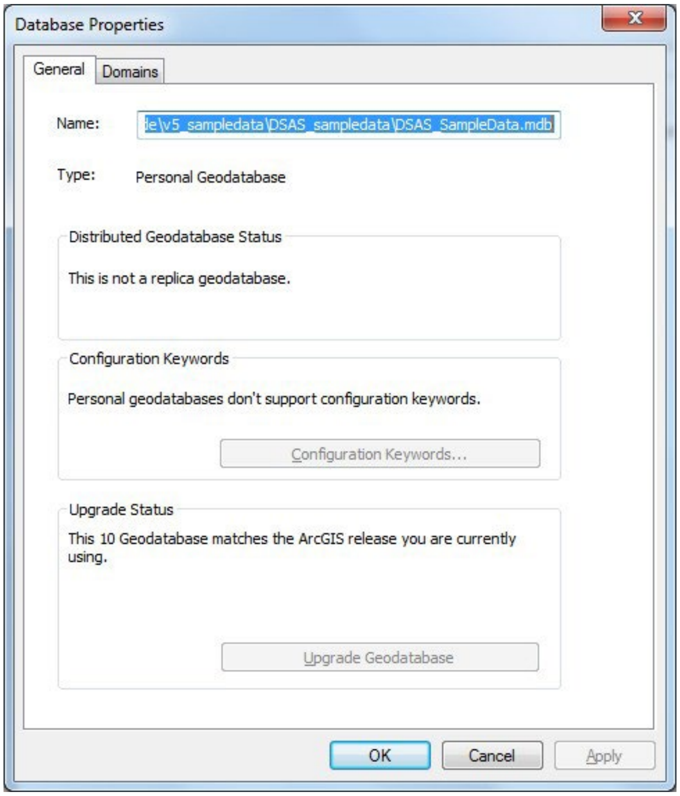


Figure 2. The database properties window, which provides information on the status of the geodatabase version. If a geodatabase is viewed from a previous version of ArcGIS, this window provides the option to upgrade to the current version so that the geodatabase and ArcGIS version match as required by the Digital Shoreline Analysis System.

5.2 Shorelines

Guidelines on collecting shoreline data are provided in this section as well as a list of the necessary attribute fields users must create in the shoreline feature class. All shoreline data must reside in a single feature class within a personal geodatabase. If the shorelines are collected as shapefiles, they must be in the same projection, appended or merged into a single file, and then imported into a geodatabase within ArcCatalog. DSAS also requires that the feature class be in meter units in a projected coordinate system and meet the attribute field requirements described in **section 5.2.1**.

5.2.1 Checklist of Shoreline Requirements

- Must be a feature class within a personal geodatabase.
- Must be in a projected coordinate system in meter units.
- An individual shoreline date may consist of a single line or be a collection of segments.
- Must meet the “Shoreline Attribute Field Requirements” (**section 5.2.4**).

5.2.2 Tips for Collecting Shoreline Data

Shoreline positions can reference any consistent linear feature such as the vegetation line, the high-water line, the low-water line, or the wet/dry line. The shorelines can be digitized from a variety of sources (for example, digital orthophotos, georeferenced historical coastal-survey maps, or satellite imagery), collected by global-positioning-system field surveys, or extracted from light detection and ranging (lidar) surveys. It is strongly recommended that initial data-preparation steps be taken to reference all shoreline vectors to the same feature (for example, mean high water) before use of DSAS to compute change statistics. See **section 13** (app. 2) for an example of how to reconcile horizontal offsets between different shoreline proxies. Although any single shoreline proxy may be used with DSAS, using data from more than one proxy type (without use of a proxy-bias correction) to generate statistics is not recommended.

Each shoreline vector represents a specific position in time and must be assigned a date in the shoreline feature-class attribute table. The measurement transects that are cast by DSAS from the baseline intersect the shoreline vectors. The points of intersection provide location and time information used to calculate rates of change. The distances from the baseline to each intersection point along a transect (fig. 3) are used to compute the selected statistics.

The calculated rates of change provided by DSAS are only as reliable as the input shoreline data. To better quantify the statistical reliability of the computed rates, users must account for measurement and sampling errors when compiling each shoreline position (Anders and Byrnes, 1991; Crowell and others, 1991; Thieler and Danforth 1994; Moore 2000). Users have the option of specifying for each shoreline an overall uncertainty value, which should account for both positional and measurement uncertainties. See **section 5.2.5** and refer to Morton and others (2004), Morton and Miller (2005), Hapke and others (2011), and Ruggiero and others (2013) for additional examples of how to calculate an overall shoreline uncertainty. The shoreline uncertainty is incorporated into the calculations for the standard error, correlation coefficient, and confidence intervals, which are provided for the simple and weighted linear regression methods (linear regression rate [LRR] and weighted linear regression [WLR] attributes in rate file, respectively). For any shoreline vectors assigned an uncertainty value of zero or null, DSAS uses the default uncertainty value specified by the user in the Set Default Parameters window. Refer to **section 6.2.2** for more information.

DSAS also requires that the shoreline feature class be in meter units in a projected coordinate system (for more information, within ArcMap refer to Help >> ArcGIS Desktop Help). Note that you may use the new DSAS Attribute Automator tool (**section 6.1**) to add the user-created fields described in **section 5.2.3**.

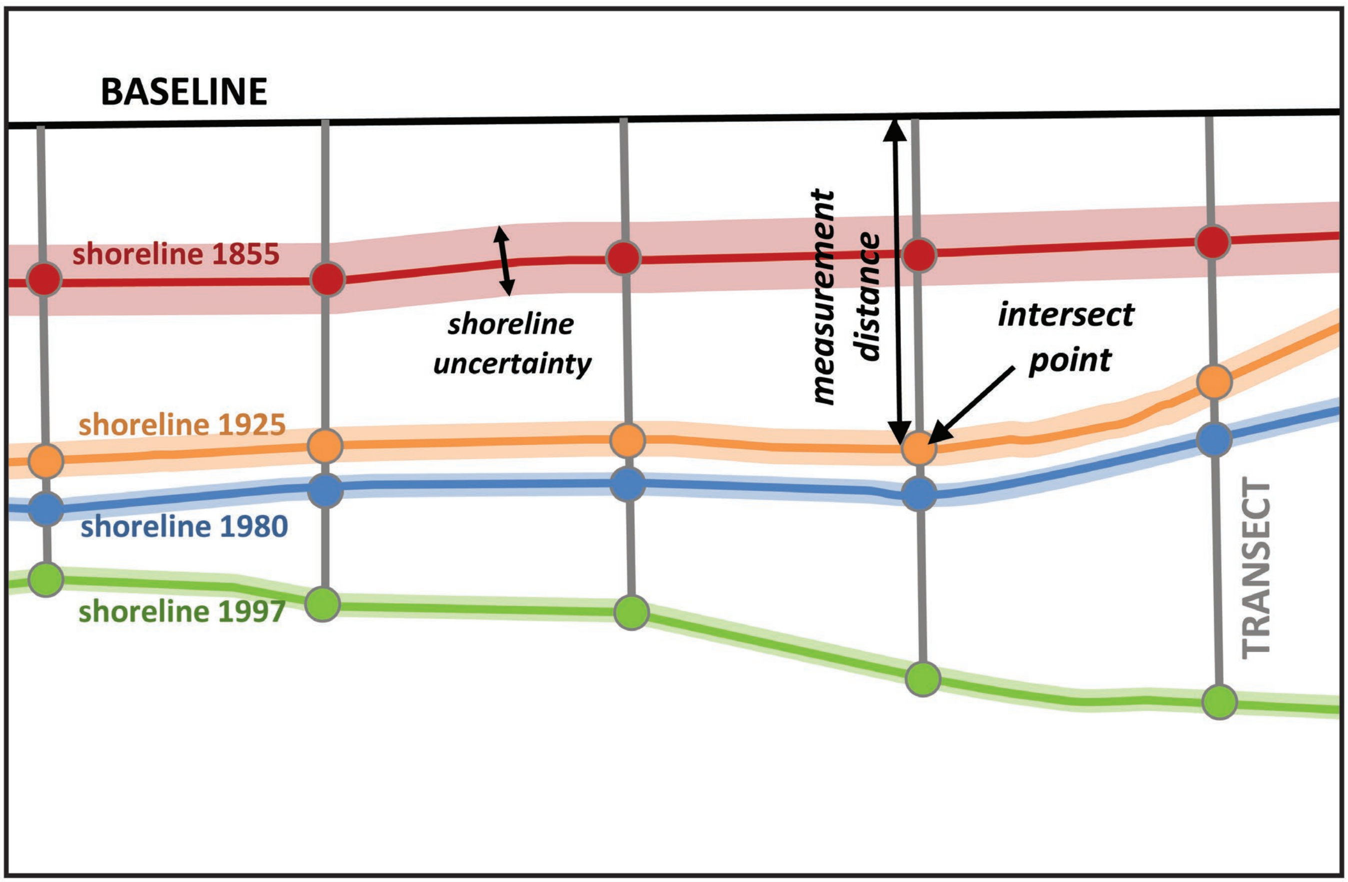


Figure 3. Shoreline and baseline shapefiles, with Digital Shoreline Analysis System (DSAS)-generated measurement transects. The measurement distance from the baseline to each intersect point is used in conjunction with the corresponding shoreline date to compute change-rate statistics.

5.2.3 Shoreline Attribute Field Requirements

Shoreline data must be formatted with the appropriate attributes for use within DSAS. Table 3 identifies the required field names and data types of the attributes, while table 4 provides a description of each attribute.

Table 3. Shoreline attribute field requirements for Digital Shoreline Analysis System (DSAS) version 5.

Field name	Data type	Attribute addition	DSAS requirement
OBJECTID	Object identifier	Autogenerated	Required
SHAPE	Geometry	Autogenerated	Required
SHAPE_Length	Double	Autogenerated	Required
DATE_(DSAS_date)[1]	Text (length=10 OR length=20)	User-created[1]	Required
UNCERTAINTY (DSAS_uncy)[1]	Any numeric field	User-created[1]	Required
SHORELINE_TYPE (DSAS_type)[1]	Text	User-created[1]	Optional (unless dataset includes the proxy-datum bias, in which case this field is required)

[1]These fields can be added using the Attribute Automator tool, described in **section 6.1**.

Table 4. Descriptions of shoreline attribute fields for Digital Shoreline Analysis System (DSAS) version 5.

Attribute Field	Description
DATE_	The date field is required but not name specific, meaning it can be named DATE_, DSAS_date or any other user-defined name. A character length of 10 is required for shoreline change spanning days, months or years, where dates are required to be formatted as mm/dd/yyyy. A character length of 20 is required for shoreline data spanning different hours within the same day, where dates are formatted as mm/dd/yyyy hh:mm:ss (using either 24-hour time or AM/PM). *Note: The computer's date format must be set to English (USA) mm/dd/yyyy.*
UNCERTAINTY	The uncertainty field is required but not name specific, meaning it can be named UNCERTAINTY, DSAS_uncy, or any other user-defined name.
SHORELINE_TYPE	The shoreline type field is used to specify the proxy or elevation datum the shoreline is referenced to (mean high water or high-water line). It is a required field as part of the proxy-datum bias (PDB) correction when proxy-based and datum-based shorelines are combined to compute shoreline change rates. It is not name specific (for example: DSAS_type). See **section 6.2.2** for more information on the PDB. *Note: If no PDB data are used, this field is optional.*

5.2.4 Merge Tool: Shorelines

All shoreline positions that are to be used in the change-rate analysis must reside in a single feature class in the geodatabase. The following steps describe how to merge multiple feature classes into a single feature:

1. Confirm all shoreline files have the same spatial reference (meter units in a projected coordinate system) and the required shoreline attribute fields have been created and populated with data. For example, use caution when merging shorelines if the date field is not complete.
2. Open the Merge tool from ArcToolbox (Data Management Tools >> General >> Merge).
3. Add the shoreline feature classes to the input features list in the Merge window. This tool can be used on feature classes in a geodatabase as described but can also be used to merge data from multiple shapefiles and then imported into the geodatabase.
4. Specify a new output file as the combined (merged) shoreline.

5.2.5 Calculating Shoreline Positional Uncertainty

For shoreline change statistics to be computed, each shoreline must have a positional uncertainty associated with it. Shorelines come from different data sources, and the various process steps from the source data to the line represented on the map contribute to the overall uncertainty of that shoreline position. The calculated rates of change provided by DSAS can only be as reliable as the measurement and sampling errors accounted for when compiling each shoreline position (Anders and Byrnes, 1991; Crowell and others, 1991; Thieler and Danforth, 1994; Moore, 2000). The uncertainty value should ideally account both for positional uncertainties associated with natural influences over the shoreline position (wind, waves, and tides) and measurement uncertainties (for example, digitization or global-positioning-system errors). Ruggiero and others (2013) provide a comprehensive methods summary of analyzing shoreline change that includes a detailed section on the estimation of shoreline position uncertainty, as well as guidance on how to combine the various components of uncertainty into a single value that could be added as an attribute for shoreline data.

If the uncertainty attribute field is empty, DSAS uses the default value stored in the Shoreline Settings tab of the Set Default Parameters window (described in **section 6.2.2**).

5.3 Baseline

Proper baseline construction guidelines are provided in this section, and the necessary attribute fields users must create within the baseline feature class are listed. DSAS uses a measurement baseline method (Leatherman and Clow, 1983) to calculate rate-of-change statistics for a time series of shorelines. The baseline is constructed by the user and serves as the starting point for all transects cast by the DSAS application. Transects intersect each shoreline to create a measurement point, and these measurement points are used to calculate shoreline change rates.

5.3.1 Checklist of Baseline Requirements

- Must be a feature class within a personal geodatabase.
- Must be in a projected coordinate system in meter units.
- May consist of a single line or be a collection of segments.
- Must meet the “Baseline Attribute Field Requirements” (**section 5.3.3**).

5.3.2 Tips for Constructing a Baseline

In previous versions of DSAS, a reference baseline segment had to be placed adjacent to the series of shoreline positions, entirely onshore or offshore. In DSAS v5, the baseline can be drawn anywhere relative to the shoreline vectors: onshore, offshore, midshore between and among the shorelines, or a combination of positions (fig. 4). Transects will still be cast perpendicular (orthogonal) to the baseline at a user-defined spacing and will intersect the shorelines to establish measurement points on one or both sides of the baseline.

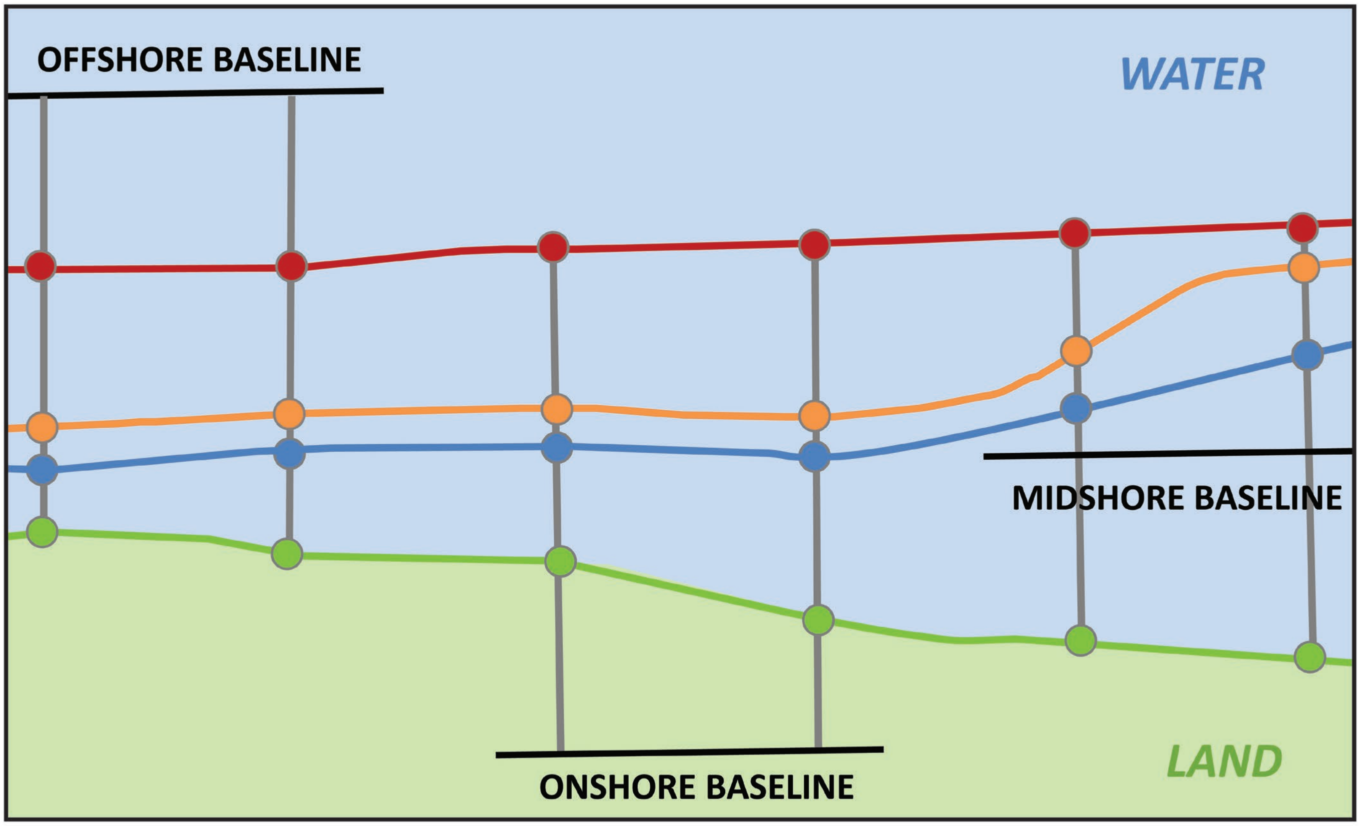


Figure 4. An example of how to place a baseline onshore, offshore, or through the data (midshore). The resulting transects will intersect the shorelines, regardless of placement. Baselines in a dataset may be all of one type or a combination of all three.

The orientation of a transect through the shorelines depends on the position of the baseline (fig. 5) and the smoothing distance used to cast transects. The trend of the baseline with respect to the shorelines influences the angle at which the transects intersect the shorelines and can affect shoreline change rates. Edits to baseline orientation with respect to the shoreline trend should be completed before casting transects.

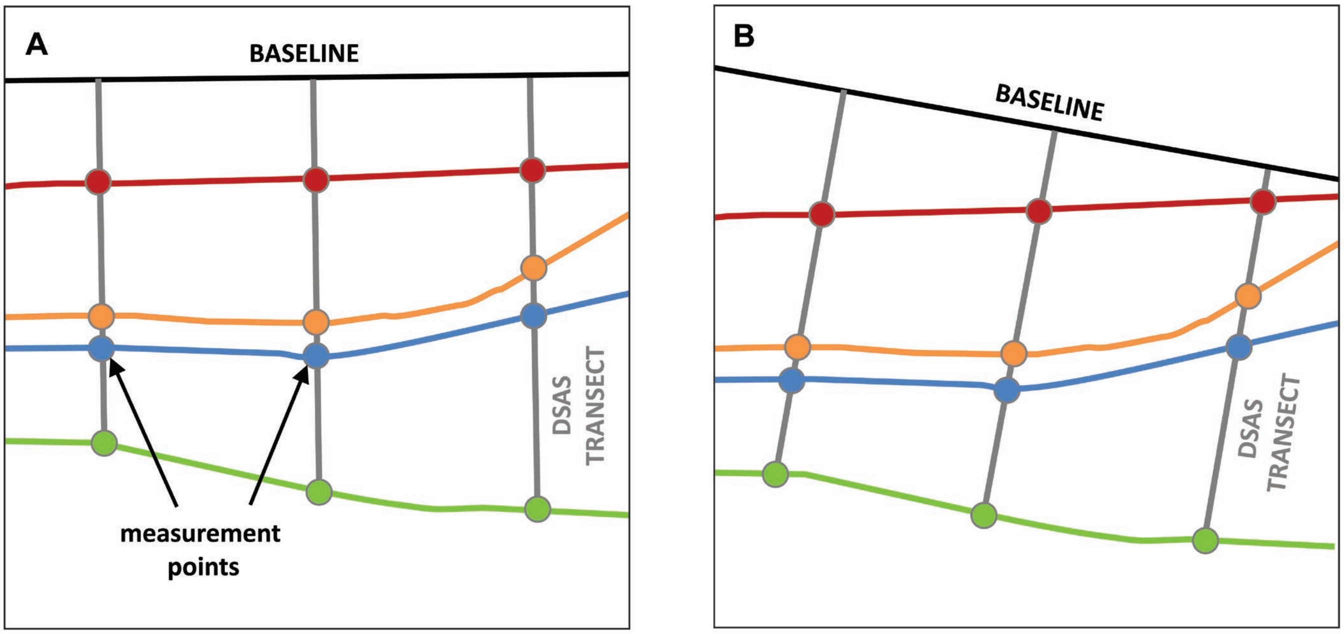


Figure 5. Two examples of how baseline orientation/placement can affect how the Digital Shoreline Analysis System (DSAS) transects intersect a shoreline. *A*, A baseline parallel to the shoreline trend is ideal, whereas *B*, a baseline oblique to the shoreline trend is not ideal.

5.3.3 There Are Three Ways To Create a Baseline:

1. Start with a new feature class.
2. Smooth or buffer an existing shoreline.
3. Update an existing baseline.

Approach One: Start With a New Feature Class

Create a new personal geodatabase in ArcCatalog by right-clicking on the destination folder in the file tree and choosing New >> Personal Geodatabase. Once you have a geodatabase, right-click on it and choose New >> Feature class. Provide a name (for example, "baseline") and choose Line Features from the drop-down menu under "Type of features stored in this feature class." Click the Next button and define the coordinate system. DSAS requires data to be in a projected coordinate system using meter units.

Once your baseline feature class is created, you can add it to an ArcMap project. Begin an edit session with the target being set to the new baseline feature class. Manually draw and edit the line using standard ArcMap editing tools. Refer to the ArcGIS Desktop Help menu for further instructions by entering "lines," "vertices," or "moving features" as keywords.

Approach Two: Smooth or Buffer an Existing Shoreline

Generate a baseline from an offset or a smoothed version of an existing shoreline. Select one of the shoreline segments that best represents the general trend of all shorelines. To buffer, refer to the ArcGIS Desktop Help menu for how to (1) create a buffer and isolate it from the shoreline feature class, (2) convert the polygon buffer to a polyline, and (3) split and remove unwanted segments. Suggested keywords are "buffering selected graphics," "copying features," "splitting features," and "polygon to line." To smooth, refer to the ArcGIS Desktop Help menu for more detailed information on the Smooth Line (Cartography) tool available in ArcToolbox.

Approach Three: Use a Preexisting Baseline

DSAS v5 recognizes baselines created in previous versions if the feature class meets the field requirements described in "Baseline Attribute Field Requirements" (**section 5.3.6**). The baseline may be constructed landward, seaward, or through the middle of the shorelines (fig. 4). If a baseline is not recognized by DSAS, follow the troubleshooting steps in **section 12** (app. 1). *Note: Regardless of baseline origin, all edits to the baseline should be completed before casting transects. DSAS v5 no longer supports dynamic topology, so any changes made to the baseline after transects are cast are not applied to previously generated transects.*

5.3.4 Baseline Placement

DSAS v5 supports a baseline located anywhere—offshore, onshore, or in the middle of the shoreline data (midshore). Because of this increased functionality, there are changes to the baseline component of the Set Default Parameters window from prior versions of DSAS. Previously, transect length was set to a single value specified by the user. In v5, DSAS searches from either side of the baseline for shoreline data and extends transects to a length that intersects all shoreline data within range. If the baseline is exclusively onshore or offshore, the search behavior can be modified by clicking the option under "Baseline placement," and DSAS will only search on the specified side for shorelines.

5.3.5 Baseline Search Distance Field

New in DSAS v5 is an optional baseline attribute called the Baseline Search Distance Field. Transects are cast by searching out from the baseline, either by using the Maximum Search Distance From Baseline (in Cast Transect settings) or the Baseline Search Distance Field. In some areas, the user may want to restrict or modify the transect length to prevent DSAS from selecting adjacent shoreline data. Adding a search distance attribute (for example, DSAS_search) allows the user to enter a unique value for the search distance for each baseline segment (see **section 6.2.1**).

5.3.6 Baseline Attribute Field Requirements

The attribute field requirements for the baseline provide necessary information to DSAS about the alongshore order of transects and optional information about the grouping of transects (to provide rate averages); and a new (optional) field which allows the user to specify a unique search distance for each baseline segment (tables 5 and 6).

Table 5. Baseline attribute field requirements in the Digital Shoreline Analysis System (DSAS) version 5.

Field name	Data type	Attribute addition	DSAS requirement
OBJECTID	Object identifier	Autogenerated	Required
SHAPE (alias: Shape)	Geometry	Autogenerated	Required
SHAPE_Length (alias: Shape_Leng)	Double	Autogenerated	Required
ID	Long integer	User-created	Required
Group (DSAS_group)	Long integer	User-created	Optional
Search_Distance (DSAS_search)	Double	User-created	Optional

Table 6. Descriptions of baseline attribute fields in the Digital Shoreline Analysis System (DSAS) version 5.

Field name	Description
ID	The baseline identifier (ID) field is required field that is not name specific. DSAS uses this value to determine the ordering sequence of transects when the baseline feature class contains multiple segments. If this attribute field is created prior to drawing baseline segments, the ID value defaults to zero. The attribute table must be edited, and a unique ID value must be designated for each segment of the baseline. It is best to have baseline segment IDs in order alongshore. DSAS will not cast transects along baseline segments where the ID value is zero.
GROUP	The group field is an optional field that is not name specific, meaning it can be named GROUP, DSAS_group, or any other user-defined name. This field is to be used for data management purposes only. Providing a group attribute will not affect any of the change statistics provided within DSAS or returned in the rate feature class. New to DSAS version 5, the summary report text file that is generated each time rate calculations are run uses the group attribute field to provide rate averages for each group. See **sections 6.2.1** and **9**.
SEARCH DISTANCE	The search distance field is an optional field that is not name specific (for example: DSAS_search). It provides users with an option to set a search distance, in meters, that DSAS will use to search for shorelines, extending out from either side of the baseline. The distance value can be unique for each baseline segment depending on the organization of shorelines with respect to the baseline. In some shoreline configurations, it will be necessary to specify different search distances for each baseline segment. For example, islands and barrier islands or areas with recurved shorelines could be assigned a small distance value to prevent shorelines on the opposite side of the island from being included. Values populated in this field will override the Maximum Search Distance From Baseline value entered in Cast Transects settings. For more information on search distance, see **section 6.2.1**.

5.4 Proxy-Datum Bias Information

The development of many features in DSAS has been influenced by the needs of the USGS's National Assessment of Shoreline Change project (Morton and others, 2004; Morton and Miller, 2005; Miller and others, 2005; Hapke and others, 2006, 2011; Hapke and Reid, 2007; Ruggiero and others, 2013). One of these needs is to calculate the rate of change using multiple shoreline features derived from various data sources. For example, proxy-based high-water line (HWL) shorelines are often included in the same dataset as datum-based mean high water (MHW) shorelines. Since it has been shown that HWL shorelines are landward of MHW shorelines (Ruggiero and List, 2009), this mixing of shoreline types within a dataset can lead to incorrect estimates of the rate of change. The unidirectional offset between these two shoreline types is called the proxy-datum bias (PDB), and it can be estimated from wave and slope data (Ruggiero and List, 2009).

DSAS has the capability to ingest user-provided PDB values to shift the HWL shorelines so that they can be directly compared to MHW shorelines, resulting in a more accurate estimate of shoreline change rates. When the PDB correction is applied by DSAS, distance values for the proxy-based HWL (stored in the intersect shapefile) are shifted seaward by using the PDB value stored in the bias feature. DSAS uses the adjusted distance measurements to determine shoreline change rates along the transect. Both the adjusted distance and the nonbias (NB) distance values are stored in the final intersect output file. For more information on how the proxy-datum bias is created, calculated and applied, see **section 13** (app. 2).

5.4.1 Shoreline Type (attribute)

The shoreline type field is required when using the proxy-datum bias. DSAS requires an input of either MHW or HWL to the Shoreline Type field in order to perform the PDB correction correctly. Other inputs will result in an error message.

5.4.2 Bias Feature

New to DSAS v5.1, the bias feature is a polyline shapefile that holds the proxy-datum bias information (including bias and the bias uncertainty) for a location. DSAS uses the bias information from the bias feature and applies the offset to the intersect values. If used, the bias feature must be stored in a personal geodatabase with the shoreline and baseline files. For more information on creating the proxy-datum bias feature, see **section 13**.

5.4.3 Using the Proxy-Datum Bias in DSAS

To implement the proxy-datum bias in DSAS, a user must assign each shoreline segment with the shoreline type attribute (MHW or HWL) and provide a bias feature. The user must add the bias feature into the map project containing the baseline and shoreline data. The feature will then be selectable in the Shoreline Settings tab of the Default Parameters (see **section 6.2.2**). When rates are calculated, DSAS will use values stored in the bias feature to perform the proxy-datum bias correction.

The outputs generated by DSAS that are affected by the proxy-datum bias are as follows:

1. Rate transect outputs: Two versions of each user-selected statistic are reported in the attribute table of the rate transects—one with the bias applied, and one without the bias applied. Statistics without the bias applied will have a “NB_” (NB is short for nonbias) preceding the statistic heading. For example, “NB_LRR” does not have the PDB correction applied.

2. Intersect outputs: The intersect feature class is a point file that stores positional information about each transect/shoreline intersection. When the PDB is applied, additional attributes are added to the intersect feature-class output, including the value of PDB applied, PDB uncertainty, and the new distance to the PDB corrected shoreline value.

For a full list and description of the DSAS-generated rate transect and intersect output attributes, see section 6.7.4.

6. DSAS Workflow

Once the required geodatabase and input feature classes have been created or imported from shapefiles and properly attributed, DSAS can be used within ArcMap to establish transect locations and calculate change statistics. Figure 6 shows a typical DSAS workflow.

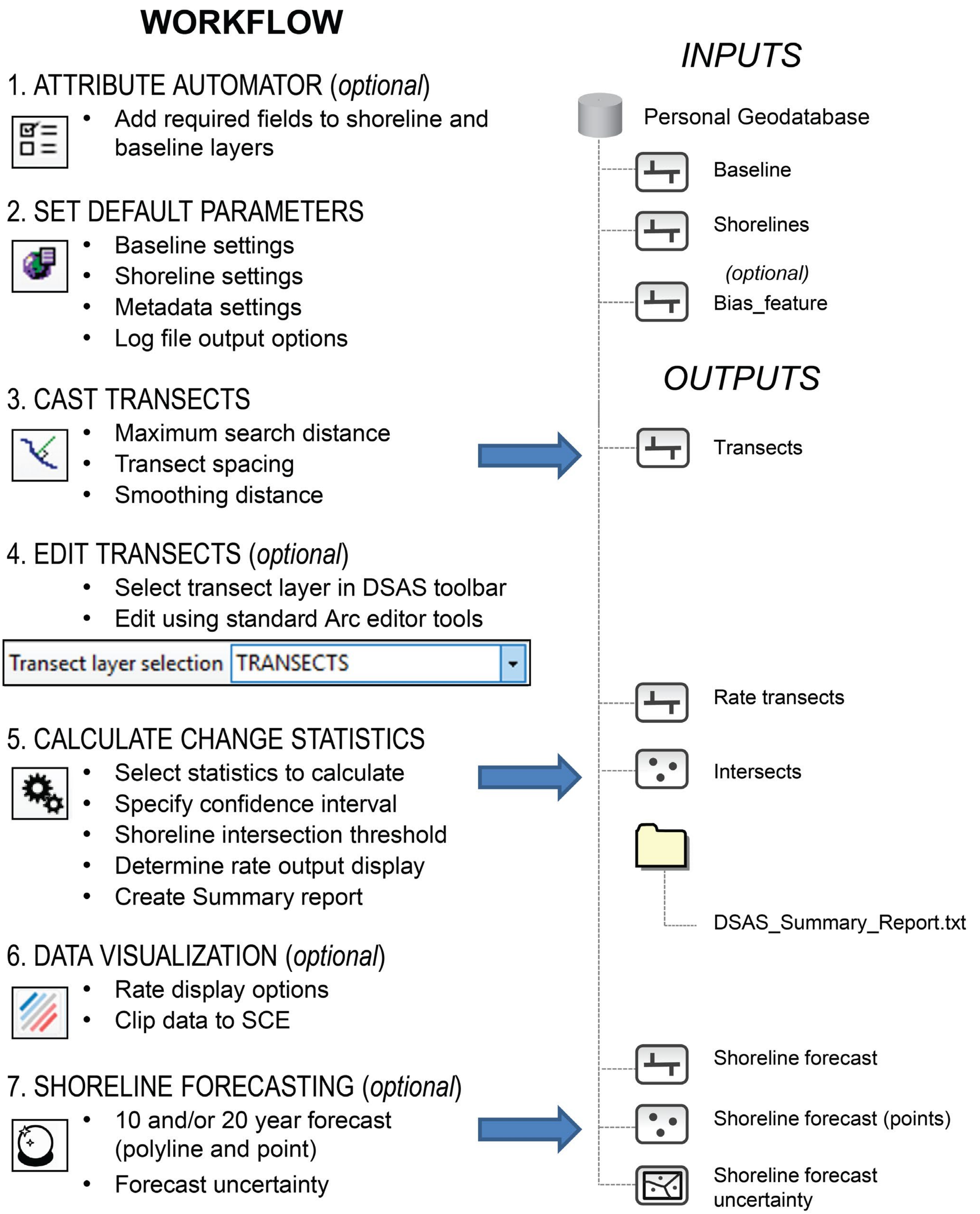


Figure 6. The Digital Shoreline Analysis System (DSAS) workflow with steps necessary to establish transects and compute change-rate statistics. SCE, shoreline change envelope.

6.1 Attribute Automator

In the Attribute Automator interface (figs. 7 and 8) the user may click a button and automatically add required fields to shoreline and (or) baseline data layers. With one or more shoreline layers selected, the user can add a date field (default is DSAS_date), an uncertainty field (DSAS_uncy), and a field indicating shoreline type (DSAS_type). These fields can then be populated from existing data in the shoreline file by using the standard ArcMap field calculator or edited to include new information. For baseline files, required fields such as the ID field name (DSAS_ID) and optional fields such as the group field (DSAS_group) and the search distance field (DSAS_search) can be added as well. See **sections 5.2** and **5.3** for complete descriptions of each field.

Note: Adding attribute fields to shoreline or baseline feature classes through this tool is an optional step provided by DSAS as a convenience. If the required fields are already in place (even if they use a different field name), this step may be skipped.

Figure 7. The Digital Shoreline Analysis System (DSAS) version 5 toolbar showing the Attribute Automator icon selected.

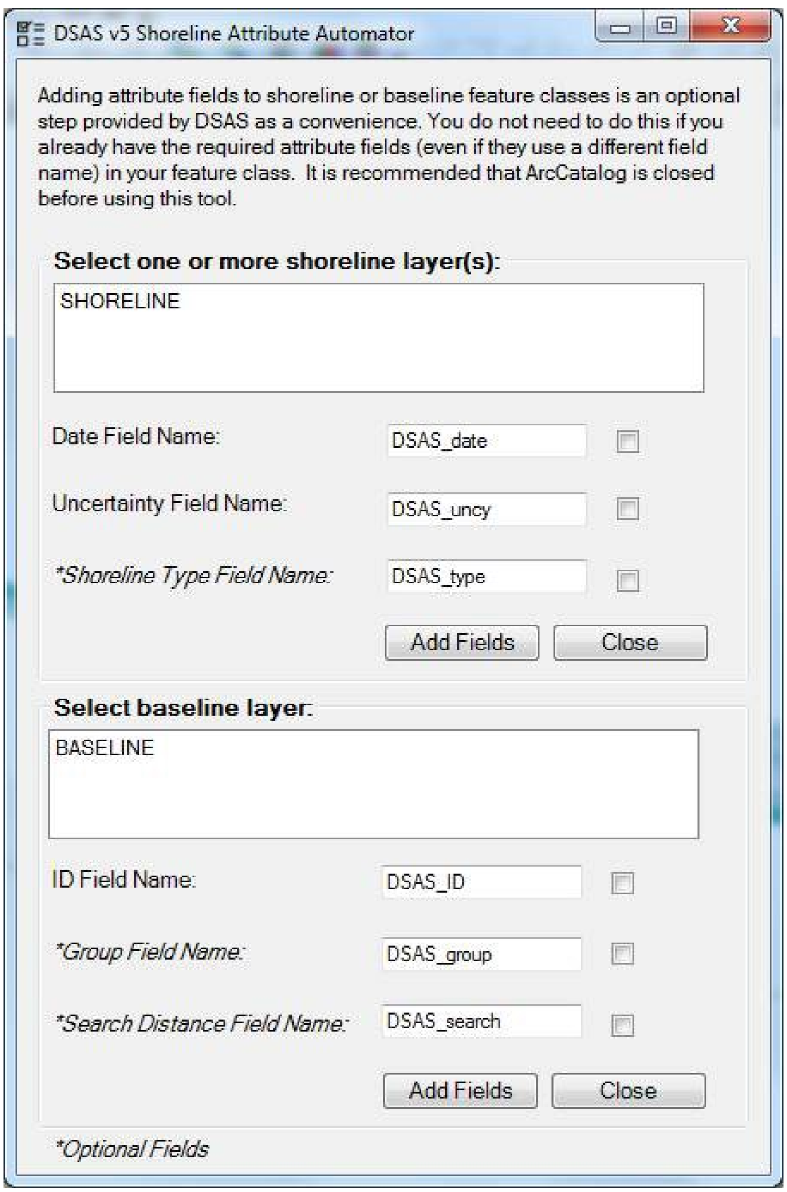


Figure 8. The Attribute Automator user interface within the Digital Shoreline Analysis System (DSAS) version 5.

6.2 Set Default Parameters

Before generating transects and calculating rates of change, shoreline and baseline information must be entered in the Set Default Parameters window. This window can be accessed from the DSAS toolbar (fig. 9) and contains three tabs:

- Baseline Settings (**section 6.2.1**),
- Shoreline Settings (**section 6.2.2**), and
- Metadata Settings (**section 6.2.3**).

At any time while filling in the default parameters, the user may cancel (discarding any information entered and closing the window) or click “OK” (saving the entered information as the default parameters).

Figure 9. The Digital Shoreline Analysis System (DSAS) version 5 toolbar with the Default Parameters icon selected.

6.2.1 Baseline Settings Tab

The Baseline Settings tab (fig. 10) is one of the three components of the Set Default Parameters window. These settings manage the baseline fields and location of land relative to the baseline. The following options are available in the tab.

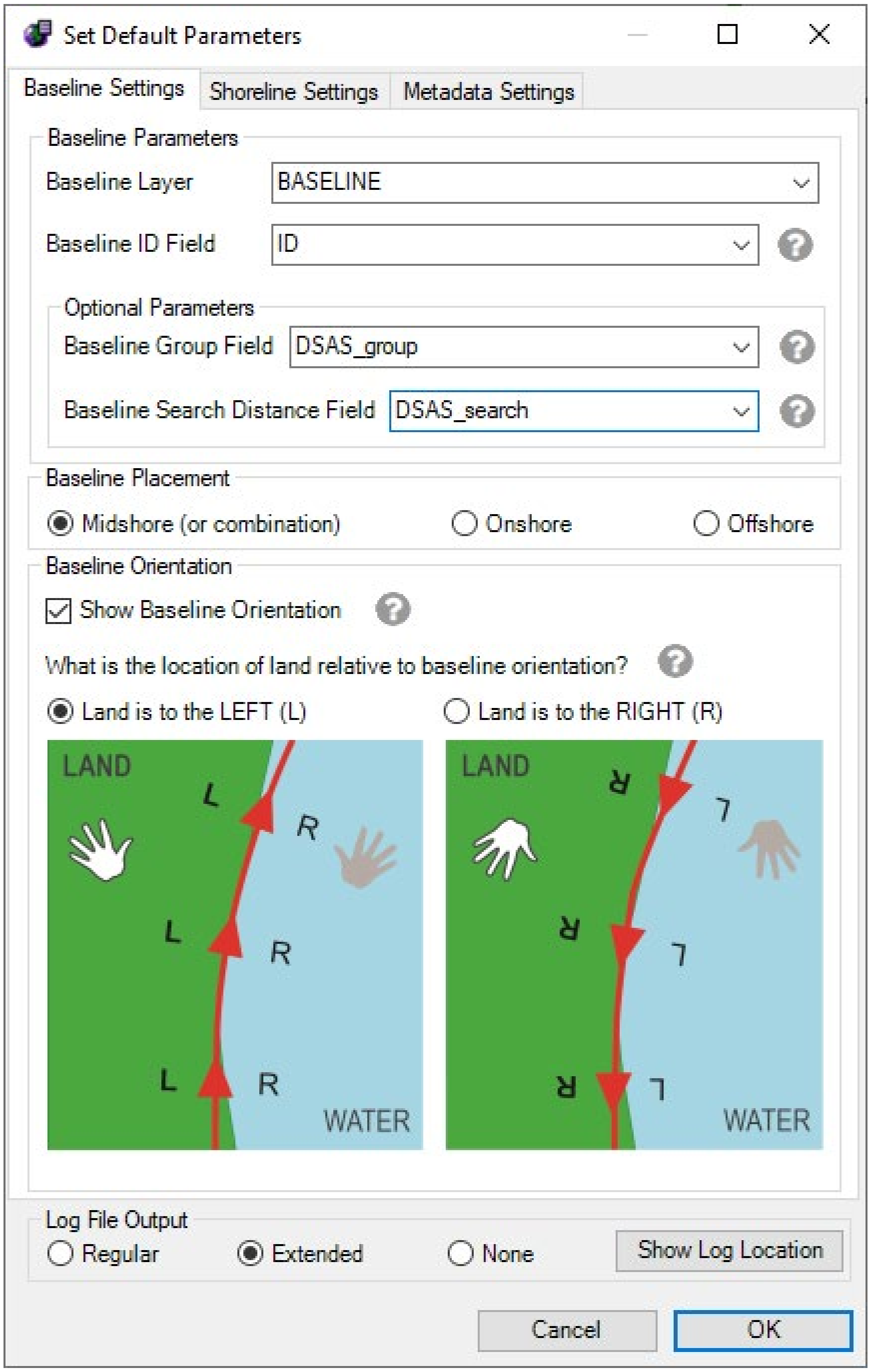


Figure 10. The Set Default Parameters window, showing options in the Baseline Settings tab.

Baseline Layer

Select the baseline layer to be used (for example, the “baseline” feature class in the sample data). It is one of the required input feature classes within the geodatabase.

Baseline ID Field

The baseline identifier (ID) field is a required field that is not name specific. DSAS uses this value to determine the ordering sequence of transects when the baseline feature class contains multiple segments. If this attribute field is created prior to drawing baseline segments, the ID value defaults to zero. The attribute table must be edited, and a unique ID value must be manually designated for each segment of the baseline. For best results, it is recommended that the baseline segment IDs are in order alongshore. If IDs are out of order, rates will generate, but certain attribute values (such as the total cumulative distance alongshore, TCD) will not be accurate. DSAS will not cast transects along baseline segments where the ID value is zero.

Baseline Group Field (Optional)

The group field, which is optional, can be used to help organize the results of the rate calculations. For example, the user may want to group a series of baselines into a subregion of interest. A group value may be assigned to each baseline segment, and multiple baseline segments can have the same value. This setting has no effect on the transect output but, rather, influences the way the statistics are reported in the DSAS summary report (see **section 9**).

Baseline Search Distance (Optional)

The optional Baseline Search Distance Field allows a user to set a unique search distance for each baseline segment. This configuration may be useful when a large search distance is needed for one section of the study area but only a small distance is required in another area (fig. 11*A*). The Baseline Search Distance Field (for example, DSAS_search) may be added by using the Attribute Automator tool in the DSAS toolbar (see **section 6.1**) or added manually to the baseline attribute table with a user-specified name. Defining a unique Baseline Search Distance for each baseline segment is one of two ways the user can define the search distance for casting transects. The other is to set a single Maximum Search Distance From Baseline (which applies to all baseline segments) in the Cast Transect settings. See **section 6.3.3** for additional details.

The following steps describe how to use the Baseline Search Distance Field:

1. Use the DSAS Attribute Automator tool to add the Baseline Search Distance Field (for example, DSAS_search) to the baseline file. Once DSAS_search is added, begin an edit session, open the baseline attribute table, and edit the search values so they are large enough to reach the shoreline data farthest from the baseline. Ensure that each baseline segment has a unique ID and that the order of segment is sequential. Save edits. (See note about baseline segmentation and ID order below).

2. From the Baseline Settings tab within the Set Default Parameters window, select DSAS_search for the Baseline Search Distance Field (fig. 11*B*).

3. DSAS will now use the value(s) in DSAS_search to search for shorelines and cast transects. If blank or <Null> values are present, the Maximum Search Distance From Baseline will be applied.

Note: To split the baseline into new segments, begin an edit session and use the “split tool” to cut the baseline into segments based on the need for search distance control. When a baseline is split, the two resulting segments retain the same identifier (ID). The baseline ID value must be manually edited following the original baseline direction. Verify that the baseline ID order is correct before casting transects, as this will influence the order in which they are sequenced alongshore.

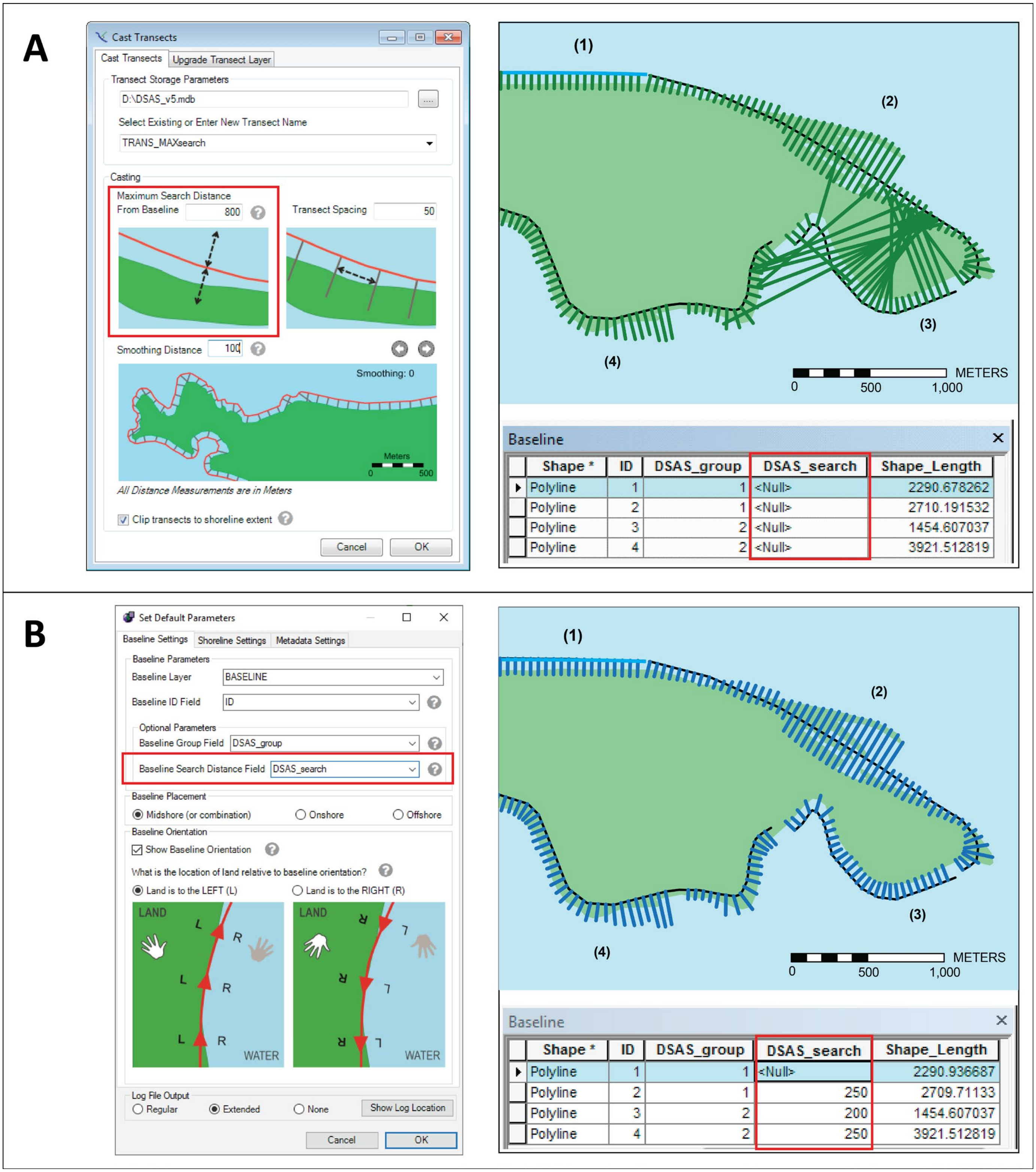


Figure 11. The location of search distance settings within the Digital Shoreline Analysis System (DSAS) version 5: *A*, Maximum Search Distance from Baseline (in the Cast Transects window). Where the attribute DSAS_search (shown in the Baseline attribute table) has <Null> values, or there is no search attribute, the search distance will be used, and *B*, the Baseline Search Distance Field (in the Set Default Parameters window). When DSAS_search is selected in Baseline Settings, DSAS uses the value recorded in the Baseline attribute “DSAS_search” and will override any value in Cast Transects (Maximum Search Distance). In the map on the right, numbers beside the baseline segments refer to the ID value, which correlates to the Baseline attribute table.

Baseline Placement

In DSAS v5, transects are cast by searching on either side of the baseline for shorelines. If the “midshore (or combination)” option for baseline placement is selected, DSAS will search on either side of the baseline for shorelines. If, however, the user has a baseline that is exclusively onshore or offshore, selecting either of these options for baseline placement will instruct DSAS to search only on the specified side for shorelines.

Baseline Orientation

The Baseline Orientation section allows the user to display and determine the direction that the baseline is pointing from start to end (baseline flow) and the orientation of the baseline with respect to land. Clicking the “show baseline orientation” button adds arrows showing the direction of flow and “Left/Right” (or L | R) symbology to the baseline in the map. Unclicking the box removes the symbology. Baseline direction arrows allow a user to visualize the direction of baseline flow to ensure that all baseline segments flow in the same direction. Baseline direction can be flipped in a standard Arc editing session by double-clicking the segment with the Edit tool in the Editor toolbar, then right-clicking; the option to flip will appear in the popup window (fig. 12). After ensuring that baseline flow is consistent, the location of land relative to baseline orientation can be determined.

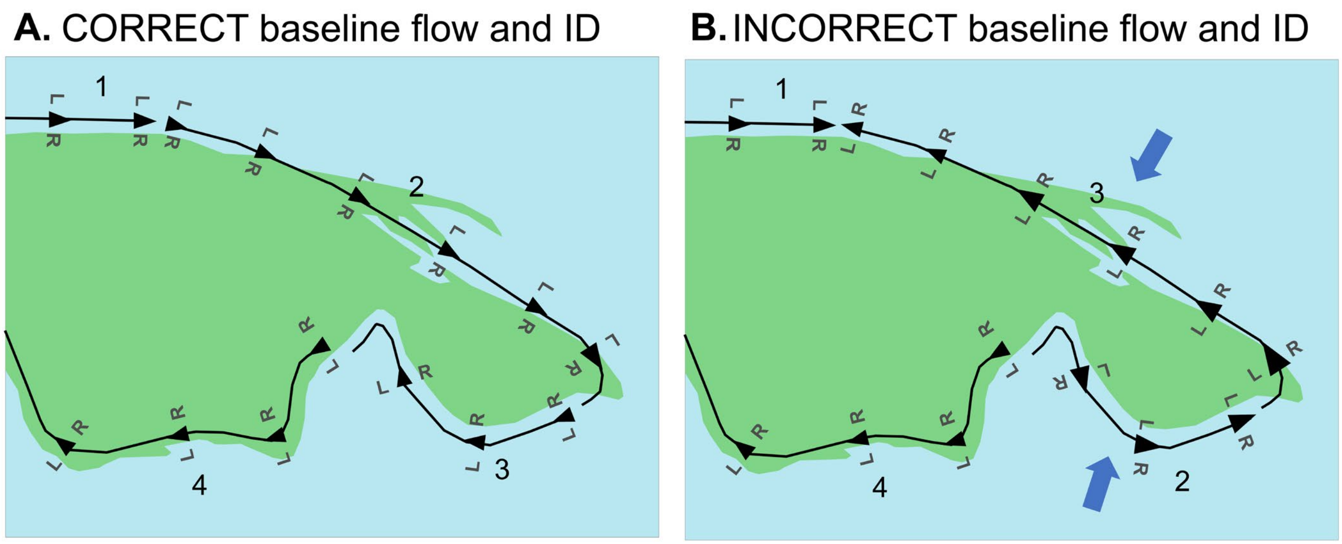


Figure 12. Baseline flow direction and orientation illustrated by clicking “Show Baseline Orientation” (Set Default Parameters: Baseline Settings), where *A*, all baseline segments and identifier (ID) values are flowing in the same direction and *B*, two baseline segments (indicated with a blue arrow) need to be flipped, and baseline ID values need to be corrected.

Identify the Location of Land Relative to Baseline

In DSAS v5, the user must indicate the location of the land relative to the baseline orientation. Clicking the “show baseline orientation” button and viewing the “L | R” symbology helps the user identify whether land is oriented predominantly to the left (L) or to the right (R) of the baseline. See figure 13 for examples of land orientation with respect to baseline. In some cases, the user must close the Set Default Parameters window and zoom in to their data to observe the correct orientation.

DSAS follows the convention that a negative rate implies erosion (landward movement of shoreline), and a positive rate implies accretion (seaward movement of shoreline). The orientation requirement ensures the proper sign (positive or negative) is attached to the calculated rates by establishing a landward/seaward orientation regardless of baseline placement (onshore, offshore, or midshore).

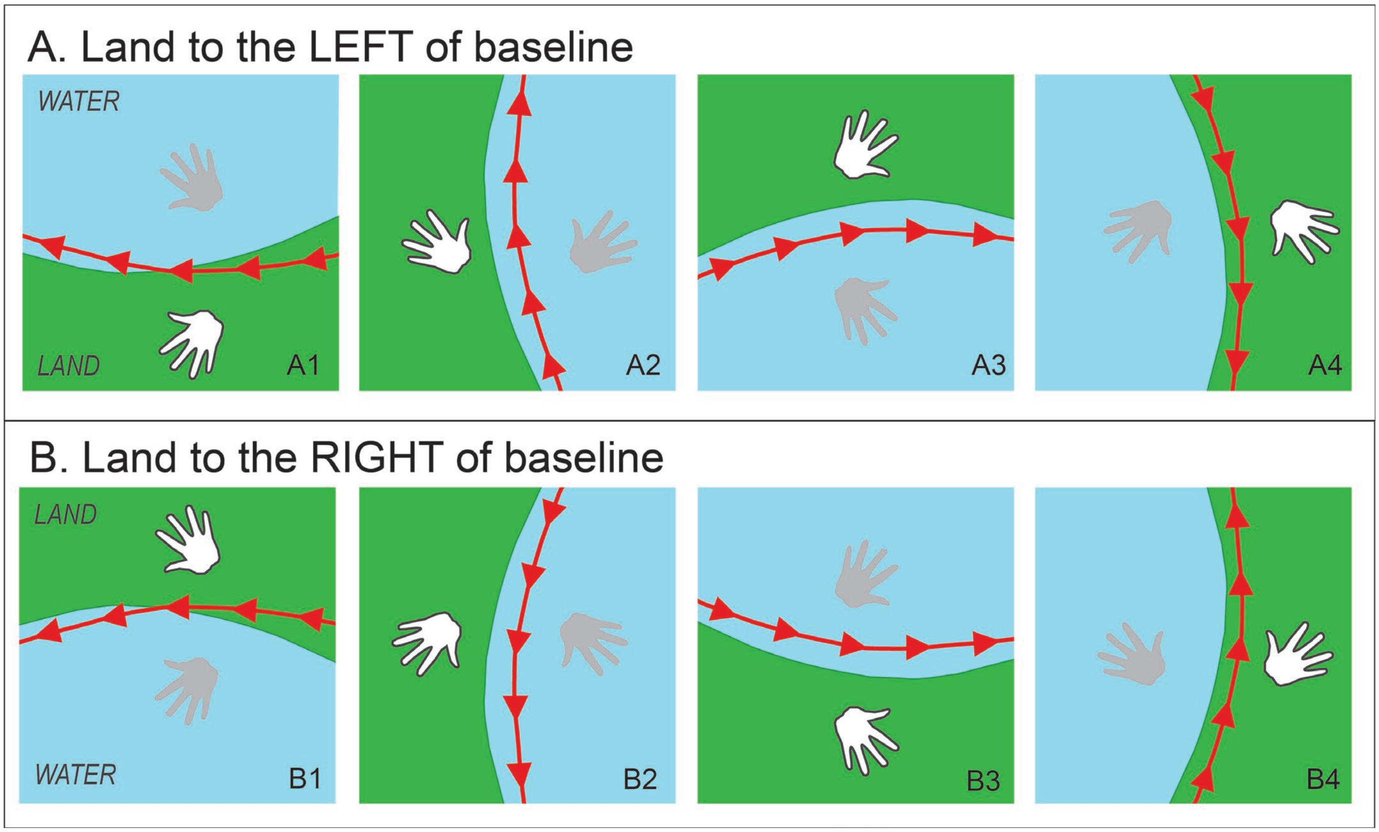


Figure 13. Examples of land oriented *A*, left of baseline and *B*, right of baseline.

6.2.2 Shoreline Settings Tab

The Shoreline Settings tab (fig. 14) is one of the three components of the Set Default Parameters window. These settings specify the shoreline attribute fields containing the date and shoreline uncertainty values. The following options are available in the tab.

Figure 14. The Set Default Parameters window, showing options in the Shoreline Settings tab. Note: Bias Parameters will only appear if a bias feature (holding the proxy-datum bias [PDB] data) is detected by the Digital Shoreline Analysis System (DSAS).

Shoreline Layer

Specify the shoreline layer in the drop-down menu to be used in rate calculations (fig. 14). All shorelines must reside in a single feature class. Individual shorelines can be selected from this feature class by using standard ArcMap selection methods to compute shoreline rates of change for a subset of the whole dataset. See **section 6.6** for more information.

Shoreline Date Field (DSAS_date)

Specify the field that stores date information within the shoreline feature class. DSAS_date is the default, but user-specified fields are also accepted. Field requirements are described in **section 5.2.3**.

Shoreline Uncertainty Field (DSAS_uncy)

Select the field storing the positional/measurement uncertainty value(s) within the shoreline feature class. DSAS_uncy is the default, but user-specified fields are also accepted. Field requirements and tips for calculating uncertainty can be found in **sections 5.2.3** and **5.2.5**.

Default Data Uncertainty

If the shoreline uncertainty field (for example, DSAS_uncy) is not populated, DSAS will use a default data uncertainty value. The USGS provides a suggested default value of 10 meters, which is the approximate average of uncertainty of various shoreline data types used in recent regional reports that the U.S. Geological Survey has published under the National Assessment of Shoreline Change project. Where possible, users are strongly encouraged to perform a quantitative assessment of the positional uncertainty (see **section 5.2.5**) associated with each shoreline they are using and enter this as the value in the uncertainty attribute field. The default value provided by DSAS may overestimate or underestimate the uncertainty of any given dataset. The user may also choose to enter a different default uncertainty value that will be applied to all shorelines within a dataset.

Intersection Parameters

If a DSAS transect crosses the same shoreline more than once, this parameter determines which intersection is used. The "seaward" and "landward" options in the Shoreline Settings tab allow the user to control which intersection is used for analysis, should the transect encounter multiple instances of the same shoreline date (fig. 15). These terms were "closest" and "farthest" in DSAS v4.x but have been updated to better represent the relationship of the baseline to land given that the baseline may be onshore, offshore, or midshore in DSAS v5. Choosing the seaward option instructs DSAS to use the intersection that is most seaward from land when a transect crosses the same shoreline date more than once (fig. 15*A*), and choosing the landward option instructs DSAS to use the intersection that is most landward (fig. 15*B*).

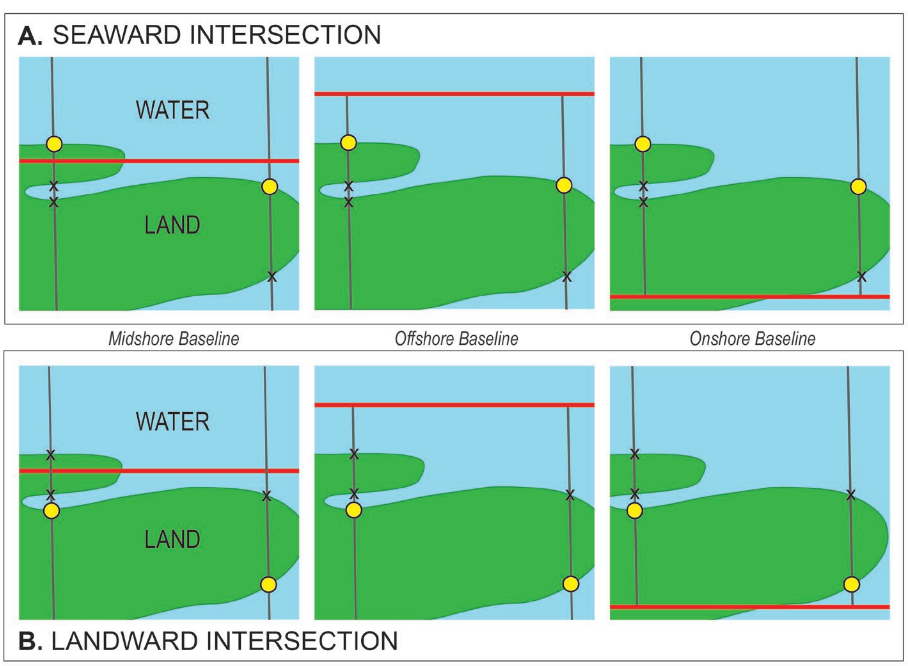


Figure 15. Intersection parameters (baseline is red, transects are gray) displaying the options for shoreline intersect (yellow dot) as *A*, seaward or *B*, landward. For the seaward selection (*A*), only the most seaward intersection (yellow dot) is used by the Digital Shoreline Analysis System (DSAS) in rate calculation; all other intersections (X) are ignored. The same principle applies to the landward intersection examples (*B*).

Bias Parameters (Advanced—Using PDB)

The Bias Parameters section of the Shoreline Settings tab is for users including proxy-datum bias (PDB) data in their analysis. These options will not appear unless DSAS detects the bias feature in the ArcMap project.

Shoreline Type Field (DSAS_type)

The shoreline type drop-down menu is used to select the shoreline type attribute (for example, DSAS_type) within the shoreline feature class. It is a required field when using the PDB correction to compute shoreline change rates.

Bias Feature

The bias feature allows DSAS to compute rate-of-change statistics for shorelines referenced to different shoreline features. The bias feature is identified here in the Bias Parameters section of the tab along with the shoreline type field. For additional information, see **section 5.4** and **section 13** (app. 2).

6.2.3 Metadata Settings Tab

Metadata are an important component of data integrity and maintenance. Capturing metadata in a format that meets accepted standards facilitates data distribution, enables replication of work, and provides automatic record-keeping for the analysis. DSAS generates Federal Geographic Data Committee (FGDC)-compliant metadata with minimal user input for all feature-class files output in the program workflow (transects, rate transects, intersects, and all shoreline forecasting elements). Metadata generated by DSAS are structured to meet the FGDC Content Standard for Digital Geospatial Metadata (CSDGM) version 2.0. The metadata record contains standardized data elements as well as a description of the process steps performed by DSAS to generate the transect feature class, compute change-rate statistics, and run the beta shoreline forecasting. The Metadata Settings tab (fig. 16) minimizes the amount of input needed from users by restricting it to standard data elements (for example, "Abstract," "Purpose," and "Contact Information") that are often specific to organizational users. Additional metadata information is provided in a template used by DSAS and appends basic information about DSAS to any data product produced by the software.

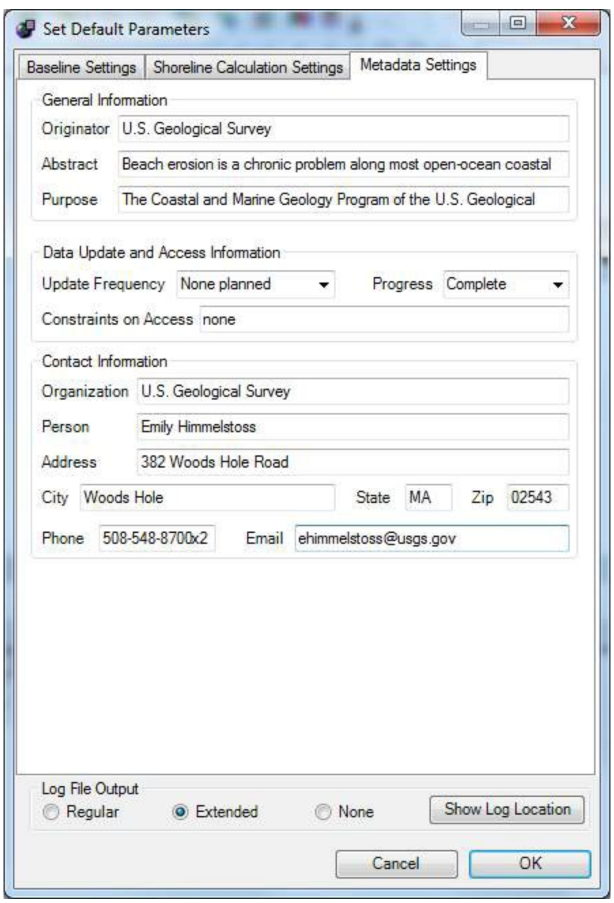


Figure 16. The Set Default Parameters window showing the required fields populated with example text in the Metadata Settings tab.

The metadata file is written in Extensible Markup Language (XML) format to the same geodatabase as the DSAS-generated output feature classes (transects, intersects, rates, shoreline forecasts, and uncertainty). DSAS captures all variables defined by the user in the three tabs of the Set Default Parameters window on the DSAS toolbar and automatically adds the bounding coordinates, spatial reference information, and attribute definitions. Several of the user-specific fields under the Metadata Settings tab of the Set Default Parameters window require input for DSAS to construct a complete metadata file that meets the FGDC CSDGM standard. Once a user has entered this information, DSAS retains it for future use. There are no restrictions on the metadata record after it is generated, so users may modify the existing file by using a metadata editor of their choice.

The metadata record will be compliant with the FGDC CSDGM version 2.0 content standard only if the user provides information for all fields under the Metadata Settings tab. For more information on the content standard, visit https://www.fgdc.gov/metadata. See **section 10** for more information on viewing and editing the DSAS-generated metadata file in ArcCatalog.

General Information

- **Originator:** the individual or organization responsible for creation of the dataset.
- **Abstract:** provides background information on the project and study area.
- **Purpose:** a general description of the shoreline dataset and the intended uses.

Data Update and Access Information

- **Update Frequency:** select from drop-down options how often transects will be updated.
- **Progress:** choose from drop-down descriptions the appropriate status of the transect dataset.
- **Constraints on access:** describe any restrictions or legal prerequisites for using the data.

Contact Information

- **Organization:** the name of the organization responsible for the data.
- **Person:** the individual within the organization who is using DSAS to cast transects.
- **Address:** contact information for the organization and (or) individual.

6.2.4 Log File Output

At the bottom of the DSAS Set Default Parameters window is an option to generate a log file (see figs. 10, 14, and 16). When the DSAS application is used to create a new transect file or to calculate change statistics, a suite of behind-the-scenes data-processing steps take place. These process steps can be written to a log file for bookkeeping or troubleshooting purposes.

- Regular: Includes basic information about each process step. Useful for bookkeeping purposes.
- Extended: Includes more detailed information about each process step. Useful for troubleshooting purposes.
- None: No log file will be generated.

Show Log Location

The Show Log Location button (see figs. 10, 14, and 16) opens a new window to the folder where the log file is stored. DSAS creates a user-specific directory upon install and writes to this location. This was implemented to prevent potential issues with user permissions in protected folders. To save the log file, either copy and paste it to a new location prior to closing ArcMap and then rename the file or, from the log file, click File >> Save as and then save the new file to the desired location. Keep in mind that the log file is added to for successive runs within an ArcMap project but will be overwritten when a new ArcMap project is opened.

6.3 Cast Transects

Beginning with DSAS version 4.0, casting transects and calculating rates are two separate process steps, allowing the user to generate, preview, and edit transects prior to running shoreline change calculations.

The Cast Transects window is accessed via the DSAS toolbar (fig. 17). The DSAS v5 interface presents the user with options to specify the storage parameters and other details required for casting transects.

Figure 17. The Digital Shoreline Analysis System (DSAS) version 5 toolbar with the Cast Transects icon selected.

6.3.1 Transect Storage Parameters

DSAS automatically selects the geodatabase where the input feature classes (baseline and shoreline) are stored (fig. 18). The user may browse to a different geodatabase to save the measurement transects if desired; however, shorelines and baselines must reside in the same geodatabase. The geodatabase must match the version of ArcGIS used for the current project where rates are being calculated. See **section 5.1** for more information on geodatabases.

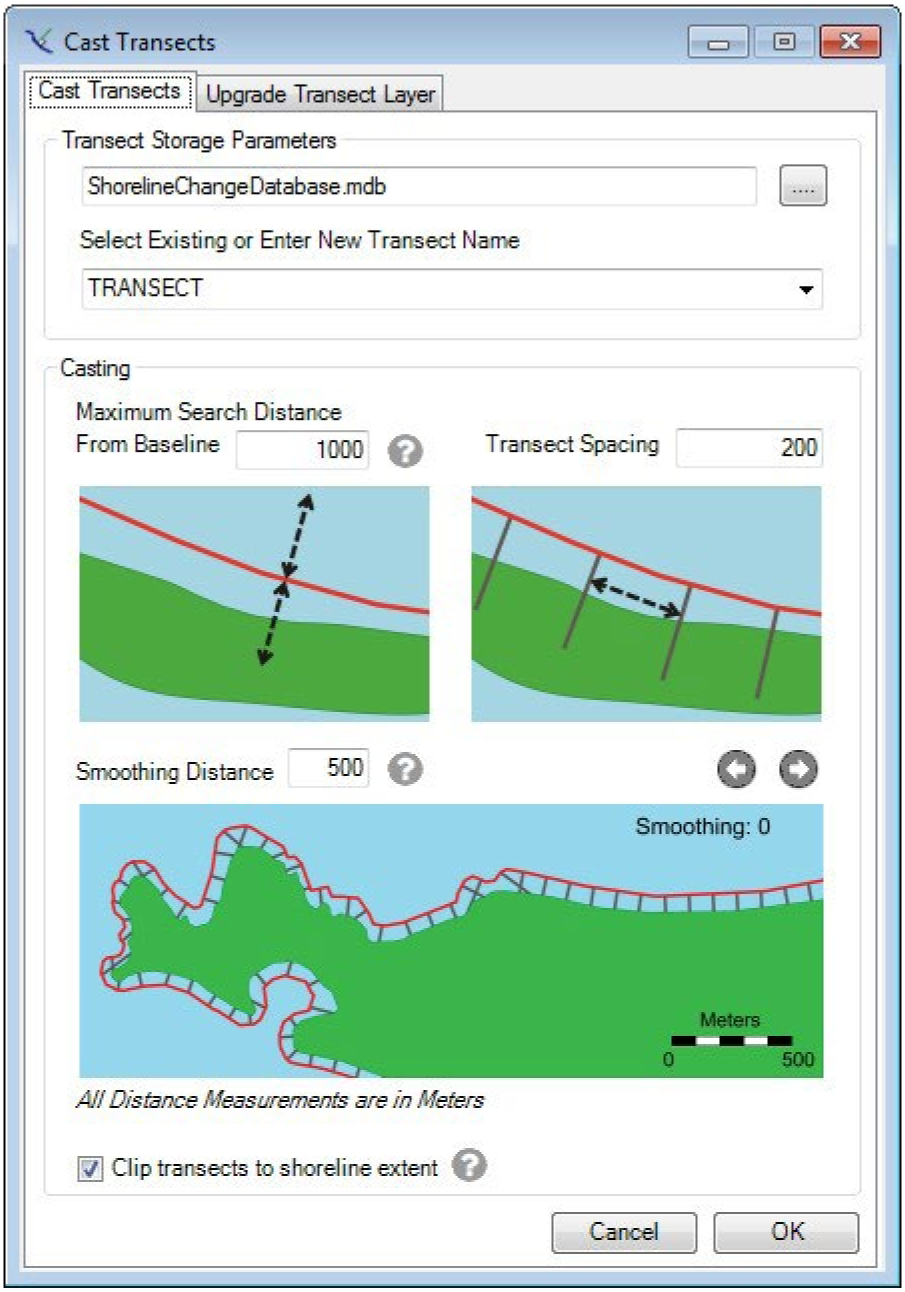


Figure 18. The Cast Transects window showing options for maximum search distance, transect spacing, and smoothing distance. Note: The gray arrows next to "Smoothing Distance" allow the user to pan through various examples of smoothing to determine the best option for their shoreline data (illustrated in fig. 19).

6.3.2 Transect Name

A new transect feature class is created by entering a name for the file in the space provided. (Esri conventions do not allow a feature-class filename to begin with a number, and the name must not contain spaces). There is a maximum character limit of 19 characters. If a transect file has already been created and added to the ArcMap project, it appears as a selectable option in the drop-down menu. If a transect layer is selected with a name that already exists, DSAS issues a prompt before overwriting the file.

6.3.3 Casting

The user inputs transect parameters to define the maximum search distance, transect spacing, and smoothing distance (fig. 18).

Maximum Search Distance

In DSAS v5, transects are cast by using a search distance from a baseline, which can be defined by the user in two places:

1. Baseline Search Distance Field (set in the Set Default Parameters window): The user sets this unique shoreline search distance value (in meters) for each baseline segment. See **section 6.2.1**.

2. Maximum Search Distance From Baseline (set in the Cast Transects window): This value (in meters) is set by the user to establish a single search distance for all baseline segments.

For example, if 50 is entered for a maximum search distance, DSAS searches up to 50 meters on either side of the baseline for shoreline data and ignores any data beyond 50 meters. See figure 11*A* for an example of the maximum search distance implementation. Although the use of maximum search distance in this example did not work for all baseline segments (prompting the use of the more specific Baseline Search Distance), the sections of the island where it did work illustrate that a single search distance can be useful in many settings.

Transect Spacing

The transect spacing variable allows the user to specify distance (in meters) between transects along the baseline. Spacing depends on the scale of the data and the intended scale of the output rate information.

Set Smoothing Distance

The user-specified smoothing value can facilitate an orthogonal transect/shoreline intersect by creating a supplemental baseline (not visible to the user) at the provided smoothing length, with the transect location at the midpoint. The intent of smoothing is to prevent transects from intersecting one another when the baseline has a curve. Examples of how smoothing distance values affect transect orientation are shown in figure 19. Larger smoothing values result in a longer reference line and produce more uniform transect orientations, particularly along relatively straight sections of coast (fig. 20). For curvy or sinuous coastlines, the smoothing distance should be longer than the width of the bends in the shoreline. Entering a smoothing value substantially longer than the extent of the baseline segment typically produces transects that are overly smoothed and are undesirably oriented parallel or nearly parallel to the baseline. Proper smoothing results in transects oriented nearly parallel to each other and perpendicular to the baseline. Within the Cast Transects window (fig. 18), there is an interactive graphic for smoothing distance that allows the user to pan through several smoothing examples to better understand how to determine the appropriate amount of smoothing for the input data.

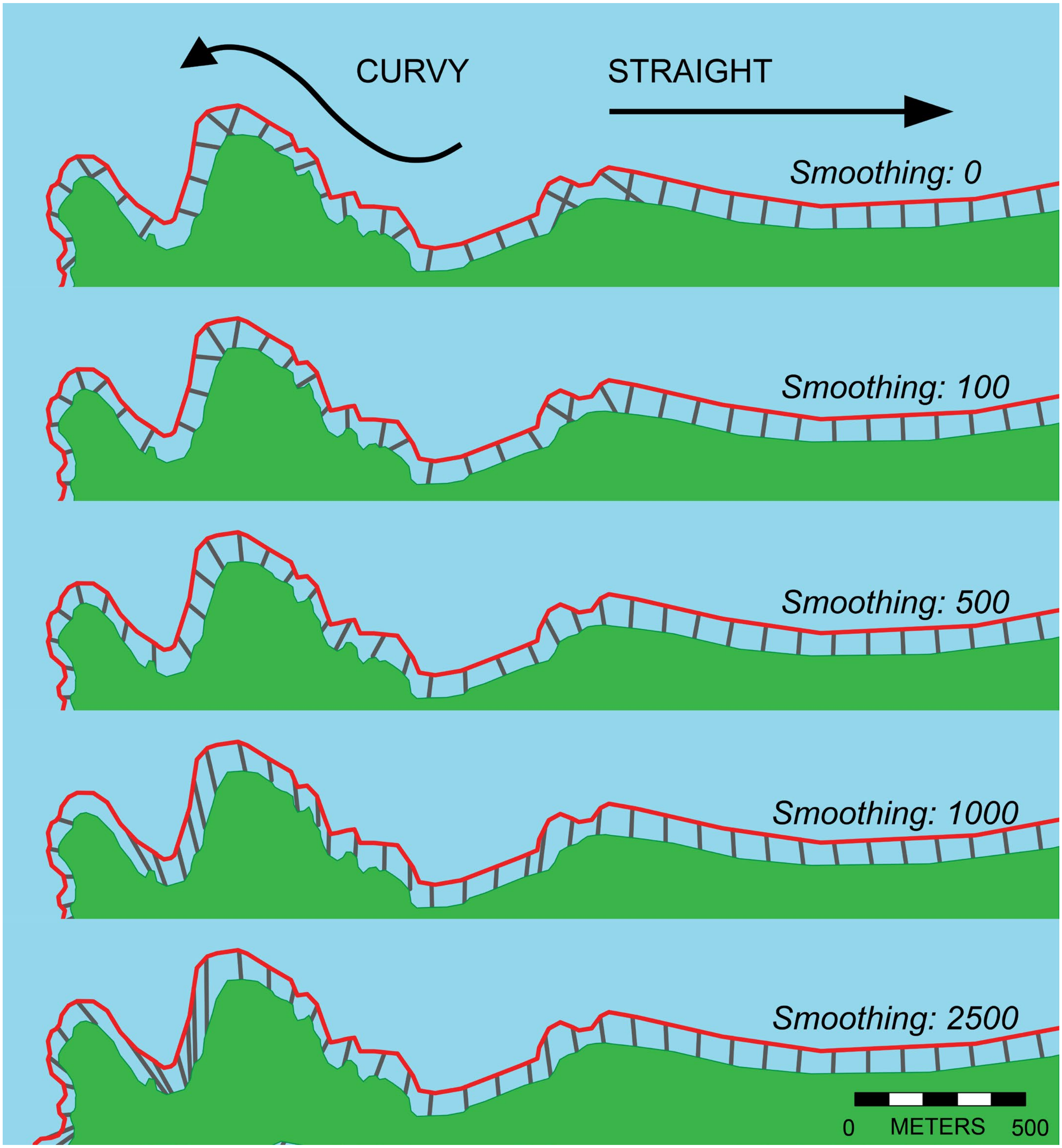


Figure 19. A sample of the interactive graphic in the Cast Transects user interface, showing how smoothing distance affects transect orientation on different types of coastline (curvy and straight). In this example graphic, a smoothing value of 500 meters is ideal to produce transects orthogonal to the coast in all areas and therefore to measure the appropriate shoreline change.

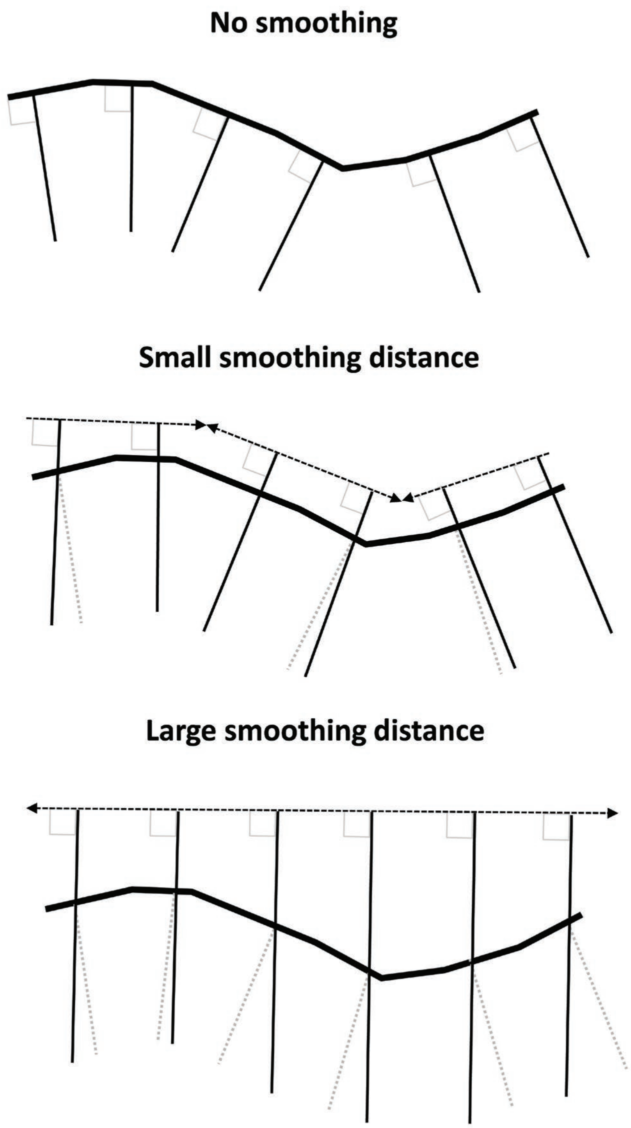


Figure 20. A simple cast (no smoothing) and transects cast by using small and large smoothing distances, which result in transects oriented more orthogonally from the baseline.

Clip to Shoreline Extent

In DSAS v5, transects are cast from the baseline and truncated to the shoreline extent if the “Clip transects to shoreline extent” box is checked in the Cast Transects window. To cast transects of uniform length, uncheck the box.

Using Select Features—Baseline

If a baseline segment is selected when transects are cast, DSAS ignores all unselected baseline features and casts transects only for the baseline selected (fig. 21).

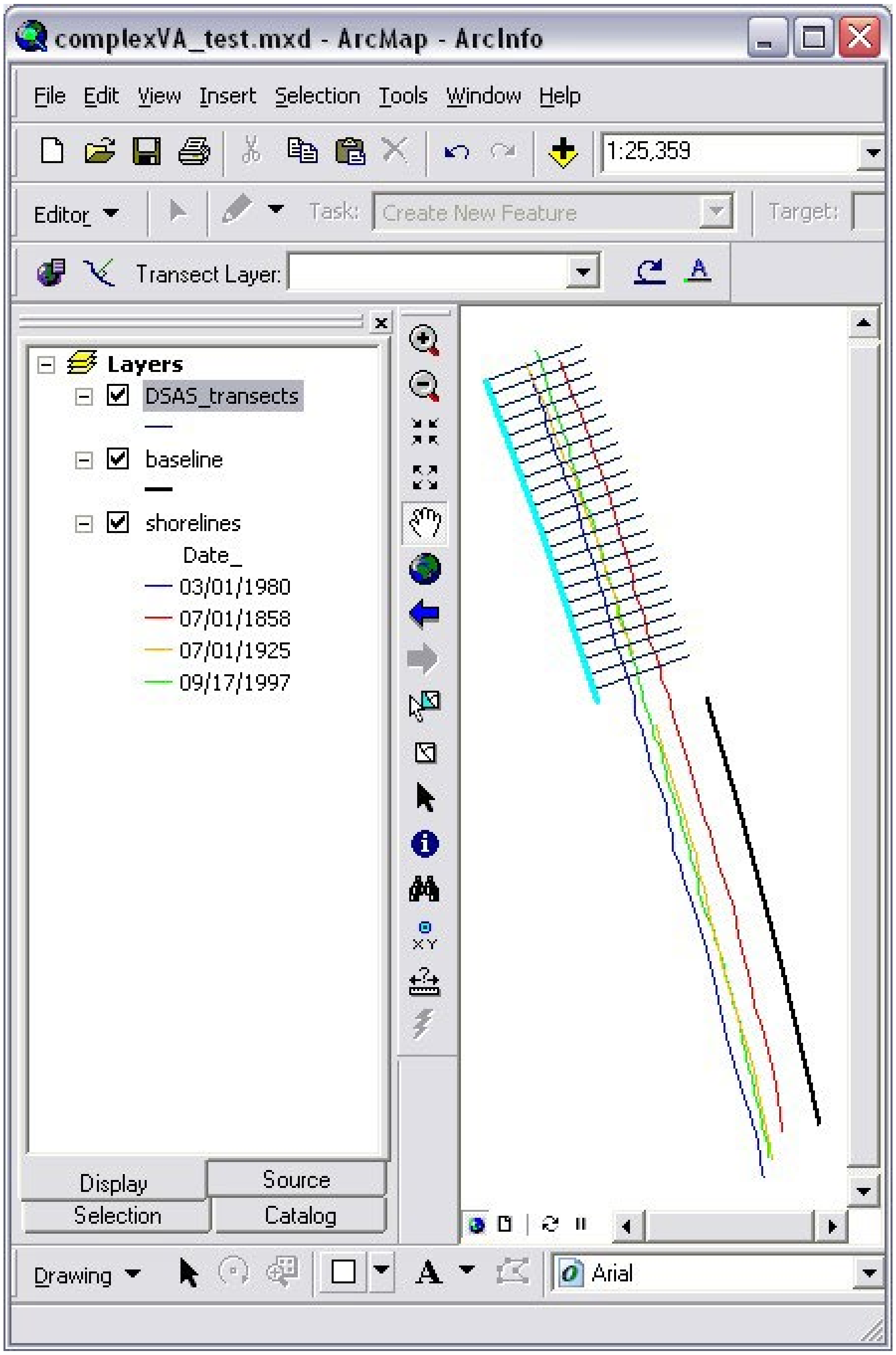


Figure 21. How selecting a baseline segment (shown here highlighted in blue) results in transects being created only for the selected feature. DSAS, Digital Shoreline Analysis System.

Transect Attribute Fields

DSAS generates a new set of measurement transects based on the settings specified by the user in the Set Default Parameters window. Before casting transects, DSAS checks the default parameter settings to ensure that the user has specified all required elements and that selected files or attribute fields will not result in a program error. The attribute fields generated for the transect feature class by DSAS are described in table 7.

Table 7. Description of Digital Shoreline Analysis System (DSAS)-generated transect attribute fields.

Field name	Data type	Field purpose
OBJECT IDENTIFIER	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique identifier (ID) for each row in the attribute table. This number is used by DSAS to relate all shoreline change results to transects. The field name may be called “ObjectIdentifier,” “ObjectID,” “OID,” or “FID.”
Geometry	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon). The field name may also be called “Shape.”
BaselineID	Long integer	Values in this field correlate to the baseline attribute field “ID” and are assigned by DSAS to identify the baseline segment used to generate the measurement transect. Baseline segments assigned an ID=0 are ignored by DSAS, and no transects will be cast along those line segments. See **section 5.3** for more information.
GroupID	Long integer	Values in this field correlate to the optional baseline attribute field “DSAS_group” and are used by DSAS if selected by user. This field is used to aggregate sections of the coast into groups. All transects within a group will have average summary statistics in the DSAS summary report. Refer to the baseline field requirements in **section 5.3.6** and a description of the summary report in **section 9** for more information.
TransOrder	Long integer	Assigned by DSAS on the basis of transect order along the baseline or baselines. If the user manually adds transects to the file in an edit session, they will be added to the end of the transect attribute table and given a new TransID (ObjectID). However, TransOrder will be updated to reflect the position of the new transect with respect to the other transects along the baseline. This field provides the user with a method to sort transect attribute data, from the start of the baseline segment (ID=1) incrementally (ID of each successive segment increasing by 1) to the end of the final baseline segment.
TransEdit	Text	Indicates whether a transect was automatically created by DSAS (0=transect was autogenerated by DSAS; 1=transect was added or edited by user).
Azimuth	Double	Used to record the azimuth of the transect measured in degrees clockwise from north.
SHAPE_Length	Double	Length of transect in meter units, assuming data were properly projected in a meter-based coordinate system. This field is automatically generated when data are within a geodatabase.

6.4 Modifying the Transect and Baseline Feature Classes

6.4.1 Editing Automatically Generated Transects

Transects can be edited in a standard ArcMap editing session, but new to DSAS v5 is the requirement that the transect field be selected in the DSAS drop-down menu prior to starting an edit session (fig. 22). In addition, the baseline and shoreline file must be defined in the default parameters.

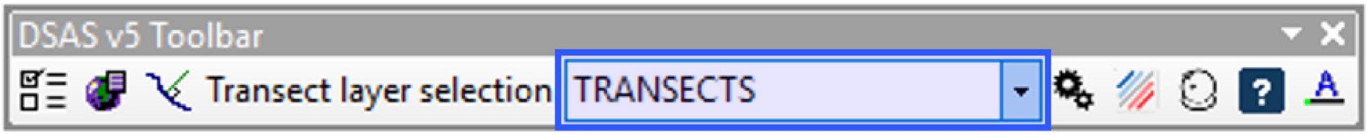


Figure 22. The Digital Shoreline Analysis System (DSAS) version 5 toolbar with the transect layer drop-down menu selected. The transect file must first be selected here to make edits to the transect and (or) begin rate calculation.

DSAS requires that the transect feature class is specified in the toolbar prior to starting an ArcMap editing session so that the software can perform a geometry check after the edit session ends. This ensures that any edits to the transects retain the required geometry while calculating rates. Should DSAS detect an issue with an edited transect, a warning message will be generated. Upon creation of a new set of transects, DSAS automatically selects the new transect layer in the toolbar, and an alert message reminds the user to make sure the desired transect layer is selected for editing (fig. 23). Once the desired transect layer is selected in the DSAS toolbar, the user may edit individual transects by using the standard ArcMap editing tools. Changes to transect length and orientation are permissible, but the addition or removal of vertices may produce undesired results and is not supported by DSAS.

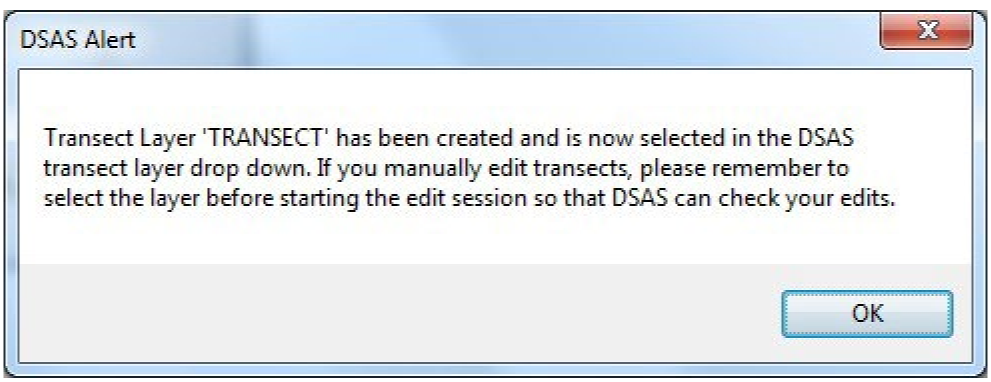


Figure 23. The alert message to the user displayed upon creation of transect layer, stating that editing of the transect must be completed with the layer selected in the "Transect layer selection" shown in the Digital Shoreline Analysis System (DSAS) version 5 toolbar (fig. 22). The message is for informational purposes and is not an error or warning.

6.4.2 Editing Baseline Features

All edits to baseline features should be completed before casting transects. DSAS v5 no longer supports dynamic topology, so any changes made to the baseline after transects are cast will not alter the transects.

6.5 Using Transects from Previous Versions of DSAS

Legacy shoreline change projects (created in DSAS v4.x) may be used in DSAS v5 by upgrading the transects using the Upgrade Transect Layer tool. This option should only be used to upgrade transects from previously established projects that do not require editing. Edits to updated legacy transect files can have integrity issues with the new DSAS v5 feature geometry, and some attributes may not be preserved or updated properly.

Located in the Cast Transects window, the Upgrade Transect Layer tool (fig. 24) allows the user to convert an existing transect file for use in DSAS v5. When using this tool, the user must:

1. Add original baseline, shorelines, and legacy transects to ArcMap.
2. Open the DSAS Set Default Parameters window and input the baseline and shoreline information.
3. Open the Cast Transects tool and click the “Upgrade Transect Layer” tab. Select the legacy transect file to be upgraded. Select baseline type (“onshore” or “offshore”) and choose the option to clip transects or keep at original length. Select “Upgrade”; a new set of transects will be added to the map with the filename suffix “ _v5” (for example, Legacy_Transects_v5).

There is a 19-character limit for transect names (including the addition of “_v5,” so 16 user-selectable characters). If the name is too long, an error message will be generated during calculation of statistics. If the legacy baseline file had both onshore and offshore segments, the legacy transects will need to be split into two files, one for all onshore transects and one for all offshore transects, to be upgraded separately. Transect feature classes from DSAS 3.x and earlier are not compatible with DSAS v5. For a complete list of compatible versions, see table 1. In some cases, a valid transect layer (DSAS v4.x) will not show up in the legacy transect upgrade. If this is the case, see troubleshooting in **section 12** (app. 1).

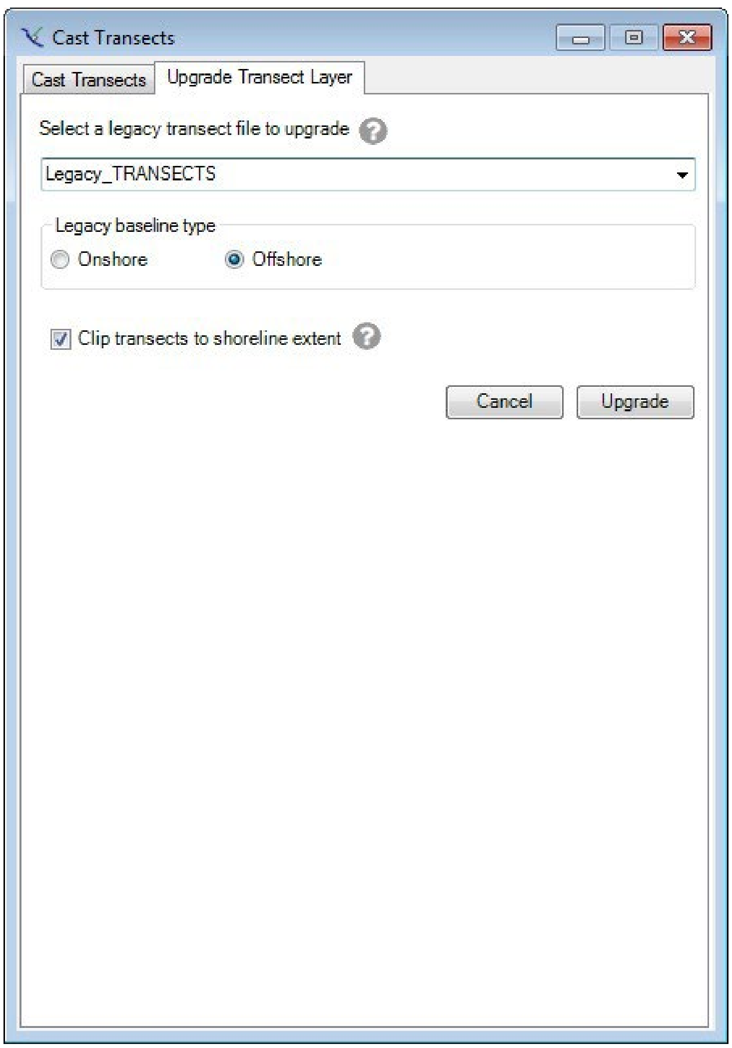


Figure 24. The Cast Transects window showing Upgrade Transect Layer options.

6.6 Select Features Tool (Shoreline)

Although DSAS requires that all shoreline data reside within a single feature class, change statistics can be computed for a subset of the dataset, if desired. Users can select specific shorelines directly in ArcMap by using the selection tool, in the shoreline attribute table, or by using the “Select by Attributes” option from the main menu in ArcMap. DSAS ignores all shorelines that are not selected and computes change statistics for the selected set (fig. 25). As this is a temporary selection, it may be subject to user error if the exact same set of shorelines is not selected for subsequent analysis. A record of each of the shorelines used for each analysis is created in the Summary Report text (see **section 9**). An alternate recommended approach would be to create subsets of the shoreline data as separate feature classes (select shorelines and export), reducing the likelihood of user error in selecting data for analysis.

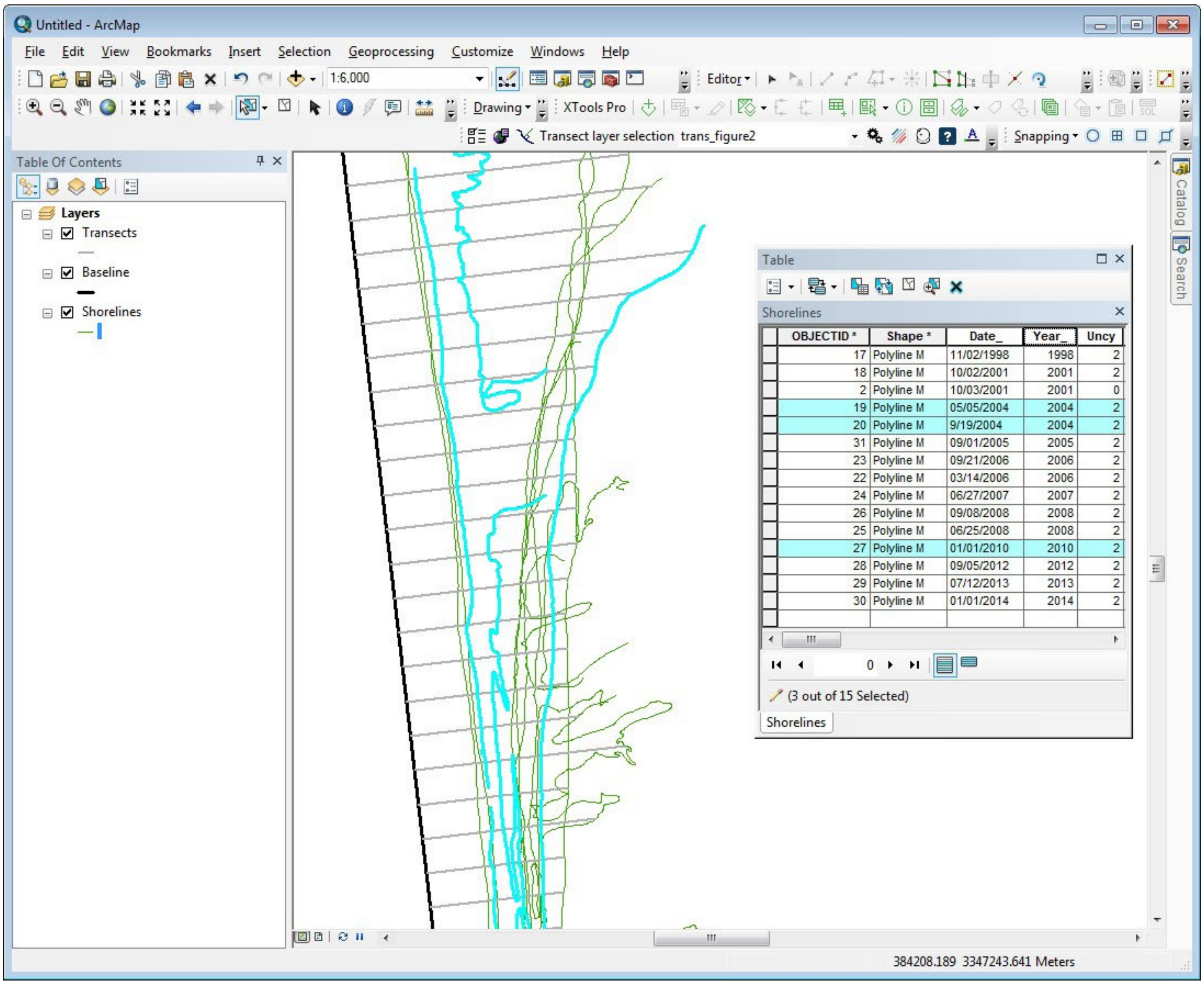


Figure 25. Shoreline change rates calculated on a selection of shorelines. Transects (gray) are cast perpendicular to a baseline (black), and three shorelines are highlighted (blue). Shoreline change statistics and intersect points are computed only for the three selected shorelines. All other shoreline data (green) are ignored.

6.7 Calculating Change Statistics

Once the transect feature class has been created and all updates, edits, and modifications have been made, the data can be used to compute change statistics. It is recommended that the user review the default settings established in the Set Default Parameters window prior to computing statistics (see **section 6.2**). Select the transect layer from the drop-down menu in the DSAS v5 toolbar and then click on the Calculate Rates button (fig. 26).

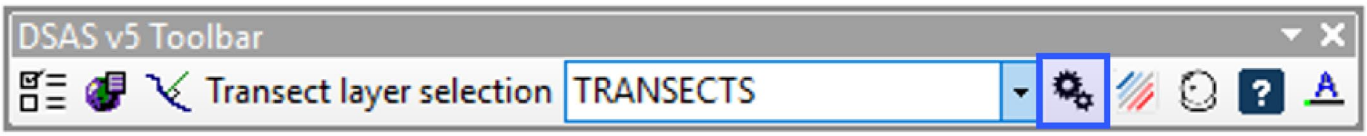


Figure 26. The Digital Shoreline Analysis System (DSAS) version 5 toolbar with the Calculate Rates icon selected.

6.7.1 Select Statistics to Calculate

Choose from the list of statistical analyses that will be performed or select all (fig. 27). Refer to **section 7** for complete descriptions of each statistic and distance measurement provided with DSAS v5.

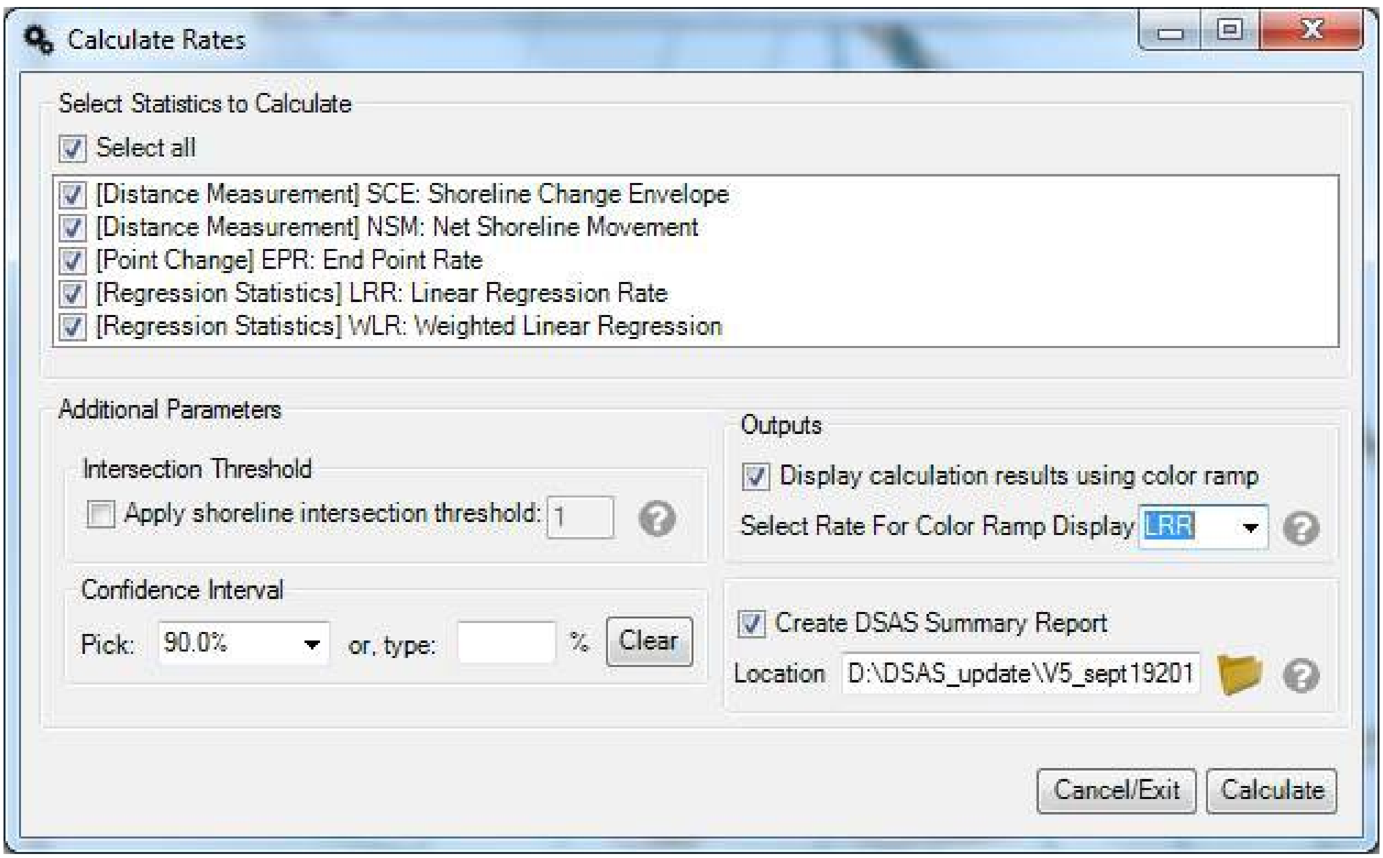


Figure 27. The Calculate Rates window showing options for statistics, additional parameters, and outputs. DSAS, Digital Shoreline Analysis System.

6.7.2 Additional Parameters

Shoreline Intersection Threshold

Users have the option to establish the minimum number of shorelines a transect must intersect to be included in the selected statistical analyses (fig. 28). For example, if a dataset consists of four historic shoreline positions, but there are gaps in coverage alongshore, setting the intersection threshold to “4” omits any transect that does not intersect all four shorelines. This feature provides a quality check so that rate results are based on a similar number of shorelines.

Three of the calculations require only two shoreline positions to run (shoreline change envelope [SCE], net shoreline movement [NSM], and end point rate [EPR]), whereas the regression statistics (linear regression rate [LRR] and weighted linear regression [WLR]) require three or more shorelines to successfully compute rates. If an intersection threshold of two is specified, there may be transects for which there are not enough shoreline intersections to compute regression statistics, in which case DSAS returns a <null> value for LRR and WLR at those transects. If the threshold is set to four, there may be instances where rate calculations are skipped on transects that do not intersect four shorelines, even though they may meet the minimum requirement (two shorelines) for the EPR, SCE, and NSM statistics.

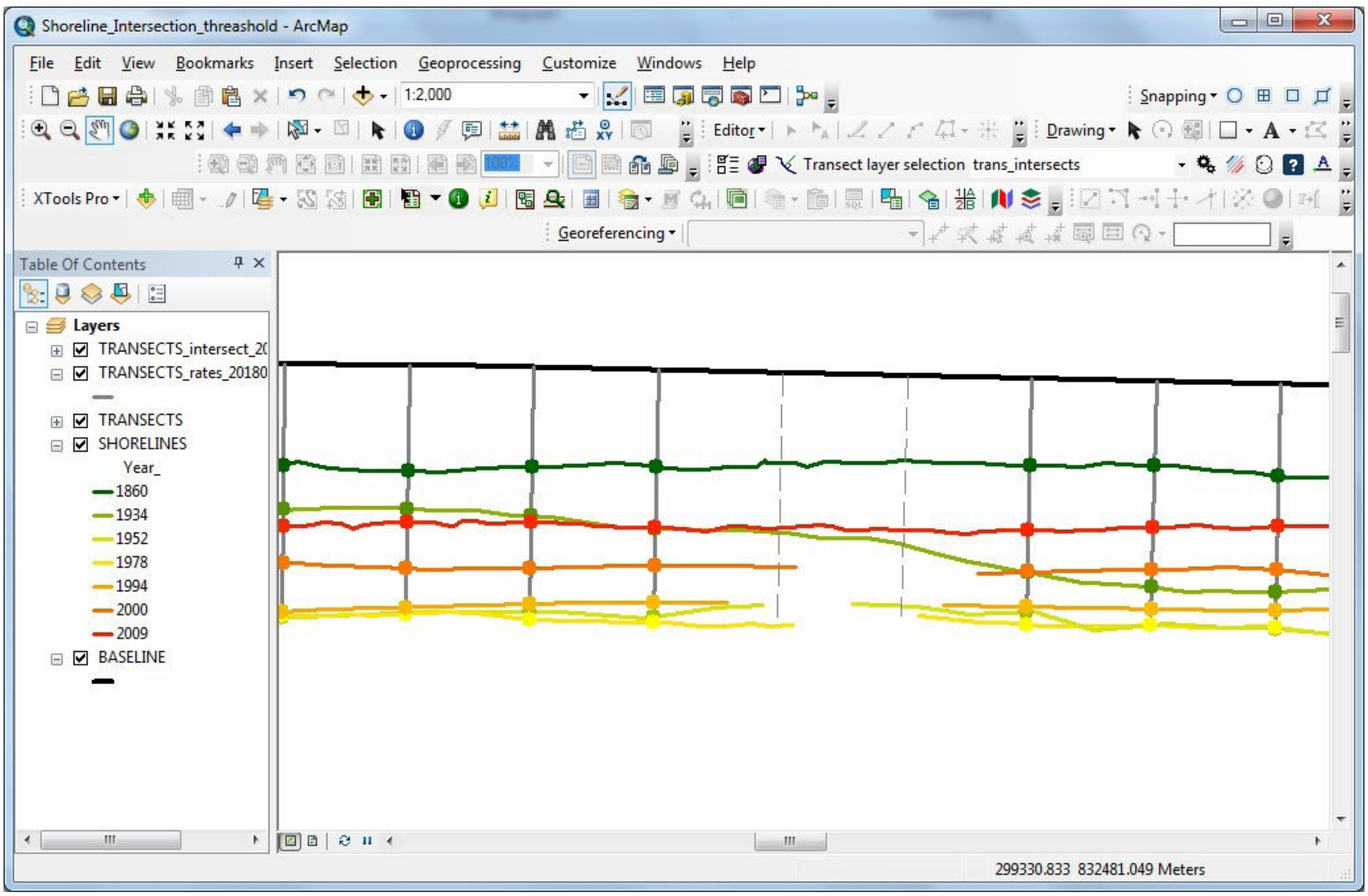


Figure 28. ArcMap project illustrating the transect-shoreline intersection points used in selected rate-change calculations. The shoreline intersection threshold will compute change statistics only for transects that intersect the number of shorelines set by the threshold (seven in this example). Transects that do not intersect at least this number of shorelines are ignored and will not be returned as rate transects.

Confidence Interval

The Confidence Interval drop-down menu (fig. 27) provides options for commonly used statistical confidence intervals that apply to certain rate-of-change calculations performed by DSAS (see **section 7.6** for more information). Users also have the option of manually entering a desired confidence interval up to two decimal places. The chosen confidence interval determines the criteria used for computing values for some of the supplemental statistics.

6.7.3 Outputs

Display Calculation Results Using Color Ramp

In DSAS v5, rate calculations are returned as a new transect feature class within the geodatabase (joining rate data to transect files is no longer part of the workflow in v5). If the user selects the option to display calculation results from the drop-down menu in the Outputs section of the Calculate Rates interface (fig. 27), DSAS will automatically return results symbolized by the rate attribute selected. The box can be unchecked to manually apply a color ramp later. Switching the display to a different attribute or scaling the color ramp to the data extent may be done via the Data Visualization options in the DSAS toolbar (**section 6.8**) after rate calculations are complete.

Create DSAS Summary Report

DSAS v5 provides an option to generate a summary report each time rate calculations are run. The report captures settings chosen by the user and automatically calculates averages for each rate calculation selected, including (optional) subset averages determined by the “Group attribute field” defined in the baseline file. Clicking on the folder will prompt the user to select the file location to save the summary report (fig. 27). The summary report filename includes the name of the transects (rates) and the calculation time stamp. See **section 9** for a complete description of the summary report.

6.7.4 Calculate

Once all parameters and outputs have been specified, clicking “Calculate” initializes DSAS processing. When processing is complete, two new feature classes (rates and intersects) are generated and automatically added to the ArcMap project.

Rates Transect Feature-Class Attribute Fields

The new rates feature class is a copy of the original transect feature class (**section 6.3.3**) with user-selected rate and distance measurement results (as specified in the Calculate Rates window) appended. The attribute fields generated for the rates transect feature class by DSAS are described in table 8.

Table 8. Description of Digital Shoreline Analysis System (DSAS)-generated rate transect attribute fields.

Field name	Data type	Field purpose
OBJECT IDENTIFIER (aliases: object identifier, OID, or FID)	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique ID for each row in the attribute table.
Geometry (alias: Shape)	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon).
TransectID	Long integer	The transectID relates directly to the original transect file “Object Identifier.”
BaselineID	Long integer	Values in this field correlate to the baseline attribute field “ID” and are assigned by DSAS to identify the baseline segment used to generate the measurement transect. Baseline segments assigned an ID=0 are ignored by DSAS, and no transects will be cast along those line segments. See **section 5.3.3** for more information.
GroupID	Long integer	Values in this field correlate to the optional baseline attribute field “DSAS_group” (Group_) and are assigned by DSAS if selected by user. This field is used to aggregate sections of the coast into groups. All transects within a group will have average summary statistics in the DSAS summary report. Refer to the baseline field requirements in **section 5.3.6** and a description of the summary report in **section 9** for more information.
TransOrder	Long integer	Assigned by DSAS on the basis of transect order along the baseline or baselines. If the user manually adds transects to the file in an edit session, they will be added to the end of the transect attribute table and given a new TransID (ObjectID). However, TransOrder will be updated to reflect the position of the new transect with respect to the other transects along the baseline. This field provides the user with a method to sort transect attribute data, from the start of the baseline segment (ID=1) incrementally (ID of each successive segment increasing by 1) to the end of the final baseline segment.
Azimuth	Double	Used to record the azimuth of the transect measured in degrees clockwise from north.
ShrCount	Long	The total number of shorelines intersected by the transect and used for change analysis.
TCD	Double	The “total cumulative distance” (TCD) is the measure (in meters) alongshore from the start of the baseline segment with an ID=1 and measured sequentially alongshore to the end of the final baseline segment.
SHAPE_Length	Double	Length of transect in meter units, assuming data were properly projected in a meter-based coordinate system. This field is automatically generated and maintained when data are within a geodatabase.
User Selected Statistics	Double	Rate fields selected for calculation (see **section 6.7.1**). If the proxy-datum bias is applied, statistics will be presented with and without the bias applied.

Intersect Feature-Class Attribute Fields

The intersect file is a point feature class that stores positional information about each transect/shoreline intersection as well as information about the proxy-datum bias, if applied. The attribute fields generated for the intersect feature class by DSAS are described in table 9.

Table 9. Description of Digital Shoreline Analysis System (DSAS)-generated intersect attribute fields.

[MHW, mean high water; HWL, high-water line; lidar, light detection and ranging; sqrt, square root]

Field name	Data type	Field purpose
OBJECT IDENTIFIER (aliases: object identifier, OID, or FID)	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique ID for each row in the attribute table.
Geometry (alias: Shape)	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon).
TransectID	Long integer	The transectID relates directly to the original transect file attribute field "Object Identifier."
TransOrder	Long integer	Assigned by DSAS on the basis of transect order along the baseline or baselines. TransOrder should always be used to relate intersects to transects.
BaselineID	Long integer	Values in this field correlate to the baseline attribute field "ID" and are assigned by DSAS to identify the baseline segment used to generate the measurement transect.
ShorelineID	String	The date (mm/dd/yyyy) of the shoreline intersect.
Distance	Double	The distance (in meters) along the transect from the baseline to the intersect point. Regardless of baseline placement, negative values indicate the intersect is landward with respect to the baseline, and positive values indicate the intersect is seaward of the baseline.
IntersectX	Double	The *x*-coordinate location of the shoreline/transect intersect point.
IntersectY	Double	The *y*-coordinate location of the shoreline/transect intersect point.
Uncertainty	Double	The uncertainty of the shoreline intersect point as defined by the positional-uncertainty value (DSAS_uncy) of the shoreline (ShorelineID).
The following terms will only be appended to the intersect file if a proxy-datum bias is applied.		
Bias_Distance	Double	The distance (in meters) along the transect from the baseline to the intersect point, with the proxy-datum bias applied.
BIAS	Double	The estimated unidirectional horizontal offset between MHW and HWL shoreline positions based on lidar data.
BIAS_X	Double	The *x*-coordinate location of the shoreline/transect intersect point with the bias applied.
BIAS_Y	Double	The *y*-coordinate location of the shoreline/transect intersect point with the bias applied.
Bias_Uncertainty	Double	This is the uncertainty associated with the shoreline once the bias has been applied. It is the quadrature sum of the shoreline positional uncertainty ("DSAS_uncy," table 4, **section 5.2.3**) and the uncertainty of the bias estimate ("UNCYB" in table 2.1, **section 13.3**): sqrt (DSAS_uncy^2 + UNCYB^2).

6.8 Data Visualization Tool

Options for enhanced data visualization, new in DSAS v5, can be accessed by clicking the Data Visualization icon in the toolbar any time after change statistics have been run (fig. 29). Rates display may be changed according to a default, set scale or scaled to user data (fig. 30*A*). In addition, there is an option to clip the transect rate feature class to the shoreline change envelope (SCE) (fig. 30*B*).

Figure 29. Digital Shoreline Analysis System (DSAS) version 5 toolbar with the Data Visualization icon selected.

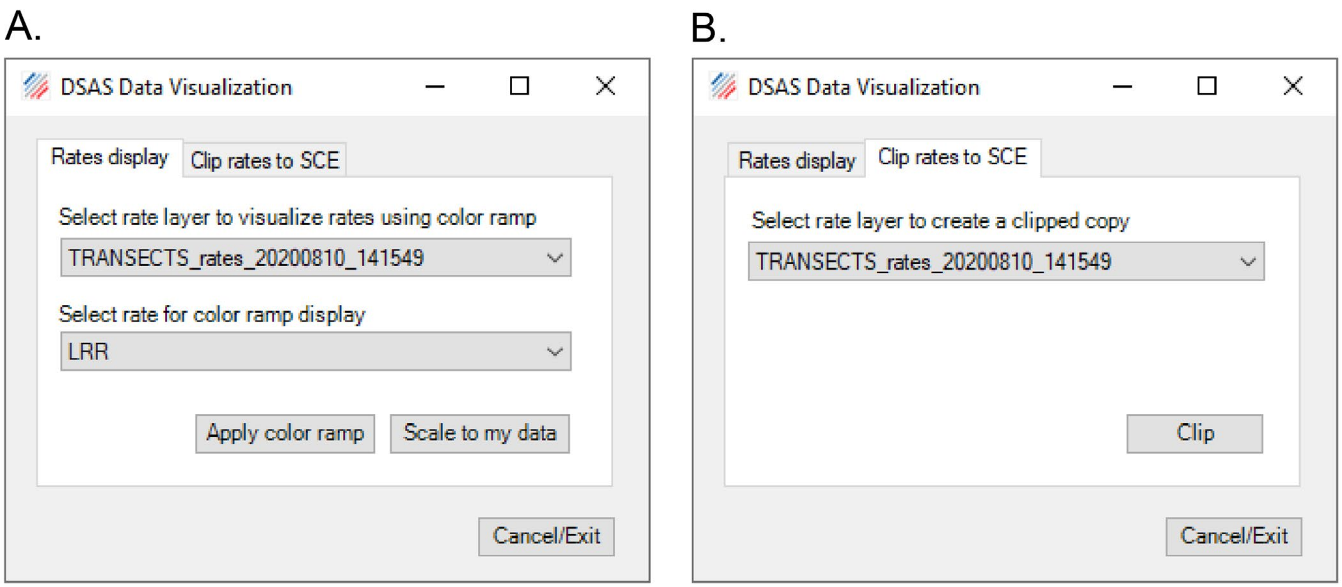


Figure 30. Digital Shoreline Analysis System (DSAS) version 5 Data Visualization window, tabs *A*, Rates display and *B*, Clip rates to SCE. LRR, linear regression rate; SCE, shoreline change envelope.

6.8.1 Rates Display

The Rates display tab is where the user can control the colorized output (color ramp) of transects based on the rate data (fig. 30*A*). Options for displaying rates default to a standardized output established by DSAS (“Apply color ramp”) or an output adjusted to user data (“Scale to my data”) that uses the range of rate values within the dataset. This symbology is designed to enhance the initial visualization of the rate data but can always be edited by using standard symbology in the layer properties in ArcMap.

Apply Color Ramp and Scale to My Data Rules

Options for symbology are limited to shoreline change statistics specified by the user (fig. 27) but can include SCE, NSM, EPR, LRR, and WLR. Should the dataset include the proxy-datum bias correction, NB_SCE, NB_NSM, NB_EPR, NB_LRR, and NB_WLR will also be displayed, providing rates of shoreline change without the bias applied. When determining the breaks for data values in visualizing data, DSAS always considers four bins for positive values depicted with shades of blue, a middle bin around 0 depicted with a neutral gray color, and four bins for negative values depicted with shades of red (fig. 31). The larger the number in magnitude, the darker the color will be. Null values are represented by a dashed gray line. Once symbology is applied (either by default at the end of rate calculation or after using the rates display tool), any transect with a null value will not be selectable in the map, and if a null value is highlighted in the attribute table, it will not show up in the map as highlighted. This is due to the exclusion of null values in the rate symbology and can be overridden by using standard symbology tools in ArcMap to select a rate display. Examples of fixed and scaled data from a sample dataset are shown in figure 32.

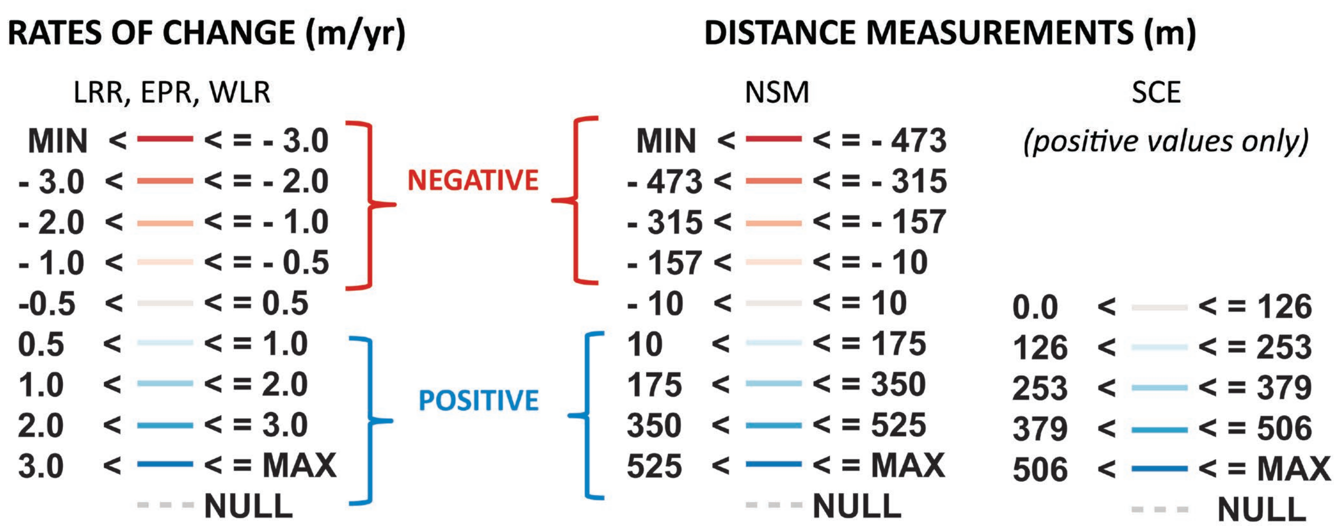


Figure 31. Fixed bin options for rates of change for an example dataset (left) and scaled to data (right). EPR, end point rate; LRR, linear regression rate; m, meter; m/yr, meter per year; MAX, maximum; MIN, minimum; NSM, net shoreline movement; SCE, shoreline change envelope; WLR, weighted linear regression rate.

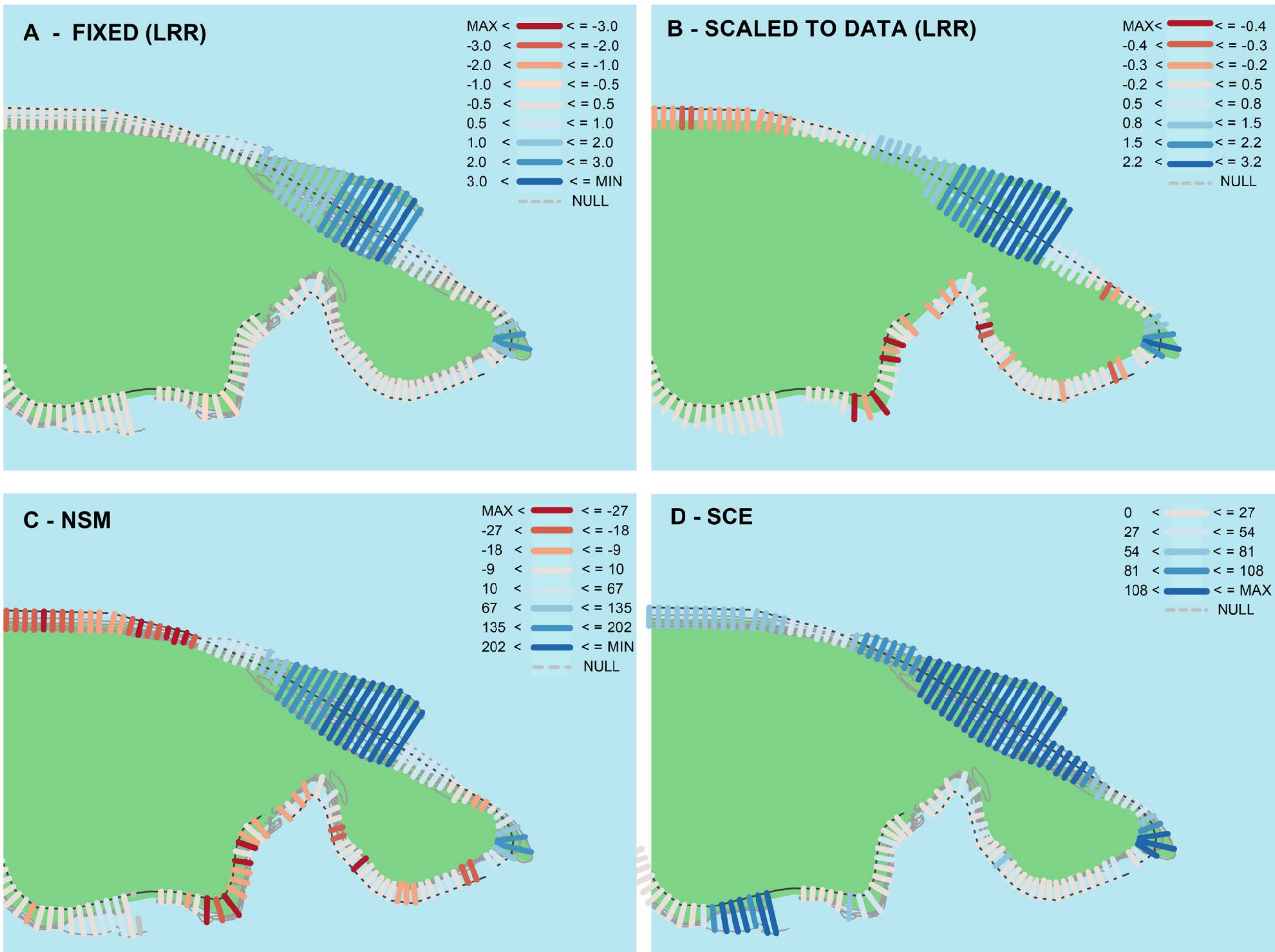


Figure 32. Data visualization *A*, with fixed scale and *B*, scaled to data options applied. Examples of *C*, net shoreline movement (NSM) and *D*, shoreline change envelope (SCE) are also displayed. The data have not changed—only the scaling and statistic selected through the Digital Shoreline Analysis System (DSAS) Data Visualization tool. LRR, linear regression rate; MAX, maximum; MIN, minimum.

When data are scaled, DSAS computes the 85th percentile of the data separately for positive and negative values. Data beyond the 85th percentile are assigned the darkest blue and red colors, which are reserved for these values. Data within the 85th percentile are broken into three bins on each side by dividing the value at the 85th percentile by 3 if there is a fixed middle bin or by 4 if there is no middle bin.

6.8.2 Clip Rates to SCE

The “Clip rates to SCE” function creates a copy of the original transects clipped to the greatest extent of the shorelines—otherwise known as the shoreline change envelope (SCE). Once the user has specified the transect file in the drop-down menu (fig. 30*B*), the clipping process creates a copy of the specified transect file, adding a number (for example, “_1” or “_2”) to the filename. Users can then visualize the clipped transects with rates as discussed in **section 6.8.2**. Clipping transects to SCE may be useful for visualization or publishing data. See figure 33 for an example of transects clipped by using this function.

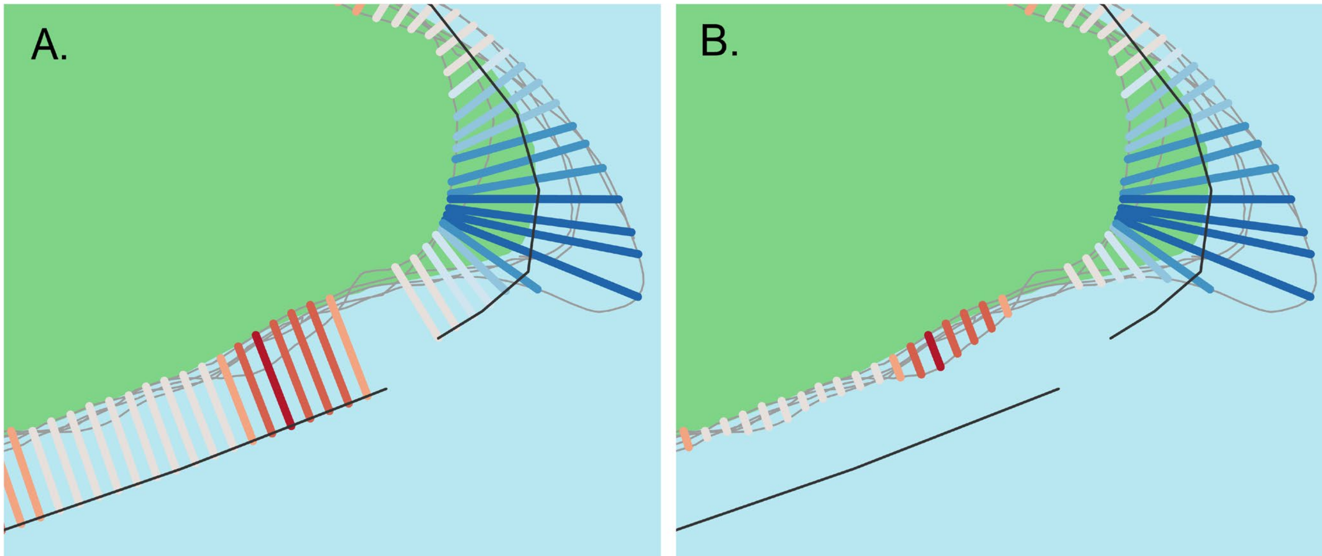


Figure 33. Transects shown as *A*, originally cast and *B*, clipped to shoreline change envelope (SCE).

7. Statistics

Each method used to calculate shoreline rates of change is based on measured differences between shoreline positions through time. The reported rates are expressed as meters of change per year as measured along transects. When the user-selected rate calculations have finished processing, DSAS outputs a new transect rate feature class and a point intersect feature class.

The rate-change statistics provided with DSAS have the standardized field headings listed in the first column of table 10 and are described in detail in this section.

Note: If rates are calculated by using the proxy-datum bias (PDB), statistics will be reported with values both where the bias has been applied (for example, LRR) and where bias has not been applied (for example, NB_LRR, where NB stands for "No bias"). Within a dataset that contains the PDB, there can be sections of coast with alternate combinations of shoreline type where the bias cannot be applied. For example, transects with only HWL shoreline intersections, or transects that include MHW shoreline intersections with no bias, will not have a bias applied. If transects encounter only HWL shorelines, the rates with and without bias will be identical as no bias is needed. However, if a transect intersects a MHW shoreline that does not contain the PDB (and no other MHW with bias is available), LRR results will be reported as NULL, and only rates without bias will be reported.

Table 10. Table of standardized field headings provided by Digital Shoreline Analysis System (DSAS) for change calculations.

[Shaded entries are uncertainty and statistical parameters. Examples are included for how the user-selected confidence interval is specified (confidence interval of linear regression [LCI] or confidence interval of weighted linear regression [WCI])]

DSAS statistics	Description
NSM	Net shoreline movement
SCE	Shoreline change envelope
EPR	End point rate
EPRunc	Uncertainty of the end point rate
LRR	Linear regression rate
LSE	Standard error of linear regression
LCI	Confidence interval of linear regression—LCI%, where % is the CI value entered in the Calculate Rates window (**section 6.7.2**)
LR2	*R*-squared of linear regression
WLR	Weighted linear regression rate
WSE	Standard error of weighted linear regression
WCI	Confidence interval of weighted linear regression—WCI%, where % is the CI value entered in the Calculate Rates window (**section 6.7.2**)
WR2	*R*-squared of weighted linear regression

7.1 Net Shoreline Movement

The net shoreline movement (NSM) is the distance between the oldest and the youngest shorelines for each transect (fig. 34); therefore, units are in meters. If this distance is divided by the time elapsed between the two shoreline position measurements, the result is the end point rate described in **section 7.3**. If the PDB is applied, two versions of this statistic are reported: "NSM" includes the PDB in the calculations; "NB_NSM" omits the PDB.

7.2 Shoreline Change Envelope

The shoreline change envelope (SCE) reports a distance (in meters), not a rate. The SCE value represents the greatest distance among all the shorelines that intersect a given transect (fig. 34). As total distance between two shorelines has no sign, the value for SCE is always positive. The transect rate file may be clipped to this span for display purposes (see **section 6.8.2**). If the PDB is applied, two versions of this statistic are reported: "SCE" includes the PDB in the calculations; "NB_SCE" omits the PDB.

7.3 End Point Rate

The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (fig. 34). The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The disadvantage is that in cases where more data are available, the additional information is ignored. Changes in sign (in other words, accretion to erosion), magnitude, or cyclical trends may be missed (Dolan and others, 1991; Crowell and others, 1997). If the PDB is applied, two versions of this statistic are reported: "EPR" includes the PDB in the calculations; "NB_EPR" omits the PDB.

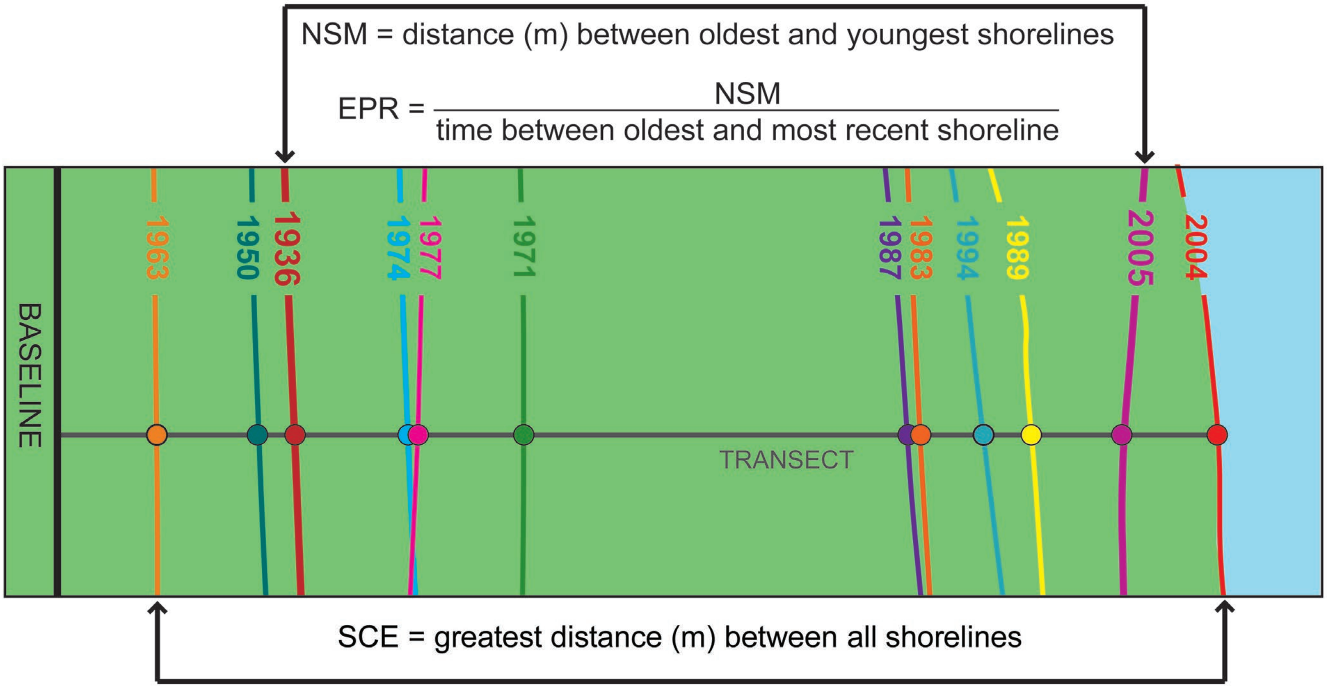


Figure 34. A shoreline dataset including baseline (black), transect (gray), and shoreline and intersect data (multicolor) to illustrate the relationship between shoreline change statistics: net shoreline movement (NSM), end point rate (EPR), and shoreline change envelope (SCE). NSM is the distance along the transect in meters (m) between the oldest shoreline (1936, red) and the most recent shoreline (2005, magenta). The EPR is the NSM distance divided by the time between the oldest (1936, red) and most recent (2005, magenta) shorelines (69 years in this example). The SCE is the greatest distance between all the shorelines regardless of date.

7.4 Linear Regression Rate

A linear regression rate-of-change statistic can be determined by fitting a least-squares regression line to all shoreline points for a transect (fig. 35). The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. The method of linear regression includes these features: (1) all the data are used, regardless of changes in trend or accuracy, (2) the method is purely computational, (3) the calculation is based on accepted statistical concepts, and (4) the method is easy to employ (Dolan and others, 1991; Crowell and others, 1997). However, the linear regression method is susceptible to outlier effects and tends to underestimate the rate of change relative to other statistics, such as EPR (Dolan, and others, 1991; Genz and others, 2007). If the PDB is applied, two versions of this statistic are reported: “LRR” includes the PDB in the calculations; “NB_LRR” omits the PDB. In conjunction with the linear regression rate, the standard error of the estimate (LSE/NB_LSE), the standard error of the slope with user-selected confidence interval (LCI/NB_LCI), and the R-squared value (LR2/NB_LR2) are also reported (**section 7.6**).

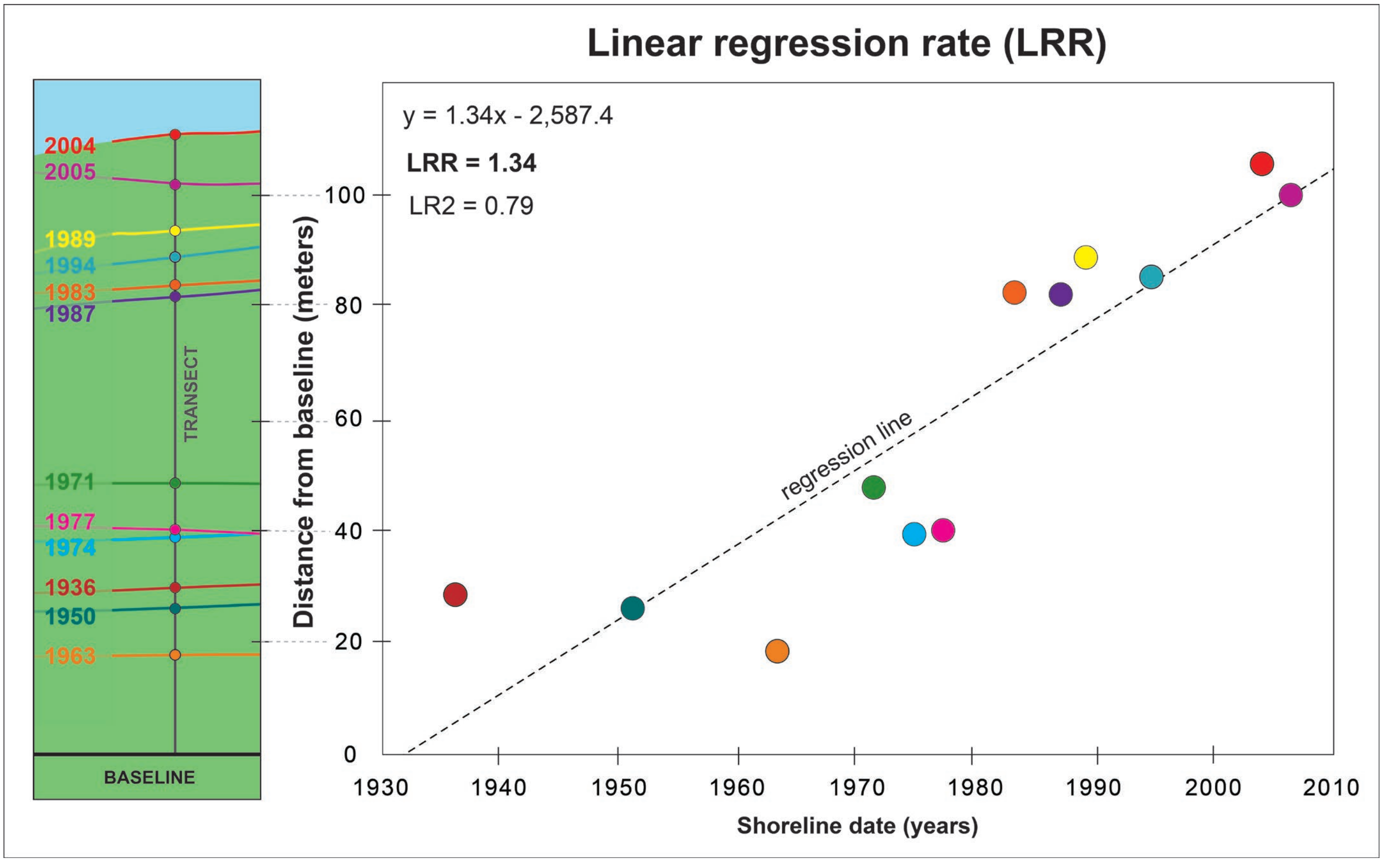


Figure 35. A shoreline dataset (baseline [black], transect [gray], and shorelines and intersects [multicolor]) presented on a map and as a graph of distance from the baseline versus the shoreline date in relation to the linear regression rate (LRR) regression line. The LRR was determined by plotting the shoreline intersect positions (distance from baseline) with respect to time (years) and calculating the linear regression equation of $y = 1.34x - 2587.4$. The slope of the equation describing the line is the rate (1.34 meters per year). LR2, R-squared of linear regression.

7.5 Weighted Linear Regression

In a weighted linear regression, the more reliable data are given greater emphasis or weight towards determining a best-fit line (fig. 36). In the computation of rate-of-change statistics for shorelines, greater emphasis is placed on data points for which the position uncertainty is smaller. The weight (w) is defined as a function of the variance in the uncertainty of the measurement (e) (Genz and others, 2007):

$$w = 1/e^2, \qquad (1)$$

where

e is shoreline uncertainty value.

The uncertainty field of the shoreline feature class is used to calculate a weight. If the PDB is applied, two versions of this statistic are reported: “WLR” includes the PDB in the calculations: “NB_WLR” omits the PDB. In conjunction with the weighted linear regression rate, the standard error of the estimate (WSE/NB_WSE), the standard error of the slope with user-selected confidence interval (WCI/NB_WCI), and the R-squared value (WR2/NB_WR2) are reported (see **section 7.6**).

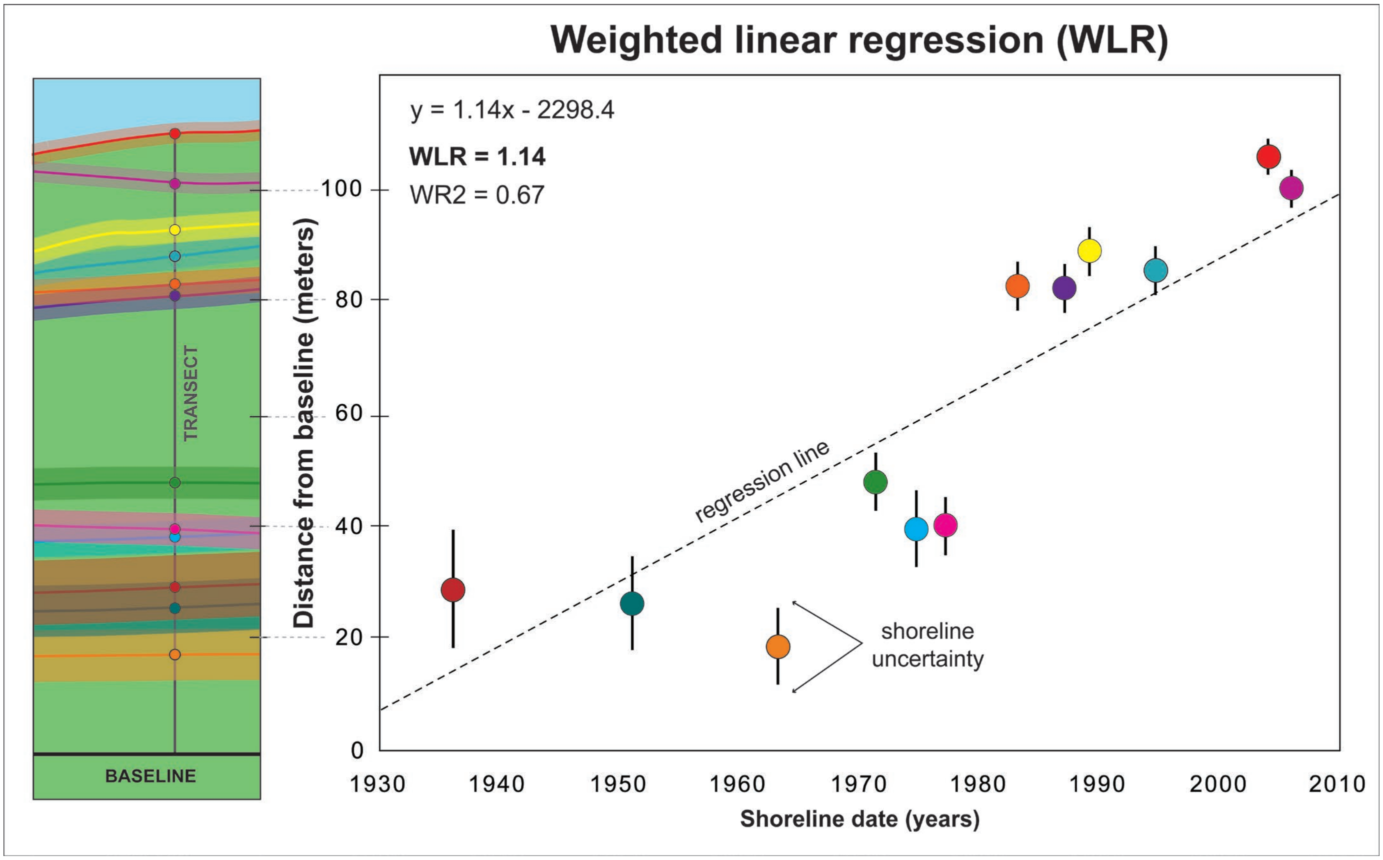


Figure 36. A shoreline dataset (baseline [black], transect [gray], and shorelines and intersects [multicolor], with shoreline position uncertainty) presented on a map and as a graph of distance from the baseline versus the shoreline date in relation to the weighted linear regression (WLR) line. The WLR rate is determined by plotting the shoreline positions with respect to time. Smaller positional-uncertainty values (shown as vertical bars around each data point in the graph) have more influence than other values in the regression calculation because of the weighting component in the algorithm. The slope of the regression line is the rate (1.14 meters per year). WR2, R-squared of weighted regression.

7.6 Supplemental Statistics

The end point rate (EPR) includes a computation of the uncertainty associated with the calculation. The standard error, correlation coefficient, and confidence interval are computed for the two linear regression methods (LRR and WLR). These additional statistics provide information that is helpful in assessing the robustness of the computed regression rates.

7.6.1 Uncertainty of End Point Rate

The shoreline uncertainties for the two positions used in the end point calculation are each squared, then added together (summation of squares). The square root of the summation of squares is divided by the number of years between the two shorelines to determine the uncertainty of the end point rate (EPRunc):

$$EPRunc = \frac{\sqrt{(uncy\,A)^2 + (uncy\,B)^2}}{date\,A - date\,B}, \tag{2}$$

where

uncy A	is uncertainty from attribute field of shoreline A,
uncy B	is uncertainty from attribute field of shoreline B,
date A	is date of shoreline A (most recent), and
date B	is date of shoreline B (oldest).

The uncertainty value for each shoreline is determined from the “Shoreline Uncertainty Field” in the shoreline feature class assigned by the user in the Set Default Parameters window. If no uncertainty is provided in the attribute field, the default value (specified in the default parameters) is used. The result of this calculation is reported as the uncertainty of the end point rate calculation (EPRunc). If the PDB is applied, two versions of this statistic are reported: “EPRunc” includes the PDB in the calculations; “NB_ EPRunc” omits the PDB. In DSAS versions prior to 5, this statistic was the confidence of the end point rate calculation (ECI).

7.6.2 Standard Error of the Estimate

The predicted (or estimated) values of *y* (the distance from baseline) are computed for each shoreline point by using the values of *x* (the shoreline date) and solving the equation for the best-fit regression line:

$$y = mx + b, \tag{3}$$

where

- y is predicted distance from baseline,
- m is slope (the rate of change), and
- b is y-intercept (where the line crosses the y-axis).

The standard error of the estimate measures the accuracy of the predicted values of *y* by comparing them to known values from the shoreline point data. It is defined as LSE for ordinary linear regression and WSE for weighted linear regression:

$$LSE \text{ or } WSE = \sqrt{\frac{\Sigma(y-y')^2}{n-2}}\ , \tag{4}$$

where

- y is known distance from baseline for a shoreline data point,
- y' is predicted value based on the equation of the best-fit regression line, and
- n is number of shorelines used.

The total number of shoreline points (n) is reduced by 2 because two of the parameters in the regression line are being estimated (the slope and the intercept). The predicted y-values are subtracted from the known y-values to compute the residuals ($y - y'$). The residual is squared, and then the squared residuals (for each shoreline point) are added (along the DSAS transect) to get the sum of the squares of the residuals (which is the numerator in eq. 4). This sum is divided by the number of degrees of freedom, and then the square root of the quotient is taken to compute the standard error of the estimate. The standard error of the estimate assesses the accuracy of the best-fit regression line in predicting the position of a shoreline for a given point in time (fig. 37). If the PDB is applied, two versions of these statistics are reported: “LSE/WSE” includes the PDB in the calculations; “NB_LSE/NB_WSE” omits the PDB.

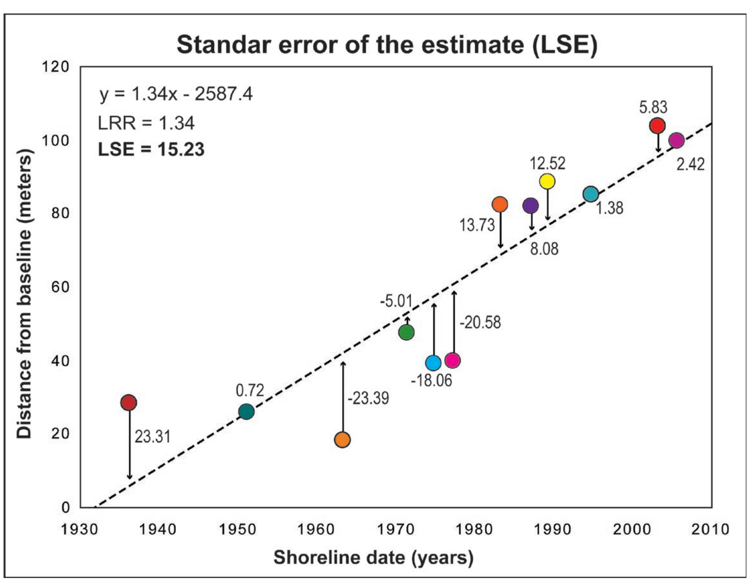


Figure 37. Shoreline change data plotted as distance from baseline (meters) versus the shoreline date (years) to highlight the calculation of the standard error of the linear regression (LSE). The equation describing linear regression rate (LRR, dashed line in figure) is used to predict values (*y*) at given dates (*x*). The residuals (actual values of *y* minus predicted values of y) are illustrated by the arrows and used to compute the LSE. The standard error evaluates the accuracy of the best-fit regression line in predicting the position of a shoreline for a specific date.

7.6.3 Standard Error of the Rate With Confidence Interval

The standard error of the rate with confidence interval (LCI for ordinary linear regression and WCI for weighted linear regression) describes the uncertainty of the reported rate. Users may choose a predetermined confidence-level percentage from the drop-down menu or manually enter a value up to two decimal places (**section 6.7.2** and fig. 27). The LRR and WLR rates are determined by a best-fit regression line through the sample data. The slope of this line is the reported rate of change (in meters per year [m/yr]). The confidence interval (LCI or WCI) is calculated by multiplying the standard error of the slope by the two-tailed test statistic at the user-specified confidence percentage (Zar, 1999). If the PDB is applied, two versions of these statistics are reported: "LCI/WCI" includes the PDB in the calculations; "NB_LCI/NB_WCI" omits the PDB.

In the example illustrated in figure 38, the reported LRR is 1.34 m/yr and the 95-percent confidence interval of the slope (LCI95) is 0.50. The band of confidence around the reported rate of change is 1.34 ±0.50. In other words, you can be 95-percent confident that the true rate of change is between 0.84 and 1.84 m/yr, leaving a 5 percent chance that the true line is outside those boundaries. This is not the same as saying that the band of confidence contains 95 percent of the data points and that some data points will fall outside the interval boundaries.

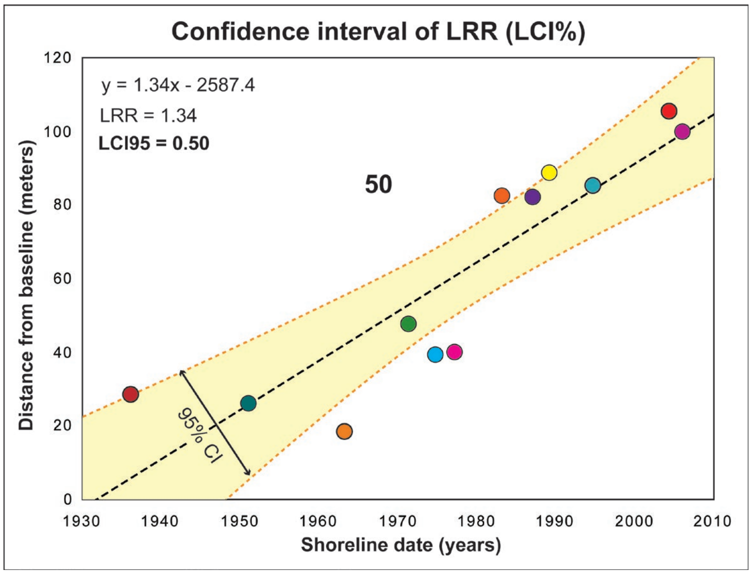


Figure 38. Shoreline change data plotted as distance from baseline (meters) versus the shoreline date (years) to highlight the calculation of the percent confidence interval statistic. The yellow-shaded region illustrates the 95-percent confidence band (95% CI) around the linear regression rate (black dashed line). LCI95, 95-percent confidence interval; LRR, linear regression rate; LSE, standard error of the estimate.

7.6.4 *r*-squared Statistic

The *r*-squared statistic (r^2), or coefficient of determination, is the percentage of variance in the data that is explained by a regression. It is a dimensionless index that ranges from 1.0 to 0.0 and measures how successfully the best-fit line accounts for variation in the data, where 1.0 is a perfect fit. In other words, it reflects the linear relationship between shoreline points along a given DSAS transect. For the linear regression rate (LRR), the statistic is defined as LR2, whereas for the weighted linear regression it is WR2. It is calculated as follows,

$$r^2 = 1 - \sqrt{\frac{\Sigma(y - y')^2}{\Sigma\left(y - \overline{y}\right)}}, \tag{5}$$

where

r^2	is the coefficient of determination,
y	is measured distance from baseline for a shoreline data point,
y'	is predicted value based on the equation of the best-fit regression line, and
$\overline{y}$	is mean of the measured shoreline distances from the baseline.

The r^2 value quantifies the proportion of the variability in the dependent variable y that is explained by the regression model through the independent variable x. The smaller the variability of the residual values around the regression line relative to the overall variability, the better the prediction.

- r^2 values close to 1.0 imply that the best-fit line explains most of the variation in the dependent variable. If x and y are perfectly related, there is no residual variance and the r^2 value is 1.0.
- r^2 values close to 0.0 imply that the best-fit line explains little of the variation in the dependent variable and is not be a useful model. If there is no relationship between the x and y variables, then r^2 is equal to 0.0.

8. Beta Shoreline Forecasting

New to DSAS v5 is an option to calculate a forecasted shoreline position (10 or 20 years into the future) based on historical shoreline position data. **It is critical to be aware that this forecasting tool is not ideal for all locations, data types, and patterns of shoreline change, and it is up to users to consider the specifications and limitations of their data when deciding on the advisability of using this tool to project a forecasted shoreline position.**

The shoreline forecasting calculation is done by using the Kalman filter (Kalman, 1960), as developed by Long and Plant (2012), to forecast future shoreline positions by combining observed shoreline positions with model-derived positions. The DSAS Kalman filter approach is initialized with the linear regression rate calculated by DSAS, it then estimates the shoreline position and change rate for every 10th of a year and provides an estimate of positional uncertainty at each time step. The processes driving shoreline change are complicated and not always available as model inputs; therefore, many factors that may be important are not considered in this methodology or accounted for within the uncertainty. The methodology assumes that a linear regression thorough past shoreline positions is a good approximation for future shoreline positions; however, this assumption may not always be valid.

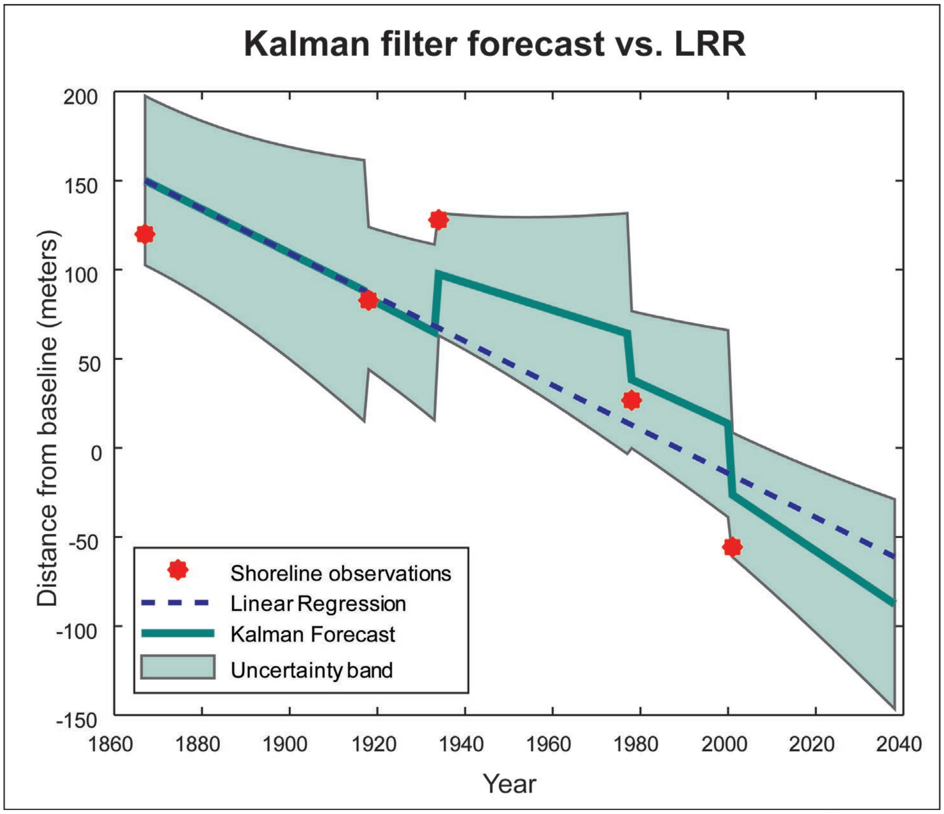


Figure 39. A comparison of the shoreline forecast by the Kalman filter approach in relation to linear regression rate (LRR). Note that the uncertainty band around the Kalman filter forecast decreases in width at each shoreline observation and that the uncertainty at a known observation is based on the shoreline uncertainty assigned to that shoreline in the attribute table.

Figure 39 shows an example of the beta shoreline forecast and uncertainty derived from the Kalman filter model. The simple linear regression is also shown for comparison.

8.1 Kalman Filter Model

The model begins at the first time step (the date of the earliest survey) and estimates the shoreline position for each successive time step until another shoreline observation is encountered. Whenever a shoreline observation is encountered, the Kalman filter performs an analysis to minimize the error between the modeled and observed shoreline positions to improve the forecast, including updating the rate and uncertainties (Long and Plant, 2012). The updated rate is then used to predict the shoreline position for each successive time step until another survey date is reached and again the new data are assimilated into the model. This process is repeated until the desired forecast date is reached. The measurement error is estimated by using the shoreline positional uncertainty associated with each shoreline used in the analysis (see **section 5.2.5**). This method tries to resolve process noise, which includes the unresolved seasonal variability at each location. Forecast uncertainty is initially estimated from the confidence interval and standard error of the linear regression previously calculated by DSAS (LCI and LSE). Because process noise is included in the forecast, the uncertainty in the forecast will continue to grow each year until another observation is assimilated.

When shoreline data are well represented by a linear fit, the Kalman filter-based forecast looks like a linear regression line extrapolated into the future. However, in cases where the shoreline change rate is changing over time, the Kalman filter approach may be able to better model this divergence from a long-term linear regression by allowing the rate to change somewhat over time. Exactly how much the rate should be allowed to vary depends on several factors. The method developed by Long and Plant (2012) has a few free parameters that can be adjusted to modify how responsive the method is to nonlinear changes. In this beta release in DSAS, those parameters were set to general values that usually keep the model relatively close to the linear regression. **Again, it is critical to recognize that this forecasting tool is not ideal for all locations, data types, and patterns of shoreline change, and it is up to the user to consider the specifications and limitations of their data when deciding on the advisability of using this tool to project a forecasted shoreline position.** When the prediction is displayed, it is strongly recommended that the uncertainty band is also displayed to responsibly visualize the uncertainty associated with the prediction.

Figure 40. The Digital Shoreline Analysis System (DSAS) version 5 toolbar with the Shoreline Forecasting icon selected.

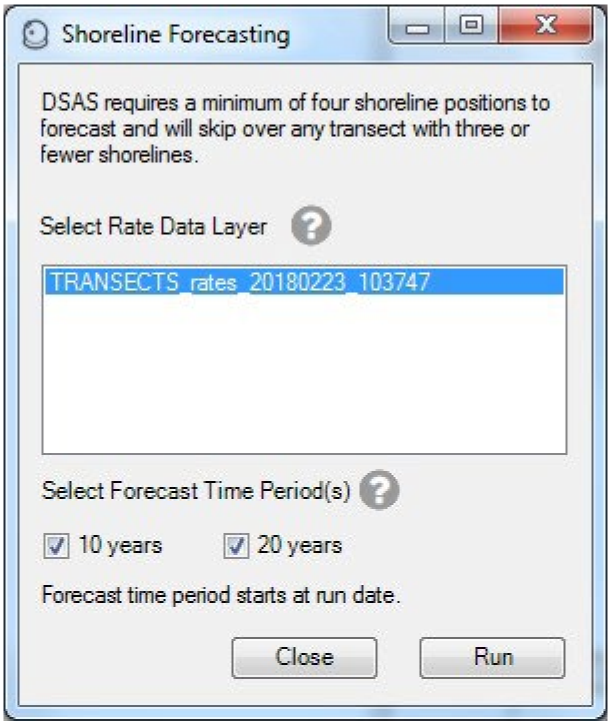


Figure 41. The Shoreline Forecasting window. Rates available for forecasting appear in "Select Rate Data Layer." DSAS, Digital Shoreline Analysis System.

8.2 Model Inputs

The Kalman filter is initialized by using a linear regression rate calculated by DSAS. The user must have already run rate calculations that include a linear regression as one of the rate metrics computed. While LRR may be calculated with three or more shorelines, shoreline forecasting is not available for data with fewer than four shorelines. Thus, a shoreline forecast will not be calculated if the input data include fewer than four shoreline dates.

After the user clicks on the Shoreline Forecasting icon in the DSAS toolbar (fig. 40), feature classes that contain the LRR attribute field appear in the drop-down menu for selection (fig. 41). DSAS shoreline forecasting uses a transect rate file and the corresponding intersect file for calculations. If an intersect file is not present in the map, the corresponding rate file will not display in the Shoreline Forecasting window for selection.

8.3 Forecast Output files

The Kalman filter approach can be used to generate a 10- or 20-year shoreline forecast horizon from the run date. One or both time frames can be selected for output. Each time frame produces output files as follows:

1. The point feature class is the forecasted location of the shoreline at the selected time frames (10 and [or] 20 years) along a single transect. The point feature class has attributes including the forecast year and the estimated forecast positional uncertainty. This point file can be used for exporting and plotting shoreline forecast data. See table 11 for output attribute fields.

2. The shoreline horizon forecast (10 and [or] 20 years), displayed as a polyline feature class, is the forecasted location of the shoreline at the selected time frame. The forecasted shoreline horizon line should always be displayed with the associated shoreline forecast uncertainty (item 3, below). See table 12 for output attribute fields.

3. The shoreline forecast uncertainty (10 and [or] 20 years) displays as a transparent polygon feature class, which can be considered the band of uncertainty for the forecasted shoreline horizon line. See table 13 for output attribute fields.

Note: When the forecasted shoreline horizon is displayed, it is strongly recommended that the uncertainty band is also displayed, as the two products are designed to be used simultaneously. The uncertainty calculated by this method incorporates only the known errors associated with past shoreline positions and assumes that the future change will be like the past change. These uncertainties cannot account for other factors that may influence the position of the shoreline in the future.

Table 11. Description of Digital Shoreline Analysis System (DSAS)-generated forecast point attributes.

Field name	Data type	Field purpose
OBJECT IDENTIFIER	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique identifier (ID) for each row in the attribute table.
Geometry	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon). The field name may also be called “Shape.”
ForecastPeriod	Long integer	The number of years the forecast is modeling. Can be 10 or 20 years.
ForecastYear	Double	The forecast year is the shoreline forecast horizon at either 10 or 20 years from the time the forecast is calculated. The forecast year is set from the run date, not from the date of the last shoreline.
Uncertainty	Long integer	The **estimated** uncertainty of the forecast.
Distance	Text	The distance in meters between the DSAS reference baseline and the future shoreline position projected along a DSAS transect.
IntersectX	Double	The *x*-coordinate location of the intersect point.
IntersectY	Double	The *y*-coordinate location of the intersect point.
TransectID	Long integer	The transectID relates directly to the original transect file “Object Identifier.”
TransOrder	Long integer	Assigned by DSAS on the basis of transect order along the baseline or baselines. TransOrder should always be used to relate intersects to transects.
TCD	Double	The “total cumulative distance” (TCD) is the number of meters alongshore from the start of the baseline segment with an ID=1 and measured sequentially alongshore to the end of the final baseline segment.

Table 12. Description of Digital Shoreline Analysis System (DSAS)-generated forecast polyline attributes.

Field name	Data type	Field purpose
OBJECT IDENTIFIER	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique identifier (ID) for each row in the attribute table.
Geometry	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon). The field name may also be called “Shape.”
ForecastPeriod	Long integer	The number of years the forecast is modeling. Can be 10 or 20 years.
ForecastYear	Double	The forecast year is the shoreline forecast horizon at either 10 or 20 years from the time the forecast is calculated. The forecast year is set from the run date, not from the date of the last shoreline.
SHAPE_Length	Double	Length of shoreline forecast polyline in meter units, assuming data were properly projected in a meter-based coordinate system. This field is automatically generated and maintained when data are within a geodatabase.

Table 13. Description of Digital Shoreline Analysis System (DSAS)-generated forecast uncertainty polygon attributes.

Field name	Data type	Field purpose
OBJECT IDENTIFIER	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique identifier (ID) for each row in the attribute table.
Geometry	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon). The field name may also be called “Shape.”
ForecastPeriod	Long integer	The number of years the forecast is modeling. Can be 10 or 20 years.
ForecastYear	Double	The forecast year is the shoreline forecast horizon at either 10 or 20 years from the time the forecast is calculated. The forecast year is set from the run date, not from the date of the last shoreline.
SHAPE_Area	Double	The area of the uncertainty polygon file in meters squared. This field is automatically generated and maintained when data are within a geodatabase.

Figure 42*A* shows the shoreline forecast horizon and estimated uncertainty plotted by DSAS as features on a map. The shoreline forecast is a solid line, and the uncertainty band is a transparent polygon extending on both sides of the forecast shoreline. The graphs in the figure are not DSAS products but illustrate the method by which the Kalman filter operates over time to achieve the resulting forecast horizon and uncertainty band that are displayed in the map. In figure 42*B* the DSAS forecast and the linear regression rate are similar. However, in figure 42*C* there is more variability in shoreline position through time, and the Kalman filter models positions on the basis of the nonlinear progression of the data. However, this results in a larger uncertainty band around the forecasted shoreline.

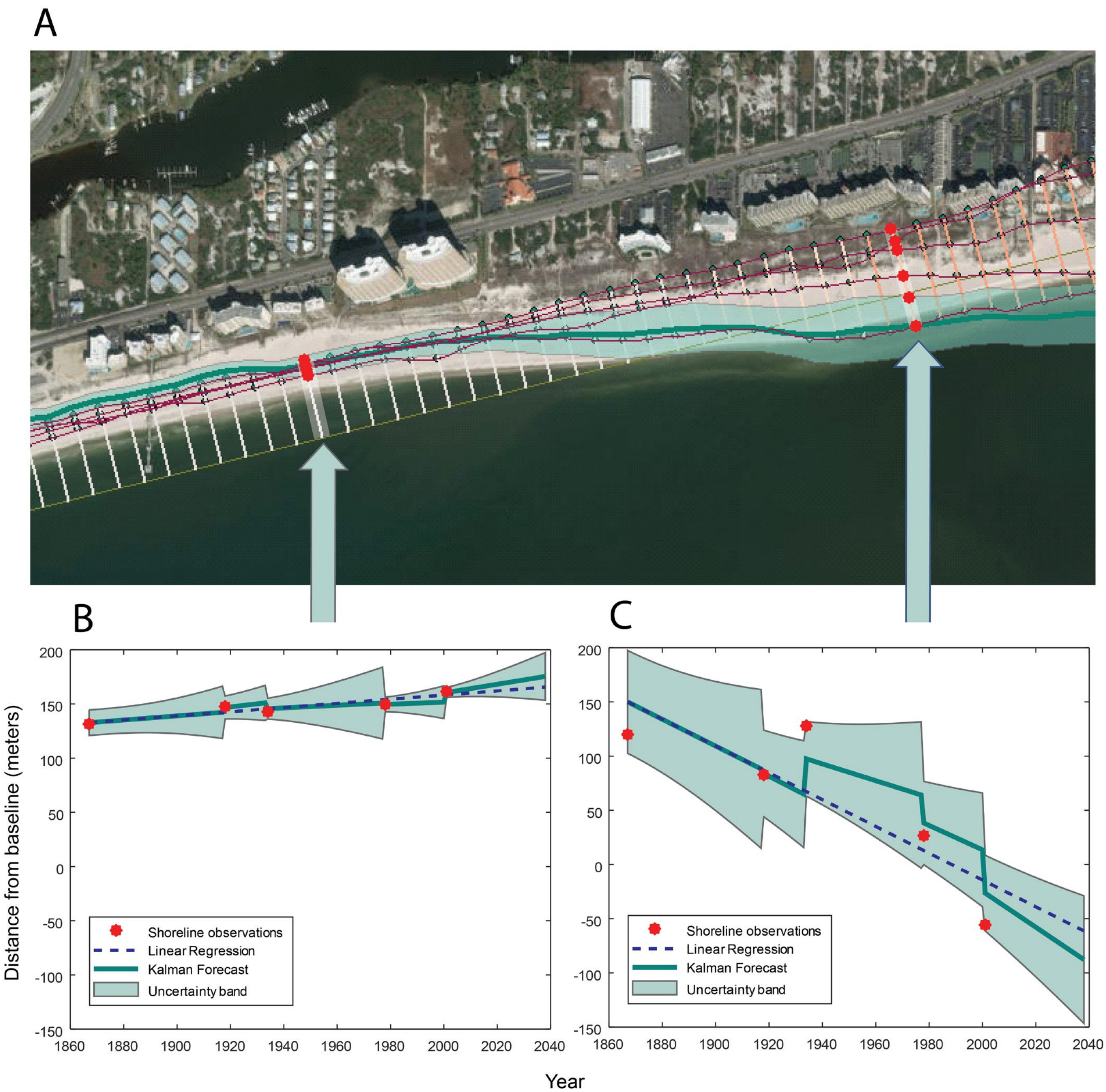


Figure 42. *A*, An example of Kalman filter shoreline forecast and uncertainty at two Digital Shoreline Analysis System (DSAS) transect locations. *B*, *C*, Graphs of the shoreline observations from two locations with the linear regression, Kalman filter forecast, and forecast uncertainty through time. The graphs are included here to help explain the method; they are not DSAS products.

8.4 Forecasting Using Datum- And Proxy-Based Shorelines

Shoreline forecasting produces 10- and (or) 20-year forecasts based on the input shoreline data. If all input shorelines are of the same type (for example, MHW), the resulting shoreline will be the potential future location of the MHW shoreline. If input data contain multiple shoreline proxies (HWL and MHW), a proxy-datum bias (PDB) must be applied to use shoreline forecasting. Using the PDB will convert the distance values in the rate and intersect files associated with the HWL shorelines by the bias amount so that they may be compared directly to the MHW shoreline position. If the PDB is applied, all forecasted shoreline positions will be referenced to MHW. If some transects do not have a PDB value, shoreline forecasting has a built-in work-around to apply a regional conversion to those transects so that all forecasted data are referenced to MHW. If the PDB value varies greatly throughout a study area, this regional conversion may introduce more error to the forecast at those transects. Options for proceeding if DSAS detects a datum conflict include skipping transects with no PDB, applying a regional average of PDB to those transects missing bias information, and stopping the forecasting altogether (fig. 43). For more information on the PDB, see **section 5.4**.

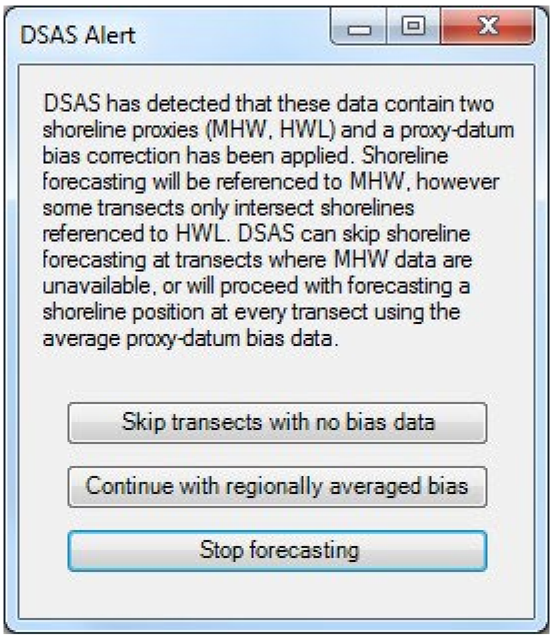


Figure 43. The Digital Shoreline Analysis System (DSAS) alert when multiple shoreline proxies are detected. HWL, high-water line; MHW, mean high water.

9. Summary Report

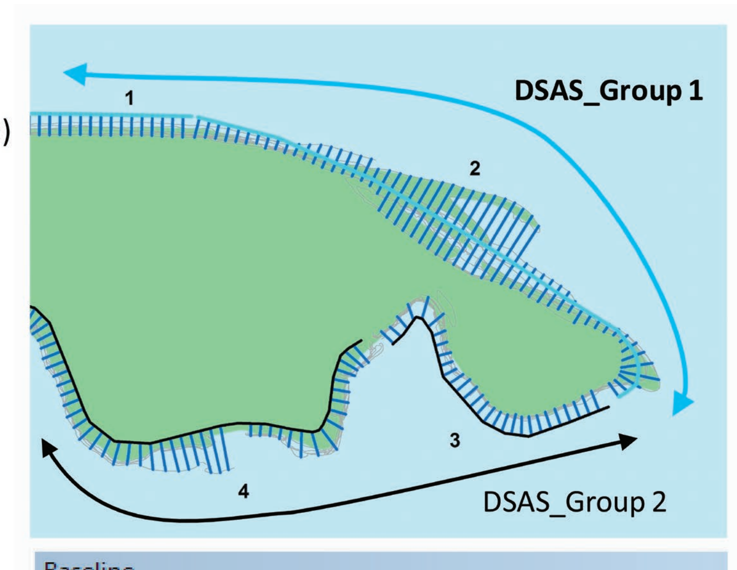
If "Create DSAS Summary Report" is selected in the Calculate Rates window (fig. 27), DSAS will generate a summary report with the results of rate calculations. The summary will include descriptive information on the selected rate calculations, including input transect filename, unique shoreline dates used, regional averages (by DSAS_group), and descriptive (minimum, maximum) values for erosion and accretion.

From the SummaryReport.txt

DISTANCE: SCE (Shoreline Change Envelope, m)

SCE REGIONAL AVERAGES [GROUP 1]
total number of transects: 101
average distance: 100.57
maximum distance: 401.81
maximum distance transect ID: 78
minimum distance: 28.78
minimum distance transect ID: 2

SCE REGIONAL AVERAGES [GROUP 2]
total number of transects: 104
average distance: 28.23
maximum distance: 147.62
maximum distance transect ID: 151
minimum distance: 1.18
minimum distance transect ID: 148



Baseline

ID	DSAS_group	DSAS_search	Shape_Length
1	1	150	2290.936687
2	1	250	2709.71133
3	2	200	1454.607037
4	2	250	3921.512819

Figure 44. *A*, An example output from a section of a Digital Shoreline Analysis System (DSAS) summary report highlighting the use of DSAS_group to organize output statistics and *B*, the corresponding map view of the data identifying DSAS_Group 1 (Baseline IDs 1 and 2) as relates to its use in the summary report. ID, identifier; m, meter.

Figure 44 illustrates the use of DSAS_group to define two regions that include multiple baseline segments. The summary report returns rates averaged for the entire dataset, as well as rates for each group. For a complete example of summary output, see **section 14** (app. 3).

9.1 Reduced *n* (*n**) and the Regionally Averaged Rate Uncertainty

As part of the summary statistics, DSAS calculates reduced *n* (or *n**) and an estimate of the uncertainty of the regionally averaged rate. This section describes how these quantities are calculated. The average rate is calculated by summing all the rates (*R*) and dividing by the number of transects (*n*):

$$\bar{R} = \frac{1}{n}\sum_{1}^{n} R_i, \tag{6}$$

where

$\bar{R}$ is the average rate,
R_i is the rate at each transect, and
n is the number of transects.

The simplest way of estimating the uncertainty of the average rate might be to calculate the average uncertainty in a similar way. That is, to sum the uncertainties associated with each transect and divide by the number of transects:

$$\bar{U}_R = \frac{1}{n}\sum_{1}^{n} U_{R_i}, \tag{7}$$

where

$\bar{U}_R$ is the average uncertainty associated with the rates,
U_{R_i} is the uncertainty associated with each rate (LCI for LRR, WCI for WLR), and
n is the number of transects.

However, this method results in an overestimate of the uncertainty because it assumes that every transect is independent of the others and therefore contains independent uncertainty (Hapke and others, 2011; Ruggiero and others, 2013). A more appropriate methodology involves calculating *n**, or reduced *n*. Reduced *n* is an estimate of the number of independent transects in the region; it is also sometimes called the effective sample size. If the transect spacing is much smaller that the scale of alongshore variability, then adjacent transects are essentially sampling the same beach, and all the processes and changes will be very similar at adjacent transects. In this case, two adjacent transects are not independent, and when *n** (reduced *n*) is calculated for the region, it will be less than *n* (the total number of transects). When transect spacing is much longer than the alongshore variability, then the processes and changes at two adjacent transects may be different. In this case, adjacent transects might be independent, and when *n** is calculated for the region it might be similar to *n*. To estimate *n**, the spatially lagged autocorrelation of each measure of rate uncertainty was used, as suggested by Garrett and Toulany (1981). In the DSAS summary report, *n** is reported as "reduced *n* (number of independent transects)."

As described in Hapke and others (2010) and Ruggiero and others (2013), *n** was used to calculate a more accurate estimate of the uncertainty of a regionally averaged change rate as follows:

$$\bar{U}_{R_{q^*}} = \frac{1}{\sqrt{n^*}}\bar{U}_R \quad , \tag{8}$$

where

$\bar{U}_{R_{q^*}}$ is the uncertainty of the regionally averaged rate using n^*,
$\bar{U}_R$ is the average uncertainty associated with the rates (from eq. 7), and
n^* is the number of independent transects.

This value is reported as "uncertainty of the average rate using reduced *n*" in the DSAS summary report.

If the baseline group function is used, reduced *n* (*n**) and the regionally averaged change rate is determined for each group. All the individual group *n** values are added together to get an estimate of *n** for the entire region, and this value is used when calculating the uncertainty of the average rate for the entire region.

9.2 Summary Report Output

9.2.1 Descriptive Data

The DSAS summary report begins with the following descriptive information about the input data and user settings:

- **File name**: name of the rates file used to compute summary stats.
- **Timestamp of rate calculation**: mm/dd/yyyy hh:mm:ss.
- **DSAS version**: version of DSAS used to compute rates.
- **ArcGIS version**: version of ArcGIS that DSAS is running in.
- **Rate types run**: list of rates selected by user to be calculated.
- **Shoreline dates used**: list of input shoreline dates used.
- **Shoreline threshold**: listed if user specified a value in the Set Default Parameters window.
- **Confidence Interval (CI) selected**: value specified in the Calculate Rates window.
- **Default uncertainty**: value specified by user in the Set Default Parameters window.
- **Transect spacing length**: specified in the Set Default Parameters window.
- **Smoothing distance**: specified by user in the Set Default Parameters window.
- **Coordinate system**: identifies the spatial reference of the dataset.
- **Is bias applied**: YES/NO value indicating if the PDB was applied.

9.2.2 Summary Statistics

After the descriptive data, the report lists the summarized statistics for each shoreline metric selected for the entire span of transects. This is followed by group averages in the summary report, if the group attribute was included in the baseline file. The following are the possible rates/distances and the summary statistics calculated for each shoreline metric selected.

Distance Measurement—SCE (Shoreline Change Envelope)

For the distance measurement SCE (see **section 7.2**), the following statistics are reported:

- **Total number of transects:** the number of transects (each with a unique ID) containing this specific rate calculation.
- **Average distance:** the sum of all distance values divided by the total number of transects.
- **Maximum distance:** the maximum distance between all shorelines.
- **Maximum distance transect ID:** the transect ID of the maximum distance.
- **Minimum distance:** the smallest distance between all shorelines.
- **Minimum distance transect ID:** the transect ID of the minimum distance.

Distance Measurement—NSM (Net Shoreline Movement)

For the distance measurement NSM (see **section 7.1**), the following statistics are reported.

- **Total number of transects:** the number of transects (each with a unique ID) containing this specific rate calculation.
- **Average distance:** the sum of all distance values divided by the total number of transects.
- **Number of transects with negative distance:** the number of transects with a negative distance value.

- **Percent of all transects that have a negative distance:** the number of transects with a negative value, divided by the total number of transects and multiplied by 100.
- **Maximum negative distance:** the value of the most negative change.
- **Maximum negative distance transect ID:** the transect ID where the most negative change is found.
- **Average of all negative distances:** the sum of all negative distance values divided by the total number of transects with a negative distance.
- **Number of transects with positive distance:** the number of transects with a positive distance value.
- **Percent of all transects that have a positive distance:** the number of transects with a positive value, divided by the total number of transects and multiplied by 100.
- **Maximum positive distance:** the value of the most positive change**.**
- **Maximum positive distance transect ID:** the transect ID where the most positive change is found.
- **Average of all positive distances:** the sum of all positive distance values divided by the total number of transects with a positive distance.

Rate Measurements

For rate measurements EPR (end point rate), LRR (linear regression), and WLR (weighted linear regression), the following statistics are reported:

- **Total number of transects:** the number of transects (each with a unique ID) containing this specific rate calculation.
- **Average rate:** the sum of all rate values divided by the total number of transects.
- **Average of the confidence intervals associated with rates:** the mean value of CI field (EPR uses EPRunc, LRR uses LCI, and WLR uses WCI) describing the average uncertainty of the rate.
- **Reduced n (number of independent transects):** the number of transects found to have an effectively independent uncertainty (see **section 9.1**).
- **Uncertainty of the average rate using reduced n:** the regionally averaged uncertainty for the number of independent transects (see **section 9.1**).
- **Average rate with reduced n uncertainty:** the average rate, ±the uncertainty of the average rate using reduced *n*.
- **Number of erosional transects:** total number of transects with a negative rate value.
- **Percent of all transects that are erosional:** the number of transects with a negative rate value, divided by the total number of transects and multiplied by 100.
- **Percent of all transects that have statistically significant erosion:** percentage of all transects that have a negative rate that has a larger magnitude than the uncertainty (plus/minus the CI value).
  - *Example: A rate of −2.3 m/yr with a CI value of 0.5 would be considered significant, as it reports a range of −2.8 to −1.8 m/yr, where the minimum and maximum values are still negative. A rate of −2.3 m/yr with a CI value of 2.8 would not be considered significant, as it reports a range of −5.1 to +0.5 m/yr, where the minimum value is negative (erosional) and the maximum value is positive (accretional); therefore, one cannot be confident that the actual rate is either erosional or accretional.*
- **Maximum value erosion:** The most negative rate. Technically, the maximum erosion rate is also the smallest number, but in terms of shoreline change rates, this number is the furthest negative value from zero, indicating the greatest rate of erosion.
- **Maximum value erosion transect ID:** the transect ID of the most negative rate.

- **Average of all erosional rates:** the sum of all negative rate values divided by the total number of transects with a negative rate.
- **Number of accretional transects:** number of transects with a positive rate value.
- **Percent of all transects that are accretional:** the number of transects with a positive rate value, divided by the total number of transects and multiplied by 100.
- **Percent of all transects that have statistically significant accretion:** percentage of all transects that have a positive rate that is larger than the uncertainty (plus/minus the CI value).
    - *Example: A rate of +0.7 m/yr with a CI value of 0.3 would be considered significant, as it reports a range of +1.0 to +0.4 m/yr, where the minimum and maximum values are still positive. A rate of ±0.7 m/yr with a CI value of 0.8 would not be considered significant, as it reports a range of +1.5 to −0.1 m/yr, where the minimum value is negative (erosional) and the maximum value is positive (accretional); therefore, one cannot be confident that the actual rate is either erosional or accretional.*
- **Maximum value accretion:** the most positive rate indicating the greatest rate of accretion.
- **Maximum value accretion transect ID:** the transect ID of the most positive rate.
- **Average of all accretional rates:** the sum of all positive rate values divided by the total number of transects with a positive rate.

For a full text example of DSAS summary report, see **section 14** (app. 3).

10. Metadata

Generating complete metadata is an important component of data integrity and maintenance. In DSAS v4.0 and higher, metadata are generated automatically when program files are created and when calculations are performed. A Metadata tab within the Set Default Parameters window (see **section 6.2.3**) allows users to input a few essential components of the metadata information. The metadata interface is simple, requiring only input of basic information often specific to individual organizations. DSAS takes these user-input variables, captures processing-step descriptions and basic dataset information (such as bounding coordinates, attributes, and spatial reference information), and includes it in the transect feature-class metadata file when transects are cast.

10.1 Configuring ArcGIS To View DSAS-Generated Metadata

Metadata written in ArcGIS 9.0 to 9.3 were based on the FGDC CSDGM format. In ArcGIS 10, Esri moved to a metadata format that more closely follows the International Organization for Standardization (ISO) 19115 standard (Geographic Information Metadata). Metadata produced by DSAS continue to be in the FGDC CDGSM standard and require a few additional steps to be viewed or edited in ArcGIS 10. Since there are no restrictions on the metadata record after it is generated, users may modify the existing file by using a metadata editor of their choice.

Users will initially be unable to view or edit metadata generated by DSAS. The Metadata tab has been replaced with a Description tab in ArcCatalog. To view the metadata, complete the following steps:

1. In ArcCatalog, click Customize >> ArcCatalog Options.
2. Click the Metadata tab (fig. 45).
3. Click “FGDC CSDGM Metadata” in the Metadata Style list.
4. Click “OK.”

Note: If you are using the Description tab when you choose a new metadata style, you will not immediately see the results of this change. Click another tab in ArcCatalog or the Item Description window, and then click the Description tab again for the new metadata style to take effect. All metadata written by DSAS are displayed under the FGDC Metadata (read-only) heading (fig. 46).

10.2 Editing DSAS-Generated Metadata in FGDC Format

An add-in is available for users who prefer to edit the FGDC-formatted metadata with the metadata editor that was available in previous ArcGIS releases. The add-in allows users to access the FGDC metadata editor by inserting a new command to the ArcCatalog toolbar. This enables users to edit the metadata content that can be previewed in the read-only section under the Description tab. More details on the add-in, as well as the download and instructions, can be found here: https://www.esri.com/arcgis-blog/products/arcgis-desktop/administration/fgdc-metadata-editor-for-arcgis-10/.

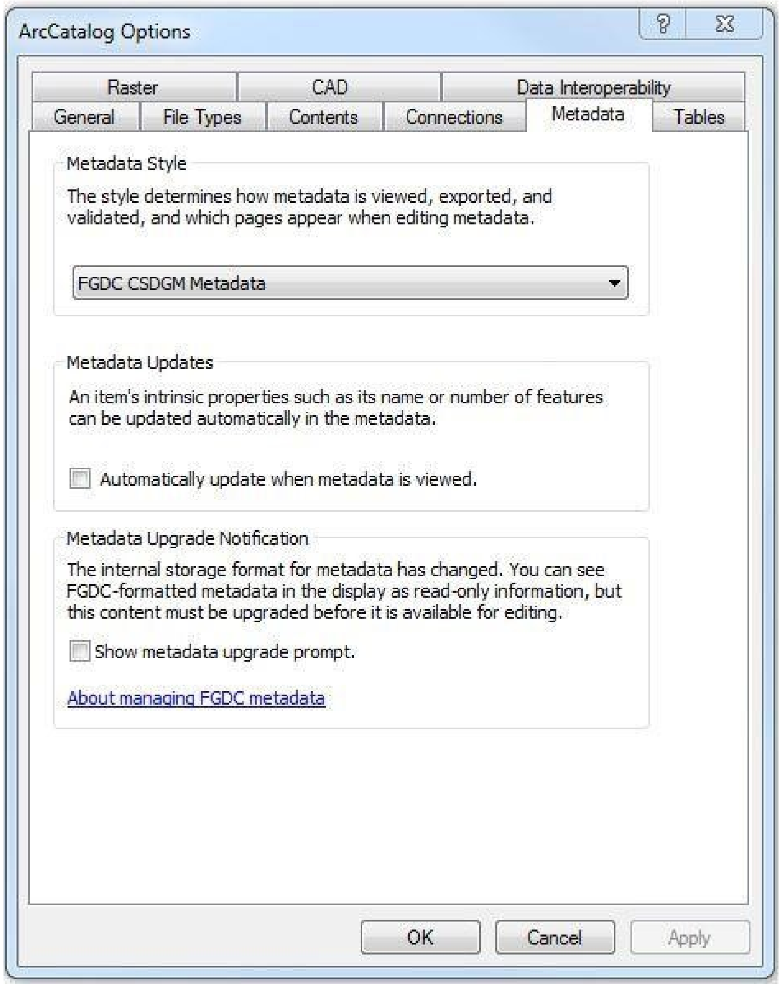


Figure 45. ArcCatalog Options window and Metadata tab properties. The Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata Data (CSDGM) standard can be selected from the drop-down menu under the Metadata Style section. This will enable Digital Shoreline Analysis System (DSAS)-generated metadata to be viewed in ArcCatalog. CAD, computer aided design.

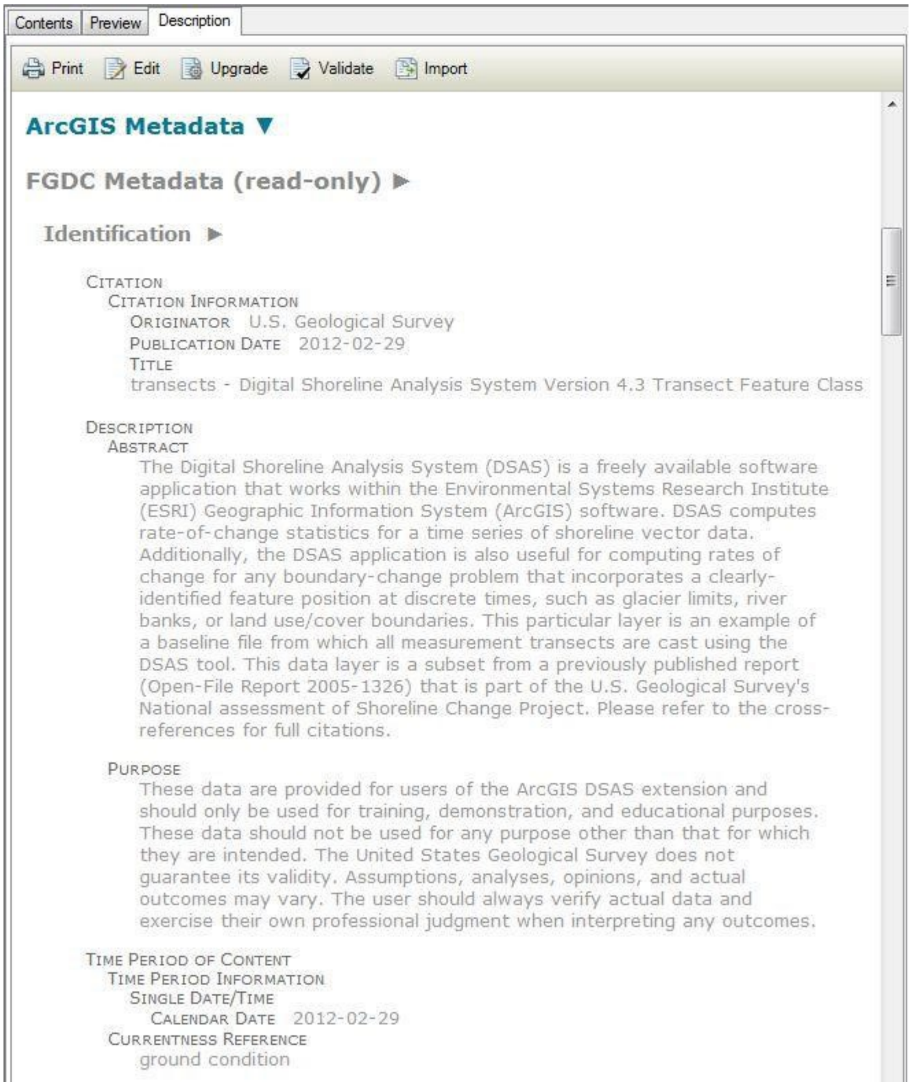


Figure 46. Digital Shoreline Analysis System (DSAS)-generated metadata viewed in ArcCatalog under the read-only section. FGDC, Federal Geographic Data Committee.

10.3 Upgrading DSAS-Generated Metadata to ArcGIS 10.x Format

Once ArcCatalog has been configured to read the FGDC CDGSM style, the read-only metadata generated by DSAS can be converted to the Esri format, if desired. It is not necessary to perform this conversion; the read-only section of the metadata can be edited by using the add-in described in the previous section. To upgrade metadata automatically, check the “Automatically update when metadata is viewed” and “Show metadata upgrade prompt” options in the Metadata tab found in Arc Catalog Options (see **section 10.1** and fig. 45). To apply an individual metadata upgrade conversion, go to ArcToolbox>> Conversion Tools >> Metadata >> Upgrade Metadata. Batch processing using this tool is available by right-clicking the Upgrade Metadata icon. Keep in mind that upgrading is the same as overwriting. Anything that is contained within the internal Esri ArcGIS metadata format (the part of the file preview that is not read-only) will be overwritten by the information extracted from the FGDC-format (read-only) part of the file. Subsequent process steps, written by DSAS after metadata are upgraded, will be added to the FGDC-compliant format and will only be visible in the read-only preview section of the Description tab in ArcCatalog. The metadata can be upgraded again later, if desired.

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12. Appendix 1. Troubleshooting

Table 1.1. Potential solutions to problems that may be encountered when using the Digital Shoreline Analysis System.

Problem	Potential solutions
A file (transect, shoreline, baseline) does not appear as a selectable option in the drop-down menu (Default Parameters, Digital Shoreline Analysis System [DSAS] toolbar).	1. Close and reopen: a. Save the ArcMap project, then close and reopen the document. b. Remove the file from the ArcMap project and then add it again. 2. Use the Attribute Automator tool to add new fields to the data file. Close and reopen the project. 3. If the previous solutions fail, the next-to-last resort is to create a new feature class and populate with the existing data as follows: a. In the existing geodatabase (with the offending file), right-click and choose “create a new feature class,” name the file appropriately, and import or select the coordinate system. Most importantly, in the window with attribute selection, select “Import” and choose the original file to add all fields from the original file to the new file. b. Copy and paste the old features into the new feature class. Check to make sure all the attribute files were properly carried over. 4. Create a new feature class and populate with the existing data as follows: a. In the existing geodatabase (with the offending file), right-click and choose “create a new feature class,” name the file appropriately, import or select the coordinate system, and finish without selecting any additional attributes. b. In ArcMap, add the required fields as described for a baseline (**section 5.3**), a shoreline (**section 5.2**), or for transects (**section 6.3**). c. Copy and paste the old features into the new feature class. Check to make sure all the attribute files were properly carried over.
Error message: Unable to calculate statistics.	If ArcCatalog is open, close it and run the statistics again.
Error message: Unable to find database table for baseline layer.	Verify that the shapefile name and “alias” are the same, otherwise DSAS will not work properly. To fix this error, create a new baseline feature class and populate with the existing data as follows: a. In the existing geodatabase (with the offending file), right-click and choose “create a new feature class,” name the file appropriately, and import or select the coordinate system. Most importantly, in the window with attribute selection, select “Import” and choose the original file to add all fields from the original file to the new file. b. Copy and paste the old features into the new feature class. Check to make sure all the attribute files were properly carried over.
Rate calculations ran, but the table contains <null> values for many (or all) transects.	You may have inadvertently run rate calculations with a specific feature (such as one segment of the baseline or one shoreline) selected. This will restrict the rate calculation to the selected features. Rates will only be calculated for the selected baseline segment or for the selected shorelines. If only one shoreline is selected, no calculations will run successfully. The metadata process step added to the transect file will indicate if features have been selected. Check for zero or null values in the “uncertainty” attribute field in the shoreline feature class (see **section 5.2.3**), or set the default data uncertainty to a value greater than zero in the Default Parameters window (see **section 6.2.2**).
When attempting to calculate rates, the following error message occurs: “Unable to find output file “C:\….\DSASCore. out.xml.”	The computer must be configured to English (USA), and the date format must be mm/dd/yyyy. From the Control Panel menu, choose “Regional Configuration and Language,” select “English (USA),” and modify the date configuration to “mm/dd/yyyy.”

Table 1.1. Potential solutions to problems that may be encountered when using the Digital Shoreline Analysis System.

Problem	Potential solutions
Legacy upgrade: Shorelines will not show up in the Set Default Parameters window.	Check all required attribute settings (**section 5.2.3**). If required fields are present and accounted for, try creating a new feature class and populating with the shoreline data as described above (in solution 1a in the first row of this table).
Legacy upgrade: Legacy transects will not show up in the upgrade transects tool.	Check legacy attribute fields. If they are all present and accurate, and the tool still does not recognize the transects, use the following work-around: Create a new feature class and populate with transect data as described above (in solutions 1c and 1d in the first row of this table).
Legacy upgrade: Legacy project file has onshore and offshore baselines (upgrade tool can only preform one baseline type at a time).	Legacy transect files must be separated into offshore and onshore projects and then each be run separately through the upgrade tool. Once they are upgraded, transects may be combined as DSAS v5 transects by copying and pasting one into the other.

13. Appendix 2. Calculating and Applying the Proxy-Datum Bias Between High-Water Line and Mean High Water Shorelines

13.1 Using Shorelines Derived From Different Data Sources

The development of many features in the Digital Shoreline Analysis System (DSAS) has been influenced by the needs of the U.S. Geological Survey's (USGS) National Assessment of Shoreline Change project (Morton and others, 2004; Morton and Miller, 2005; Miller and others, 2005; Hapke and others, 2006, 2011; Hapke and Reid, 2007; Ruggiero and others, 2013). One of these needs is to calculate the rate of change using different shoreline features derived from various data sources. Proxy-based shoreline positions are defined by the observation (in aerial photography, satellite imagery, or field observation) of physical shoreline markers, such as the instantaneous land-water interface (LWI), wet-dry line (WDL), high-water line (HWL), or the edge of vegetation line (EOV). The HWL proxy is used extensively in National Oceanic and Atmospheric Administration (NOAA) T-sheets and the National Assessment of Shoreline Change project and, as described by Ruggiero and List (2009, p. 1069), is "often identifiable in aerial photographs, [and] is typically assumed to represent the landward extent of water during the last high tide." Modern shoreline positions are increasingly derived by using elevation data from aerial topographic mapping data such as light detection and ranging (lidar). In contrast to proxy-based shorelines, these datum-based shorelines are defined by an elevation. One method for deriving a datum-based shoreline position from lidar is to calculate a linear regression through the foreshore section of an elevation profile (Stockdon and others, 2002; Weber and others, 2005) and to identify the intersection of the mean high water (MHW) tidal datum elevation with the foreshore.

Several studies have determined that there is a horizontal, unidirectional offset between proxy-based HWL shorelines and datum-based MHW shorelines, whereby the HWL position is consistently located landward of the MHW position (Ruggiero and others, 1996, 2001, 2003; Morton and others, 2004; Moore and others, 2006; Stockdon and others, 2006; Ruggiero and List, 2009). The offset between these two types of shorelines can be estimated (Ruggiero and List, 2009) and is called the proxy-datum bias (PDB). DSAS can use proxy-datum bias values to reconcile the offset so that HWL shorelines can be directly compared to MHW shorelines, and rates of change can be accurately calculated.

13.2 Calculating the Proxy-Datum Bias

The PDB is an estimate of the distance between the proxy-based HWL shoreline and the datum-based MHW shoreline. An equation was developed by Ruggiero and List (2009) to calculate the PDB:

$$\text{Bias} = (X_{HWL} - X_{MHW})$$

$$= \frac{\left(\left[\left[Z_T + 1.1\left\{0.35\tan\beta\,(H_0L_0)^{\frac{1}{2}} + \frac{\left[H_0L_0\left(0.563\tan\beta^2 + 0.004\right)\right]^{\frac{1}{2}}}{2}\right\}\right]\right] - Z_{MHW}\right)}{\tan\beta}, \tag{2.1}$$

where

X_{MHW}	is the cross-shore position of the mean high water shoreline,
X_{HWL}	is the cross-shore position of the high-water line shoreline,
Z_T	is the tide level,
$\tan\beta$	is the foreshore beach slope,
H_0	is the offshore wave height,
L_0	is the offshore wavelength, and
Z_{MHW}	is the mean high water tidal datum elevation.

Past wave conditions, typically unknown, can be estimated by using historical wave data. Offshore buoys (https://www.ndbc.noaa.gov/) can be used to estimate the offshore wavelength (L_0). The offshore wave height (H_0) can be estimated from Wave Information Studies (WIS; http://wis.usace.army.mil/). Nearby tide stations (https://tidesandcurrents.noaa.gov/) or Vdatum (https://vdatum.noaa.gov/) can provide an estimate of tide level (Z_T) and the high water datum (Z_{MHW}). The slope of the beach when the historical shoreline was collected ($\tan\beta$) can be estimated from available elevation data. For questions on the use or details of this equation, see Ruggiero and List (2009).

The uncertainty of the calculated value of the proxy-datum bias is sensitive not only to the beach slope, wave height, and wavelength but also to the uncertainty of the best estimate of each of these terms. See Ruggiero and List (2009) for the equations to calculate the proxy-datum bias uncertainty.

13.3 Storing Bias and Bias Uncertainty Data

In DSAS versions 4.x to 5.0, bias information was stored in a database table, which was connected to the lidar shoreline data via linear referencing (Himmelstoss and others, 2018). Starting in DSAS version 5.1, the bias and bias uncertainty values are stored in an alongshore polyline feature class.

Once the bias and bias uncertainty values have been calculated, they must be stored in a polyline shapefile for use in DSAS and imported into the geodatabase where shorelines and baselines are stored. In addition to meeting the requirements in table 2.1, the polyline feature must be adjacent to the shoreline data, such that the transects cast by DSAS intersect the bias feature. One way to achieve this is to use a copy of the baseline file, split this feature, and then add attributes to store the bias and uncertainty information alongshore.

Table 2.1. Proxy-datum bias feature field requirements and description for Digital Shoreline Analysis System version 5.1.

Field name	Data type	Established by	Field description
bias	Any numeric field	User-created	The field name is name specific and case sensitive. The field contains the estimated proxy-datum bias value describing the unidirectional horizontal offset between the mean high water shoreline and the high-water line shoreline.
bias_uncy	Any numeric field	User-created	The field name is name specific and case sensitive. The field contains the estimated uncertainty of the proxy-datum bias value.

13.4 Using the Bias Feature in DSAS

To use a bias feature polyline shapefile in DSAS, add the bias feature into the map project containing the shoreline data. The feature will then be selectable in the Shoreline Settings tab of the Default Parameters (see **section 6.2.2**, fig. 14). When rates are calculated, DSAS will use values stored in the bias feature to perform the proxy-datum bias correction. The bias-corrected outputs that DSAS reports are as follows:

1. Rate transect outputs: When the proxy-datum bias (PDB) is applied, two versions of each (user-selected) statistic are reported in the attribute table of the rate transects. Statistics with a “NB_” or “No bias” preceding the statistic heading (for example, NB_NSM) do not have the PDB applied. See table 8, **section 6.7.4** for additional information on rate transect outputs.

2. Intersect outputs: The intersect feature class is a point file that stores positional information about each transect/shoreline intersection. When the PDB is applied, additional attributes are added to the intersect feature-class output. Information about the proxy-datum bias, including the value of PDB applied, PDB uncertainty, and the new distance to the PDB-corrected shoreline value, is included. For a full list and description of intersect feature attributes, see table 9, **section 6.7.4**.

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14. Appendix 3. Summary Report Text

The following is an example of the complete output of the Digital Shoreline Analysis System (DSAS) summary report generated using the Advanced sample data.

File name: DSAS_Summary_TRANS_20181009_144501.txt
Timestamp of rate calculation: 10/09/2018 14:45:38
DSAS version: 5.0.20180213.1225
ArcGIS version: 10.4
Rate types run: SCE, NSM, EPR, LRR, WLR
Shoreline dates used: 7/1/1860, 7/1/1861, 7/1/1934, 7/1/1952, 7/1/1978, 10/1/1994, 9/27/2000, 3/17/2009 Shoreline threshold: 0
Confidence Interval (CI) selected: 90 Default Uncertainty: 10
Transect spacing length: 50 Smoothing distance: 200
Coordinate system: NAD_1983_StatePlane_Massachusetts_Mainland_FIPS_2001
Is bias applied: YES

All rates reported are in meters/year, distance values are in meters.

DISTANCE: SCE (Shoreline Change Envelope, m)

SCE OVERALL AVERAGES:
total number of transects: 203
average distance: 64.96
maximum distance: 403.46
maximum distance transect ID: 78
minimum distance: 3.51
minimum distance transect ID: 147

SCE REGIONAL AVERAGES [GROUP 1]
total number of transects: 100
average distance: 102.22
maximum distance: 403.46
maximum distance transect ID: 78
minimum distance: 29.37
minimum distance transect ID: 2

SCE REGIONAL AVERAGES [GROUP 2]
total number of transects: 103
average distance: 28.78
maximum distance: 144.95
maximum distance transect ID: 149
minimum distance: 3.51
minimum distance transect ID: 147

DISTANCE: NSM (Net Shoreline Movement, m)

NSM OVERALL AVERAGES:
total number of transects: 203
average distance: 13.16
number of transects with negative distance: 130
percent of all transects that have a negative distance: 64.04%
maximum negative distance: -63.63
maximum negative distance transect ID: 142
average of all negative distances: -18.01
number of transects with positive distance: 73
percent of all transects that have a positive distance: 35.96%

maximum positive distance: 325.67
maximum positive distance transect ID: 78
average of all positive distances: 68.68

NSM REGIONAL AVERAGES [GROUP 1]
total number of transects: 100
average distance: 36.75
number of transects with negative distance: 57
percent of all transects that have a negative distance: 57%
maximum negative distance: -45.27
maximum negative distance transect ID: 54
average of all negative distances: -19.97
number of transects with positive distance: 43
percent of all transects that have a positive distance: 43%
maximum positive distance: 325.67
maximum positive distance transect ID: 78
average of all positive distances: 111.92

NSM REGIONAL AVERAGES [GROUP 2]
total number of transects: 103
average distance: -9.73
number of transects with negative distance: 73
percent of all transects that have a negative distance: 70.87%
maximum negative distance: -63.63
maximum negative distance transect ID: 142
average of all negative distances: -16.49
number of transects with positive distance: 30
percent of all transects that have a positive distance: 29.13%
maximum positive distance: 23.99
maximum positive distance transect ID: 167
average of all positive distances: 6.7

RATE: EPR (End Point Rate, m/yr)

EPR OVERALL AVERAGES:
total number of transects: 203
average rate: 0.21
average of the confidence intervals associated with rates: 0.14
reduced n (number of independent transects): 8
uncertainty of the average rate using reduced n: 0.05
average rate with reduced n uncertainty: 0.21 +/- 0.05

number of erosional transects: 130
percent of all transects that are erosional: 64.04%
percent of all transects that have statistically significant erosion: 43.84%
maximum value erosion: -0.85
maximum value erosion transect ID: 142
average of all erosional rates: -0.19

number of accretional transects: 73
percent of all transects that are accretional: 35.96%
percent of all transects that have statistically significant accretion: 20.69%
maximum value accretion: 4.36
maximum value accretion transect ID: 78
average of all accretional rates: 0.92

EPR REGIONAL AVERAGES [GROUP 1]
total number of transects: 100
average rate: 0.56
average of the confidence intervals associated with rates: 0.13
reduced n (number of independent transects): 2
uncertainty of the average rate using reduced n: 0.09
average rate with reduced n uncertainty: 0.56 +/- 0.09

number of erosional transects: 57
percent of all transects that are erosional: 57%
percent of all transects that have statistically significant erosion: 44%
maximum value erosion: -0.3
maximum value erosion transect ID: 54
average of all erosional rates: -0.14

number of accretional transects: 43
percent of all transects that are accretional: 43%
percent of all transects that have statistically significant accretion: 36%
maximum value accretion: 4.36
maximum value accretion transect ID: 78
average of all accretional rates: 1.49

EPR REGIONAL AVERAGES [GROUP 2]
total number of transects: 103
average rate: -0.13
average of the confidence intervals associated with rates: 0.16
reduced n (number of independent transects): 6
uncertainty of the average rate using reduced n: 0.06
average rate with reduced n uncertainty: -0.13 +/- 0.06

number of erosional transects: 73
percent of all transects that are erosional: 70.87%
percent of all transects that have statistically significant erosion: 43.69%
maximum value erosion: -0.85
maximum value erosion transect ID: 142
average of all erosional rates: -0.22

number of accretional transects: 30
percent of all transects that are accretional: 29.13%
percent of all transects that have statistically significant accretion: 5.83%
maximum value accretion: 0.32
maximum value accretion transect ID: 167
average of all accretional rates: 0.09

RATE: LRR (Linear Regression Rate, m/yr)

LRR OVERALL AVERAGES:
total number of transects: 203
average rate: 0.16
average of the confidence intervals associated with rates: 0.77
reduced n (number of independent transects): 18
uncertainty of the average rate using reduced n: 0.18
average rate with reduced n uncertainty: 0.16 +/- 0.18

number of erosional transects: 133
percent of all transects that are erosional: 65.52%
percent of all transects that have statistically significant erosion: 15.76%
maximum value erosion: -0.77
maximum value erosion transect ID: 142
average of all erosional rates: -0.21

number of accretional transects: 70
percent of all transects that are accretional: 34.48%
percent of all transects that have statistically significant accretion: 4.93%
maximum value accretion: 3.14
maximum value accretion transect ID: 78
average of all accretional rates: 0.85

LRR REGIONAL AVERAGES [GROUP 1]
total number of transects: 100
average rate: 0.45
average of the confidence intervals associated with rates: 0.9
reduced n (number of independent transects): 5
uncertainty of the average rate using reduced n: 0.39
average rate with reduced n uncertainty: 0.45 +/- 0.39

number of erosional transects: 59
percent of all transects that are erosional: 59%
percent of all transects that have statistically significant erosion: 12%
maximum value erosion: -0.36
maximum value erosion transect ID: 89
average of all erosional rates: -0.19

number of accretional transects: 41
percent of all transects that are accretional: 41%
percent of all transects that have statistically significant accretion: 10%
maximum value accretion: 3.14
maximum value accretion transect ID: 78
average of all accretional rates: 1.38

LRR REGIONAL AVERAGES [GROUP 2]
total number of transects: 103
average rate: -0.13
average of the confidence intervals associated with rates: 0.64
reduced n (number of independent transects): 13
uncertainty of the average rate using reduced n: 0.18
average rate with reduced n uncertainty: -0.13 +/- 0.18

number of erosional transects: 74
percent of all transects that are erosional: 71.84%
percent of all transects that have statistically significant erosion: 19.42%
maximum value erosion: -0.77
maximum value erosion transect ID: 142
average of all erosional rates: -0.22

number of accretional transects: 29
percent of all transects that are accretional: 28.16%
percent of all transects that have statistically significant accretion: 0%

maximum value accretion: 0.37
maximum value accretion transect ID: 167
average of all accretional rates: 0.11

RATE: WLR (Weighted Linear Regression, m/yr)

WLR OVERALL AVERAGES:
total number of transects: 203
average rate: 0.31
average of the confidence intervals associated with rates: 1.2
reduced n (number of independent transects): 19
uncertainty of the average rate using reduced n: 0.27
average rate with reduced n uncertainty: 0.31 +/- 0.27

number of erosional transects: 138
percent of all transects that are erosional: 67.98%
percent of all transects that have statistically significant erosion: 8.37%
maximum value erosion: -1.71
maximum value erosion transect ID: 149
average of all erosional rates: -0.26

number of accretional transects: 65
percent of all transects that are accretional: 32.02%
percent of all transects that have statistically significant accretion: 3.94%
maximum value accretion: 7.06
maximum value accretion transect ID: 78
average of all accretional rates: 1.51

WLR REGIONAL AVERAGES [GROUP 1]
total number of transects: 100
average rate: 0.93
average of the confidence intervals associated with rates: 1.66
reduced n (number of independent transects): 6
uncertainty of the average rate using reduced n: 0.66
average rate with reduced n uncertainty: 0.93 +/- 0.66

number of erosional transects: 49
percent of all transects that are erosional: 49%
percent of all transects that have statistically significant erosion: 0%
maximum value erosion: -0.33
maximum value erosion transect ID: 88
average of all erosional rates: -0.08

number of accretional transects: 51
percent of all transects that are accretional: 51%
percent of all transects that have statistically significant accretion: 6%
maximum value accretion: 7.06
maximum value accretion transect ID: 78
average of all accretional rates: 1.89

WLR REGIONAL AVERAGES [GROUP 2]
total number of transects: 103
average rate: -0.29

average of the confidence intervals associated with rates: 0.77
reduced n (number of independent transects): 13
uncertainty of the average rate using reduced n: 0.21
average rate with reduced n uncertainty: -0.29 +/- 0.21

number of erosional transects: 89
percent of all transects that are erosional: 86.41%
percent of all transects that have statistically significant erosion: 16.5%
maximum value erosion: -1.71
maximum value erosion transect ID: 149
average of all erosional rates: -0.35

number of accretional transects: 14
percent of all transects that are accretional: 13.59%
percent of all transects that have statistically significant accretion: 1.94%
maximum value accretion: 0.33
maximum value accretion transect ID: 125
average of all accretional rates: 0.12

15. Appendix 4. Sample Data Workflows

Appendix 4 Contents

For the Digital Shoreline Analysis System version 5 (DSAS v5), there are two downloadable sample datasets. The first, basic sample data, is for users new to DSAS and illustrates the basic functions of DSAS. The second, advanced sample data, is for users who will be working with more complex datasets and using the updated functionality in DSAS v5. The first two workflows correspond to these two sample datasets. The third workflow illustrates how to upgrade existing (legacy) transects to DSAS v5.

15.1 Basic Sample Data Workflow

The basic sample data include four shoreline positions for a section of the North Carolina coast near Rodanthe along the Outer Banks and a reference baseline from which the DSAS transects are cast. These shoreline data are a subset of data from Miller and others (2005) and are available through the U.S. Geological Survey (USGS) Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/).

The shoreline positions from 1842, 1946, and 1980 were digitized from National Oceanic and Atmospheric Administration (NOAA) coastal topographic survey maps (T-sheets) and mark the location of the observed high-water line (HWL).

The shoreline from 1997 marks the location of the datum-based, mean high water (MHW) line and was extracted from light detection and ranging (lidar) elevation data by applying the techniques described in Stockdon and others (2002) and Weber and others (2005).

The sample data also include a reference baseline, from which the DSAS transects are cast. The basic sample dataset (DSAS_v5_Basic_SampleData.mdb) is distributed as an ArcGIS (version 10) geodatabase (fig. 1) that meets the minimum software requirements for DSAS v5. Go to https://code.usgs.gov/usgs/dsas to download basic sample dataset in the following file: DSAS_v5_Basic_SampleData.zip.

Figure 4.1 outlines the general workflow to use with the basic sample data. The following sections detail each step of the workflow. Within each window in ArcMap, there are help buttons (gray question marks), which provide additional information about each field if needed.

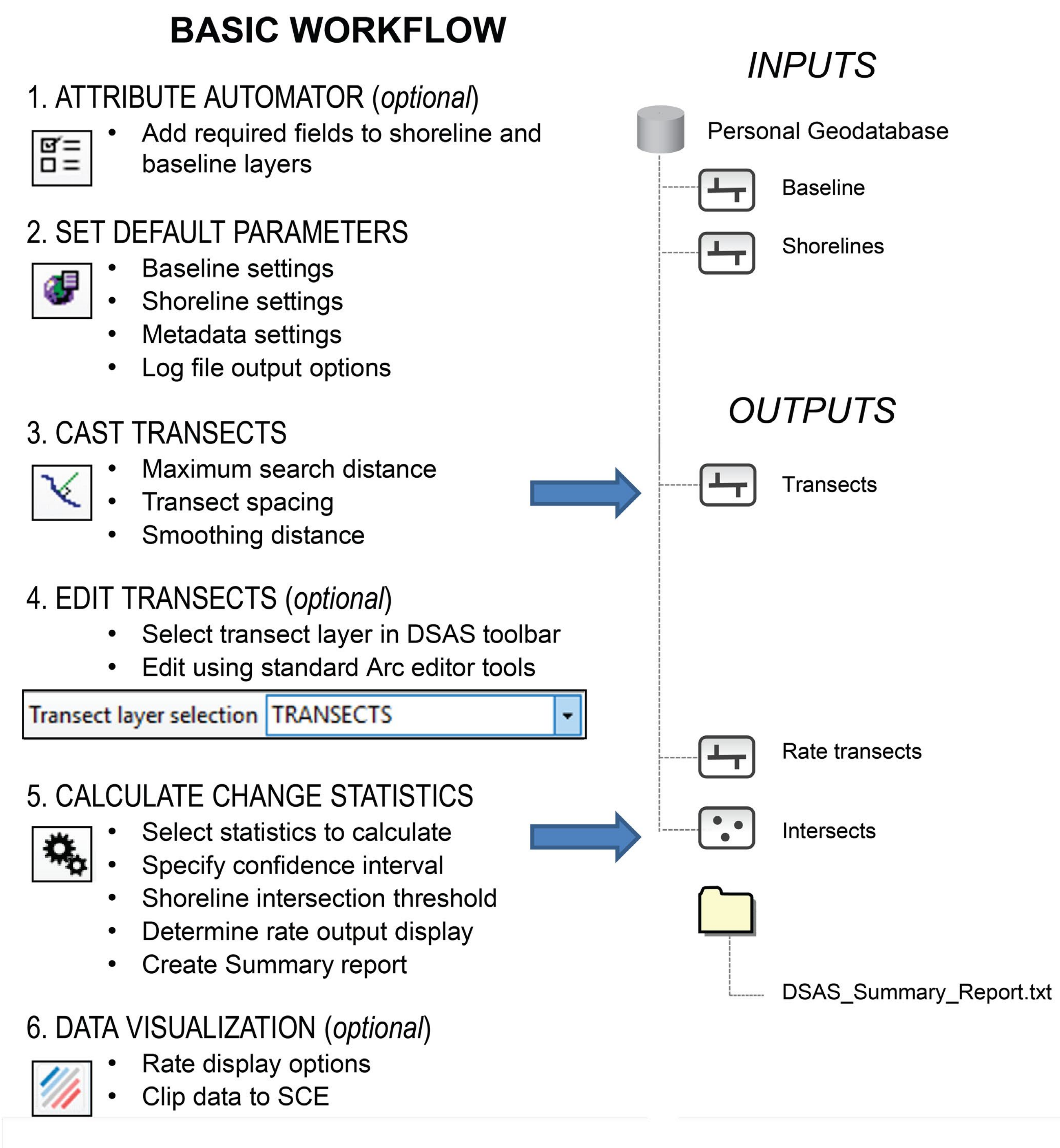


Figure 4.1. Diagram outlining the general workflow to follow with the basic sample data. DSAS, Digital Shoreline Analysis System; SCE, shoreline change envelope.

15.1.1 Set Default Parameters

Once the sample dataset has been downloaded and added to ArcMap, the following user settings should be applied to run a controlled test of the sample data. Locate the DSAS v5 toolbar and begin by selecting the Set Default Parameters icon.

Table 4.1. Baseline settings (Set default parameters): Basic sample data workflow.

<table>
<tr><th>Process description</th><th>Graphical user interface with selections</th></tr>
<tr><td>

DSAS v5 Toolbar

Click Set Default Parameters icon

</td><td>

</td></tr>
<tr><td>

Step 1. Set Default Parameters

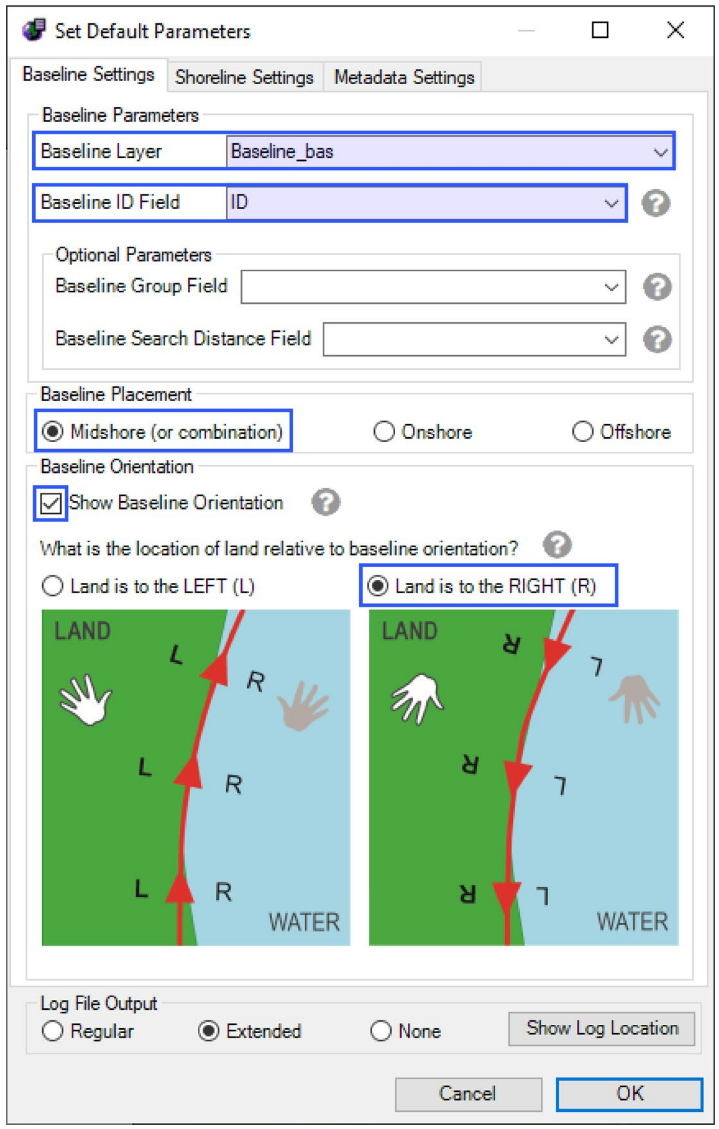
- ➢ **Baseline settings**
- • Shoreline settings
- • Metadata settings

Make selections for Baseline Settings as shown.

For the sample data, the correct "Location of Land Relative to Baseline Orientation" is RIGHT. Even though the land appears on the left, the arrow direction is to the south, so the orientation with respect to the baseline direction is to the right. See the question mark for additional examples.

Click the "Shoreline Calculation Settings" tab to proceed.

</td><td>



</td></tr>
</table>

Table 4.2. Shoreline settings (Set default parameters): Basic sample data workflow.

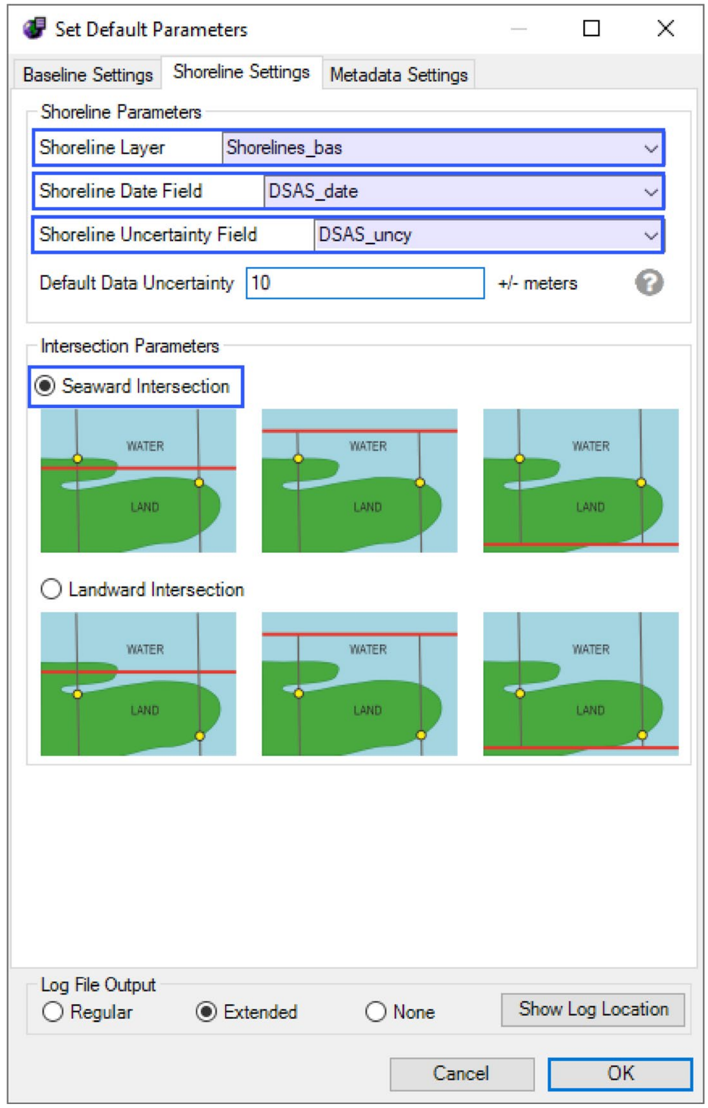
Process description	Graphical user interface with selections
Step 1. Set Default Parameters  • Baseline settings ➢ **Shoreline settings** • Metadata settings ***Make selections for Shoreline Calculation Settings as shown.*** *Click the "Metadata Settings" tab to proceed.*	

Table 4.3. Metadata settings (Set default parameters): Basic sample data workflow.

<table>
<tr><th>Process description</th><th>Graphical user interface with selections</th></tr>
<tr><td>

Step 1. Set Default Parameters

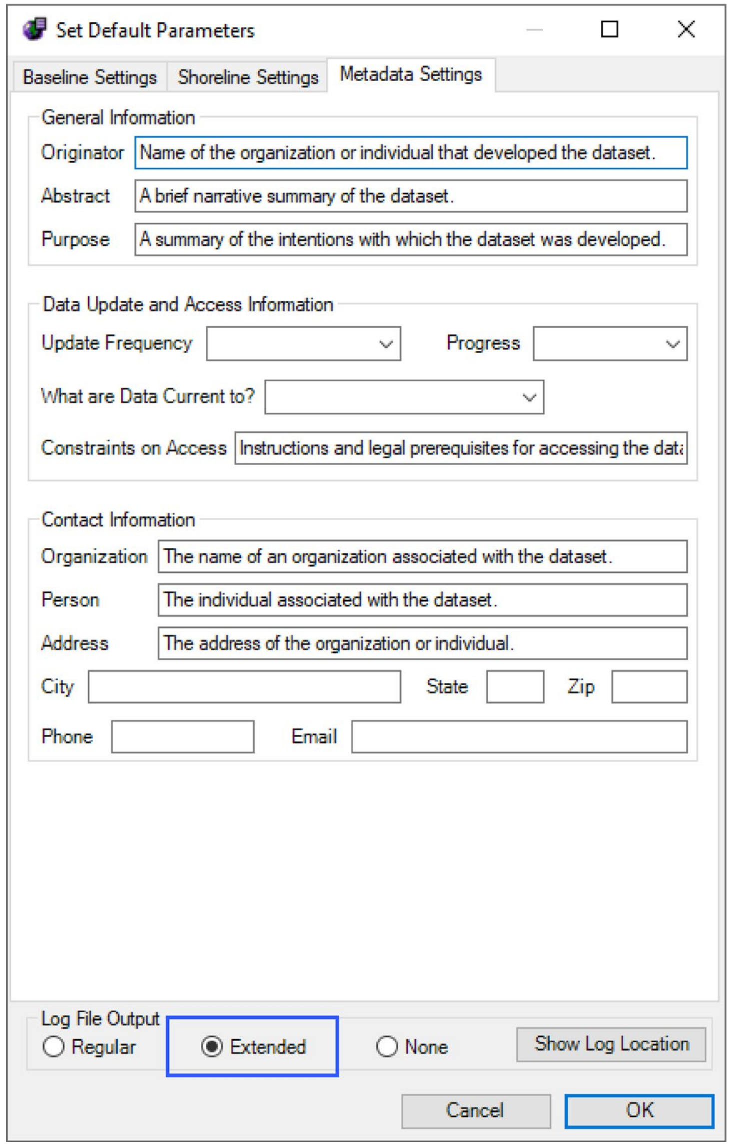
- Baseline settings
- Shoreline settings
- ➤ **Metadata settings**

All fields are required. Any missing information will prompt a DSAS warning—and rates cannot be calculated until this section is complete.

It is recommended to set the “Log File Output” to “Extended” for use in troubleshooting.

Once completed, click “OK” to close and apply default parameters.

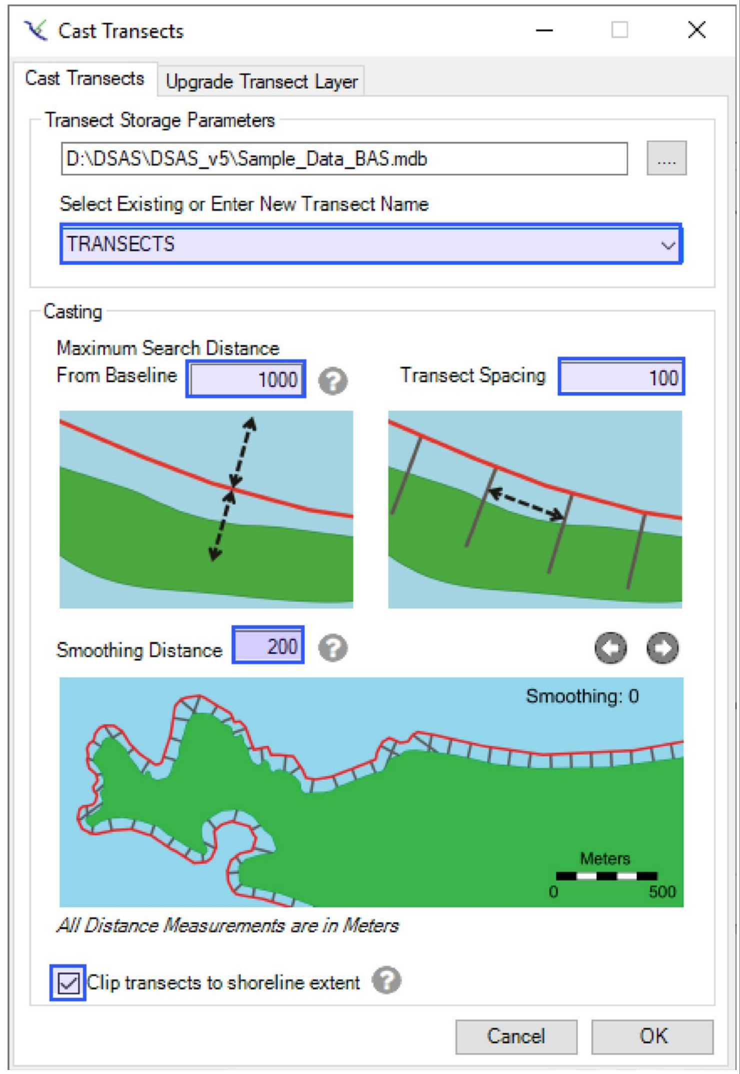
</td><td>



</td></tr>
</table>

15.1.2 Cast Transects

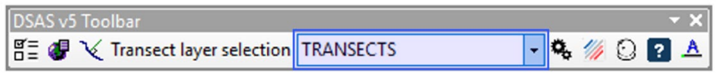
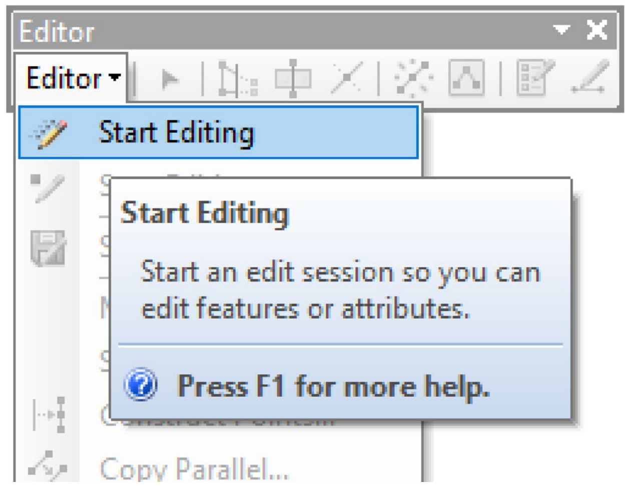
Table 4.4. Cast transects: Basic sample data workflow.

Process description	Graphical user interface with selections
DSAS v5 Toolbar *Click the Cast Transects icon*	
Step 2. Cast Transects  • Maximum search distance • Transect spacing • Smoothing distance **Transect Storage**—The new transect file will be stored by default to the same geodatabase as the baseline and shorelines file. **Enter New Transect**—Enter a name for the new transect file, such as "TRANS." **Make selections for all other "Casting" variables as shown.** Click "OK" to cast transects.	

15.1.3 Edit Transects (Optional)

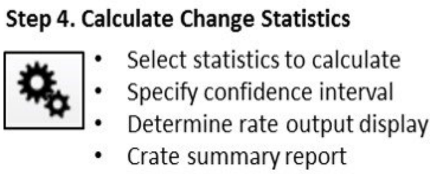
Transects can be edited in a standard ArcMap editing session, but new to DSAS v5 is the requirement that the transect field must be selected in the DSAS drop-down menu prior to starting an edit session. In addition, the baseline file must be defined in default parameters. See **section 6.4** for details. This section is shown for reference, no edits are needed in the sample dataset.

Table 4.5. Edit transects (optional).

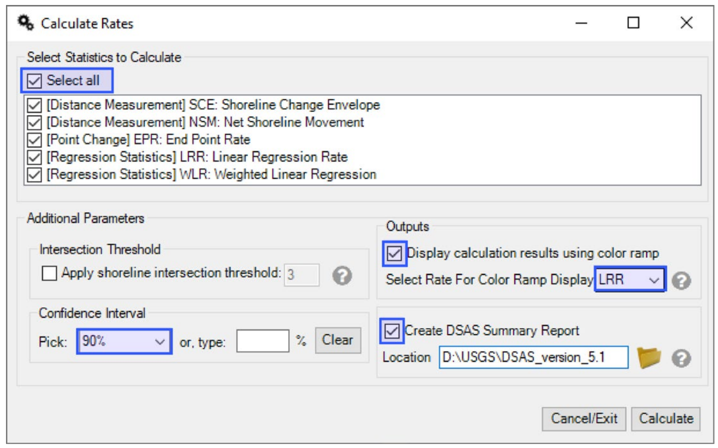
Process description	Graphical user interface with selections
DSAS v5 Toolbar *Select Layer in DSAS toolbar*	
Step 3. Edit Transects (optional) • Select Layer in DSAS toolbar • Edit using Arc Editor tools To edit transects, make sure the newly created transect file-name appears in the DSAS toolbar drop-down menu, and proceed to edit using standard ArcMap editing tools. **For the basic sample dataset, no edits are needed.**	

15.1.4 Calculate Change Statistics

Table 4.6. Calculate change statistics: Basic sample data workflow.

<table>
<tr><th>Process description</th><th>Graphical user interface with selections</th></tr>
<tr><td>DSAS v5 Toolbar
Click the Calculate rates icon</td><td>
</td></tr>
<tr><td>

Make selections as shown.

Click “Calculate” to run statistics.</td><td>
</td></tr>
</table>

15.1.5 Results

If the user follows this sample workflow, the results (TRANSECT_rates_*datestamp* and TRANSECT_intersects_*datestamp*) should appear as follows in figure 4.2. If not, verify settings such as “Location of Land Relative to Baseline Orientation” (see Baseline Settings tab of the Set Default Parameters window) and “Maximum Search Distance From Baseline” (Cast Transects window and tab). If an alternative statistic (other than linear regression rate [LRR]) was selected (visible below “TRANSECT_rate” layer), use the Data Visualization workflow (**section 15.1.6**) to change statistics to LRR for comparison with figure 4.2.

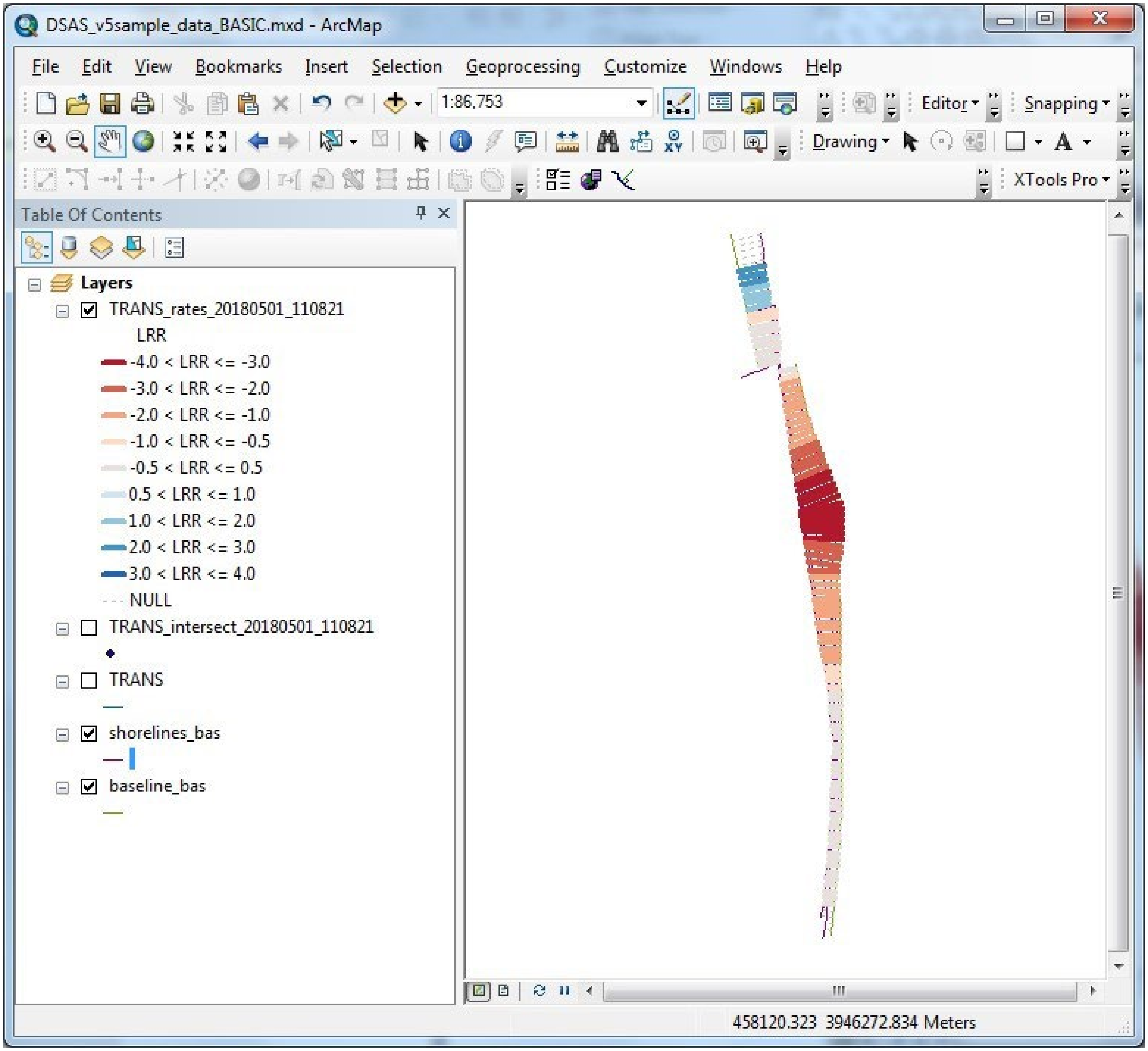
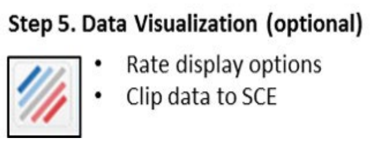
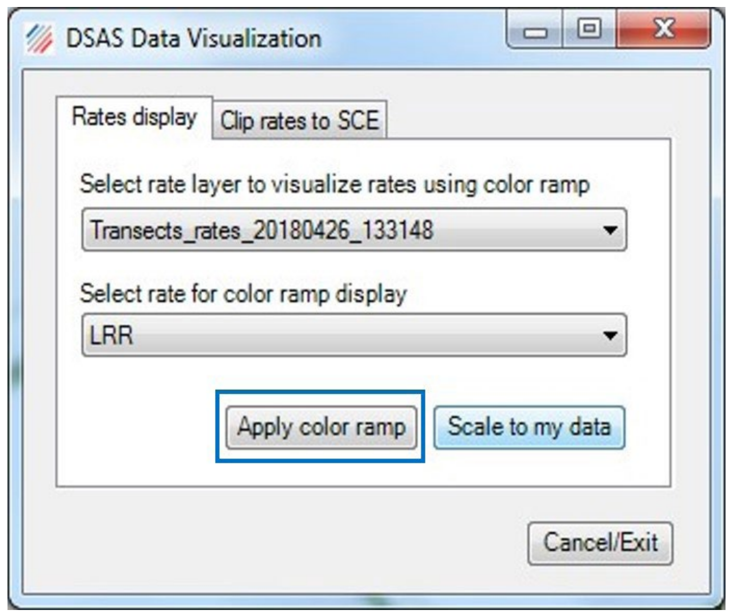


Figure 4.2. Screen capture showing transect shoreline change-rate results generated by using the Digital Shoreline Analysis System (DSAS), the DSAS_v5_Basic_SampleData.mdb data, and the basic workflow with linear regression rate (LRR) selected for visualization. Transect line thickness has been adjusted for display.

15.1.6 Data Visualization (Optional)

If an alternative statistic (other than LRR) was selected while running rates, use the Data Visualization workflow to change statistics to LRR for comparison with figure 4.2.

Table 4.7. Data visualization (optional).

Process description	Graphical user interface with selections
DSAS v5 Toolbar *Click the Data Visualization icon*	
 **Rates display**—To change the way the results are displayed, select the transect rate file and choose the desired statistic. To compare with sample data results (fig. 4.2), select LRR and click "Apply color ramp." **Clip rates to SCE**—If desired, the transect file may be clipped to the shoreline change envelope (SCE). See **section 6.8.2.**	

15.2 Advanced Sample Data Workflow

The advanced sample data include seven shoreline positions for a section of the Cape Cod Bay coast near Barnstable, Massachusetts, and a reference baseline from which the DSAS transects are cast. These shoreline data are a subset of data from the Massachusetts Coastal Zone Management shoreline change update (Smith and others, 2013) and are available through the USGS Coastal Change Hazards Portal (https://marine.usgs.gov/coastalchangehazardsportal/). The shoreline positions from 1860, 1934, and 1952 were digitized from NOAA coastal topographic survey maps (T-sheets) and mark the location of the inferred mean high-water line (MHW), although the actual feature digitized is assumed to be the HWL. Additional HWL shorelines for 1978, 1994, and 2009 were digitized from aerial photographs. The 2000 shoreline marks the location of the datum-based MHW line and was extracted from lidar elevation data by applying the techniques described in Stockdon and others (2002) and Weber and others (2005). This shoreline dataset illustrates how to incorporate shoreline data with multiple shoreline proxies into DSAS analysis. The sample data also include a reference baseline from which the DSAS transects are cast. The advanced sample dataset (DSAS_v5_Advanced_SampleData.mdb) is distributed as an ArcGIS (version 10) geodatabase (fig. 1) that meets the minimum software requirements for DSAS v5 while providing advanced options (such as Baseline Search Distance and proxy-datum bias) to illustrate the range of new DSAS v5 features. Go to https://code.usgs.gov/usgs/dsas to download the advanced sample dataset in the following file: DSAS_v5_Advanced_SampleData.zip.

Figure 4.3 outlines the general workflow to use with the advanced sample data. The following sections detail each step of the workflow. Within each step are help buttons (gray question marks), which provide additional information about each field if needed.

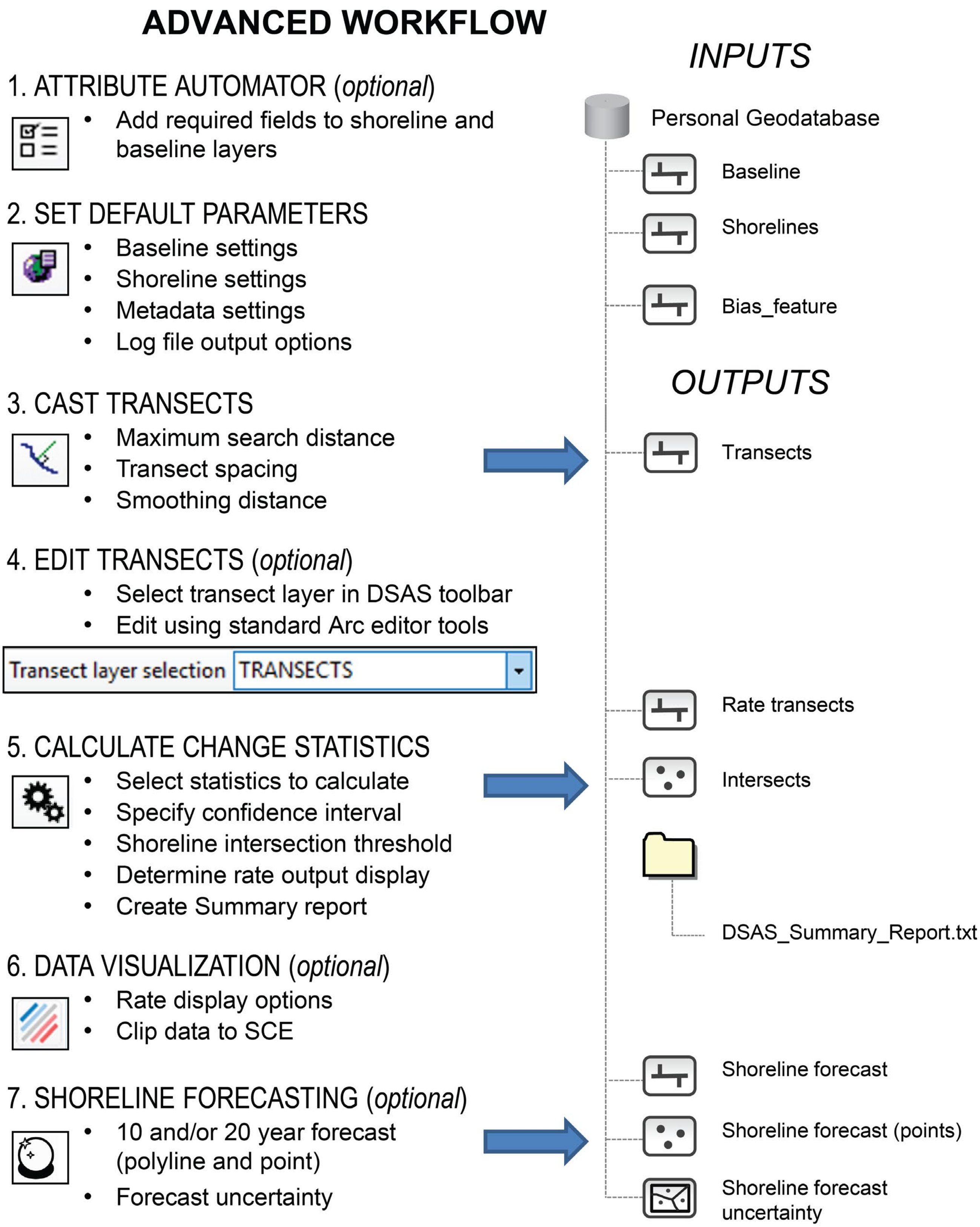


Figure 4.3. Diagram outlining the general workflow to follow with the advanced sample data. DSAS, Digital Shoreline Analysis System; SCE, shoreline change envelope.

15.2.1 Set Default Parameters

Once the sample dataset has been downloaded, add the shorelines, baseline, and bias feature to ArcMap. The following user settings should be applied to run a controlled test of the sample data. Click on the Set Default Parameters icon in the DSAS toolbar to begin.

Table 4.8. Baseline settings (Set default parameters): Advanced sample data workflow.

<table>
<tr><th>Process description</th><th>Graphical user interface with selections</th></tr>
<tr><td>DSAS v5 Toolbar
Click the Set Default Parameters icon</td><td></td></tr>
<tr><td>
Make selections for Baseline Settings as shown.

For the sample data, the correct “Location of Land Relative to Baseline Orientation” is RIGHT. Even though the land appears on the left, the arrow direction is to the south, so the orientation with respect to the baseline direction is to the right. See the question mark for additional examples.

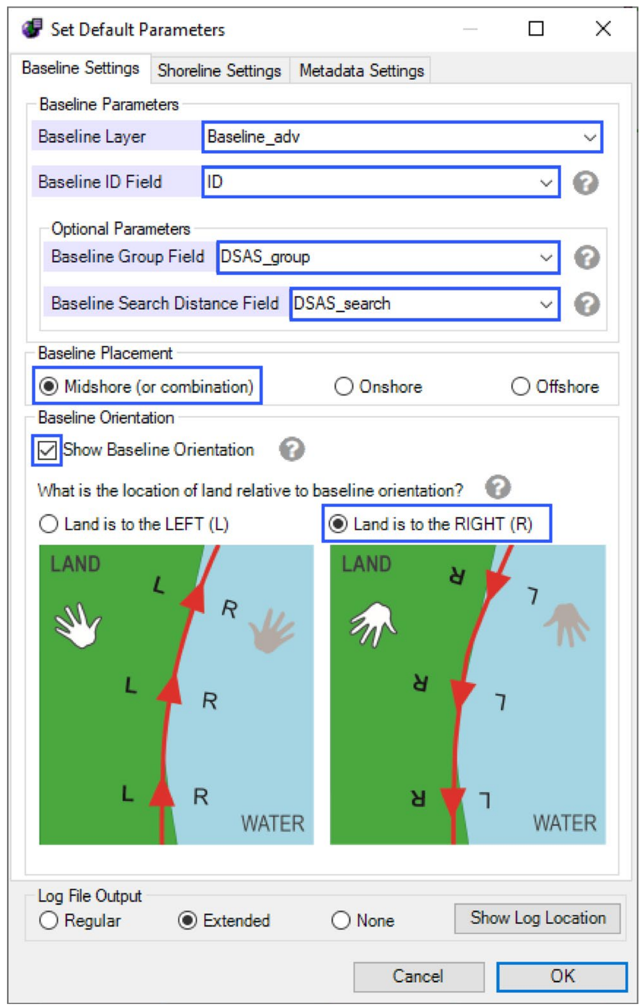
Click the “Shoreline Calculation Settings” tab to proceed.</td><td></td></tr>
</table>

Table 4.9. Shoreline settings (Set default parameters): Advanced sample data workflow.

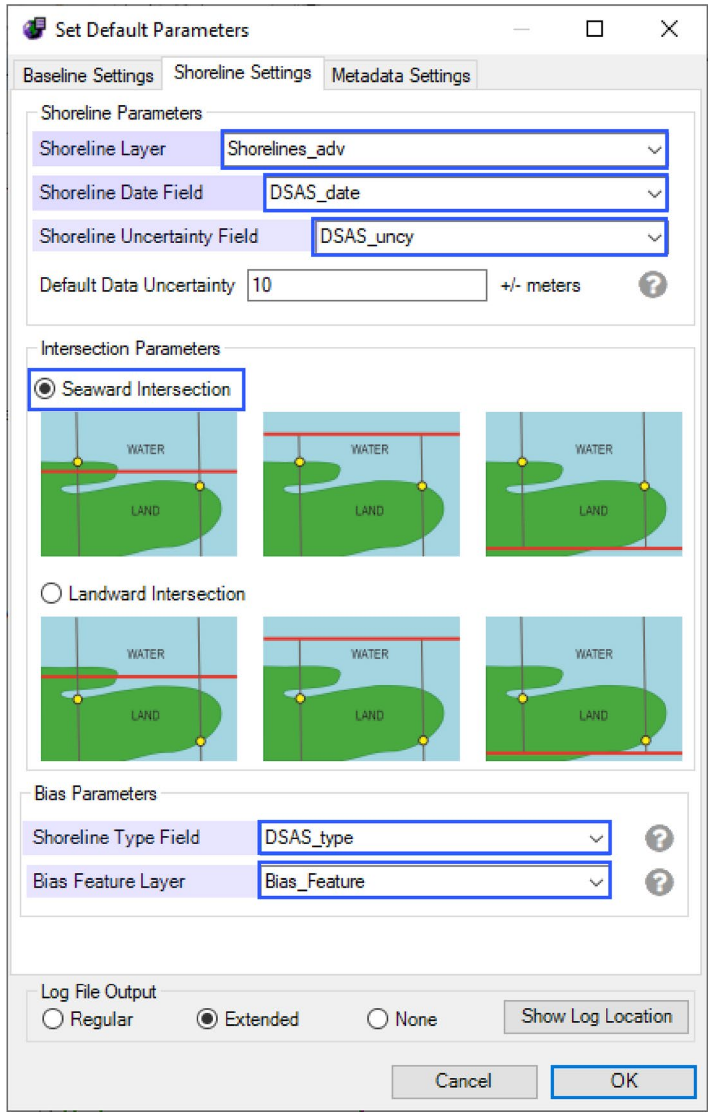
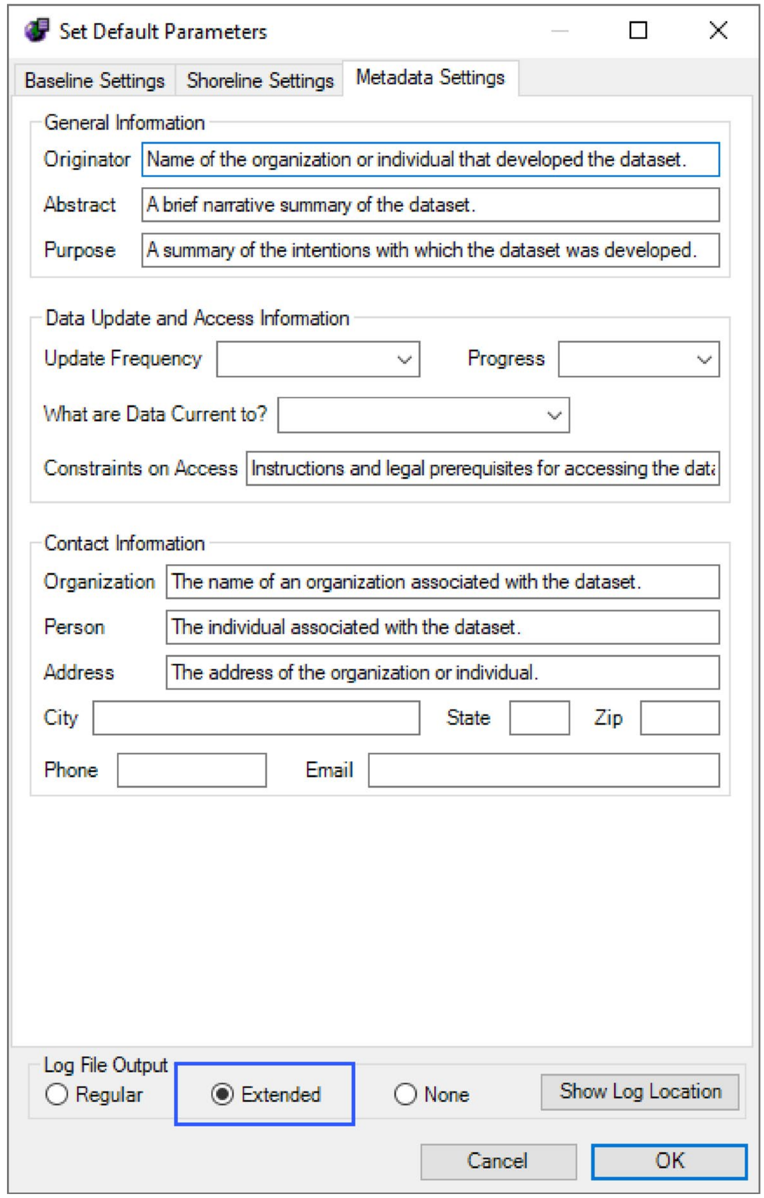
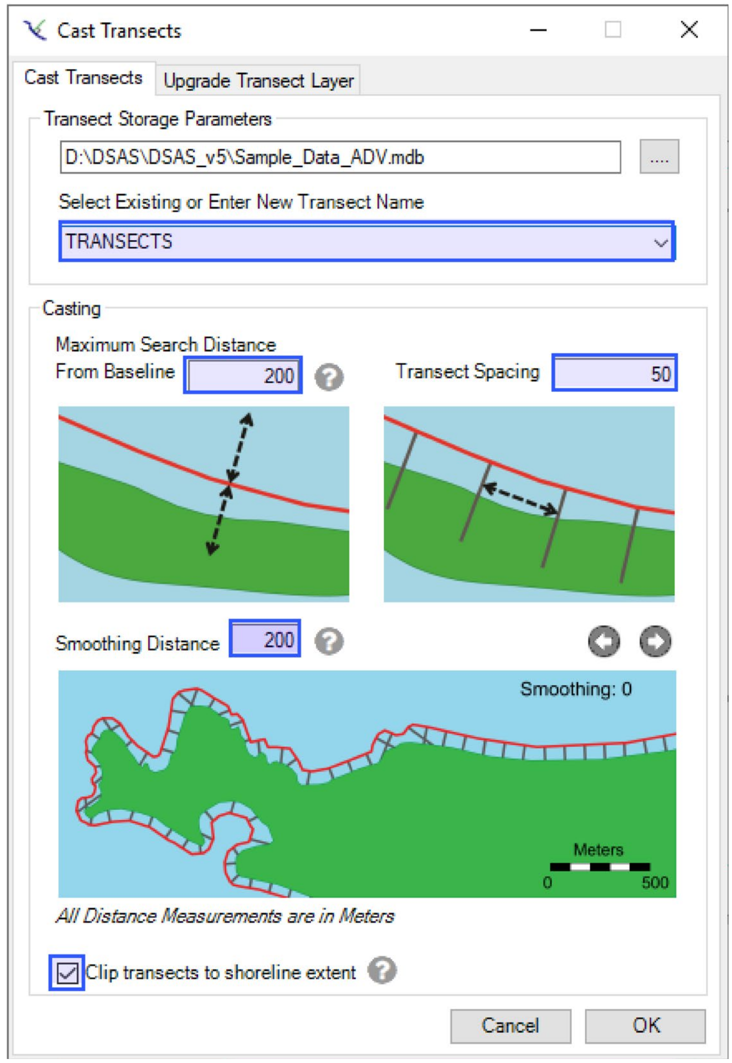
Process description	Graphical user interface with selections
Step 1. Set Default Parameters • Baseline settings ➢ **Shoreline settings** • Metadata settings ***Make selections for Shoreline Calculation Settings as shown.*** *Click the “Metadata Settings” tab to proceed.*	

Table 4.10. Metadata settings (Set default parameters): Advanced sample data workflow.

Process description	Graphical user interface with selections
Step 1. Set Default Parameters  • Baseline settings • Shoreline settings ➢ **Metadata settings** All fields are required. Any missing information will prompt a DSAS warning—and rates cannot be calculated until this section is complete. It is recommended to set the "Log File Output" to "Extended" for use in troubleshooting. *Once completed, click "OK" to close and apply default parameters.*	

15.2.2 Cast Transects

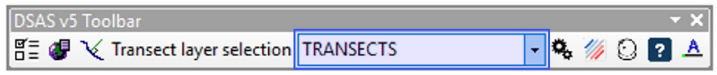
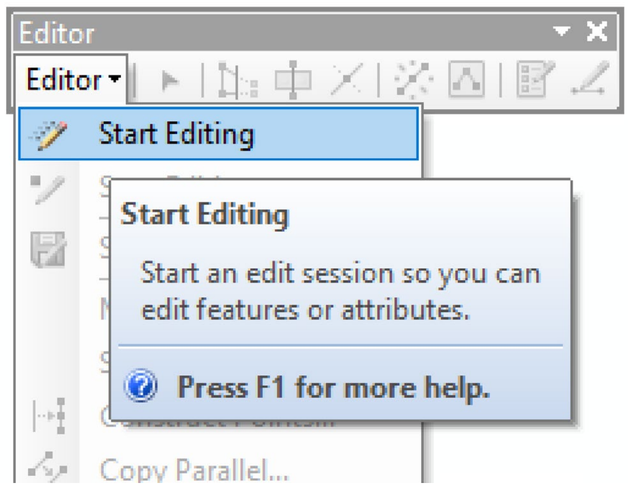
Table 4.11. Cast transects: Advanced sample data workflow.

Process description	Graphical user interface with selections
DSAS v5 Toolbar *Click the Cast Transects icon*	
Step 2. Cast Transects  • Maximum search distance • Transect spacing • Smoothing distance **Transect Storage**—The new transect file will be stored by default to the same geodatabase as the baseline and shorelines file. **Enter New Transect**—Enter a name for the new transect file, such as “TRANS.” **Make selections for all other “Casting” variables as shown.** Click “OK” to cast transects.	

15.2.3 Edit Transects (Optional)

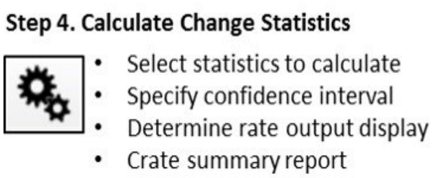
Transects can be edited in a standard ArcMap editing session, but new to DSAS v5 is the requirement that the transect field must be selected in the DSAS drop-down menu prior to starting an edit session. In addition, the baseline file must be defined in default parameters. See **section 6.4** for details. This section is shown for reference, no edits are needed in the sample dataset.

Table 4.12. Edit transects (optional).

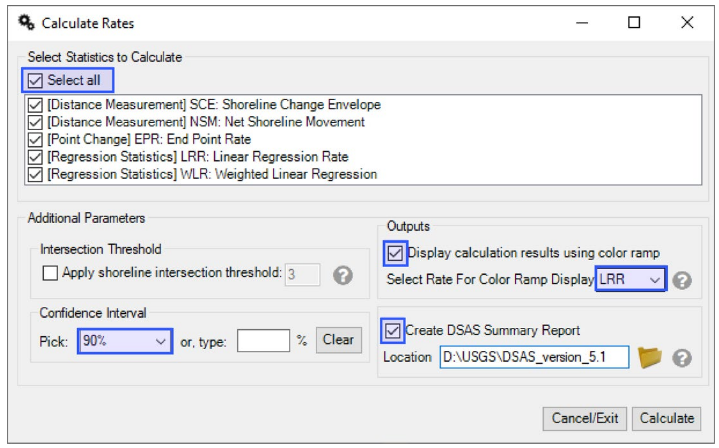
Process description	Graphical user interface with selections
DSAS v5 Toolbar *Select Layer in DSAS toolbar*	
Step 3. Edit Transects (optional) • Select Layer in DSAS toolbar • Edit using Arc Editor tools To edit transects, make sure the newly created transect filename appears in the DSAS toolbar drop-down menu, and proceed to edit using standard ArcMap editing tools. **For the advanced sample dataset, no edits are needed.**	

15.2.4 Calculate Change Statistics

Table 4.13. Calculate change statistics: Advanced sample data workflow.

<table>
<tr><th>Process description</th><th>Graphical user interface with selections</th></tr>
<tr><td>DSAS v5 Toolbar
Click the Calculate rates icon</td><td>
</td></tr>
<tr><td>

Make selections as shown.

Click “Calculate” to run statistics.</td><td>
</td></tr>
</table>

15.2.5 Results

The results returned to the map, if the user follows this sample workflow, should appear as follows in figure 4.4. If not, verify settings such as "Location of Land Relative to Baseline Orientation" (see Baseline Settings tab of the Set Default Parameters window), and "Maximum Search Distance From Baseline" (Cast Transects window and tab). If an alternative statistic (other than LRR) was selected, use the Data Visualization workflow (**section 15.2.6**) to change statistics to LRR for comparison with figure 4.4.

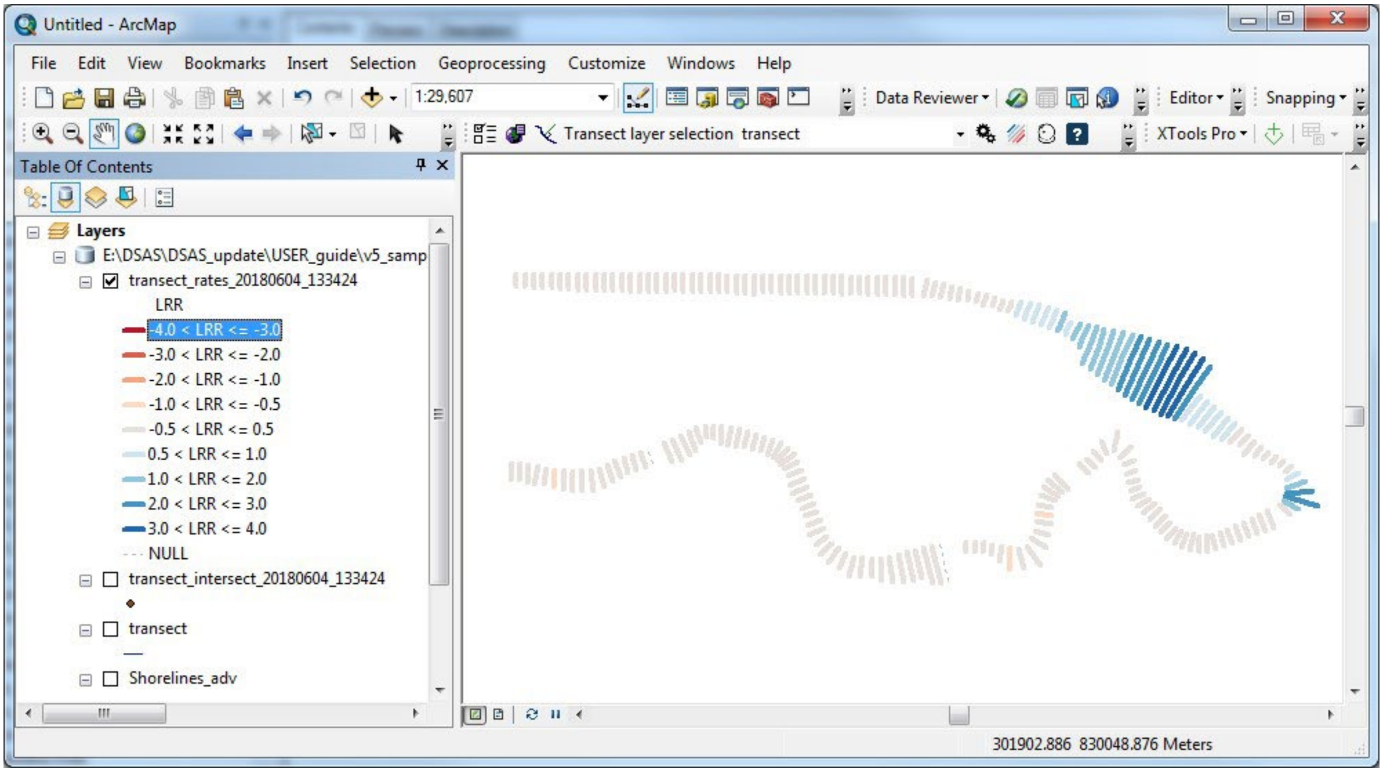
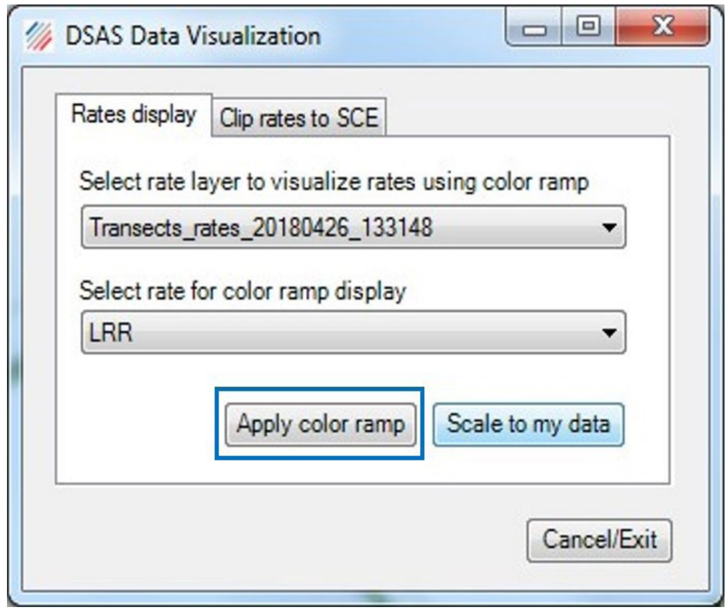


Figure 4.4. Screen capture showing transect shoreline change-rate results of the Digital Shoreline Analysis System (DSAS), using the DSAS_v5_Advanced_Sample_Data.mdb data and the advanced workflow with linear regression rate (LRR) selected for visualization. Line thickness has been adjusted for display.

15.2.6 Data Visualization

To use the Data Visualization toolbar, follow the instructions below and compare the output to figures 4.4 and 4.5. These examples show the difference between a fixed bin color scheme (“Apply color ramp”) and a color scheme scaled to the input data (“Scale to my data”).

Table 4.14. Data Visualization (optional).

Process description	Graphical user interface with selections
DSAS v5 Toolbar *Click the Data Visualization icon*	
Step 5. Data Visualization (optional)  • Rate display options • Clip data to SCE **Rates display**—To change the way the results are displayed, select the transect rate file and choose the desired statistic. • To compare with sample data results (fig. 4.4), select LRR and click “*Apply color ramp*.” • For results shown in figure 4.5, select “*Scale to my data*.” **Clip rates to SCE**—If desired, the transect file may be clipped to the shoreline change envelope (SCE). See **section 6.8.2.**	

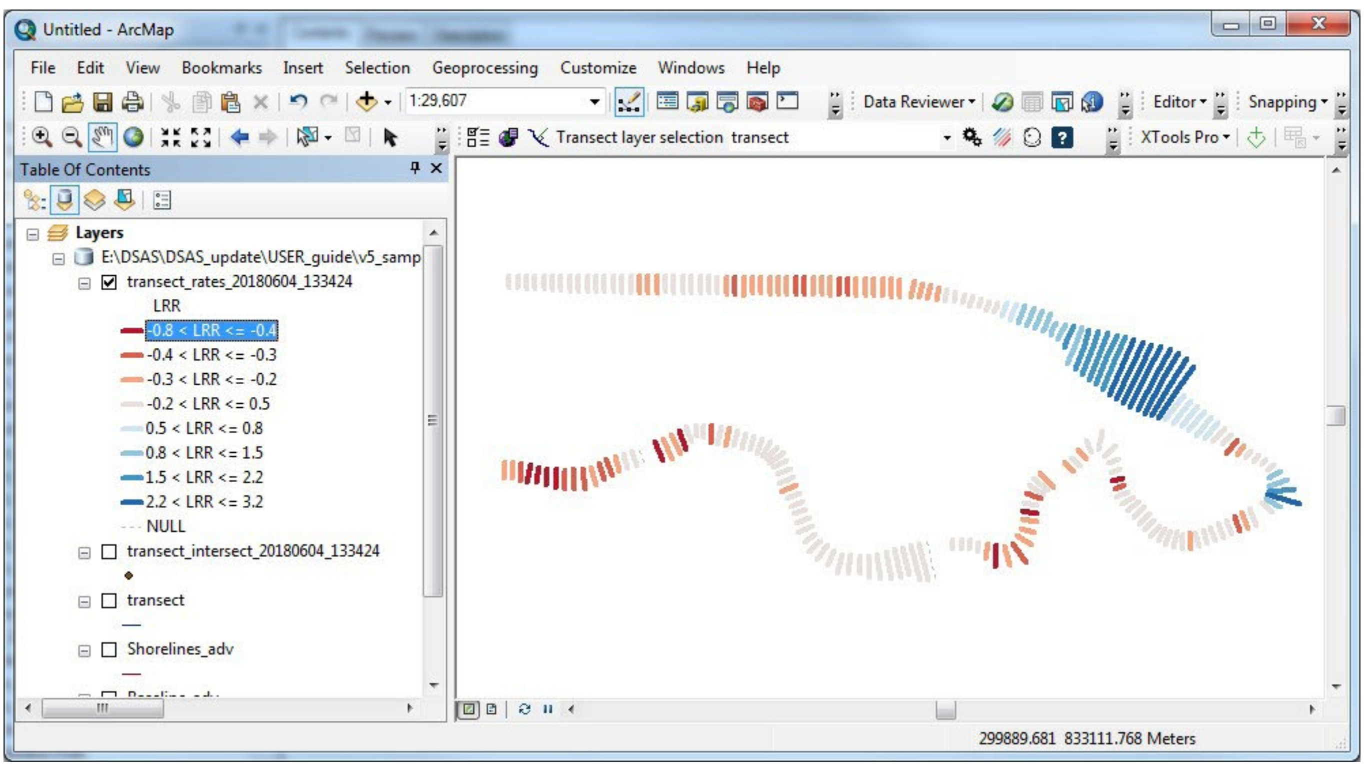
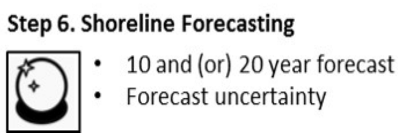
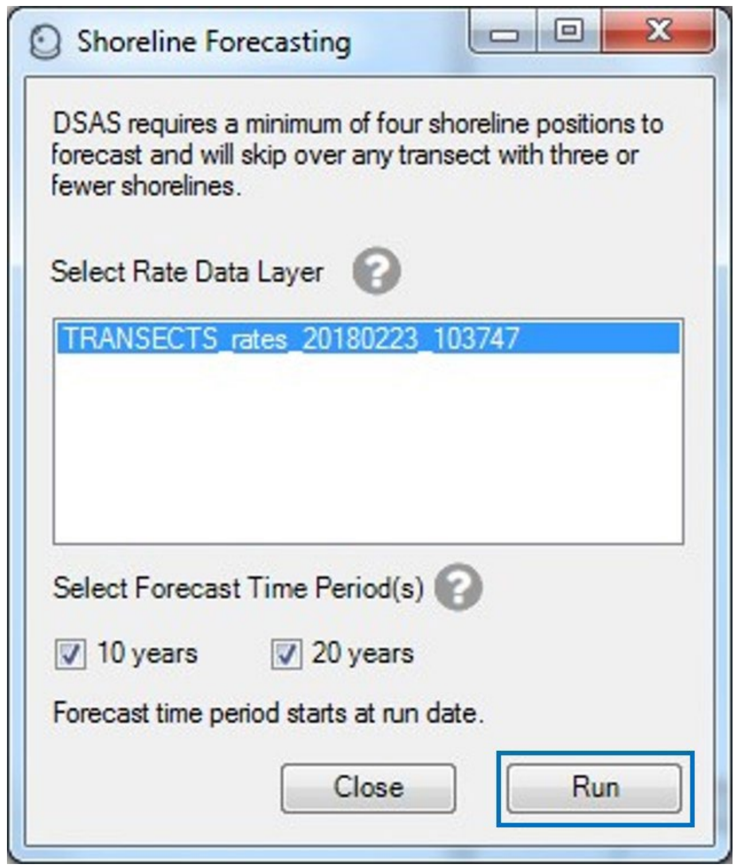
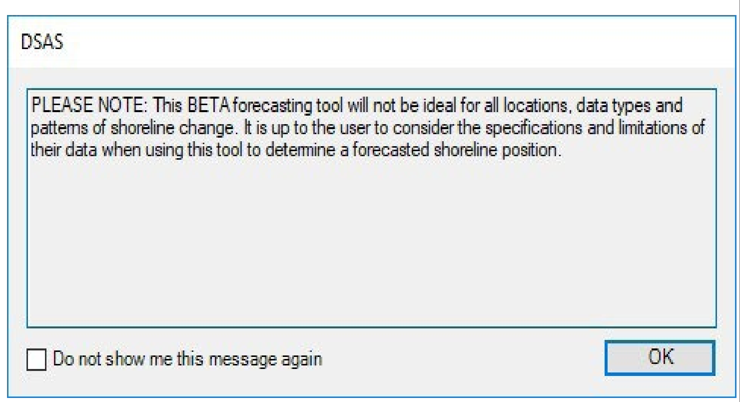


Figure 4.5. Screen capture showing results of linear regression rate (LRR) rates for advanced sample data, with “Scale to my data” selected for data visualization. Line thickness has been adjusted for display.

15.2.7 Beta Shoreline Forecasting

Results of forecasting, shown in Figure 4.6, will include a polyline and point file of the potential shoreline position, along with a polygon uncertainty band (transparent). *When the prediction is displayed, it is strongly recommended that the uncertainty band is also displayed, as it is critical to consider the uncertainty associated with the prediction.*

Table 4.15. Shoreline forecasting: Advanced sample data workflow.

Process description	Graphical user interface with selections
DSAS v5 Toolbar *Shoreline Forecasting icon*	
 **Select the Rate Data layer**—All available rate layers will be displayed—choose the desired layer. **Select Forecast Time Period(s)**—Choose the forecast period at 10 and (or) 20 years. Select "Run" to begin the forecast.	
Forecast Warning—The first time a forecast is run, a warning message is issued describing the limitations of the beta shoreline forecasting tool. Please read carefully and consider system usage (shared/private) if opting out of the message display.	

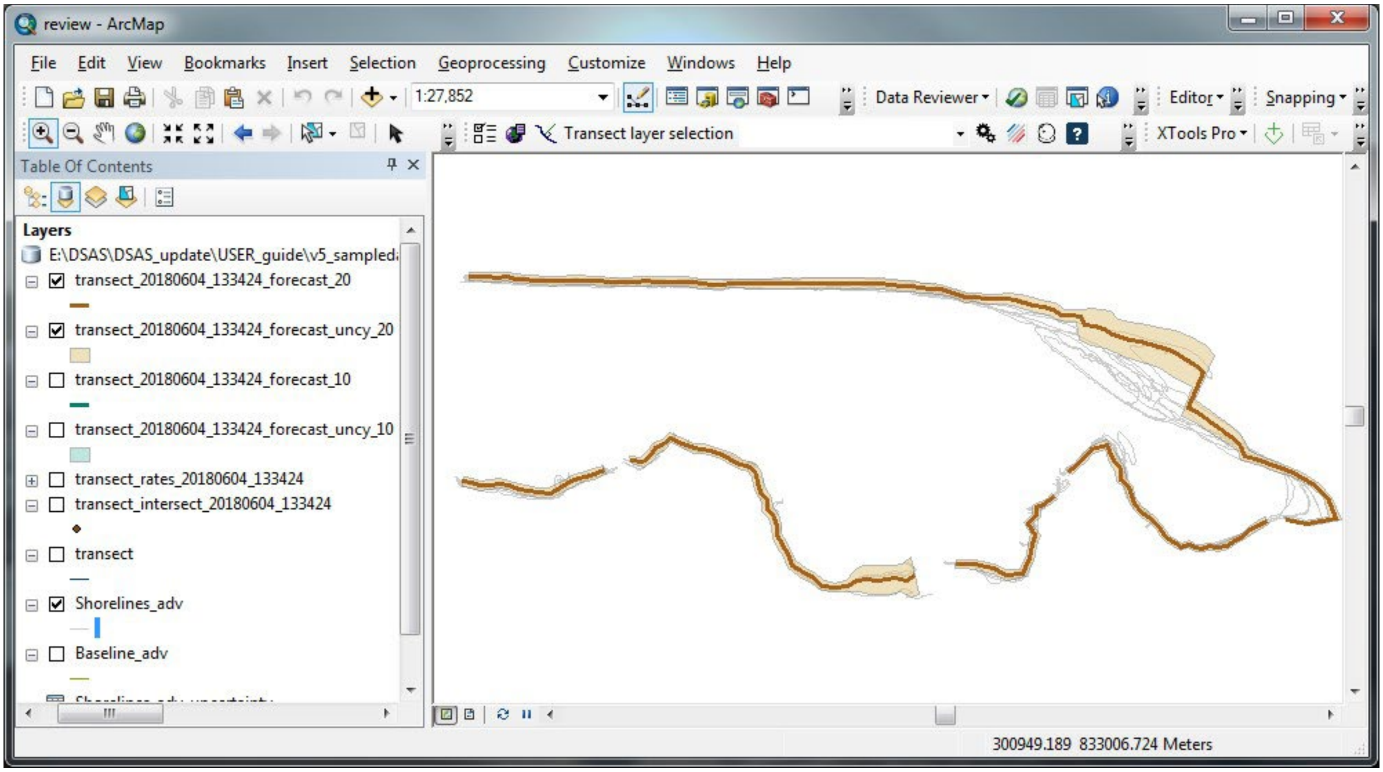


Figure 4.6. Screen capture showing shoreline forecasting results for the advanced sample data—20 years displayed.

15.3 Upgrading Legacy Transects to DSAS v5

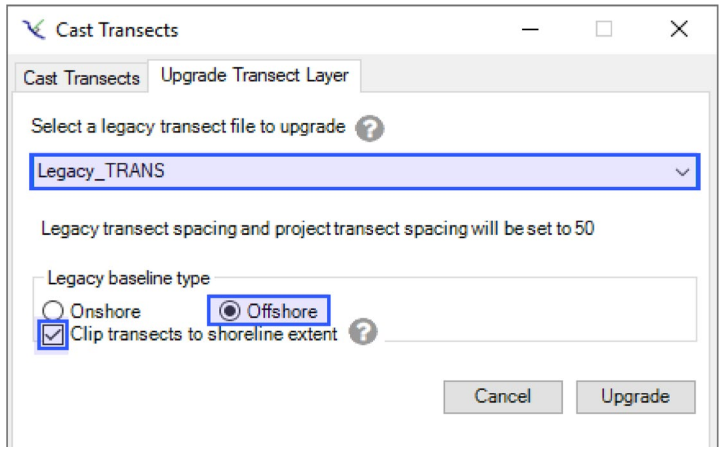
To upgrade an existing project to DSAS v5, transects must be upgraded by using the Upgrade Transects tool, in the Cast Transects window. With the legacy project files (baseline, shorelines, and transects) added to an ArcMap project, update the default parameters with the legacy baseline and shorelines as shown in the basic (or advanced) workflow. The upgrade tool will use these settings when upgrading the transects. See **section 6.5** for additional details on legacy transect upgrade.

DSAS detects legacy transects within the ArcMap project. Select the transect filename you wish to upgrade. If the legacy transect file does not appear, see **section 12** (app. 1) for troubleshooting tips.

Table 4.16. Upgrade transect layer using legacy project data.

<table>
<tr><th>Process description</th><th>Graphical user interface with selections</th></tr>
<tr><td>DSAS v5 Toolbar
Click the Cast Transects tool</td><td>
</td></tr>
<tr><td>From the Cast Transects window
Select for the legacy baseline “onshore” or “offshore,” and click “Upgrade.”

If the legacy baseline file has onshore and offshore segments, these will need to be upgraded separately. See section 6.5.

Note: If you would prefer the legacy transects to keep their original length (and not be clipped to shorelines), uncheck the default setting for “clip transects to shoreline extent.”</td><td>
</td></tr>
</table>

15.4 References Cited

Miller, T.L., Morton, R.A., and Sallenger, A.H., 2005, The National Assessment of Shoreline Change—A GIS compilation of vector shorelines and associated shoreline change data for the U.S. Southeast Atlantic Coast: U.S. Geological Survey Open-File Report 2005–1326, variously paged, accessed September 2018 at http://pubs.usgs.gov/of/2005/1326.

Smith, T.L., Himmelstoss, E.A., and Thieler, E.R., 2013, Massachusetts shoreline change project—A GIS compilation of vector shorelines and associated shoreline change data for the 2013 update: U.S. Geological Survey Open-File Report 2012–1183, accessed September 2018 at http://pubs.usgs.gov/of/2012/1183/.

Stockdon, H.F., Sallenger, A.H., List, J.H., and Holman, R.A., 2002, Estimation of shoreline position and change from airborne topographic lidar data: Journal of Coastal Research, v. 18, p. 502–513.

Weber, K.M., List, J.H., and Morgan, L.M.M., 2005, An operational mean high water datum for determination of shoreline position from topographic lidar data: U.S. Geological Survey Open-File Report 2005–1027, accessed September 2018 at http://pubs.usgs.gov/of/2005/1027.

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