



Land Change Science Program

# **Social/ Values for *Ecosystem* Services, Version 3.0 (SoLVES 3.0)—Documentation and User Manual**

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U.S. Geological Survey

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## Abbreviations

ASCII	American Standard Code for Information Interchange
AUC	Area Under the Curve
CSR	Completely Spatially Random
CSV	Comma separated values
GEOSC	Geosciences and Environmental Change Science Center
GIS	Geographic information system
HTML	Hypertext Markup Language
ICR	Information Collection Request
OMB	Office of Management and Budget
PRA	Paperwork Reduction Act
PSI	Pike and San Isabel National Forests
ROC	Receiver Operating Characteristic
SoVES	Social Values for Ecosystem Services
SQL	Structured Query Language
USGS	U.S. Geological Survey

# **Social Values for *Ecosystem Services*, Version 3.0 (SolVES 3.0)—Documentation and User Manual**

By Benson C. Sherrouse and Darius J. Semmens

## **Abstract**

The geographic information system (GIS) tool, *Social Values for Ecosystem Services* (SolVES), was developed to incorporate quantified and spatially explicit measures of social values into ecosystem service assessments. SolVES 3.0 continues to extend the functionality of SolVES, which was designed to assess, map, and quantify the social values of ecosystem services. Social values—the perceived, nonmarket values the public ascribes to ecosystem services, particularly cultural services, such as aesthetics and recreation—can be evaluated for various stakeholder groups. These groups are distinguishable by their attitudes and preferences regarding public uses, such as motorized recreation and logging. As with previous versions, SolVES 3.0 derives a quantitative 10-point, social-values metric—the value index—from a combination of spatial and nonspatial responses to public value and preference surveys. The tool also calculates metrics characterizing the underlying environment, such as average distance to water and dominant landcover. SolVES 3.0 is integrated with Maxent maximum entropy modeling software to generate more complete social-value maps and offer robust statistical models describing the relationship between the value index and explanatory environmental variables. A model's goodness of fit to a primary study area and its potential performance in transferring social values to similar areas using value-transfer methodology can be evaluated. SolVES 3.0 provides an improved public-domain tool for decision makers and researchers to evaluate the social values of ecosystem services and to facilitate discussions among diverse stakeholders regarding the tradeoffs among ecosystem services in a variety of physical and social contexts ranging from forest and rangeland to coastal and marine.

## Disclaimer

Although this software program has been used by the U.S. Geological Survey (USGS), no warranty, expressed or implied, is made by the USGS or the U.S. Government as to the accuracy and functioning of the program and related program material nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the USGS in connection therewith.

SOLVES is a tool for mapping and analyzing social survey response data. It is not a tool designed for the collection of survey data, nor is any survey attached to SOLVES. Any survey or survey response data referred to in the SOLVES documentation, sample data, or publications are the work and responsibility of the persons or groups who developed and performed that survey. Please note that before a Federal agency may collect information or sponsor a collection of information, the Paperwork Reduction Act of 1995 requires approval from the Office of Management and Budget. Any Federal agency or sponsored program interested in developing and performing a survey for use with SOLVES is responsible for submitting an Information Collection Request to the Office of Management and Budget.



## Introduction

*Social Values for Ecosystem Services*, Version 3.0 (SolVES 3.0) is a geographic information system (GIS) application developed by the USGS Geosciences and Environmental Change Science Center (GECSC). SolVES incorporates quantified and spatially explicit social-values information into ecosystem service assessments. Social values are defined here as the perceived, nonmarket values the public ascribes to ecosystem services, particularly cultural services, such as aesthetics and recreation. SolVES was originally developed to address the need to account for differing values, attitudes, and preferences among diverse stakeholders in the analysis of tradeoffs among ecosystem services (Sherrouse and others, 2011, 2014). Ecosystem services provide tangible and intangible benefits to human life (Daily, 1997). Although these benefits may be quantified in monetary terms, they also exist as public goods that bypass the economy (Costanza and others, 1997). Further, monetary values, even if available, are not always desirable because they can distract decision makers and stakeholders from the primary purpose of ecosystem management (Maleki, 2008). Decision makers require estimates of social values beyond those defined economically to assess the full range of ecosystem values. These social values involve sociocultural perceptions of human well-being derived from nature, measured using social assessments and other nonutilitarian means of capturing their value (Millennium Ecosystem Assessment, 2003; Cowling and others, 2008; Kumar and Kumar, 2008; Nijkamp and others, 2008). SolVES uses previous social-values mapping research (Brown and Reed, 2000; Brown and others, 2002, 2004; Reed and Brown, 2003; Brown, 2005; Brown and Alessa, 2005; Alessa and others, 2008) to implement a methodology for incorporating social values into the ecosystem service assessment process by quantifying and mapping these values across a study area as a “value index,” which provides a spatial, nonmonetary metric statistically related to characteristics of the underlying physical environment.

SolVES 3.0 provides functionality to assess, map, and quantify social values such as aesthetics, biodiversity, and recreation by deriving social-value maps rendered as a 10-point value index (ranging from 0 to 10) from a combination of spatial and nonspatial responses to public value and preference surveys. SolVES 3.0 also calculates metrics characterizing the underlying environment, such as average distance to water and dominant landcover. Through its integration with Maxent maximum entropy modeling software (Phillips and others, 2004, 2006; Phillips and Dudík, 2007; Elith and others, 2010), SolVES 3.0 can generate more complete social-value maps and offer statistical models describing the relationship between the value index and explanatory environmental variables. Because of its flexible design, SolVES 3.0 users are able to define their own social values and public uses, model any number and types of environmental variables, select weighting options for mapped survey data, and modify the spatial resolution of analysis. SolVES 3.0 provides an improved public-domain tool for decision makers and researchers to evaluate the social values of ecosystem services and to facilitate discussions among diverse stakeholders regarding the tradeoffs among ecosystem services in a variety of physical and social contexts ranging from forest and rangeland to coastal and marine.

## Additional Information Regarding Maxent Maximum Entropy Modeling Software

SolVES 3.0 is designed to run in conjunction with Maxent maximum entropy modeling software. Maxent was developed to model the geographic distribution of species; however, its modeling structure provides a framework that can be readily adapted to mapping the social values of ecosystem services. Maxent relies on point data representing observations of plant or animal species presence. Without true absence data (points where species are actually observed to be absent) available, Maxent

generates randomly selected background points. Using these point data along with environmental variables that are judged to influence the suitability of the environment for a selected species, Maxent applies a machine-learning method to estimate a probability distribution of maximum entropy (closest to uniform) but satisfying constraints represented by the environmental variables. The logistic surfaces Maxent generates are most pertinent to its use with SOLVES. Each cell contains a value from 0 to 1, representing the probability that a location is suitable habitat for a species given the environmental conditions and the known presence of that species. In a social-values mapping context, the logistic output represents the relative intensity that survey respondents assign to a social-value type (analogous to a species) at a location given the underlying environmental characteristics and the respondents' identification of such locations as representing a particular social-value type. Together with the kernel density method already used by SOLVES, Maxent's logistic output provides more complete maps within a study area where survey value and preference survey data are available.

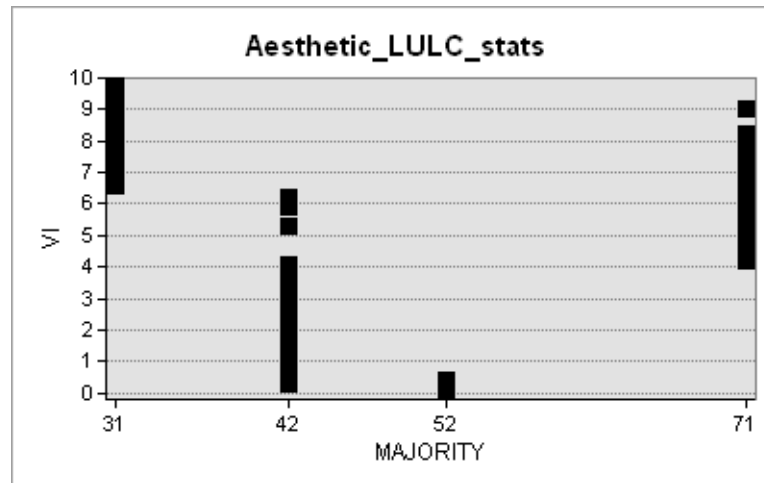
Maxent also enhances SOLVES functionality by generating statistical models describing the relationship between mapped points and environmental variables (or features as operationalized by Maxent). Additionally, Maxent calculates Area Under the Curve (AUC) statistics for each model to evaluate its goodness of fit to the study area and the potential performance of the model in transferring social values to similar areas where primary survey data are not available. Maxent output includes jackknife statistics that can help SOLVES users improve models by adjusting the environmental variables included in their analysis. Through an iterative process, SOLVES users have the ability to repeat their selected analyses as different projects to generate models best suited for their purposes. More information regarding Maxent's AUC statistics is in the section on Interpreting and Adjusting Maxent's AUC Statistics.

This user manual does not attempt to provide an exhaustive description of Maxent. Its focus is instead on those features most pertinent to SOLVES users. For additional information regarding Maxent, please refer to the Maxent website [www.cs.princeton.edu/~schapire/maxent/](http://www.cs.princeton.edu/~schapire/maxent/) with links to journal articles, tutorials, user groups, and software.

## New in SolVES 3.0

### Revised Categorical Data Graphs

Graphs of categorical environmental data were previously presented as bar graphs on the map layouts generated by SolVES. This resulted in overlapping bars that obscured all but the maximum value of each category. Graphs are now presented as modified scatterplots (fig. 1) to allow users to observe the majority or dominant category across the range of the value index.



**Figure 1.** Example of a modified scatterplot categorical data graph with the majority land use and land cover (LULC) categories indicated across the value index (VI) range.

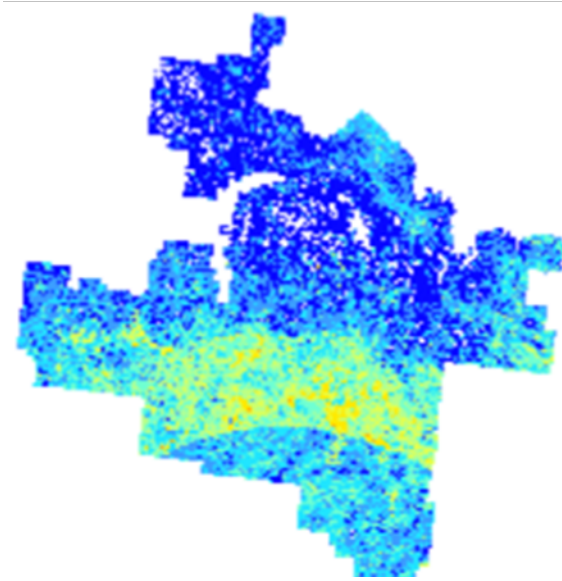
### Weight Survey Points Option

Users can now choose to not apply weights to the survey points used to generate social-value maps. These weights are derived from the total amount allocated to each social-value type by all survey respondents and are applied to points of the same social-value type. This option allows users to directly compare analyses performed with and without weights. It also facilitates the analysis of survey data that does not include any value-allocation data.

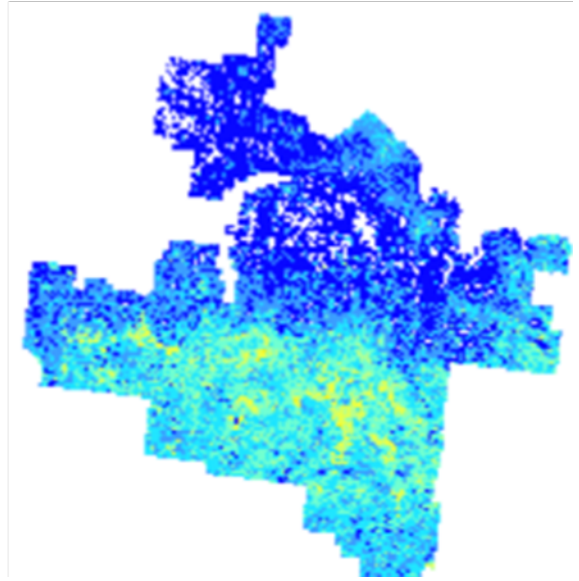
### Threshold Features Option

SolVES relies on features calculated by Maxent from user-supplied environmental variables to generate its final output. When combined, these features serve as the basis of Maxent's model exponents. The inclusion of various combinations of these features allows Maxent to generate the best-fitting model for the provided point and environmental data. However, one of these Maxent features, a threshold, can result in abrupt changes in social-value maps, which are caused by steps introduced into the function describing the relationship between the value index and explanatory environmental variables. Users can now choose to exclude threshold features from a SolVES analysis in order to eliminate spatial artifacts from social-value maps (fig. 2).

With Threshold Feature



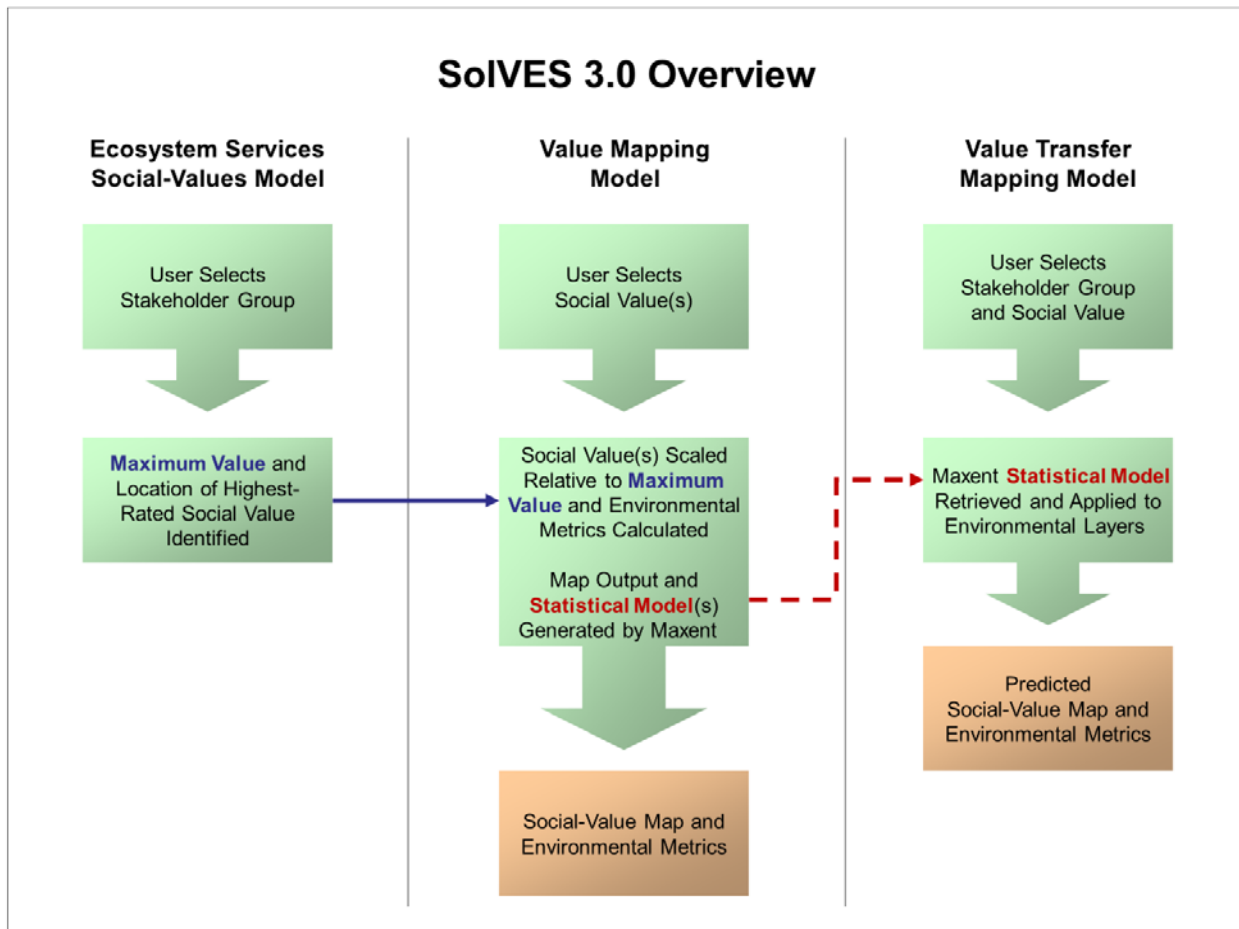
Without Threshold Feature



**Figure 2.** Example of social-value maps from the same area with (left) and without (right) threshold features.

## SolVES 3.0 Overview

SolVES 3.0 was developed with VB.NET as a custom toolbar Add-In for the Environmental Systems Research Institute's (Esri's) ArcGIS 10 software. SolVES uses geospatial and tabular data as inputs to three separate models—the Ecosystem Services Social-Values Model, the Value Mapping Model, and the Value Transfer Mapping Model. The general process flow of these models is shown below (fig. 3).



**Figure 3.** Generalized SolVES 3.0 process flow.

The Ecosystem Services Social-Values Model and the Value Mapping Model operate together in a sequence as follows:

1. The user selects a public use and an attitude or preference regarding that use (for example, favor or strongly favor motorized recreation) to define a stakeholder group (survey subgroup). If a survey subgroup is not selected, SolVES will analyze all survey data.
2. Based on the user's selections, the Ecosystem Services Social-Values Model retrieves mapped points and social-value allocation amounts, if available, for the matching survey subgroup.

3. Using the amounts the survey subgroup allocated to each social-value type as weights (beginning with SOLVES 3.0, weights are optional), the model calculates kernel density surfaces and average nearest neighbor statistics for the mapped points associated with every social-value type included in the survey.
4. By comparing kernel density surfaces, the model identifies the highest rated social-value type and the location where it is most highly valued (Maximum Value in fig. 3).
5. The user starts the Value Mapping Model by selecting one or more social-value types (for example, aesthetics and recreation).
6. The model uses the Maximum Value to normalize the kernel density surface(s) of the selected social-value type(s) and then standardizes the calculated surface to produce a kernel density-based value-index surface.
7. The model provides Maxent maximum entropy modeling software with the selected survey point data along with user-selected environmental layers for the study area.
8. Maxent produces a map output based on the relationship between the provided points and environmental layers, and generates Statistical Model(s) describing the relationship (see fig. 3).
9. The Value Mapping Model then derives a final social-value map from the Maxent map output in conjunction with data from the corresponding kernel density, value-index surfaces. Additionally, the Value Mapping Model calculates environmental metrics using the final social-value map. The map and associated metrics can then be compiled into a composite report.

The Value Transfer Mapping Model operates independently of the other models but relies on their statistical model output. It operates as follows:

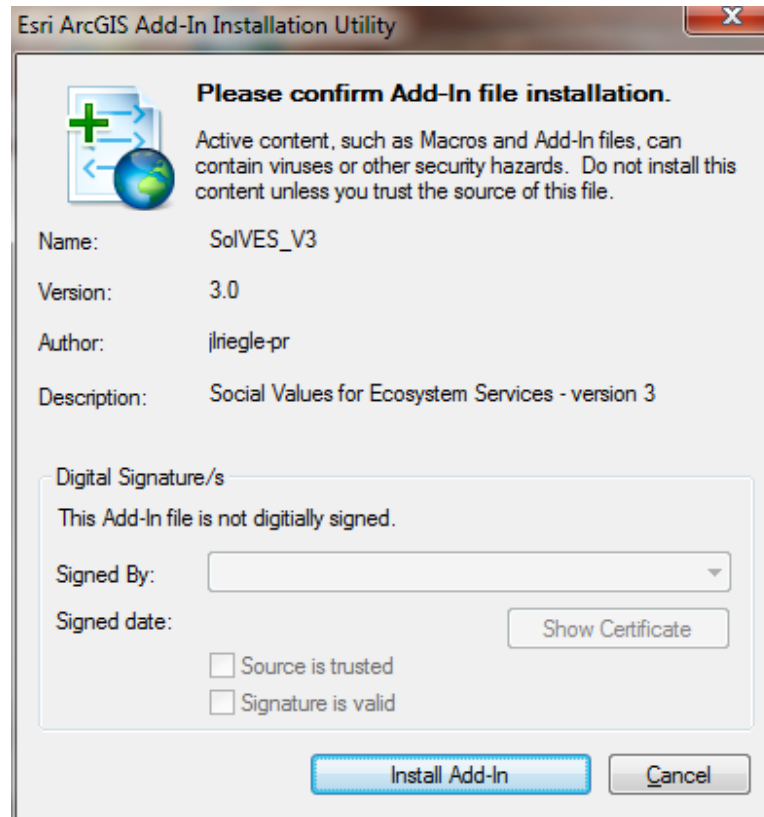
1. The user starts the Value Transfer Mapping Model and selects a stakeholder group (survey subgroup) and social-value type.
2. Based on the user's selections, the model retrieves the appropriate Statistical Model generated by Maxent (see fig. 3).
3. Maxent applies the retrieved Statistical Model to the environmental layers for the receiving study area.
4. The model standardizes the Maxent output to generate a predicted social-value map and calculates environmental metrics using the predicted social-value map. The map and associated metrics can then be compiled into a composite report.

## Hardware and Software Requirements

SOLVES 3.0 requires the Esri ArcGIS 10.x (currently 10.0, 10.1, or 10.2) software and the Spatial Analyst Extension for working with grid-based data. The application is available as a custom toolbar Add-In that must be installed in ArcMap. SOLVES 3.0 was developed and tested on systems running Microsoft Windows 7 Enterprise Edition but should function with other operating systems supported by ArcGIS 10.x. SOLVES 3.0 also requires the installation of Maxent maximum entropy modeling software, version 3.3.3k. Additionally, the user's computer must also run the .NET Framework and Java. Processing time will vary depending on factors such as the computer's processor speed, the spatial resolution and extent of the study area, and the number of variables selected for analysis.

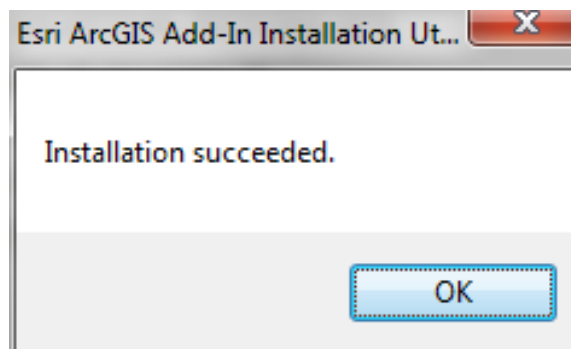
## Installation

1. Download the SolVES\_V3.zip file from the SolVES website <http://solves.cr.usgs.gov>.
2. Unzip the file.
3. Double-click the SolVES\_v3.esriAddIn file.
4. Click Install Add-In on the Esri ArcGIS Add-In Installation Utility screen (fig. 4).



**Figure 4.** Esri ArcGIS Add-In Installation Utility screen.

5. Click OK at the Installation succeeded prompt (fig. 5).

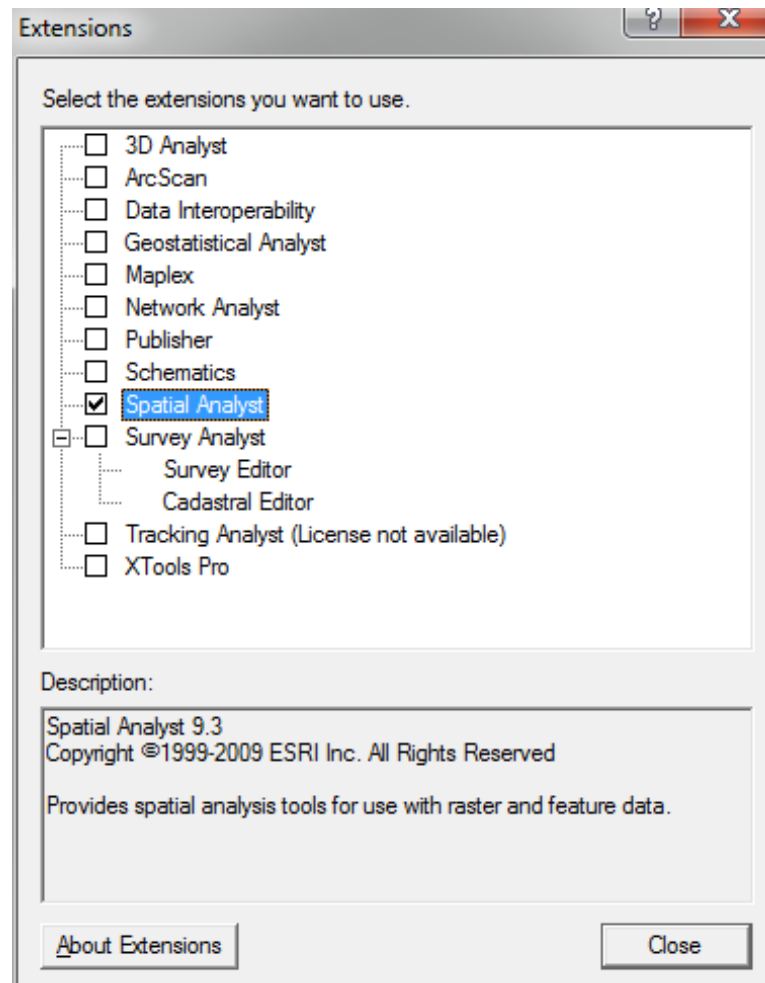


**Figure 5.** Installation succeeded prompt.



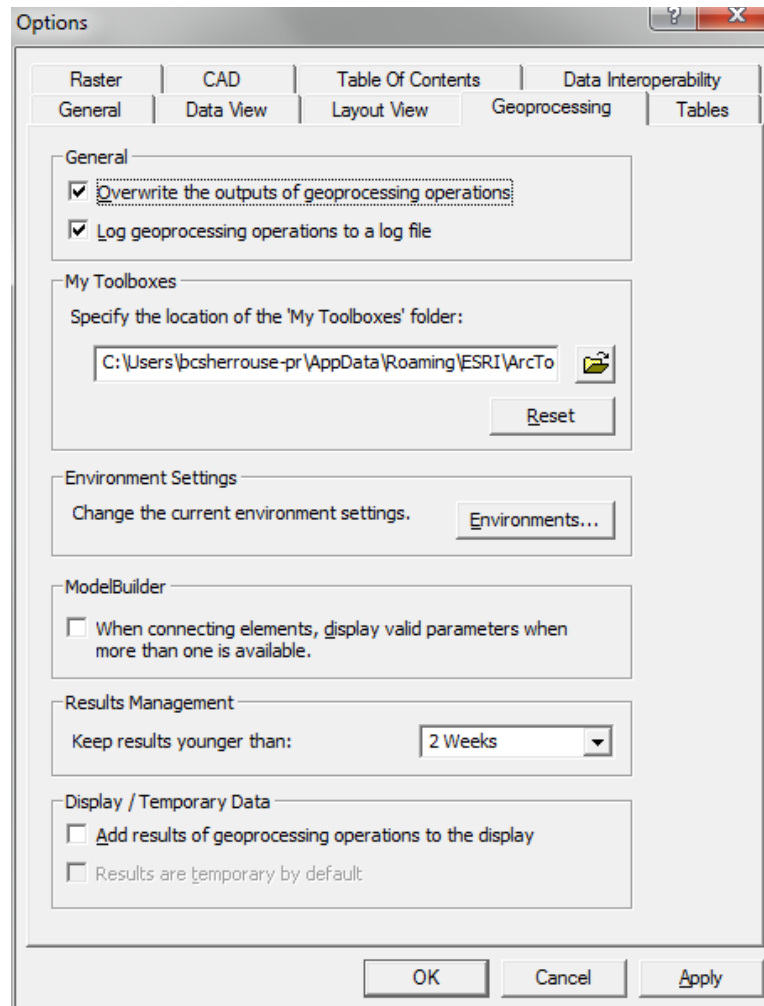
## Confirming ArcMap Settings for SolVES 3.0

1. Open ArcMap.
2. Choose Customize > Extensions from the main menu.
3. Confirm the checkbox next to Spatial Analyst is checked (fig. 6).



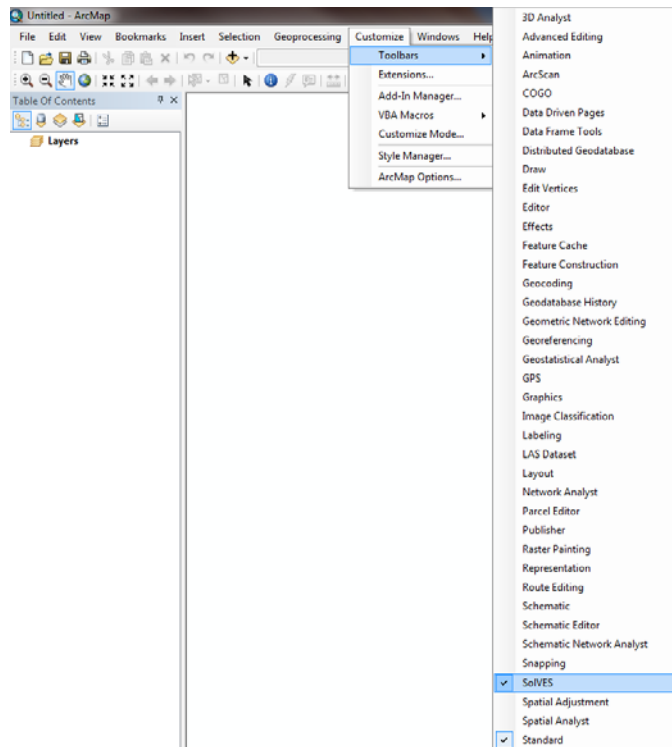
**Figure 6.** Confirming Spatial Analyst extension activation.

4. Close the Extensions form.
5. Choose Geoprocessing > Geoprocessing Options from menu.
6. On the General tab, confirm the checkbox next to Overwrite the outputs of geoprocessing operations is checked (fig. 7).



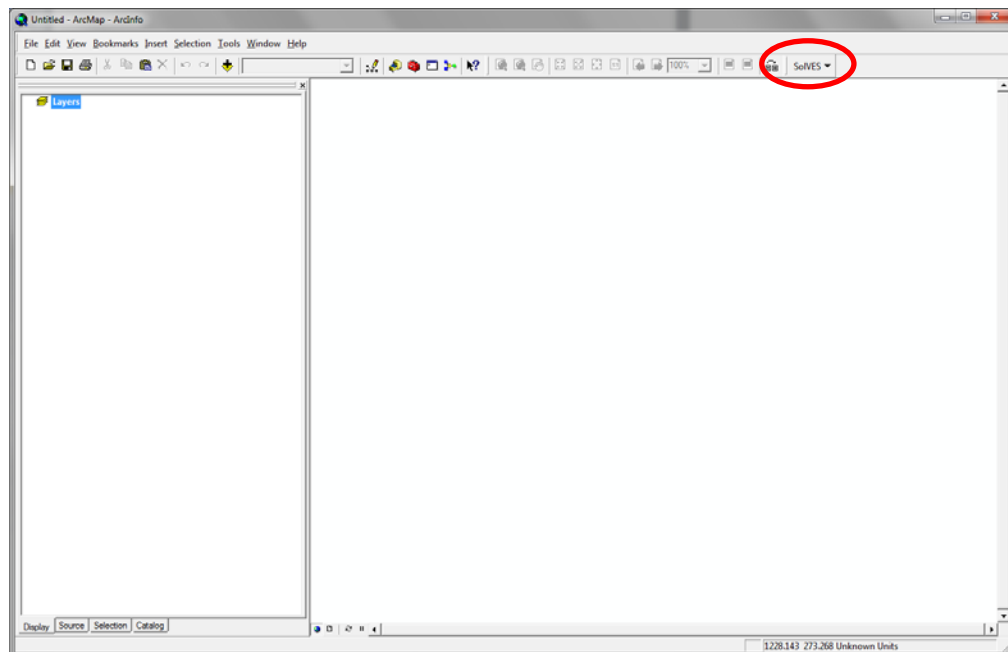
**Figure 7.** Confirming overwrite of geoprocessing outputs.

7. Select OK to close the Options form.
8. If the SolVES toolbar is not already displayed in ArcMap, Choose Customize > Toolbars from the main menu.
9. Click on SolVES (fig. 8).



**Figure 8.** Selecting SolVES toolbar.

10. If not already docked to the top of the ArcMap window, click and drag the SolVES toolbar there (fig. 9).

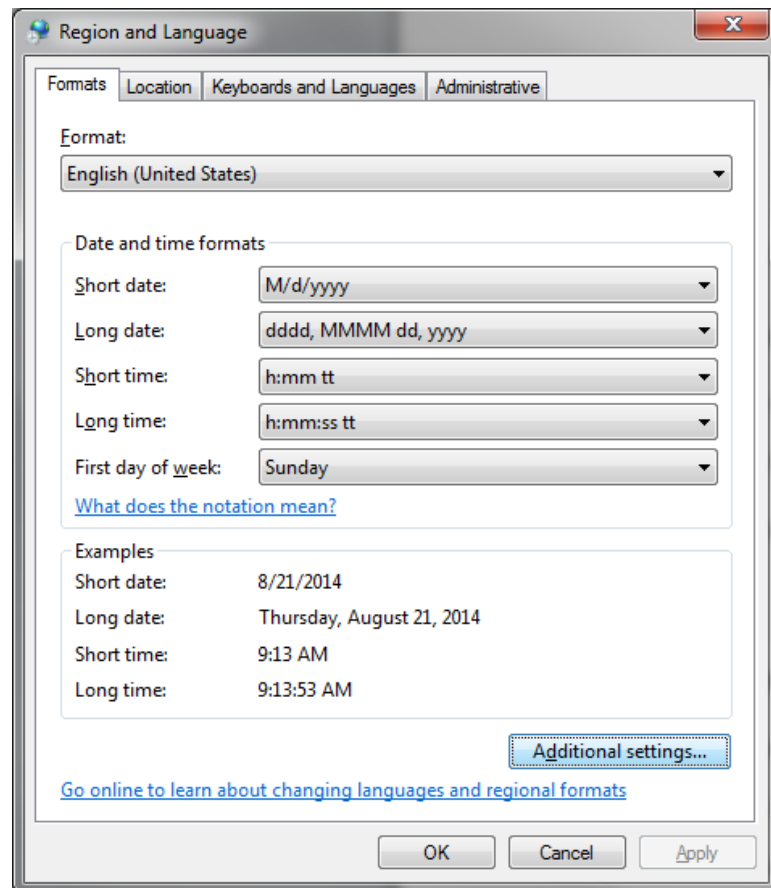


**Figure 9.** SolVES 3.0 toolbar docked to top of ArcMap window.

## Confirming Windows Regional Settings

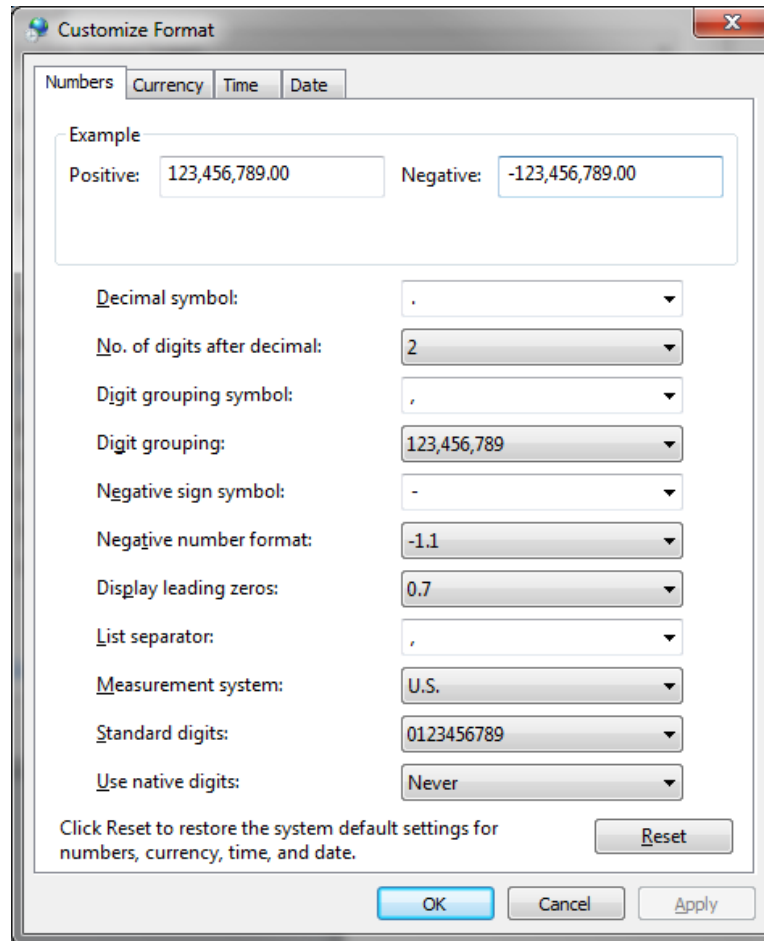
SOLVES users outside the United States should access the Windows Control Panel Region and Language settings on their computer to confirm these settings are compatible with SOLVES.

1. Click on the Additional Settings button on the Formats tab (fig. 10).



**Figure 10.** Windows Control Panel Region and Language settings.

2. Compare the values entered on the Numbers tab shown below (fig. 11) to those on the computer running SOLVES and adjust them to match those shown in the figure. Users should note the original settings on the Numbers tab to ensure they are correctly restored. When finished using SOLVES, the Reset button on the Numbers tab can be selected to restore the system default settings.



**Figure 11.** Numbers format for SolVES processing.

## Maxent Maximum Entropy Modeling Software Installation Instructions

Maxent maximum entropy modeling software is freely available for educational and research activities; however, it is not authorized for redistribution by its users. Maxent must be downloaded directly from the Maxent website at [www.cs.princeton.edu/~schapire/maxent/](http://www.cs.princeton.edu/~schapire/maxent/). The website also contains various links to additional information regarding Maxent. After navigating to the website, complete the following steps.

1. Follow the website instructions to download Maxent version 3.3.3k.
2. Return to the location of the unzipped SolVES 3.0 download file and copy the three downloaded Maxent files (maxent.bat, maxent.jar, and readme.txt) into the Maxent folder contained within the SolVES directory (\\SolVES\\Maxent). (If needed, please see the Data Management section, including fig. 12, for information regarding the SolVES directory structure.)

## Data Installation

1. Copy the SolVES folder to a local directory that will serve as the SolVES home directory (for example, D:\\SolVES).
2. If a properly loaded file geodatabase containing study area data is available, copy it into the \\SolVES\\Data folder to make it accessible to SolVES. (If needed, please see the *Data Requirements* and *Data Management* sections, including fig. 12, for information regarding data formatting requirements and the SolVES directory structure.)



File geodatabases containing sample datasets for the Pike and San Isabel National Forests and Grand County, Colorado, can be downloaded from the SolVES website <http://solves.cr.usgs.gov> to provide hands-on experience using SolVES. These data, along with the supplied social-value models generated from these data, are meant for demonstration only.

## Data Requirements

SOLVES 3.0 uses various geospatial and tabular data, which may be obtained in a variety of ArcGIS-supported formats, including coverages, shapefiles, grids, and spreadsheet files. For use with SOLVES, these data must be imported into a file geodatabase format. Instructions on how to import to the file geodatabase format can be found in the Source File Geodatabase Structure and Contents section. The rest of this section describes the required data.

### Environmental Data

SOLVES 3.0 requires only one environmental data layer to run; however, for practical application, users may include any number and type of environmental data in their analyses. All environmental data layers must be raster-based and share a common projection and extent. See the Environmental Layer Extents section under Troubleshooting Common Errors for more information.


### Survey Data

Specifically formatted value and preference survey response data are required to use the Ecosystem Services Social-Values Model and Value Mapping Model. These data are not required, however, if only using the Value Transfer Mapping Model. The format of these data are based on value and preference survey results obtained from J.M. Clement (written commun., 2008) for the Pike and San Isabel National Forests in Colorado that, in turn, are based on data collection procedures described by Brown and others (2002).

SOLVES was initially developed from responses to a random mail survey of 2,000 households within 45 miles of the Pike and San Isabel National Forests (PSI) performed in late 2004 and early 2005 (J.M. Clement, written commun., 2008). The response rate was approximately 33 percent, with 684 surveys returned. The survey was divided into five sections. Section 1 requested information regarding each respondent's familiarity with the PSI, such as when and how often they visited, if they derived any income from the PSI, and their interest level in what happens to the PSI in the next 10 to 15 years. Using a 5-point Likert scale ranging from Strongly Favor to Strongly Oppose, section 2 requested respondents to indicate their attitudes regarding 18 public uses of the PSI such as logging for wood products, motorized recreation, and wilderness. Section 3 allowed respondents to indicate their views regarding various issues impacting the PSI, such as the extent and purpose of road building and logging, reservoir development, and tradeoffs between recreational use and environmental quality. The first part of section 4 (4A) requested that respondents allocate or "spend" \$100 among 12 social-value types such as aesthetics, biodiversity, and recreation associated with the PSI. Although dollar units were used for convenience to express value denominations (for example, points could have been used instead of dollars), the survey instructions included an explanation that this was not a reference to any actual money held by the respondent or the U.S. Department of Agriculture Forest Service. When the allocation exercise was completed, respondents were then instructed in the second part of section 4 (4B) to hand-mark points (later digitized into a geographic data layer) on a series of maps of the PSI corresponding to the social-value types to which they had allocated dollars. If the respondent had allocated dollars to aesthetic value, for example, they were to place a point on the map at as many as four locations indicating aesthetic, label and number each mark accordingly, and provide a place name describing the location of the point. Of the 684 surveys returned, the mapping section was completed for 55 percent of them. Finally, section 5 of the survey requested various demographic and

socioeconomic information from each respondent. Further details regarding the PSI survey are provided in Sherrouse and others (2011).

The survey data used by SolVES 3.0 are based on survey sections 2, 4A, and 4B; however, the only survey data required to use SolVES 3.0 are the point data from survey section 4B. To analyze user-supplied survey data with SolVES 3.0, the structural requirements set forth in the remainder of this section must be met. Surveys designed to collect data containing the specific elements described below, even if not otherwise designed like the PSI survey, can be used with SolVES 3.0.

 Users providing their own survey data must assign a unique identifier (SURVEY\_ID), an integer value, to each survey in order to distinguish each survey and to relate its separate sections. See the *Source File Geodatabase Structure and Contents* section for additional details regarding the location of SURVEY\_ID within the geodatabase schema.

USE\_ATTITUDE (based on survey section 2)—SolVES 3.0 supports public use data that include responses as to whether or not such uses are favored or opposed. Based on the Likert scale used in the original PSI survey, these responses are structured as an integer range from 1 to 5 by default (table 1). However, the allowable values can be modified as described in the *Recoding the ATTITUDE\_TYPES Table* section under Advanced Options. For information regarding how parameters other than public uses might be used by SolVES, see the section, Substituting the Public Use Parameter, under Advanced Options. Please note the USE\_ATTITUDE table can be left unpopulated if these data were not collected or if a user wishes to only analyze data from all surveys without distinguishing any survey subgroups. Please note that the By Social Value Type Across Survey Subgroups Value Comparison Type option will not function if USE\_ATTITUDE data are not provided.

**Table 1.** Default Likert scale attitude or preference integer values used by SolVES 3.0.

Attitude or preference	Integer value
Strongly Favor	1
Favor	2
Neutral	3
Oppose	4
Strongly Oppose	5

VALUE\_ALLOCATION (based on survey section 4A)—SolVES 3.0 supports numeric values allocated among the survey's social-value types; however, with the new Weight Survey Points option, the inclusion of value-allocation data is now optional.

SURVEY\_POINTS (based on survey section 4B)—SolVES 3.0 supports point layers representing the points that survey respondents marked on a map or maps of a study area. Each point must be identified as representing one of the social-value types included in the survey. It must share a common projection with all environmental data layers and STUDY\_AREA. See the Notes Regarding the Digitization of Points Mapped by Survey Respondents section for additional information.

## Other Spatial Data

SolVES 3.0 requires a STUDY\_AREA polygon feature representing the study area boundary. It must share a common projection with all environmental data layers and SURVEY\_POINTS. This feature may exist as multiple parts, but it must be defined as a single feature. One way to confirm this is

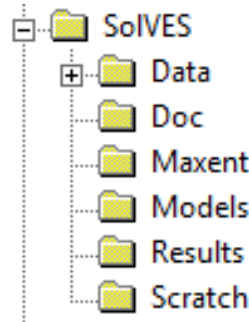


to view the attribute table for the STUDY\_AREA feature class to ensure it contains only one record. This is necessary to prevent the malfunction of the buffering option and average nearest-neighbor statistics calculations.

## Data Management

### Directory Structure

SolVES uses the directory structure illustrated below (fig. 12). SolVES is the primary directory containing the folders described below (table 2).



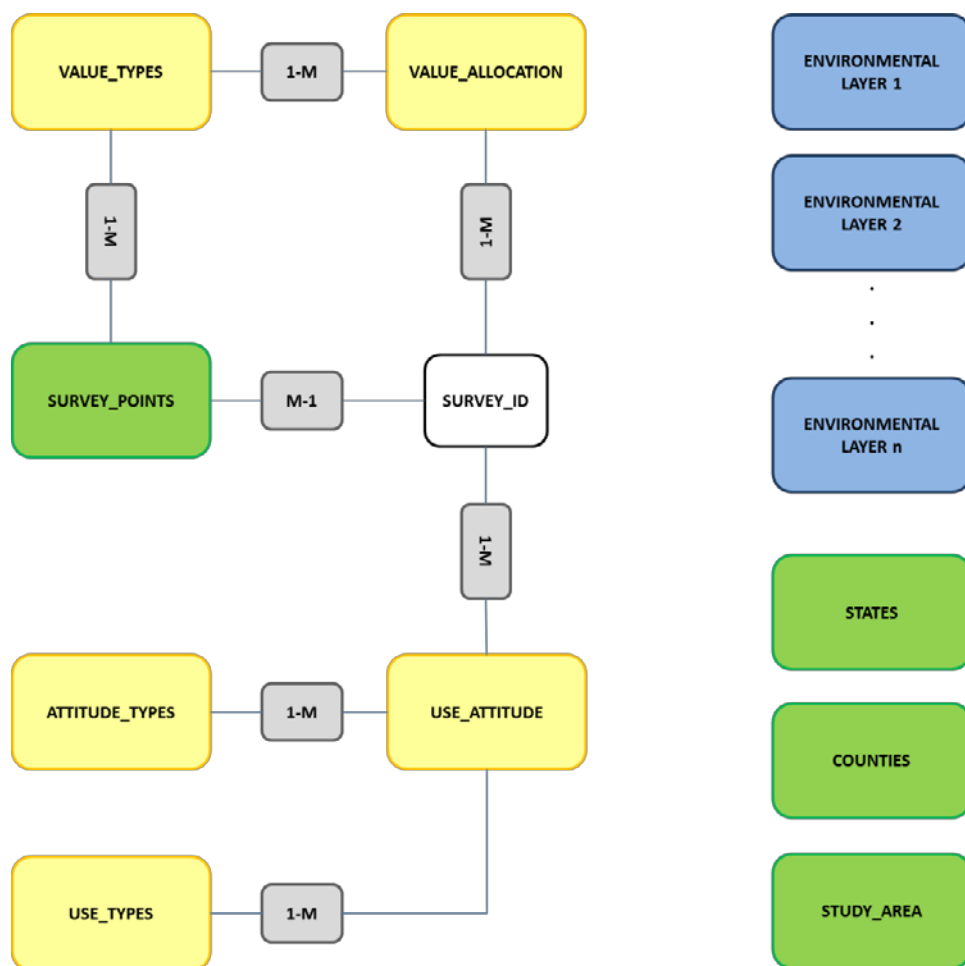
**Figure 12.** SolVES directory structure.

**Table 2.** Description of the SolVES directory structure.

Folder name	Folder description
Data	This folder holds the required source file geodatabase, SolVES.gdb, necessary for SolVES to function. All environmental and survey data will be loaded into this geodatabase. This folder also contains a layer defining the value index map color scheme.
Doc	The SolVES readme file and metadata template are stored here.
Maxent	The Maxent maximum entropy modeling software files (maxent.bat, maxent.jar, and readme.txt) are downloaded to this folder.
Models	This folder contains statistical models previously generated by Maxent in the form of lambdas files, which enable SolVES' value-transfer functionality.
Results	All final data SolVES generates are written here.
Scratch	All intermediate data SolVES generates are written here.

### Source File Geodatabase Structure and Contents

A schematic of the SolVES.gdb source file geodatabase structure is shown below (fig. 13). The diagram summarizes the contents of a fully loaded geodatabase and the relations between each survey data element. SURVEY\_ID does not exist as a distinct entity in the geodatabase; instead, it is a field included in the attribute table of each of the related elements. The field is included in the schematic to emphasize its role as a primary key for relating the data. The (1-M) symbology indicates a one-to-many relationship between elements. For example, one survey (SURVEY\_ID) may be related to many SURVEY\_POINTS. Additional descriptions of the geodatabase contents are included in the remainder of this section.



**Figure 13.** Schematic of the SolVES.gdb source file geodatabase.

*Environmental Layers* (blue, fig. 13)—These layers are supplied by the user and may range from one to any number of raster datasets. It is recommended that users also supply a raster dataset such as a hillshade to serve as a background layer for the social-value maps; however, a background layer is not required.

*Tables* (yellow, fig. 13)—These tables are present when SolVES 3.0 is downloaded. The default contents of the ATTITUDE\_TYPES table are already loaded, but users must load their own survey data into the remaining tables. Individual table structures are described next to serve as guide to users for preparing and properly formatting their survey data (table 3). These data may be prepared for loading into SolVES.gdb by compiling them into database or spreadsheet file formats such as DBF or XLS.

**Table 3.** Source file geodatabase table formatting requirements.


Table name	Field names	Field data type	Field description
ATTITUDE_TYPES	ATTITUDE_ID	Short Integer	Unique attitude or preference identifier.
	ATTITUDE_NAME	Text	Name of the attitude or preference.
	ATTITUDE_CODE	Text	Code used for defining survey subgroups.
USE_ATTITUDE	SURVEY_ID	Long Integer	Unique survey identifier.
	USE_ID	Short Integer	Unique public use identifier.
	ATTITUDE_ID	Short Integer	Unique attitude or preference identifier.
	USE_NOTES	Text	Additional (optional) use notes.
USE_TYPES	USE_ID	Short Integer	Unique public use identifier.
	USE_NAME*	Text	Name of public use. These values will be used to populate the Public Use dropdown.
	USE_DESCRIPTION	Text	Additional (optional) public use description.
VALUE_ALLOCATION	SURVEY_ID	Long Integer	Unique survey identifier.
	VALUE_ID	Short Integer	Unique social-value type identifier.
	AMOUNT	Double	Amount allocated to social-value type.
VALUE_TYPES	VALUE_ID	Short Integer	Unique social-value type identifier.
	VALUE_NAME*	Text	Name of social-value type. These values will be used to populate the Social Value Type dropdown.
	VALUE_DESCRIPTION	Text	Additional (optional) social-value type description.

\*Text values entered in these fields are used to name rasters written to the Results geodatabase, so their length should be limited.

*Feature Classes* (green, fig. 13)—These features include the mapped points along with polygon layers representing the study area and other boundaries as listed in table 4. Users must supply their own SURVEY\_POINTS and STUDY\_AREA layers. STATES and COUNTIES are included in the SolVES 3.0 download and are available to use for generating a locator map that assists in orienting the study area within a broader geographic area. For study areas outside the contiguous 48 United States, we recommend that users supply an appropriate polygon layer for generating the locator map; however, this is not required.

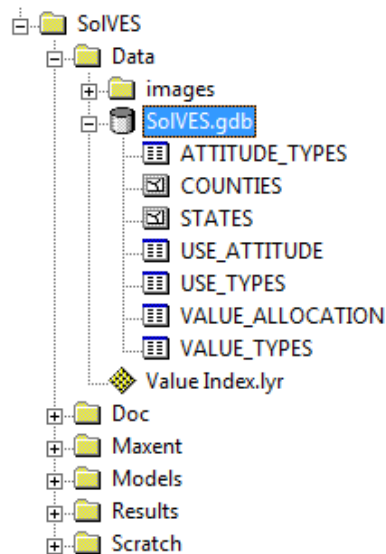
**Table 4.** Formatting requirements for feature classes.

Feature class name	Field names	Field data type	Field description
SURVEY_POINTS	SURVEY_ID	Long Integer	Unique survey identifier.
	VALUE_ID	Short Integer	Unique social-value type identifier.
	PLACE_NAME	Text	Place name at location of point (optional).
STUDY_AREA	NAME	Text	Name of study area.
	Shape_Length	Double	ArcGIS adds when loaded to SolVES.gdb.
	Shape_Area	Double	ArcGIS adds when loaded to SolVES.gdb. The value is used as a parameter for calculation of average nearest neighbor statistics.

 Any projected coordinate system suitable for the study area may be used; however, the projection should have linear units defined in meters. All spatial data must share a common projection and all environmental data layers must have identical extents before completing any SolVES analyses. Failure to do so will result in SolVES failing to function properly.

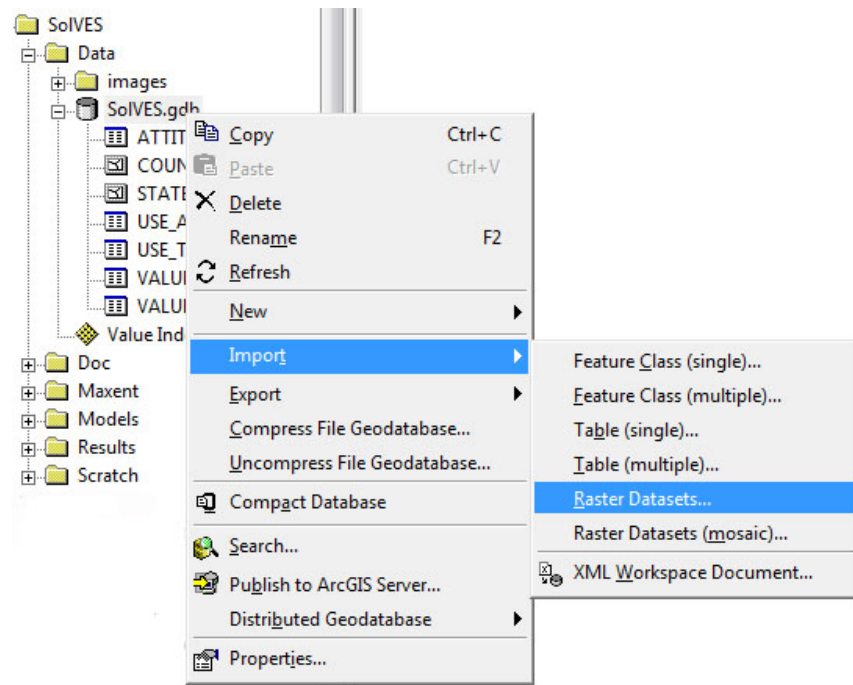
## Importing and Loading Data to the Source File Geodatabase

As previously noted, the environmental and survey data used by SolVES may come from numerous sources in a variety of formats. Because SolVES was designed to work in conjunction with a file geodatabase, user-supplied data must be imported or loaded into SolVES.gdb. Open ArcCatalog and navigate to SolVES.gdb as shown in figure 14, and complete the following steps.



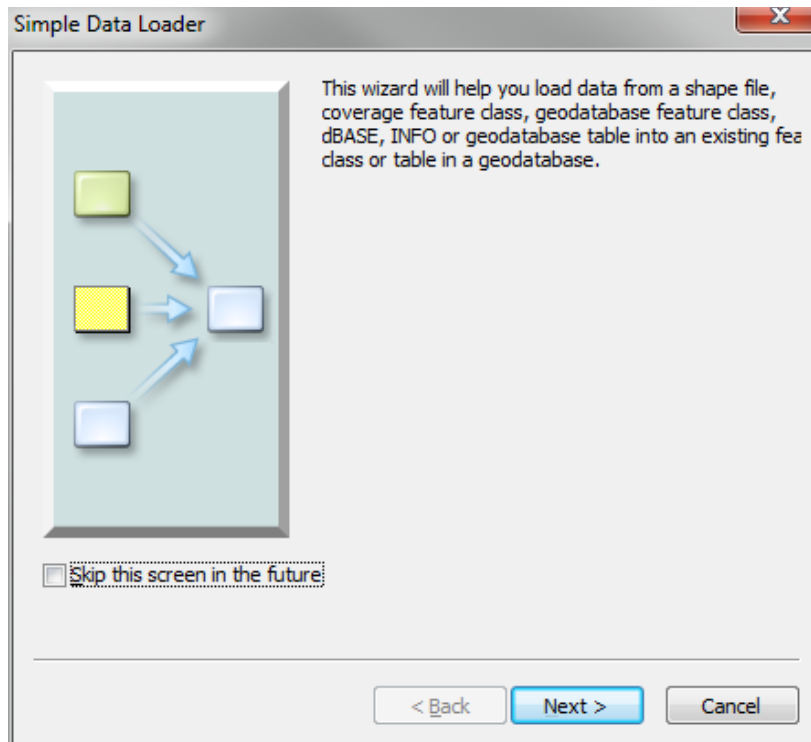
**Figure 14.** SolVES.gdb as seen in ArcCatalog.

1. Import each environmental layer into SolVES.gdb by right-clicking on SolVES.gdb, selecting Import, and then selecting Raster Datasets as shown below (fig. 15).



**Figure 15.** Importing rasters in ArcCatalog.

2. Navigate to where the user-prepared raster data are stored, select them all, and complete the import in a single process.
3. Import each feature class (SURVEY\_POINTS, STUDY\_AREA, and any feature class that will be used in replacement of STATES or COUNTIES) by right-clicking on SolVES.gdb, selecting Import, and then selecting Feature Class (multiple).
4. Using the Import tool, navigate to where the user-prepared feature classes are stored, select them all, and complete the import in a single process.
5. Load the user-prepared data to the USE\_ATTITUDE, USE\_TYPES, VALUE\_ALLOCATION, and VALUE\_TYPES by right-clicking on each, selecting Load, selecting Load Data, and following the Simple Data Loader Wizard (fig. 16) instructions. This process will need to be repeated separately for each table. After loading is complete, SolVES is ready for use.

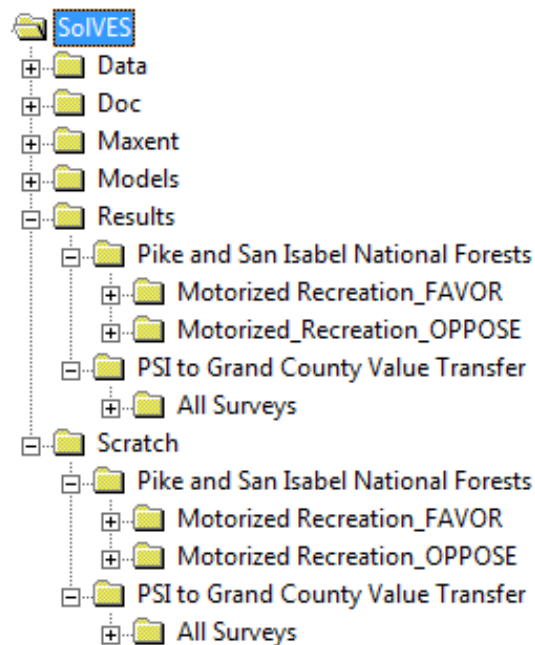


**Figure 16.** Simple Data Loader Wizard.

## Final Results and Intermediate Data

### Output Structure

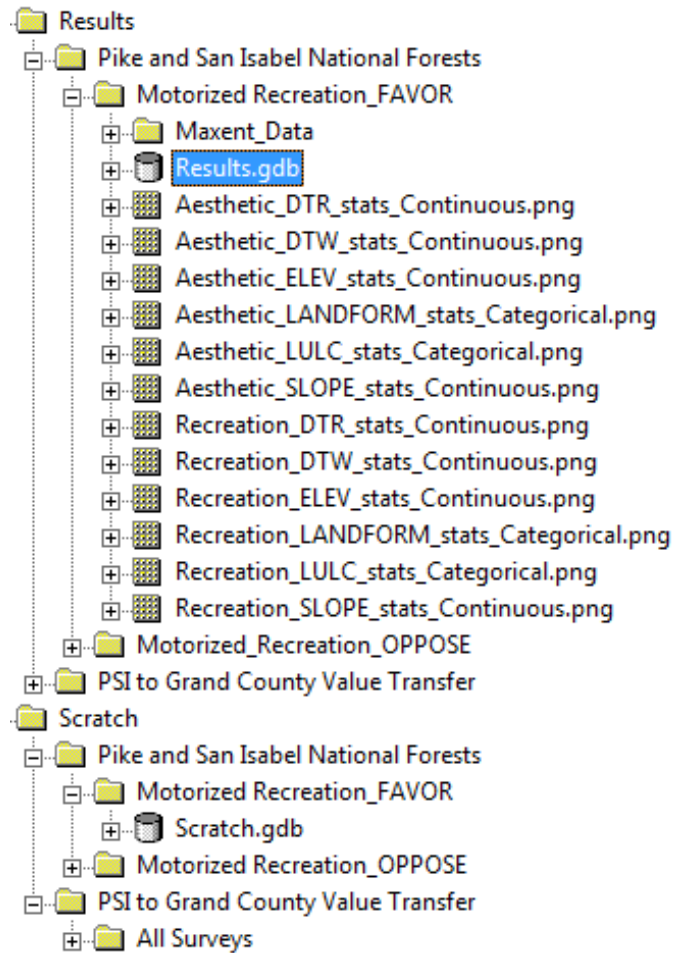
As SolVES is processing, project-level folders bearing the Project Name and analysis-level folders bearing the name of the selected survey subgroup (“All Surveys” if no survey subgroup is selected) or social-value type within the project-level folder are created within the Results and Scratch folders of the SolVES directory (fig. 17).



**Figure 17.** Project-level and analysis-level folders created under the Results and Scratch Folders.

As additional analyses are completed for the same project, separate analysis-level folders will be added within each corresponding project-level folder. File geodatabases named Results.gdb and Scratch.gdb containing final results and intermediate data, respectively are generated in the corresponding analysis-level folders (fig. 18).

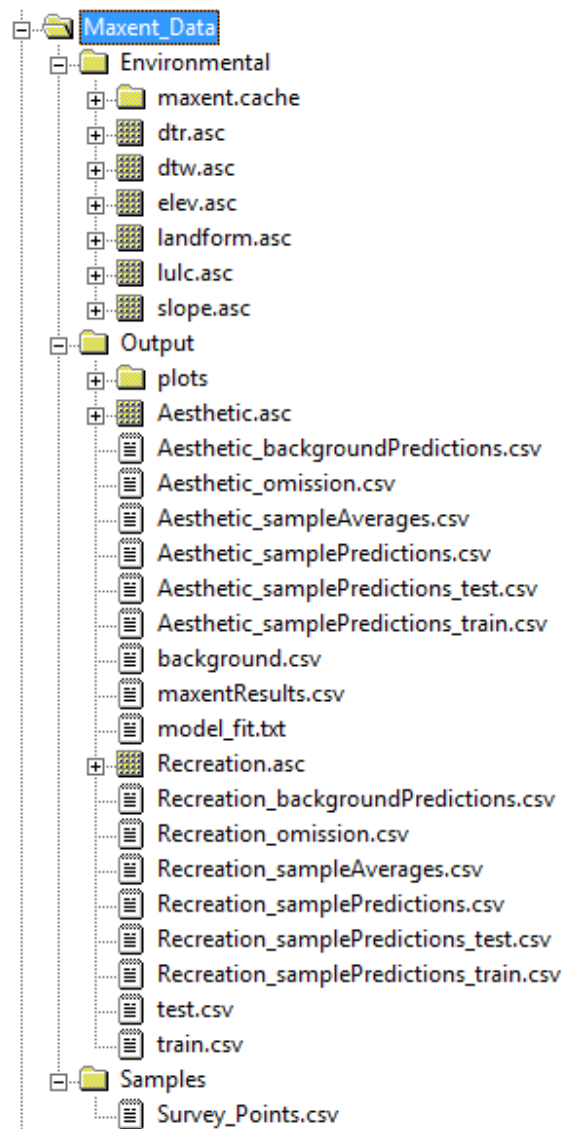




**Figure 18.** Results and Scratch file geodatabase locations.

## Results Folder Contents

In addition to the Results file geodatabase, other SolVES and Maxent output are written to the Results analysis-level folders. All environmental metric graphs generated for the final map layout, including those that will not fit on the map layout, are saved here as PNG files. Log files for each SolVES run are written to each analysis-level folder. A Maxent\_Data folder is also written here that contains output from Maxent and specially formatted survey point and environmental data inputs for Maxent (fig. 19). The Environmental folder contains resampled environmental layers from SolVES.gdb that have been converted to ASCII format. The Samples folder contains the user-selected survey points converted to CSV format. The Output folder contains logistic value grids generated by Maxent as ASCII files, along with other files describing Maxent results. (The Samples folder will remain empty and the Output folder will only contain the ASCII logistic value grids when the Transfer Values tool is used.)



**Figure 19.** Maxent\_Data folder contents as seen in ArcCatalog.

Accessing the Output folder through Windows, users will also see Hypertext Markup Language (html) files associated with each model generated by Maxent that provide additional information regarding the Maxent results (including AUC statistics, jackknife graphs, variable contribution percentages), along with links to the other files contained in the Output folder (fig. 20). See the *Interpreting and Adjusting Maxent's AUC Values and Variable Contributions* section for additional information regarding these html file contents.

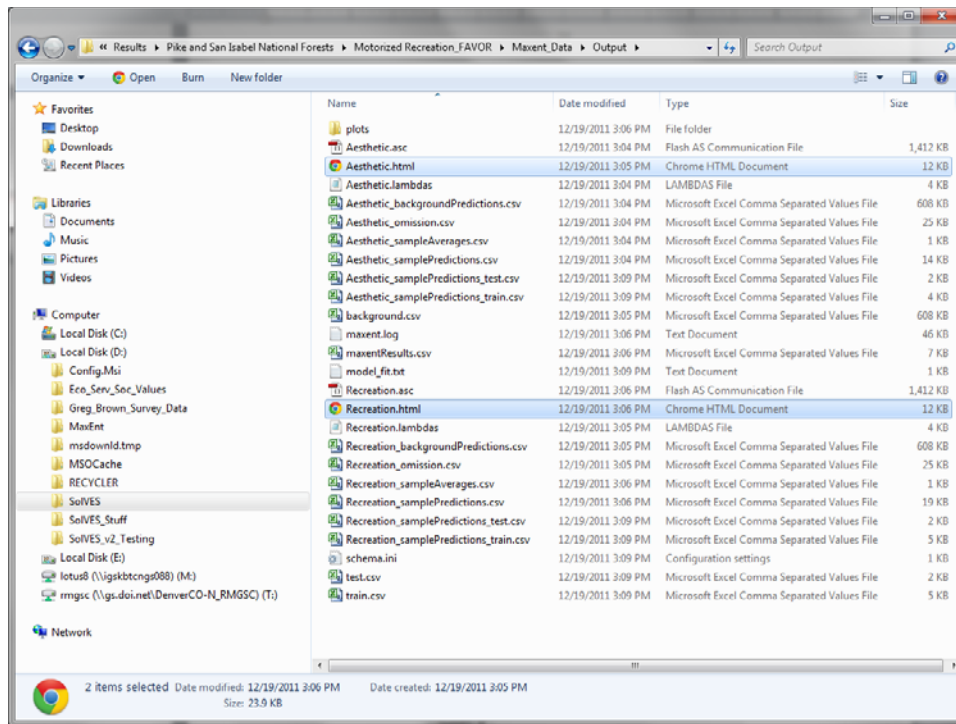
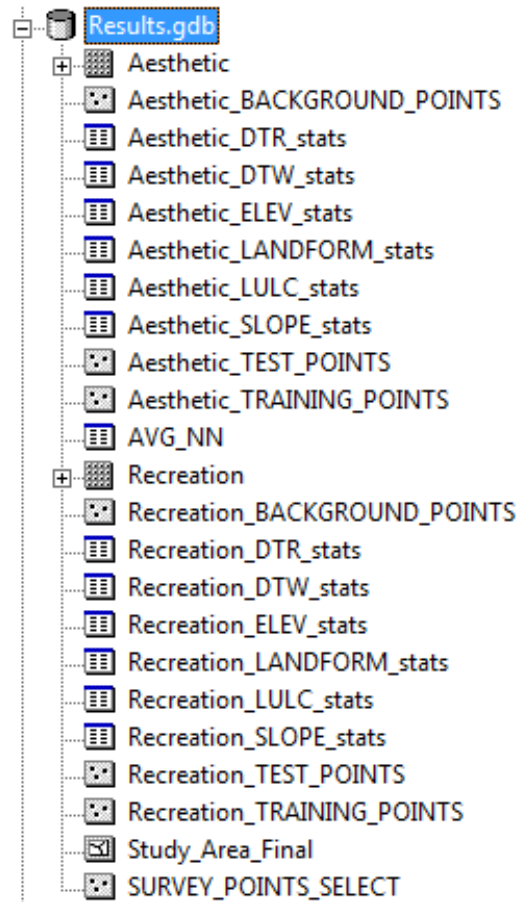


Figure 20. Maxent\_Data\Output folder contents as seen in Windows.

The Results.gdb contains the final results generated by SolVES (fig. 21). A general description of the contents is provided in table 5.



**Figure 21.** Example Results.gdb contents.

**Table 5.** Results.gdb contents description.

Table, feature, or grid name	Description
[Social Value Type or Survey Subgroup]	Final raster dataset containing the final value-index surface (social-value map) generated from Maxent output for the social-value type or survey subgroup for which it is named (for example, Aesthetic).
*_BACKGROUND_POINTS	Background points selected at random by Maxent for the user-selected social-value type or survey subgroup (*). Not applicable for Transfer Values tool output.
*_stats	Environmental metrics (average or dominant) with * being the associated social-value type or survey subgroup and the environmental layer.
*_TEST_POINTS	The 25 percent of survey points withheld by Maxent as test points for the user-selected social-value type or survey subgroup (*). Not applicable for Transfer Values tool output.
*_TRAINING_POINTS	The 75 percent of survey points used by Maxent as training points for the primary study area for the user-selected social-value type or survey subgroup (*). Not applicable for Transfer Values tool output.
AVG_NN	Table containing average nearest neighbor statistics. Not applicable for Transfer Values tool output.
Study_Area_Final	Study area boundary including any user-selected buffer.
SURVEY_POINTS_SELECT	Survey points for the user-selected social-value types or survey subgroups. Not applicable for Transfer Values tool output.
*_clamping	Raster dataset indicating environmental layer values for a study area where the Value Transfer tool is applied falling outside the range of environmental layer values for the primary study area where a Maxent model was originally generated. (*) indicates the user-selected social-value type or survey subgroup. Not applicable for Analyze Survey Data tool output.

## Scratch Folder Contents

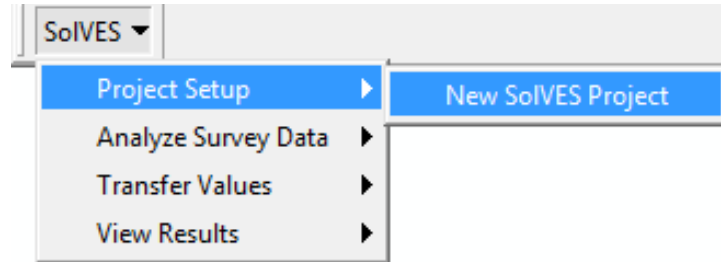
The Scratch.gdb contains intermediate data generated by SOLVES. A general description of the contents is provided in table 6.

**Table 6.** Scratch.gdb contents description.

Table, feature, or grid name	Description
[Social Value Type or Survey Subgroup]	Maxent logistic output for the user-selected [Social Value Type or Survey Subgroup] for which it is named (for example, Aesthetic or Motorized Recreation_FAVOR).
*_100	The _plus grid converted to an integer grid for the user-selected social-value type or survey subgroup (*).
*_KD	Initial kernel density surface generated for each social-value type or survey subgroup (*).
*_KDnorm	Result of kernel density surface of user-selected social-value type or survey subgroup (*) divided by MAX_GRID.
*_KDsqr	The square root of the _KDnorm grid for the user-selected social-value type or survey subgroup (*).
*_KDVI	The value index surface generated from the kernel density surface for the user-selected social-value type or survey subgroup (*).
*_KDVIMax	The maximum attained value on the kernel density value index surface for the user-selected social-value type or survey subgroup (*).
*_plus	Addition of 0.5 to the _times grid so values will properly round when converted to an integer grid for the user-selected social-value type or survey subgroup (*).
*_times	Multiplication of Maxent logistic output by 10 to convert values to a 10-point scale for the user-selected social-value type or survey subgroup (*).
*_timesTen	Multiplication of _times by 10 to convert values to a 100 point scale for use in calculating zonal statistics for the user-selected social-value type or survey subgroup (*).
[Environmental Layer]	*_extract resampled according to user-entered output cell size.
*_extract	Extract of environmental layer (*) from SolVES.gdb within the study area boundary.
MAX_ALL	The maximum value found in each grid cell after evaluating all _KD grids.
MAX_GRID	The single, maximum value found in the MAX_ALL grid.
MAXENT_POINTS	The user-selected survey points to be converted to CSV format.
Survey_Points_Clip	The SURVEY_POINTS layer from SolVES.gdb to include only points within the final study area boundary (including the buffer, if selected).
SurvPntSelect_#	Survey points selected for each individual social-value type or survey subgroup (#) used for kernel density analysis.
UseAttSel	A summary of all public use and attitude or preference data for the user-selected social-value type or survey subgroup.
VALUE_ALLOCATION_SUM	The total amount allocated to each social-value type by each survey subgroup (if provided). Used as the weight parameter for kernel density analysis.

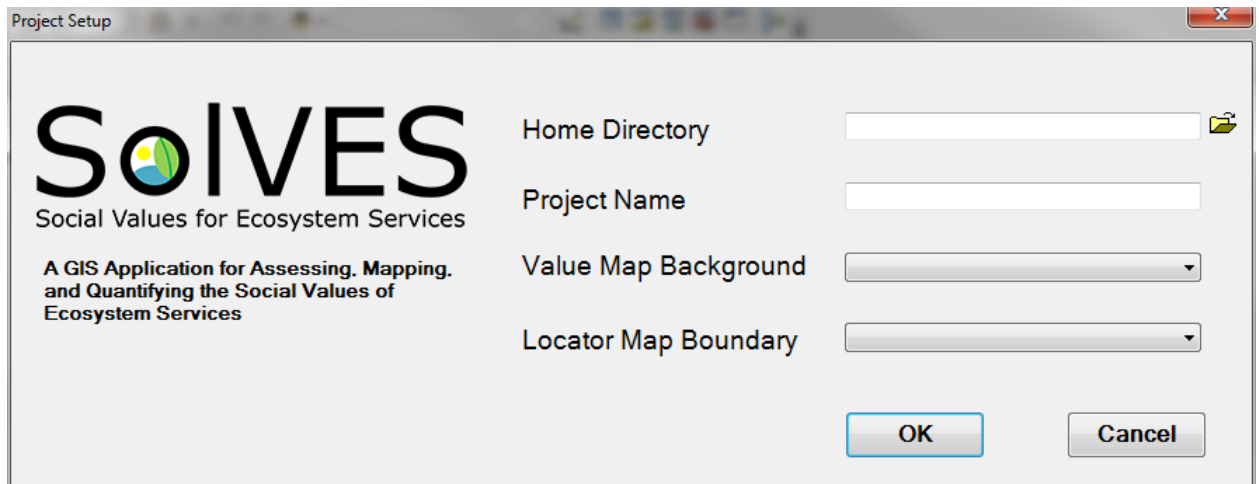
## Project Setup

1. To begin using SolVES 3.0, a new project will need to be started by selecting Project Setup and New SolVES Project from the toolbar (fig. 22).

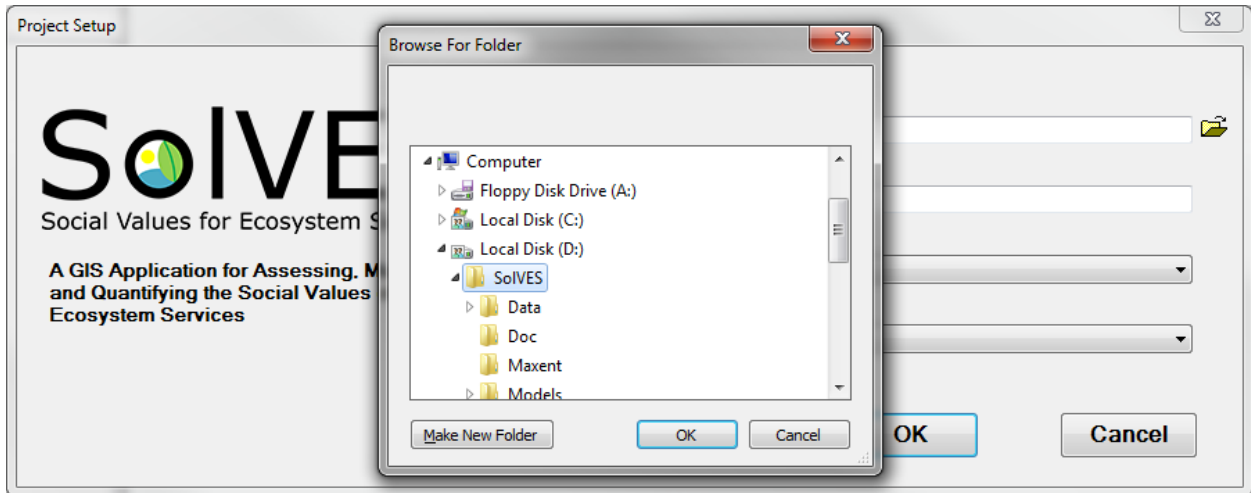


**Figure 22.** Starting a new project.

2. Once the Project Setup form is open (fig. 23), navigate to the SolVES directory location to set the Home Directory (fig. 24).

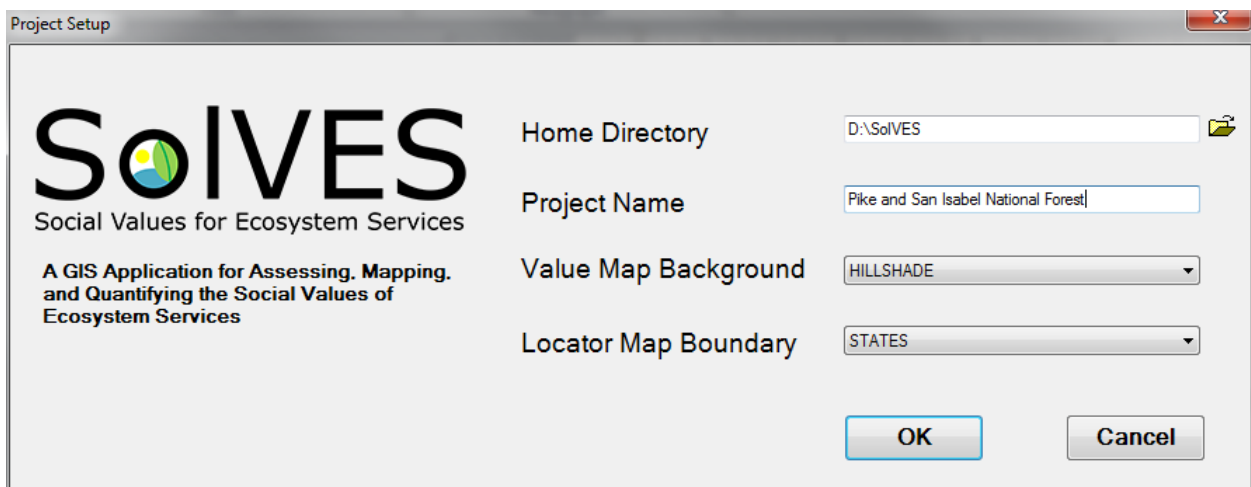
A screenshot of the 'Project Setup' dialog box. On the left side, there is the SolVES logo (a stylized 'S' with a green leaf and a blue circle) and the text 'Social Values for Ecosystem Services' followed by 'A GIS Application for Assessing, Mapping, and Quantifying the Social Values of Ecosystem Services'. On the right side, there are four input fields: 'Home Directory' (with a folder icon), 'Project Name', 'Value Map Background' (a dropdown menu), and 'Locator Map Boundary' (a dropdown menu). At the bottom right, there are two buttons: 'OK' and 'Cancel'.

**Figure 23.** The Project Setup form.



**Figure 24.** Navigating to the Home Directory from the Project Setup form.

3. Enter a Project Name. This can simply be the name of the study area or some other unique, descriptive name.
4. If a hillshade raster has been provided to serve as the Value Map Background, it will be selected by default. Otherwise, select the name of the provided Value Map Background or leave blank if none was provided.
5. STATES will be selected as the default Locator Map Boundary (fig. 25), but may be left blank or changed to COUNTIES or another polygon feature provided as the Locator Map Boundary.
6. Select OK.

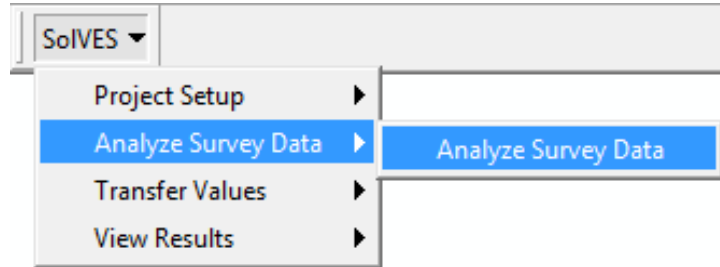


**Figure 25.** A completed Project Setup form.



## Analyze Survey Data

1. Select the Analyze Survey Data tool from the toolbar (fig. 26).



**Figure 26.** Selecting the Analyze Survey Data tool.

2. The Analyze Survey Data tool (fig. 27) provides access to the Ecosystem Services Social Values and Value Mapping Models.

A screenshot of the 'Analyze Survey Data' dialog box. The dialog is titled 'Analyze Survey Data' and has a standard Windows window frame. It is divided into several sections. On the left, under 'Value Comparison Type', there are two radio button options: 'By Survey Subgroup Across Social Value Types' (selected) and 'By Social Value Type Across Survey Subgroups'. Below the first option are dropdown menus for 'Public Use' and 'Attitude or Preference'. Below the second option is a dropdown for 'Social Value Type'. On the right, under 'Environmental Layers', there is a list of layers: DTR, DTW, ELEV, LANDFORM, LULC, and SLOPE. Each layer has a checked checkbox and a 'Continuous' dropdown menu. Below this list is a 'Select/Deselect All' button. At the bottom of the dialog, there are input fields for 'Output Cell Size' and 'Search Radius', both followed by 'meters'. There are also radio button options for 'Weight Survey Points' (Yes/No), 'Buffer Study Area' (Yes/No), and 'Threshold Features' (Yes/No). A 'Width' input field with 'meters' is also present. At the bottom right are 'OK' and 'Cancel' buttons. A progress bar is visible at the very bottom of the dialog.

**Figure 27.** The Analyze Survey Data tool.

3. Select either By Survey Subgroup Across Social Value Types to analyze a specific survey subgroup or By Social Value Type Across Survey Subgroups to analyze a specific social-value type.
4. If the selected Value Comparison Type is By Survey Subgroup Across Social Value Types, select the Public Use and Attitude or Preference parameters to define the desired subgroup. (Leave these parameters blank to analyze results from all surveys.)  
-OR-

If the selected Value Comparison Type is By Social Value Type Across Survey Subgroups, then select the desired Social Value Type.



The values available for the Public Use and Social Value Type parameters are determined by the text values entered in the USE\_TYPES.USE\_NAME and VALUE\_TYPES.VALUE\_NAME fields in SolVES.gdb. These text values are also used to name rasters written to the Results geodatabase, so their length should be limited.

5. Enter the desired Output Cell Size. This should be calculated from the scale of the map or maps used in a survey. A general rule of thumb is to apply a cell size that is one thousandth the value of the denominator of the survey map scale. For example, if the map scale is 1 to 450,000, then the output cell size is set to 450 meters (m). The assumption is that a hand-marked point on the map is approximately 1 millimeter (mm) in width.
6. The Search Radius parameter used by the kernel density function defaults to 10 times the Output Cell Size. Enter a new value into the Search Radius field if the default value is not adequate for a specific analysis. Larger values will generate more generalized kernel density surfaces.
7. The Weight Survey Points option defaults to Yes. If no allocation data were provided in the VALUE\_ALLOCATION table or the user wishes to analyze data without the weights derived from provided allocation data, select No.
8. The Buffer Study Area option defaults to No. If a buffer is desired, select Yes, and then enter a buffer size, in meters, into the Width field. This option allows users to include points in their analysis that fall just outside the formal study area boundary.
9. The Threshold Features option defaults to Yes. We recommend that users accept the default setting for initial analysis. If they find spatial artifacts in their results as described in the *Threshold Features Option* section, they may then wish to reanalyze their data with the option set to No.
10. Select the environmental layers to be included in the analysis by confirming the appropriate checkboxes are marked under the Environmental Layers section. All layers are selected by default. At least one layer must be selected.
11. Use the dropdown box next to each selected environmental layer to indicate whether it is continuous or categorical data. All layers are continuous by default.
12. After all options and parameters have been set (see fig. 28 for an example), select OK, and the Ecosystem Services Social-Values Model will process as described below (fig. 29). Processing may take several minutes. The main ArcMap application window will not be visible during processing.

Analyze Survey Data

### Value Comparison Type

☒ **By Survey Subgroup Across Social Value Types**  
 Leave Public Use and Attitude or Preference blank to analyze results from all surveys.

**Public Use**

**Attitude or Preference**

☐ **By Social Value Type Across Survey Subgroups**  
 Individual respondents can belong to more than one survey subgroup.

**Social Value Type**

### Environmental Layers

Must select at least one. Designate any categorical variables.

<input checked="" type="checkbox"/> DTR	Continuous
<input checked="" type="checkbox"/> DTW	Continuous
<input checked="" type="checkbox"/> ELEV	Continuous
<input checked="" type="checkbox"/> LANDFORM	Categorical
<input checked="" type="checkbox"/> LULC	Categorical
<input type="checkbox"/> SLOPE	Continuous

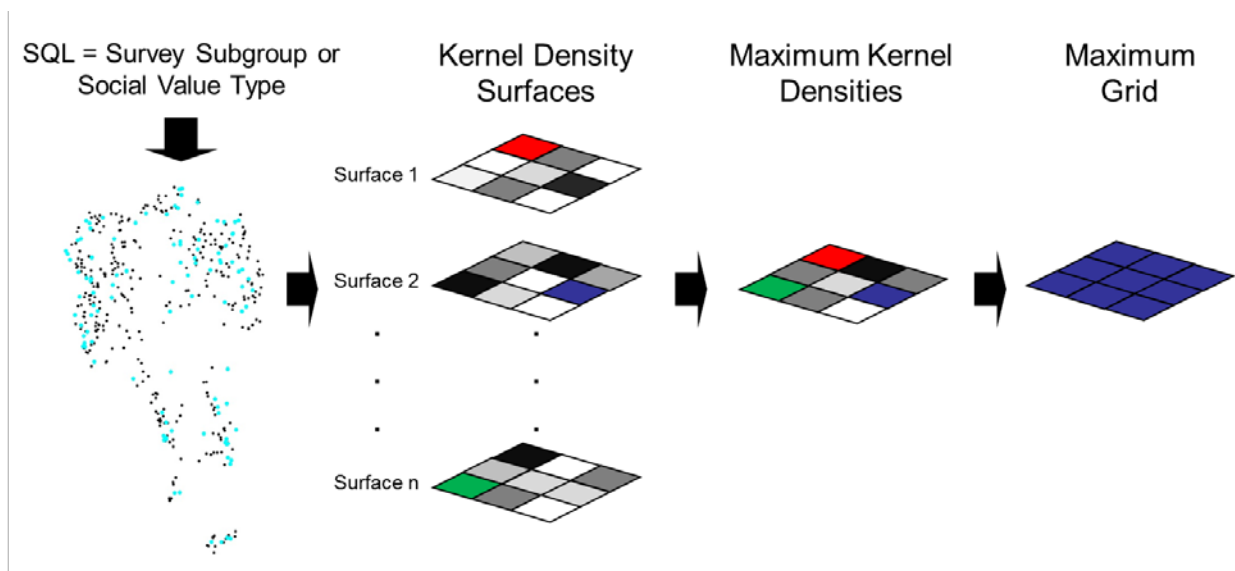
**Output Cell Size**  **meters** **Search Radius**  **meters**

**Weight Survey Points** ☒ Yes ☐ No

**Buffer Study Area** ☒ Yes ☐ No **Width**  **meters**

**Threshold Features** ☒ Yes ☐ No

**Figure 28.** The Analyze Survey Data tool ready to process the Ecosystem Services Social-Values Model.



**Figure 29.** Ecosystem Services Social-Values Model generalized process flow.

The survey subgroup (public use and attitude or preference) parameters (or the social-value type parameter depending on the selected value comparison type) are converted to a Structured Query Language (SQL) statement, which is then used to select the corresponding mapped survey points. Kernel density surfaces weighted by the total amount of value allocated to each social-value type (or not weighted if the Weight Survey Points option is set to No) are generated for each social-value type (or each survey subgroup). The values contained in every cell are compared among all kernel density surfaces, and the maximum kernel density value at each cell location is identified and written to a single grid. The red, blue, and green cells indicated in figure 29 represent examples of maximum kernel density values identified at those cell locations within those particular surfaces (for example, the red cell indicates that the highest value at that cell location was found in Surface 1). The grid of maximum kernel densities is then evaluated, and a grid containing the single, overall maximum kernel density value is generated (for example in fig. 29, this overall maximum value was in the blue cell in Surface 2). This “Maximum Grid” will be used by the Value Mapping Model to normalize the kernel density surfaces and ultimately generate social-value maps. In addition, during model processing, the selected mapped points are converted to a CSV file and the environmental layers are resampled to the user-provided output cell size and converted to ASCII format for use by Maxent.

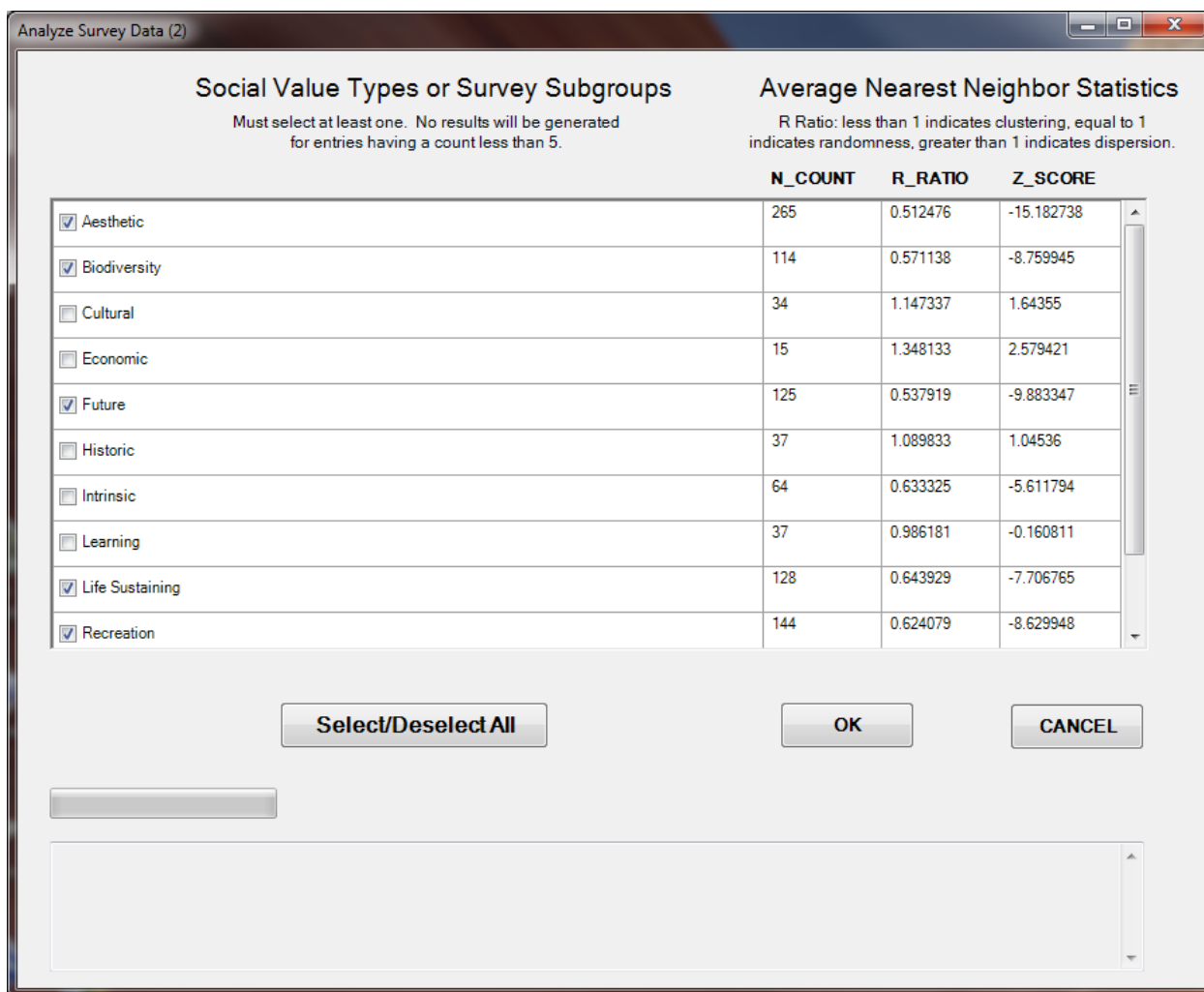


Because a survey respondent can be a member of more than one survey subgroup (as opposed to each mapped point representing a single social-value type), a single point mapped by a survey respondent may be included in the calculation of more than one kernel density surface if the By Social Value Type Across Survey Subgroups Value Comparison Type is selected.

The kernel density surfaces are generated following a methodology similar to that of Alessa and others (2008) in their mapping of social-ecological hotspots on Alaska’s Kenai Peninsula. As opposed to simple point density, the basis of kernel density is a quadratic kernel function (Silverman, 1986). This function defines a smoothly curved surface fit over each point and extending out to a defined search radius. The volume below each surface is equal to the weight assigned to the point.

To assist users with the selection of social-value types of survey subgroups for further analysis by the Value Mapping Model, the Ecosystem Services Social-Values Model generates average nearest neighbor statistics describing the relative dispersion, clustering, or randomness of the mapped points. Following the example of Clement (2006) and Brown and others (2002), the point data are subjected to Completely Spatially Random (CSR) hypothesis testing through the calculation of average nearest neighbor statistics. The ratio of the observed distance between points to the expected distance between points is represented by an R value. Each R value, along with its number of standard deviations from the mean, or Z score, identifies point patterns for which statistically significant clustering is observed. Such clustering is indicated by R values of less than 1 and large negative Z scores. Average nearest neighbor statistics are calculated based on the total area within the study area boundary. These statistics can be used to limit a user’s focus to social-value types occupying locations with specific levels of significance. Individual users may be less concerned about the relative spatial distribution of the mapped points, but the average nearest neighbor statistics do provide an initial indication of the social-value maps that will likely display the most intensely valued hotspots.

Once processing of the Ecosystem Services Social-Values Model is complete, the second Analyze Survey Data tool screen is opened to provide access to the Value Mapping Model. A list of all social-value types or survey subgroups available for analysis is presented, along with their associated point counts and average nearest neighbor statistics. An example showing user-selected social-value types is shown below (fig. 30).



**Figure 30.** The Analyze Survey Data tool ready for processing the Value Mapping Model.

1. Based on average nearest neighbor statistics, or other user criteria, select the desired social-value types or survey subgroups to include in the analysis. All social-value types or survey subgroups are selected by default. At least one social-value type of survey subgroup must be selected. Because of how SOLVES instructs Maxent to partition points into training and test data, results will not be generated for any entry having less than 5 points.
2. Select OK. Processing may take several minutes. The main ArcMap application window will not be visible during processing; however, when the Maxent maximum entropy modeling software is processing, its interface will be temporarily visible behind the Analyze Survey Data screen (fig. 31). The model will process as described below in fig. 32.

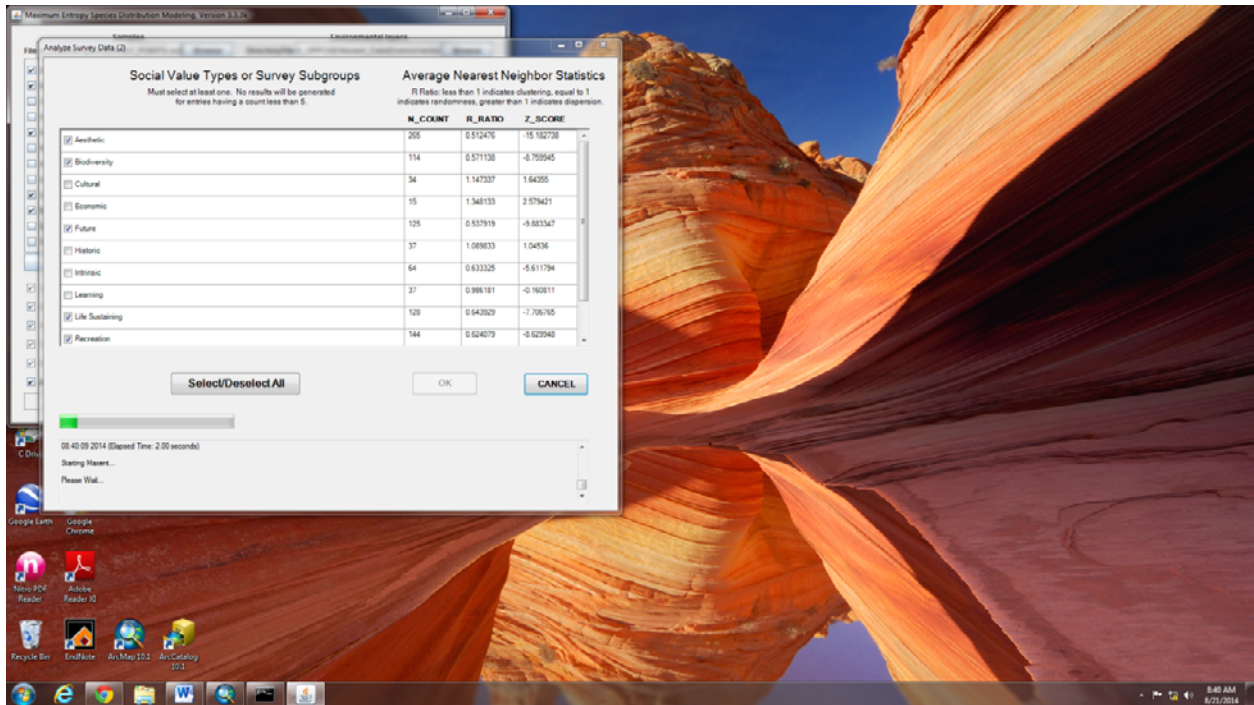


Figure 31. The Value Mapping Model with Maxent partly visible during processing.

⚠ Programming limitations that existed during the development of SolVES 3.0 prevented the desired option of having the Maxent interface completely hidden from view during processing. It is critical that users do not attempt to adjust or otherwise interact with the Maxent user interface. Doing so may cause SolVES to malfunction.

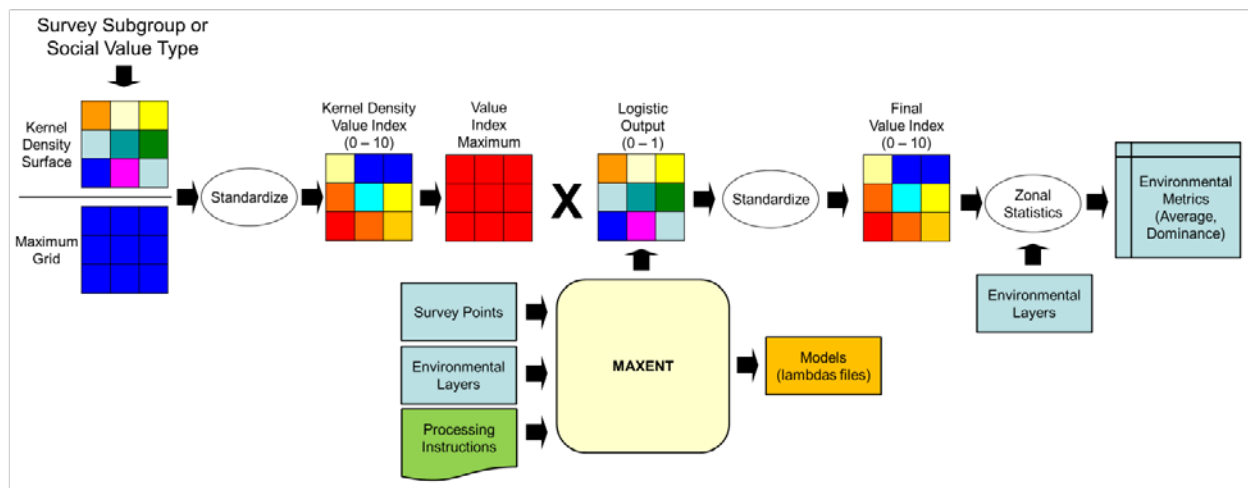


Figure 32. Value Mapping Model generalized process flow.



Given the selected social-value types or survey subgroups, the Value Mapping Model identifies the matching kernel density surfaces that were generated by the Ecosystem Services Social-Values Model. The selected kernel density surfaces are then divided by the Maximum Grid generated by the Ecosystem Services Social-Values Model. The normalized grids are standardized into the 10-point, kernel-density based value-index integer grid, and a constant grid of the maximum value in each value-index grid is generated (Value Index Maximum). The Value Mapping Model then sends processing instructions to Maxent by means of a batch file. Maxent uses the specially formatted point and environmental data converted by the Ecosystem Services Social-Values Model to generate logistic value layers (ranging from 0 to 1) for each selected social-value type or survey subgroup. Maxent also generates models as lambdas files for each selected social-value type or survey subgroup based upon the relationship between the mapped points and the environmental layers. Included along with these models are AUC statistics indicating the goodness of fit of each model for the study area and their potential performance in transferring social values to similar areas. The Value Mapping Model converts Maxent's logistic output to social-value maps of the final value-index surface (ranging from 0 to 10) by multiplying each value layer with its corresponding Value Index Maximum and rounding the result to the nearest integer. Finally, the Value Mapping Model uses the social-value maps generated from the Maxent output to calculate zonal statistics (that is, the environmental metrics) from each environmental layer.



Given the range of values included in the Maxent logistic output, it is possible that the process of multiplying the Value Index Maximum by the logistic output will result in the final maximum attained index value being reduced to the next lowest integer value. For example, if the Value Index Maximum for a particular social-value type is 10 and the maximum value in the logistic output is less than 0.95, the resulting value-index surface will have a maximum value of 9. It is also possible that the minimum value in the logistic output is greater than or equal to 0.05, resulting in final value-index surfaces having a minimum value greater than 0.

## Notes Regarding Calculation and Interpretation of the Value Index

As a result of normalizing to the Maximum Grid, the value of every cell on every kernel density grid is scaled relative to the highest kernel density value among all social-value types or survey subgroups (values ranging from 0 to 1). This normalization, however, can result in highly positively skewed value distributions. This can limit the usefulness of social-value maps generated for all but a few of the most highly rated social-value types. To counter this effect and thereby improve the utility of a greater number of social-value maps produced during an analysis, the square root of each normalized grid is taken as part of the standardization process that converts the normalized grid to the kernel-density based value-index surface. Because the normalized grids have dimensionless values ranging from 0 to 1, the resulting transformation is monotonic.

The value index can be used to measure and compare the magnitude of value differences across social-value types and survey subgroups and to produce social-value maps and associated environmental metrics. For analysis of multiple social-value types across a single survey subgroup, the higher the value attained on the value index by a social-value type, the more highly it is valued by that survey subgroup. A social-value type that attains a 10 on the value index corresponds to one or more locations within the study area where that survey subgroup values that social-value type more highly than at any other location and more highly than any of the other social-value types, regardless of location. For social-

value types that attain less than a 10 on the value index, the value corresponds to locations where that social-value type is valued more highly than at any other location by that survey subgroup. For analysis of a single social-value type across multiple survey subgroups, a value index of 10 will indicate the survey subgroup that most highly values the selected social-value type. Because survey respondents can belong to more than one survey subgroup, relative value, as measured by the value index, will be sensitive to the number of respondents who are members of each subgroup. The maximum value attained on the value index will tend to increase as the relative size of the subgroup increases. This sensitivity to subgroup size should be kept in mind when making comparisons across subgroups for a single social-value type.



The Analyze Survey Data tool can be repeatedly processed under the same project in order to complete analyses for multiple survey subgroups or social-value types (depending on the value comparison type selected). However, if it is necessary to perform repeated analyses for the same survey subgroup or social-value type (for example, when performing analyses for the same survey subgroup or social-value type but with different environmental layers, output cell size, point weighting, buffers) a new project should be created for each individual analysis. Failure to do so will cause results of the previous analysis under the same project to be overwritten.

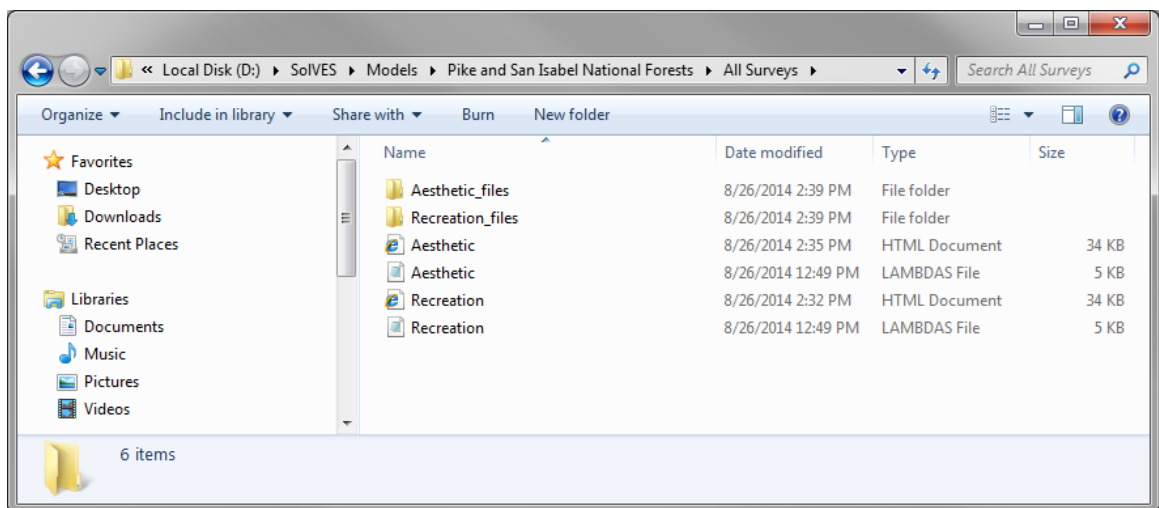


## Transfer Values

The Value Transfer Mapping Model, accessible through the Transfer Values tool, can be used when survey data are unavailable for a study area having similar physical and social contexts to a primary study area. It relies on statistical models generated by Maxent from previous SOLVES analyses in study areas having available survey data. For more information regarding the SOLVES value-transfer implementation, see Sherrouse and Semmens (2014). Prior to running the Value Transfer Mapping Model, it will be necessary to review the individual social-value model's metadata to acquire the appropriate environmental data, to identify the necessary parameter values for the Transfer Values tool, and to determine if the model's physical and social context is sufficiently similar to the receiving study area for value transfer to be a viable option.

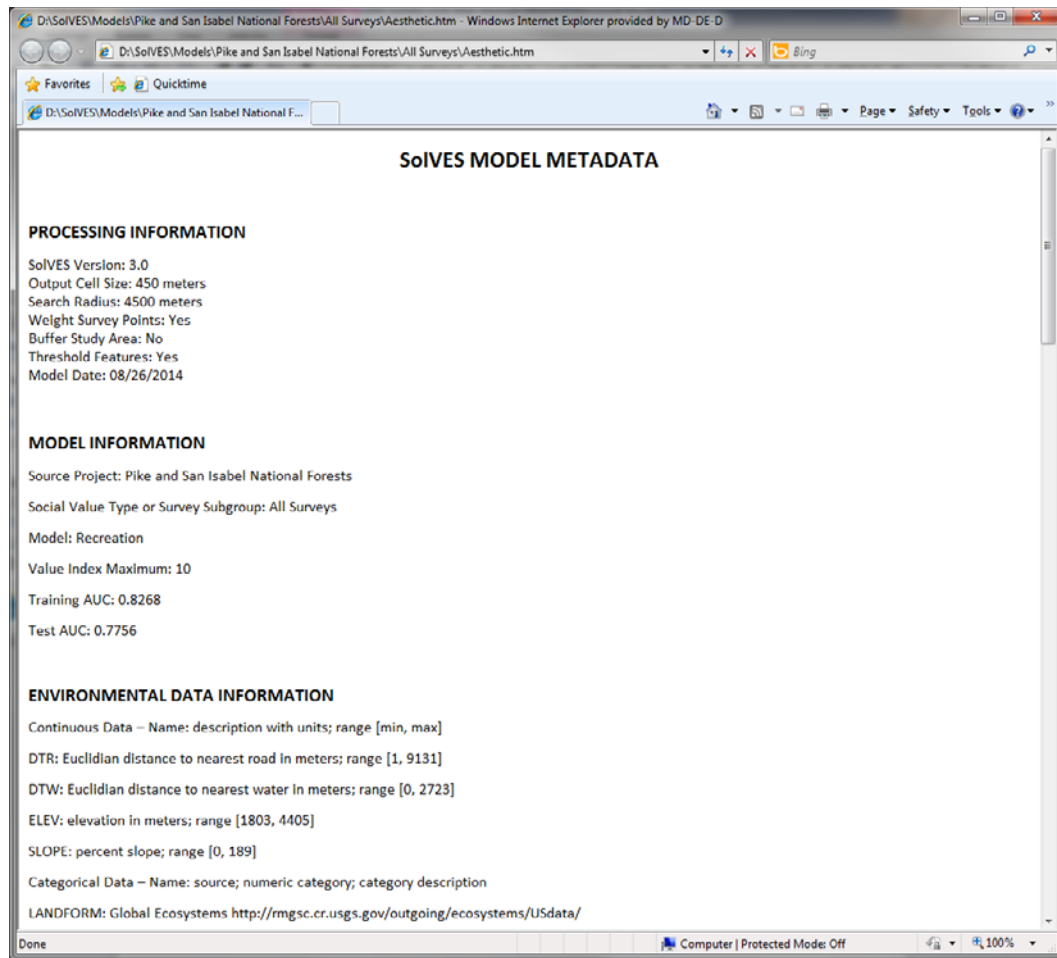
Complete the following steps to apply the Transfer Values tool to a selected study area.

1. Use Windows to navigate to the Models folder contained within the SOLVES directory.
2. Navigate to the desired project and analysis-level folders (fig. 33).



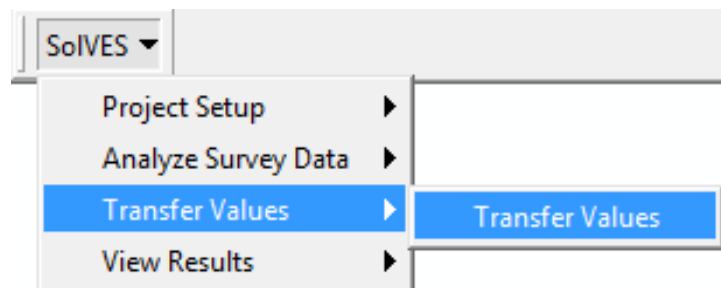
**Figure 33.** Navigating to the location of models and metadata for use with the Transfer Values tool.

3. Open the html file for the desired model to examine the metadata (fig. 34). Although the lambdas files contain the actual models, the matching html files include the original model processing parameters and information, descriptions of the environmental data used to generate the models, graphs illustrating the modeled relationship among the environmental data and the value index, and any available information regarding the model's social context such as socioeconomic and demographic summaries. Please note the social-value models and associated metadata included with the SOLVES 3.0 download are meant for demonstration only.

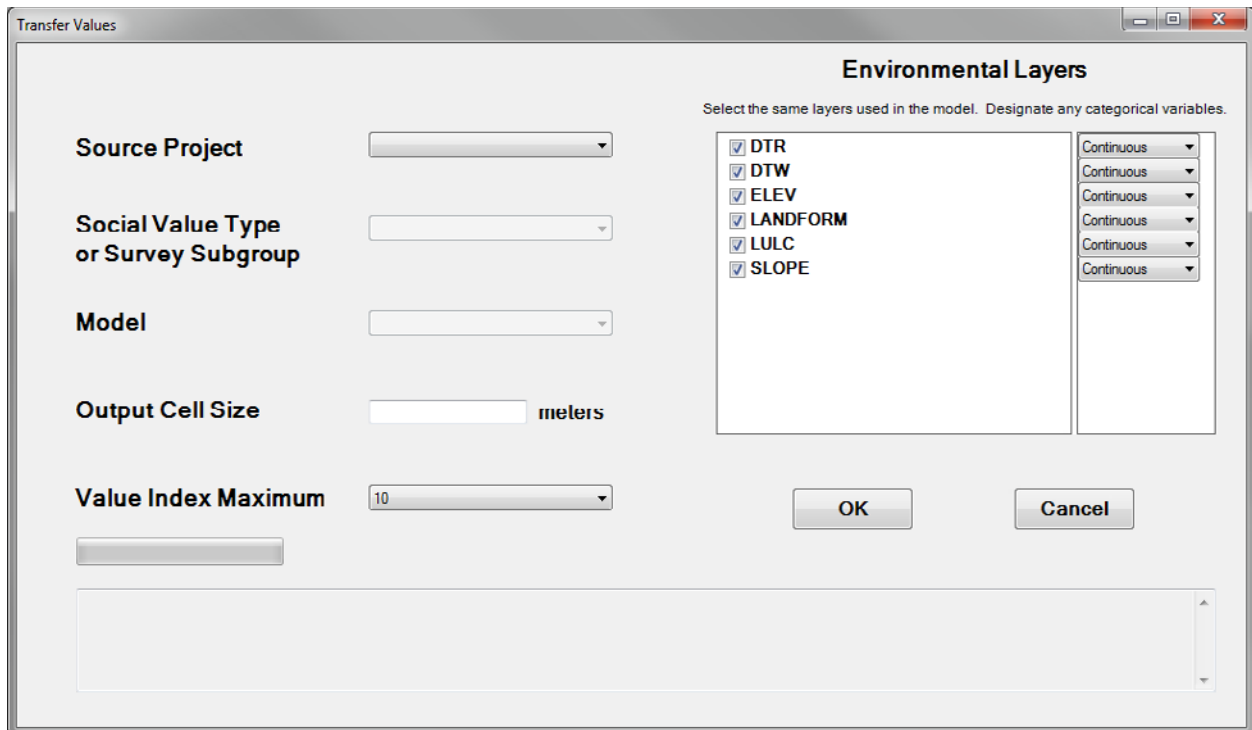


**Figure 34.** Partial contents of a value transfer model metadata file.

4. If not already completed, load the required environmental layers into SolVES.gdb using the same layer names as those used in the metadata, and ensure that SolVES.gdb has been placed in \\SolVES\Data.
5. Set up a new project as described in the Project Setup section.
6. Access the Value Transfer Mapping Model by selecting Transfer Values from the toolbar (figs. 35 and 36).

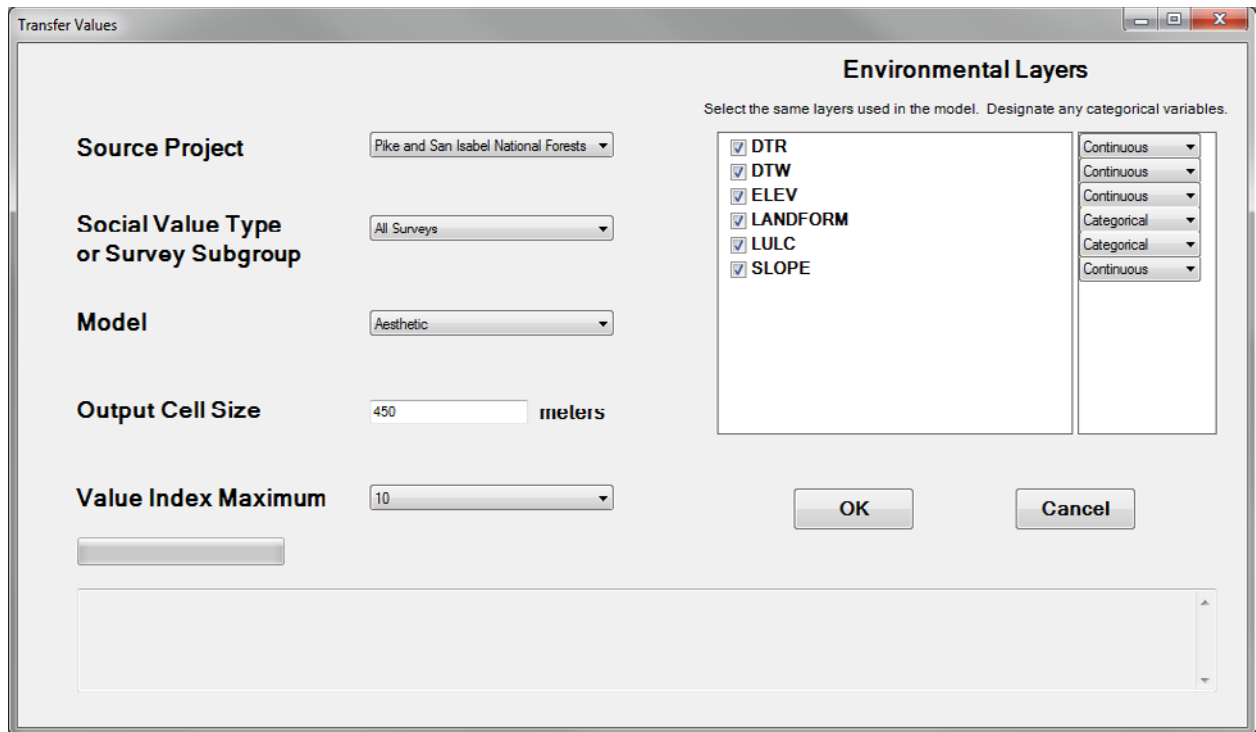


**Figure 35.** Selecting the Transfer Values tool.

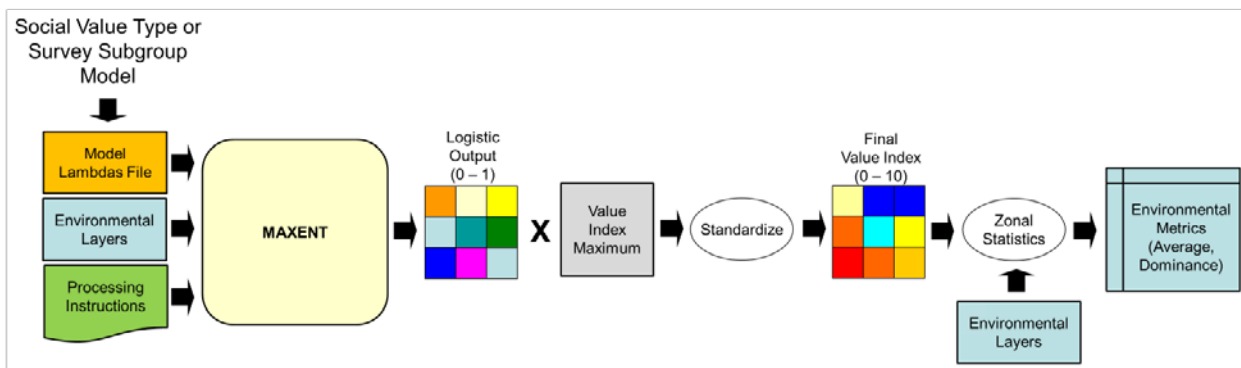


**Figure 36.** The Transfer Values tool.

7. Select the Source Project.
8. Select the Social Value Type or Survey Subgroup.
9. Select the Model. (Social-value models included with the SolVES 3.0 download are meant for demonstration only).
10. Enter the Output Cell Size from the model metadata.
11. Enter the Value Index Maximum from the model metadata. (The default value is 10.)
12. Confirm that the checkboxes for all the environmental layers required for the model are checked (and those that are not required are unchecked) in the Environmental Layers section. (All are selected by default.)
13. Designate any categorical data using the dropdown for the appropriate environmental layers. (All are designated as continuous by default.)
14. After entering all parameters, the Transfer Values tool screen should look something like the example shown in figure 37. Select OK. The model will process as shown in figure 38. Processing may take several minutes. The main ArcMap application window will not be visible during processing.



**Figure 37.** The Transfer Values tool screen after parameter selection.



**Figure 38.** Value Transfer Mapping Model generalized process flow.

The Source Project and Social Value Type or Survey Subgroup selections navigate the user through the project-level and analysis-level folders contained in the Models folder to the selected Model. The selected Model informs the Transfer Values tool which lambdas file to select. The selected environmental layers are resampled to the designated Output Cell Size, and the Value Transfer Mapping Model sends processing instructions to Maxent as a batch file. Maxent applies the selected lambdas file to the resampled environmental layers to generate a logistic value layer for the selected model. The Value Transfer Mapping Model then multiplies the resulting logistic value layer by the selected Value Index Maximum and standardizes the result to a social-values map of the final value-index surface

(ranging from 0 to 10). Lastly, the social-values map is used to calculate metrics from each environmental layer.



Analyses performed with the Transfer Values tool should be completed under a separate project from analyses performed with the Analyze Survey Data tool.

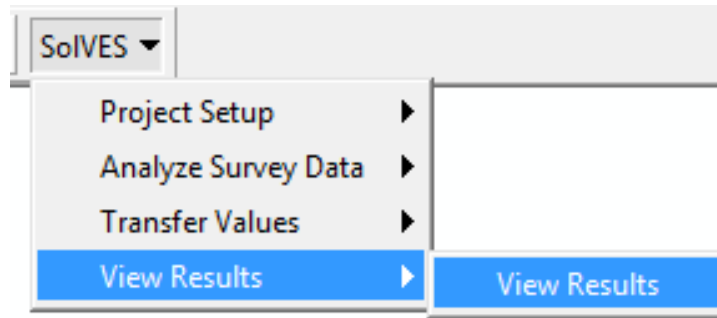


If a new model is generated that a user wishes to apply with the Transfer Values tool, the lambdas file for that model should be placed within the project-level and analysis-level folders inside the \\SOLVES\Models folder (for example, \\SOLVES\Models\Pike San Isabel National Forest\\All Surveys\\Aesthetic.lambdas).

## View Results

The View Results tool allows users to produce composite reports of social-value maps and graphs of associated environmental metrics from the results of a current project or from previously completed projects. Complete the following steps to view results generated by SolVES.

1. Select the View Results tool from the toolbar (fig. 39).

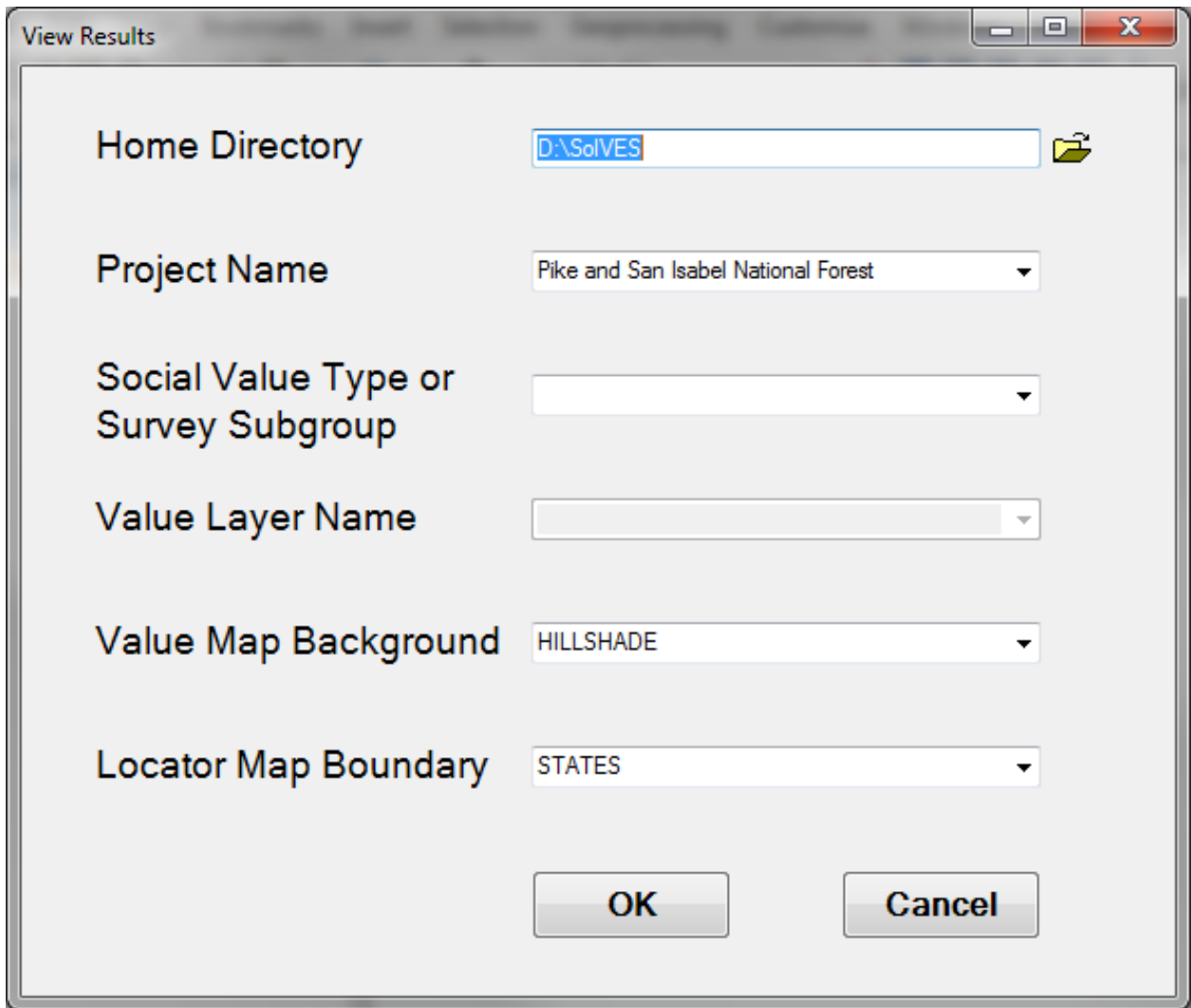


**Figure 39.** Selecting the View Results tool.



The View Results tool is the only SolVES tool that can be accessed without first setting up a new project; however, users should confirm that the appropriate source geodatabase for the desired results is in the \\SolVES\Data folder and the appropriate results geodatabase is in the \\SolVES\Results folder before using the View Results tool.

2. If a project is currently in progress, the Home Directory, Project Name, Value Map Background, and Locator Map Boundary parameters will already be set according to the values previously entered in the Project Setup screen (fig. 40). If a different value map background or locator map boundary or results from another project are desired, those parameters may be changed here. If the View Results tool is directly accessed without setting up a new project, all parameters will be blank, and the Home Directory must be set by navigating to the location of the SolVES directory containing the desired existing results.



**Figure 40.** Accessing the View Results tool during a current project.

3. Select the Social Value Type or Survey Subgroup.
4. Select the Value Layer Name.
5. Select OK. Within a few seconds, a composite report should be generated in the map layout (figs. 41 and 42).

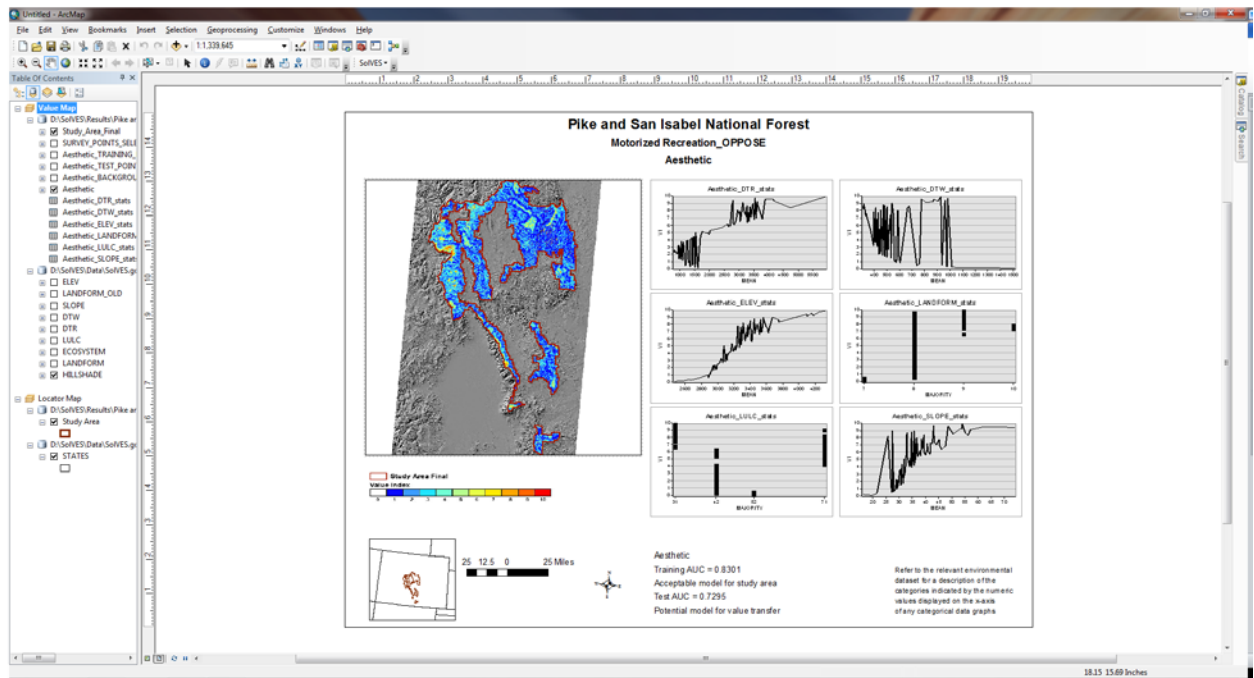


Figure 41. View Results from the Analyze Survey Data Tool.

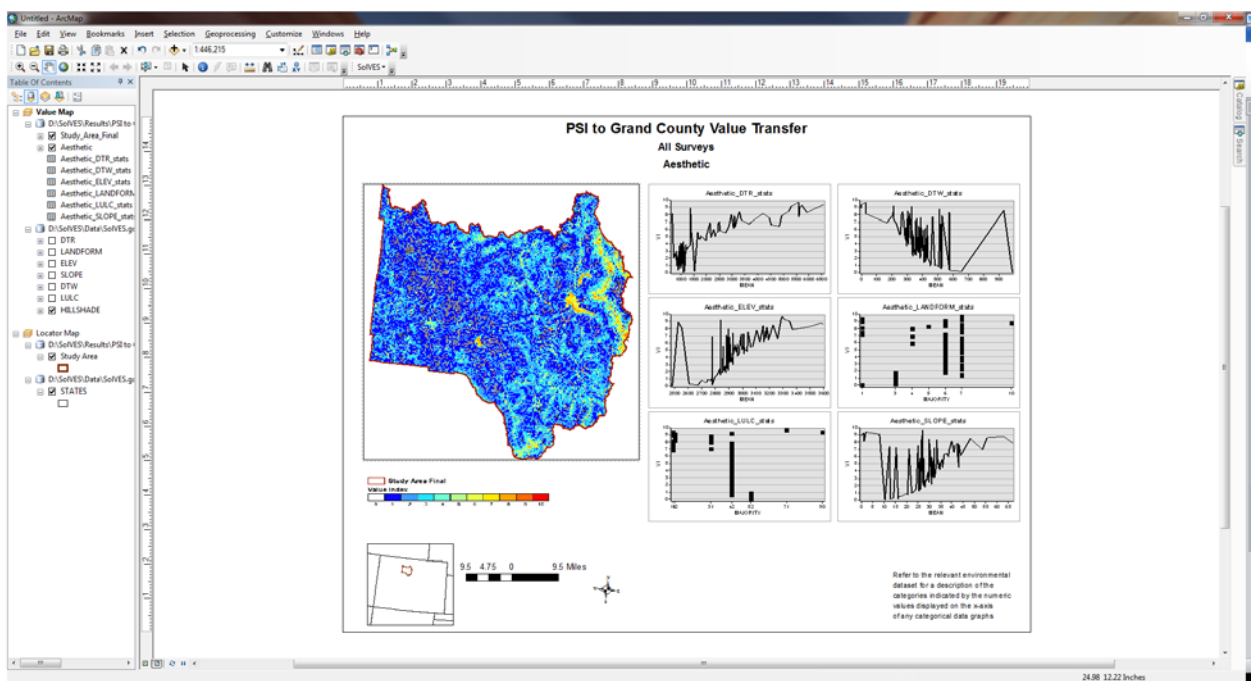


Figure 42. View Results from the Transfer Values Tool.

The map layout contains the selected Value Index map, including the study area boundary and selected background. The locator map in the lower left corner indicates the location of the study area



within a larger geographic region. Graphs of environmental metrics are limited to a maximum of six on the map layout, but those, along with any additional graphs, are saved to the analysis-level folder of the project results. Continuous data are displayed as line graphs. Categorical data are displayed as modified scatterplots. The x-axis labels for the scatterplots have the integer value designating each category. The description field for each categorical data layer in SOLVES.gdb or the layer's metadata should be consulted if the meaning of the integer value is not known. The notation below the environmental metrics graphs indicates the training AUC and test AUC for the displayed results along with a statement describing the model's goodness of fit for the current study area and potential performance in transferring social values to similar study areas. AUC notations are not included in the map layout for results generated by the Transfer Values tool.

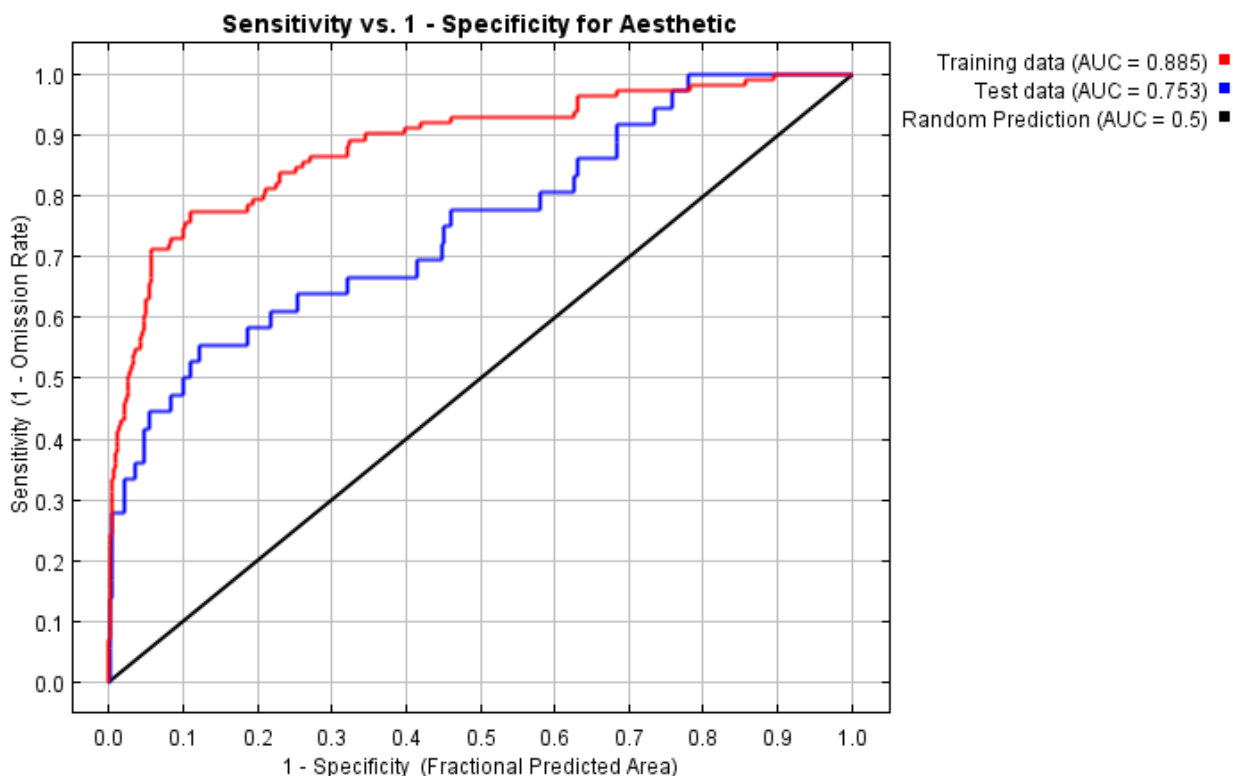
The table of contents includes the final study area boundary (including a buffer if selected), the selected value surface, environmental layers, the value map background, the selected survey points, the survey points designated as training points and test points by Maxent, and the background points generated by Maxent. Point layers are not included in the table of contents for results generated by the Transfer Values tool.



The map layout produced by the View Results can be manipulated to suit an individual user's needs. Titles can be modified, map and graph elements can be moved and resized, and other data layers can be turned on or added to the table of contents. Map layouts can be exported using various formats including JPG and PDF. The ArcMap document (MXD) can also be saved for viewing at a later time; however the MXD will need to maintain a pathway to the appropriate source and results geodatabases in order to properly display the map layout.

## Interpreting and Adjusting Maxent's AUC Values and Variable Contributions


When the SOLVES Analyze Survey Data tool is used, Maxent produces a model for each user-selected social-value type or survey subgroup. Along with these models, Maxent produces additional statistics describing the performance of each model. Included in these is the AUC statistic. The AUC statistic represents the area under the Receiver Operating Characteristic (ROC) curve. This is a curve in which the false positive rate (specificity or commission error) of predicted class membership is plotted on the x-axis and the true positive rate (sensitivity or omission error) is plotted on the y-axis. Maxent does not rely on true absence points, so the ROC curves it generates plot fractional predicted area on the x-axis, which considers the fact that Maxent is analyzing presence-random data instead of presence-absence data. An example of a ROC curve generated by Maxent and included in its html output is shown in figure 43.



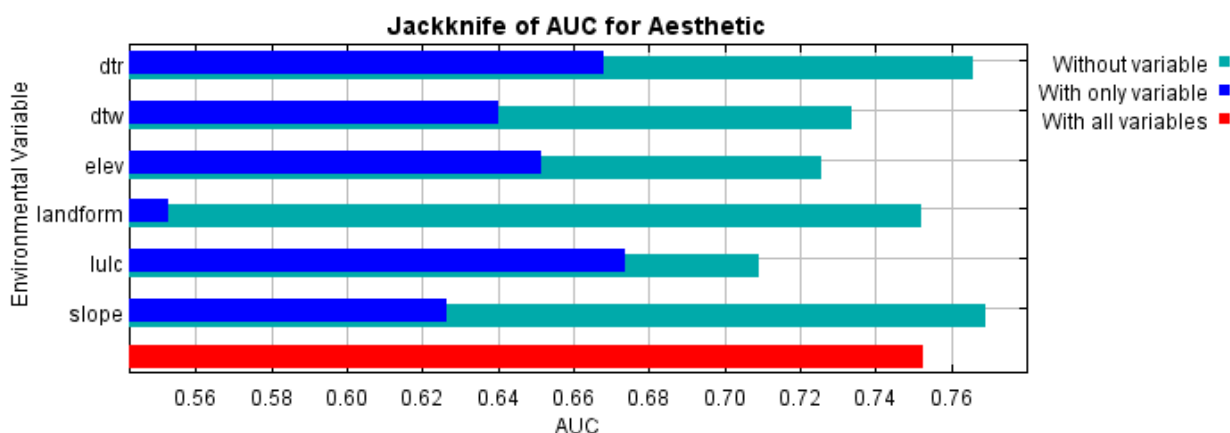
**Figure 43.** Example of Receiver Operating Characteristic (ROC) curve and associated Area Under the Curve (AUC) statistics generated by Maxent.

Models with AUC values of 0.5 or less perform at the level of random prediction (Phillips and others, 2006) or worse. Models with AUC values beginning at 0.70 (Swets, 1988; Hosmer and Lemeshow, 2000) to 0.75 (Elith and others, 2006) and above are considered potentially useful. SOLVES instructs Maxent to withhold 25 percent of the points from each user-selected social-value type or survey subgroup as test points so that Maxent can calculate AUC statistics for training points (the remaining 75 percent) and test points. The training AUC indicates how well the model fits the primary study area whereas the test AUC indicates the potential performance of the model in transferring social-values to a similar area. When the View Results tool is used to generate map layouts of output generated

by the Analyze Survey Data tool, the training AUC and test AUC statistics are reported at the bottom of the map layout, along with a brief statement interpreting the reported values.

 A summary of all AUC statistics and associated interpretations for all models included in a single analysis can be found in the model\_fit.txt file included in the Maxent\_Data\Output folder.

Based on the test AUC statistic reported by the View Results tool, a user may wish to make adjustments to the model to potentially improve its social-value transfer performance. However, it should be kept in mind that higher test AUC values are not a guarantee of improved transfer performance (Sherrouse and Semmens, 2014). If necessary, users can adjust a model by changing the environmental variables it includes. One way to identify environmental variables that may be good candidates for removal is to examine the jackknife graphs of test AUC included in Maxent's html output (fig. 44). In the example below, the test AUC of the model could potentially be improved by removing *dtr* or *slope* from the model because the green bar indicating the test AUC of the model without the environmental variable extends beyond the red bar indicating the current test AUC. Users can complete such changes by setting up a new SolVES project and running the Analyze Survey Data tool without including the indicated environmental layers.



**Figure 44.** Example jackknife graph of test AUC generated by Maxent.

There is not a corresponding jackknife graph for training AUC; however, a user may wish to improve the goodness of fit of a social-value model to a primary study area instead of developing a more generalized, transferrable model. In this situation, a user can evaluate various environmental variable combinations by repeating analyses as separate SolVES projects. The percentage contribution of each environmental variable to a model (fig. 45) and the effect of each resulting variable combination on training AUC can be observed. Variable contribution percentages should be interpreted cautiously if a model includes highly correlated variables.

<b>Variable</b>	<b>Percent contribution</b>
dtw	31.5
hlc	20.7
dtr	19.6
slope	13.8
elev	10.4
landform	4

**Figure 45.** Example of variable contributions included in Maxent's html output.

## Digitizing Points Mapped by Survey Respondents

Survey data collected using paper maps (unlike spatial data collected using online surveys) will require the use of a GIS to digitize the points mapped by survey respondents. As described in the *Survey Data* section, adequately designed public value and preference surveys include instructions directing respondents on how to mark and annotate points on the provided maps. Assuming a survey structure similar to that described in the *Survey Data* section, if a respondent properly follows instructions, there will be a point on the map notated with an indicator of its corresponding value type (for example, an A for aesthetic value) and a place name describing the location of the point. This point would be digitized at the location marked by the survey respondent, and all attributes of that point (SURVEY\_ID, VALUE\_ID, PLACE\_NAME) would be entered into the SURVEY\_POINTS attribute table accordingly. See the *Source File Geodatabase Structure and Contents* section for additional information regarding data formatting.

Individual survey respondents may interpret survey instructions differently, so some general rules should be followed to avoid ambiguity by consistently guiding the digitization of each point. The following examples illustrate various ways in which survey respondents might deviate from instructions and the recommended approaches for attempting to preserve the intent of the respondent and to obtain data that is in a quantity and format useful for SOLVES analyses.

- If a respondent indicates a location on the map with an annotation such as an A for aesthetic value or indicates a specific place name but neglects to mark an actual point, digitize a point at the centroid of the annotation characters.
- If a respondent marks an area on the map using a circle or a polygon instead of a point, digitize a point at the centroid of the marked area.
- If a respondent marks a location on the map with a line segment representing a linear feature, digitize a point at the approximate middle of the line segment.
- If a respondent marks a single point on the map but indicates through annotation that it represents more than one value type, digitize a separate point for each indicated value type and attribute each point accordingly (for example, if a single point is annotated to indicate three value types, then digitize and attribute three points at that location).
- If a respondent marks a point on the map without indicating the value type it represents, the point should not be digitized (and if it is digitized, the point would not be included in any analyses).
- If a respondent indicates a value type and place name somewhere on the survey other than a location on the map without marking a corresponding point on the map itself, no point is digitized. (If a specific place name is unambiguous, can be resolved to a single point on the map, and has also been identified as representing a specific value type, it may be acceptable to digitize a point representing that location).
- If a respondent only indicates that they generally value the study area for all value types without providing any other information, no points are digitized.

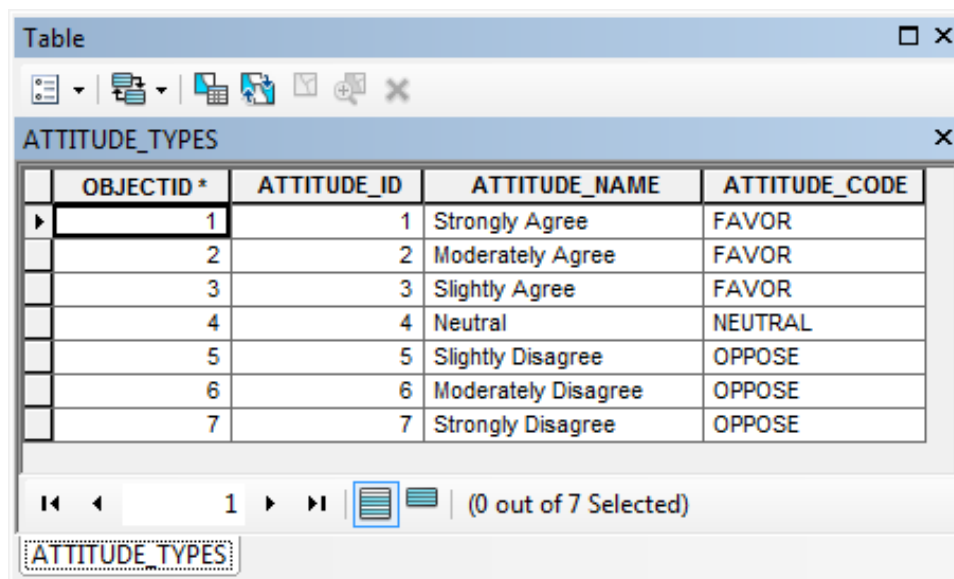
Despite these recommended approaches to digitization, methodologies can vary depending on the skill, experience, or specific objectives of the individual(s) who complete(s) the digitization process. These variations should be kept in mind if relying on survey data digitized by other individuals or groups.

## Advanced Options

### Recoding the ATTITUDE\_TYPES Table

As described in the *Survey Data* section, SolVES 3.0 supports, by default, survey responses using a 5-point Likert scale of attitudes ranging from Strongly Favor to Strongly Oppose. Survey data capturing a larger range of Likert scale values or different attitude descriptions can also be supported by modifying the ATTITUDE\_TYPES table contents; however, even with such modifications, SolVES 3.0 will still only support the segmentation of data by attitude type into two groups. This is controlled by the two available options available through the Analyze Survey Data tool's Attitude or Preference dropdown box and the ATTITUDE\_CODE to which they correspond (Favor or Strongly Favor = FAVOR and Oppose or Strongly Oppose = OPPOSE). Any modifications must conform to this dichotomous pattern.

The recoding example illustrated in figure 46 presents a change in the number of Likert scale values (from 5 to 7) and what the values represent (relative agreement instead of favorability) in order to match the corresponding response data the user would have loaded into the USE\_ATTITUDE table. In this example, if "Favor or Strongly Favor" is selected with the Analyze Survey Data tool, records from the USE\_ATTITUDE table having ATTITUDE\_ID values of 1, 2, or 3 (ATTITUDE\_CODE = FAVOR) will be selected. If "Oppose or Strongly Oppose" is selected, records with an ATTITUDE\_ID of 5, 6, or 7 (ATTITUDE\_CODE = OPPOSE) will be selected. In all situations, any response data coded as NEUTRAL will not be included in the analysis. Modifications could also be made to support scales having less than 5 points. In all situations, the ATTITUDE\_NAME field can be used to enter descriptions that will allow users to track the actual meaning of their survey response data versus the limited values supported by the user interface.



OBJECTID*	ATTITUDE_ID	ATTITUDE_NAME	ATTITUDE_CODE
1	1	Strongly Agree	FAVOR
2	2	Moderately Agree	FAVOR
3	3	Slightly Agree	FAVOR
4	4	Neutral	NEUTRAL
5	5	Slightly Disagree	OPPOSE
6	6	Moderately Disagree	OPPOSE
7	7	Strongly Disagree	OPPOSE

Figure 46. Example of recoded ATTITUDE\_TYPES table.

## Substituting the Public Use Parameter

SOLVES is designed to accept a Public Use parameter for defining survey subgroups along with the Attitude or Preference parameter; however, if a user has survey results that would be useful for defining survey subgroups in a manner other than with public uses (for example, attitudes or preferences regarding particular issues impacting a study area such as fire management or species conservation), they may do so as long as the attitude or preference responses are structured in the same format as indicated in table 1 or can be supported by adjustments to ATTITUDE\_TYPES as described in the *Recoding the ATTITUDE\_TYPES Table* section. Assuming the response structure is suitable for SOLVES to support through the USE\_ATTITUDE and ATTITUDE\_TYPES tables, users may load their parameter data into the USE\_TYPES table in SOLVES.gdb as a substitute for Public Use. Be aware that the SOLVES user interface will still refer to the parameter as Public Use, but this will have no effect on the analysis.

## Creating Survey Data Subgroups Prior to Loading SOLVES

The SOLVES Analyze Survey Data tool only accepts Public Use (or user-provided substitutes) and Attitude or Preference parameters to define subgroups; however, users may wish to subdivide their survey data in some manner, such as by certain demographic characteristics like age or income. This can be accomplished by creating separate datasets for each subgroup, loading them into separate SOLVES.gdb source geodatabases for analysis, and leaving the Public Use and Attitude or Preference parameters blank to process all survey data within each geodatabase. Users, of course, will need to track and manage the results because SOLVES will not recognize or meaningfully label the results as belonging to a specific subgroup. Users should also be aware that overly restrictive criteria may result in subgroups that are too small for SOLVES to analyze for any meaningful results.

## Sharing Models for Value Transfer

At some point, users may wish to share a social-value model they have generated with others who would like to apply the model in a similar study area using the Transfer Values tool. Although the lambdas file generated by Maxent contains the actual model that other SOLVES users would apply to environmental layers for their own study area, additional metadata describing the content and format of the required environmental layers and other model parameters are necessary. To apply a model using the Transfer Values tool, users will require the following information:

- The model's output cell size.
- The maximum value the model attained on the value index (results will otherwise default to 10).
- For continuous data, users will need a description of the value range and units.
- For categorical data, users will need the numerical and textual description of each value type.
- The source of the environmental data used to generate the model may also assist other users in finding the environmental layers necessary to apply the model to their own study area.
- The model's test AUC as an indicator of its potential performance in transferring social values to similar study areas.
- Copies of the environmental data graphs generated by SOLVES so other users can observe the relationships between the environmental variables and the value index.

- Where possible, the metadata should include some description of the social-value model's social context such as brief demographic profile of the respondents whose data were used to generate the model.

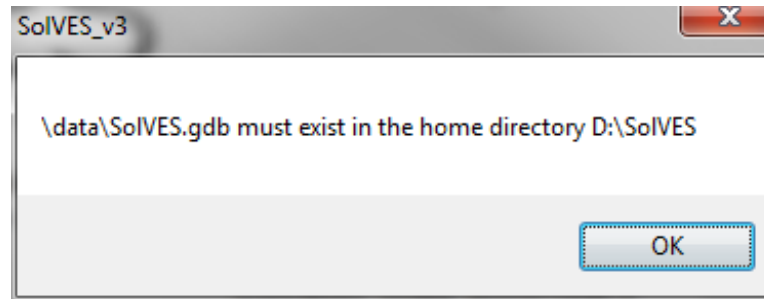
As a guide to metadata format and contents, see the metadata template included in the \\SOLVES\Doc folder and the sample model metadata included as html files in \\SOLVES\Models as part of the SOLVES 3.0 tool download. Completed metadata files should be placed in the same Models subfolder as the corresponding lambdas file (for example, \\SOLVES\Models\Pike and San Isabel National Forest\All Surveys\Aesthetic.html).



## Troubleshooting Common Errors

### Source File Geodatabase Not in Directory

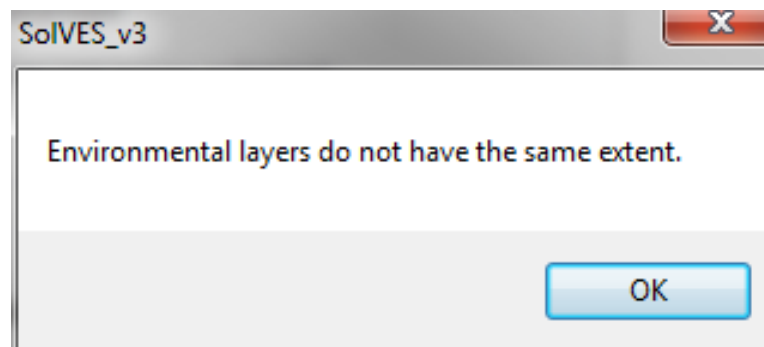
The following error message will appear during project setup if SolVES.gdb is not in the Data folder under the SolVES directory (\\SolVES\Data) or if the Home Directory path is not properly set (fig. 47). Please see the *Data Installation* section for instructions on how to add data to the SolVES directory.



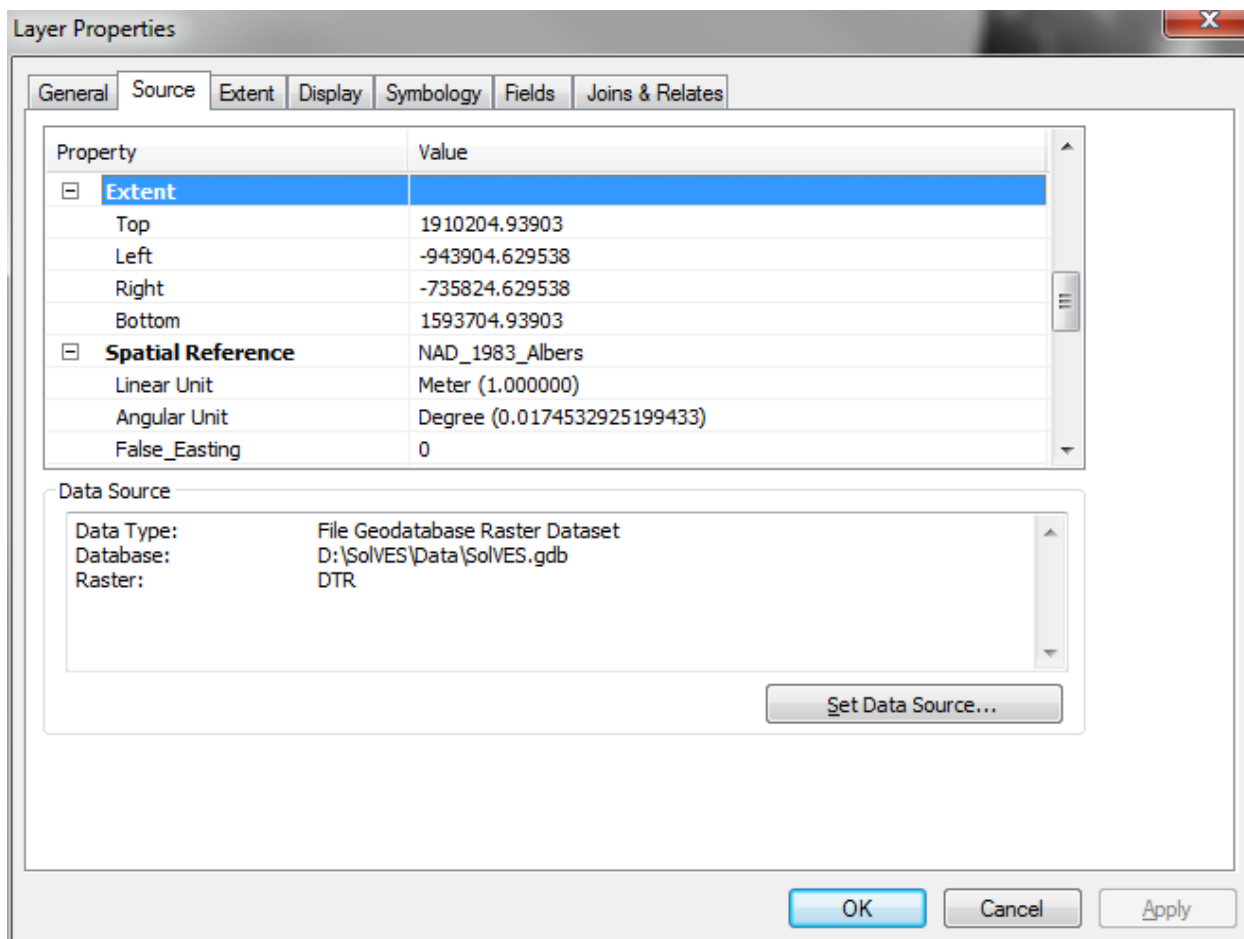
**Figure 47.** Missing SolVES.gdb error message.

### Environmental Layer Extents

If the following error is received when attempting to run the Analyze Survey Data or Transfer Values tools, the environmental data layers loaded in SolVES.gdb have not been properly aligned to the share the same extent (fig. 48). The spatial extent of each environmental data layer can be confirmed by accessing their properties through ArcMap or ArcCatalog (fig. 49). The Top, Left, Right, and Bottom extent values listed for each environmental data layer loaded in SolVES.gdb must be identical among all layers. One option for aligning environmental layers to the same extent is to set the Snap Raster parameter of the ArcGIS Environment Settings to an environmental layer already having the desired extent (fig. 50). This setting should then be maintained for all geoprocessing steps used to generate and prepare all environmental data layers to be loaded into SolVES.gdb.



**Figure 48.** Environmental layer extent error message.



**Figure 49.** Accessing environmental layer extent values.

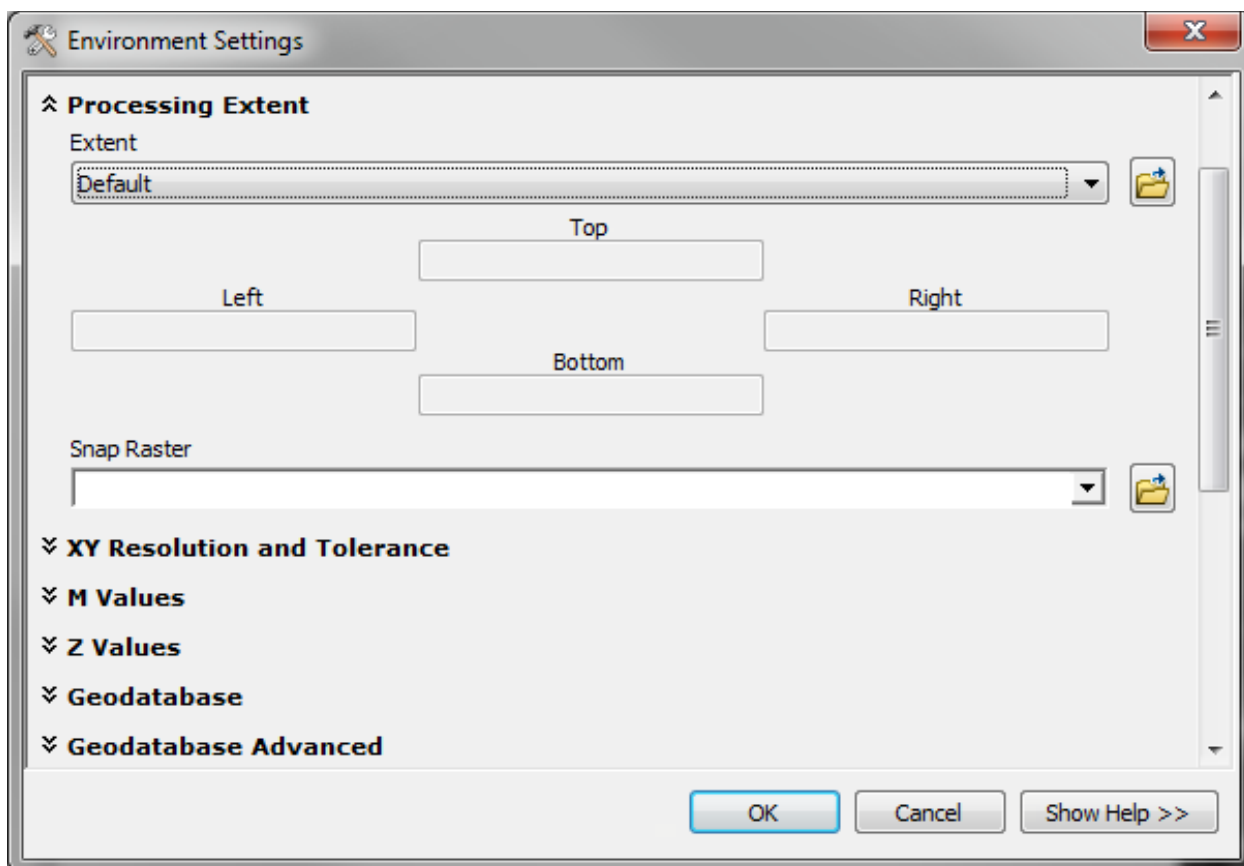


Figure 50. Accessing ArcGIS environment settings to set Snap Raster value.

## Error Processing—Processing Failed

The following error message (fig. 51) can appear when expected data are unavailable such as when a user has chosen to weight points but has not entered any data in the VALUE\_ALLOCATION table or when a user selects a survey subgroup for which no point data are found. Please see the Data Requirements section for additional information.

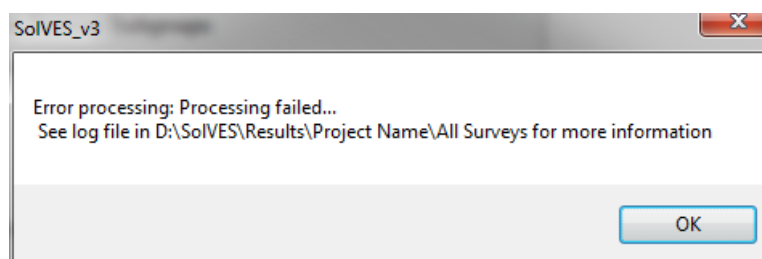


Figure 51. Processing failed error message.

## **Incorrect Regional Settings**

Sometimes SolVES will complete processing without generating final results. This can normally be attributed to incorrect regional settings on the user's computer (particularly for users outside the United States). This will usually be accompanied by a warning message in the SolVES and Maxent log files similar to:

“Warning: Sample at [Long], [Lat] in SURVEY\_POINTS.csv is outside the bounding box of environmental data, skipping.”

Please see the Confirming Windows Regional Settings section for instructions on how to update these settings.

## **Failed at genKernDens Error**

The following error can occur when either the Spatial Analyst extension has not been activated or when special characters such as hyphens, slashes, or other punctuation have been included in a text field of the SolVES.gdb source geodatabase:

“Error in – Failed at genKernDens Error HRESULTS E\_FAIL has been returned from a call to a COM component. Check the Spatial Analyst Extension.”

If this error occurs, first please see the Confirming ArcMap Settings for SolVES 3.0 section for instructions on how to activate the Spatial Analyst extension. If the extension is already activated, then review all text fields in the SolVES.gdb source geodatabase to ensure any special characters are removed (for example, change “non-motorized” to “nonmotorized”).

## **Error in zonStat**

The following error can occur when a valid NAME field has not been included in the STUDY\_AREA attribute table:

“Error in zonStat Error HRESULT E\_FAIL has been returned from a call to a COM component.”

It is possible for this error to occur even as SolVES continues to process until completion. An initial sign of this error can be the absence of environmental data graphs when using the View Results tool. The error can be confirmed by viewing the SolVES log files. If this error occurs, confirm that a NAME field exists in the STUDY\_AREA attribute table that meets the requirements described in the Source File Geodatabase Structure and Contents section.

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