1.3 SURFACE WATERBODIES MODULE

The Surface Waterbodies (SWB) Module is designed to provide users of the AWRD with quick and easy access to data on the surface waterbodies of Africa, as well as providing users with a method to predict potential SWB yields based on two possible models. The module is designed to work with a variety of surface waterbody datasets, including seven of the surface waterbody (SWB) layers resident within the SWB portion of the AWRD.

Open the Surface Waterbodies Viewer by clicking on the  button in the AWRD Interface, or by clicking the "*Open Surface Waterbodies Viewer…*" menu option in the AWRD Modules menu (Figure 1.21)

FIGURE 1.21
Surface Waterbodies Module

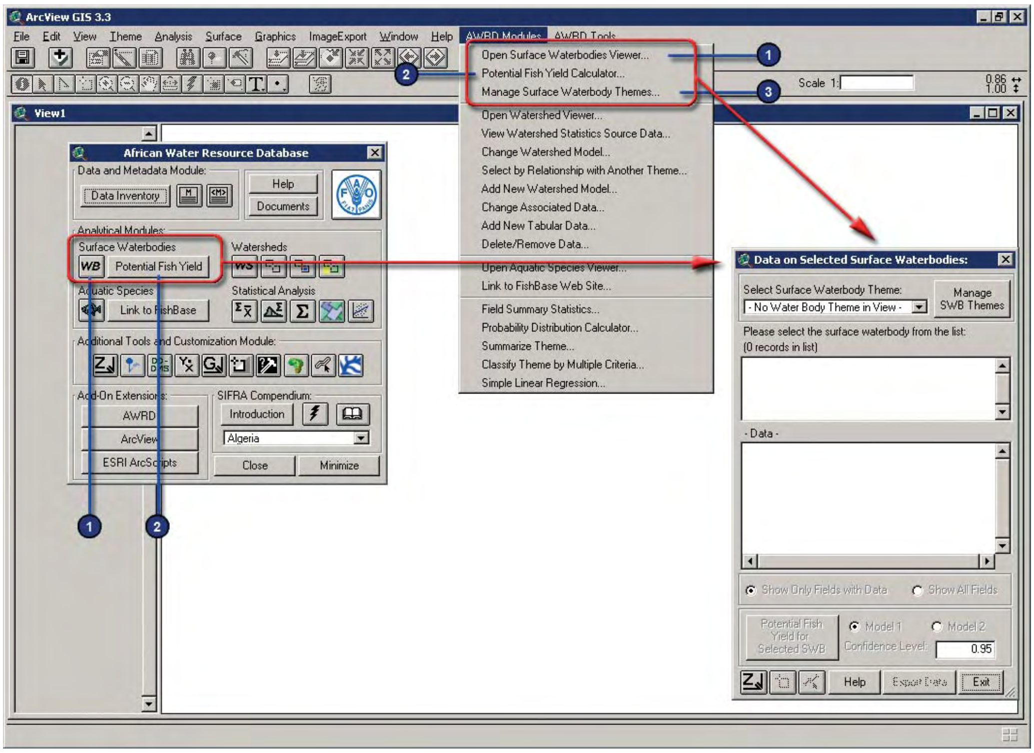


Table 1.16 provides a summary of the buttons available in the Surface Waterbodies Module.

TABLE 1.16
Surface Waterbodies Module buttons and menu items

Label (Fig. 1.21)	AWRD button	AWRD menu option	Action executed
1	WB	AWRD Modules *"Open Surface Waterbodies Viewer…"*	*Open Surface Waterbodies Viewer*: this tool opens the main Surface Waterbodies Viewer window is the basic interface for the Surface Waterbodies Module.
2	Potential Fish Yield	AWRD Modules *"Potential FishYield Calculator…"*	*Potential Fish Yield Calculator:* this function takes advantage of models developed by Halls (1999) to predict potential yield of a surface waterbody in tonnes per year based on the surface area of the waterbody and, potentially, the mean annual air temperature of that waterbodies drainage basin.
3	Manage SWB Themes	AWRD Modules *"Manage Surface Waterbody Themes…"*	*Manage Surface Waterbodies Themes*: this function allows you to register new surface waterbody themes so that they can be used with the Surface Waterbodies Module, or delete currently registered themes.

Surface waterbodies viewer

The surface waterbodies viewer dialog contains five buttons for estimating Potential Fish Yield; finding Locations; selecting surface waterbodies; reporting Geostatistics and exporting data (Figure 1.22 and Table 1.17).

FIGURE 1.22
The surface waterbodies viewer dialog

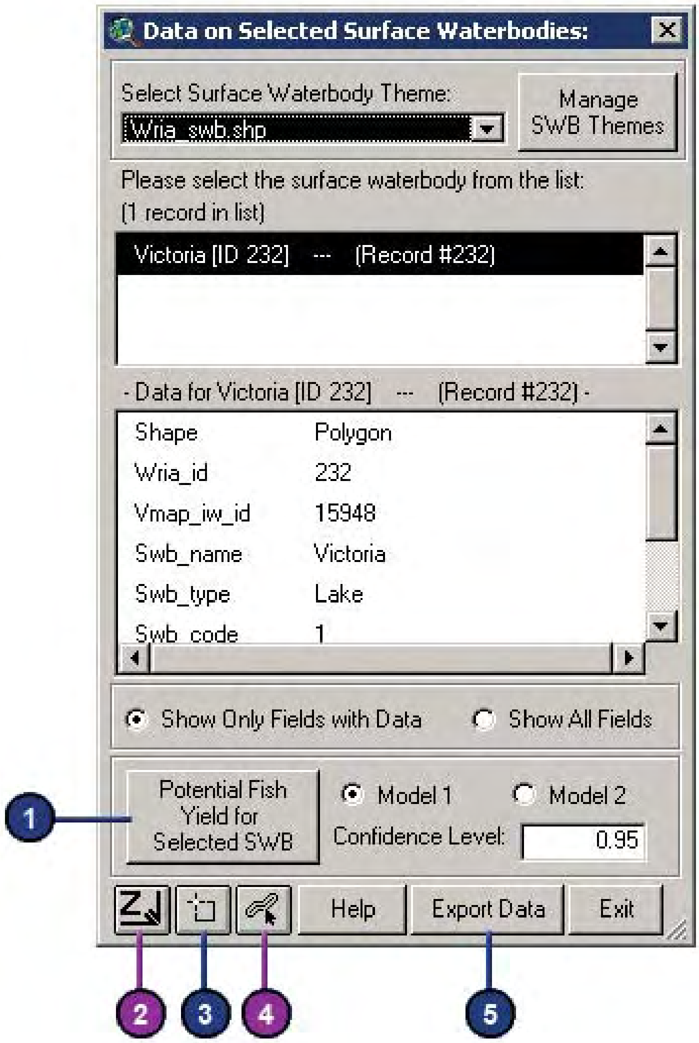
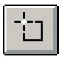


TABLE 1.17
Data on selected waterbodies module

Label (Fig. 1.22)	AWRD button	AWRD menu option	Action executed
1	Potential Fish Yield for Selected SWB	N/A	*Potential Fish Yield Calculator for selected SWB:* this tool automatically reports results on Potential Fish Yield for the selected waterbody.
2		AWRD Tools *"Find Location by Theme..."*	*Find Location by Theme*: this tool allows you to find and zoom to particular features by selecting that feature from a list.
3		N/A	*Select Surface Waterbodies:* this tool works as the standard ArcView selection tool, permitting users to select features by clicking on the map.
4		N/A	*Report GeoStats for Lines or Polygons You Select:* this tool reports the length of line features, and the area and perimeter length of polygon features, using both projected and spherical coordinates.
5	Export Data	N/A	The Export Data button allows users to save the current set of selected waterbodies, plus the summary statistics, to a new dBASE table where it can be used with many other software packages.

Note: Numbers 2 and 4 are shown in violet color because they originate from the "Additional Tools and Customization Module".

Manage surface waterbody themes

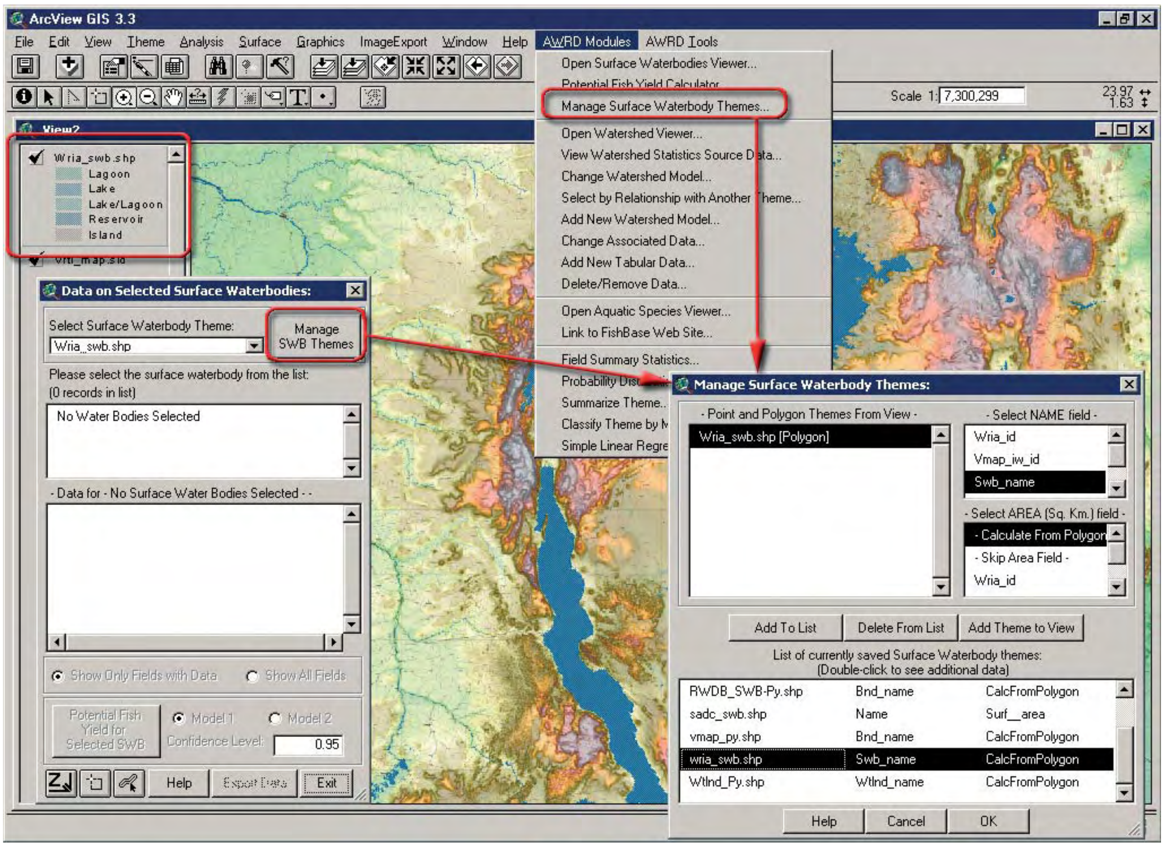
Surface waterbody themes must be registered so that the SWB Viewer will know which fields to use to identify the SWB name and surface area. Registration also allows the SWB Viewer to determine if any of the themes are currently present in the view. If so, the module lists these themes in the drop-down selection list at the top of the module and lets the user choose between them.

As with the Watersheds Module of the AWRD, users of the SWB Module are also provided with the means to register their own datasets for examination with the module. The minimum fields required for registering a new theme within the module are a "Name" and a "Surface Area" field, which are necessary for identifying individual waterbodies and for determining whether the Potential Fish Yield calculator can be used with them. If no surface area value is available, then the Potential Fish Yield functions are disabled. The "Name" field can be either a character or numeric attribute field, but the Surface Area field (if it exists) must be numeric and must reflect the surface area in square kilometres. If the surface water body theme is a Polygon theme (see below), then area values may be calculated directly from the actual polygon and therefore a Surface Area field is not necessary.

1. Click on the "Add Basemap Image to View" tool  to load one of the image backgrounds (e.g. "Vrtl_Map.sid") from the image database component folder. This background image is not necessary for proper functioning of the SWB management tool, but it makes it easier to locate your area of interest in the view.
2. Open the "Manage Surface Waterbody Themes:" dialog by either clicking on the "Manage SWB Themes" button on the SWB Viewer, or by clicking the "*Manage Surface Waterbody Themes...*" menu option in the AWRD Modules menu (Figure 1.23). Using this dialog, users can add or delete waterbody themes from the list of registered waterbody themes.

Surface waterbody themes can be either Point or Polygon themes, meaning the waterbody is represented by either a dimensionless point or by an irregular-shaped polygon representing the waterbody shoreline. When opened, the "Manage Surface Waterbody Themes:" dialog will present a listing of all the Point and Polygon themes currently present within a view. The user may add any of these to the list of registered waterbody themes.

FIGURE 1.23
Opening the "Manage Surface Waterbody Themes"



To add the SWB theme, simply select the theme from the list and then specify the fields associated with the SWB theme's Name and Surface Area values. The Name field should uniquely identify each waterbody. If a unique Name field is not available in the table, the user can create a field of record numbers where each record number uniquely identifies the waterbody. To do this:

1. Close the "Manage Surface Waterbody Themes:" dialog and the Surface Waterbodies Module.
2. Open an attribute table of a theme (e.g. "wria_swb") by clicking on the icon [icon] and then select the "Edit" menu item, followed by the "*Add Record Numbers…*" item from the pull-down menu.
3. Click "Yes"to add a new field containing record numbers.
4. Specify the name "rec_num" as the new Record Number field.
5. Close the attribute table.
6. Reopen the Surface Waterbodies Module and the "Manage Surface Waterbody Themes:" dialog.
7. Select "wria_swb"from the waterbody theme list.
8. Select "Add Theme To View", click OK.
9. Re-open "Manage SWB Themes. Select "Sbwname"as the NAME field and Calculate from Polygon as the AREA Field. Then click OK.

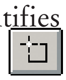
If a field for Surface Area is not available, users can select either the "–Skip Area Field–" option or, if the theme is a Polygon theme, the "–Calculate from Polygon–" option from the list of Area fields (see below). Then, click the "Add To List" button to register the theme to the list of registered themes. In a similar manner, users can delete any of the themes from the list by finding that theme in the list of currently saved themes list box, clicking on it, and then clicking the "Delete From List" button. This delete function will not delete the theme from your hard drive; it will only remove the theme from the list of registered themes.

If the user anticipates calculating potential yield from the new waterbody theme, then an area attribute must also be available for the SWBs in the theme. If the waterbodies are represented by points, then the attribute table must have an "Area" field containing the surface areas of the waterbodies in square kilometres. If the waterbodies are represented by polygons, then the user can select the "– Calculate from Polygon –" option to force the extension to automatically calculate surface area values.

Notes The "–Calculate from Polygon–" option is especially valuable when the user expects that they may edit the waterbody shapes; i.e. making them larger or smaller. This option will cause the extension to calculate the area of the polygon correctly each time the Surface Waterbody Module is used. However, the "–Calculate from Polygon–" option will only be available if the waterbody theme is a polygon theme.
The "Calculate from Polygon" option calculates surface areas using the Lambert Equal Area Projection, centered at 20° Longitude by 5° latitude.

Surface Waterbody viewer

Once the SWB Viewer is opened if any of the currently registered SWB themes are present in the view, they will appear in the listbox at the top of the Surface Waterbody viewer.

After the user selects one of the themes from the "Select Surface Waterbody Theme" pull-down list, the module makes a connection to that theme in the active view and identifies any waterbodies that are currently selected. A surface waterbody selection tool  has been included in the SWB Viewer dialog to allow users to easily select surface waterbodies by clicking or drawing rectangles on the map.

The module will update this selection list whenever the user changes the selected set of waterbodies in the theme identified for analysis. A listing of the current SWB selection-set is contained in the list box labeled "Please select the surface water body from the list:", and clicking on one of these waterbodies causes the module to display a report of the attribute data associated with that waterbody.

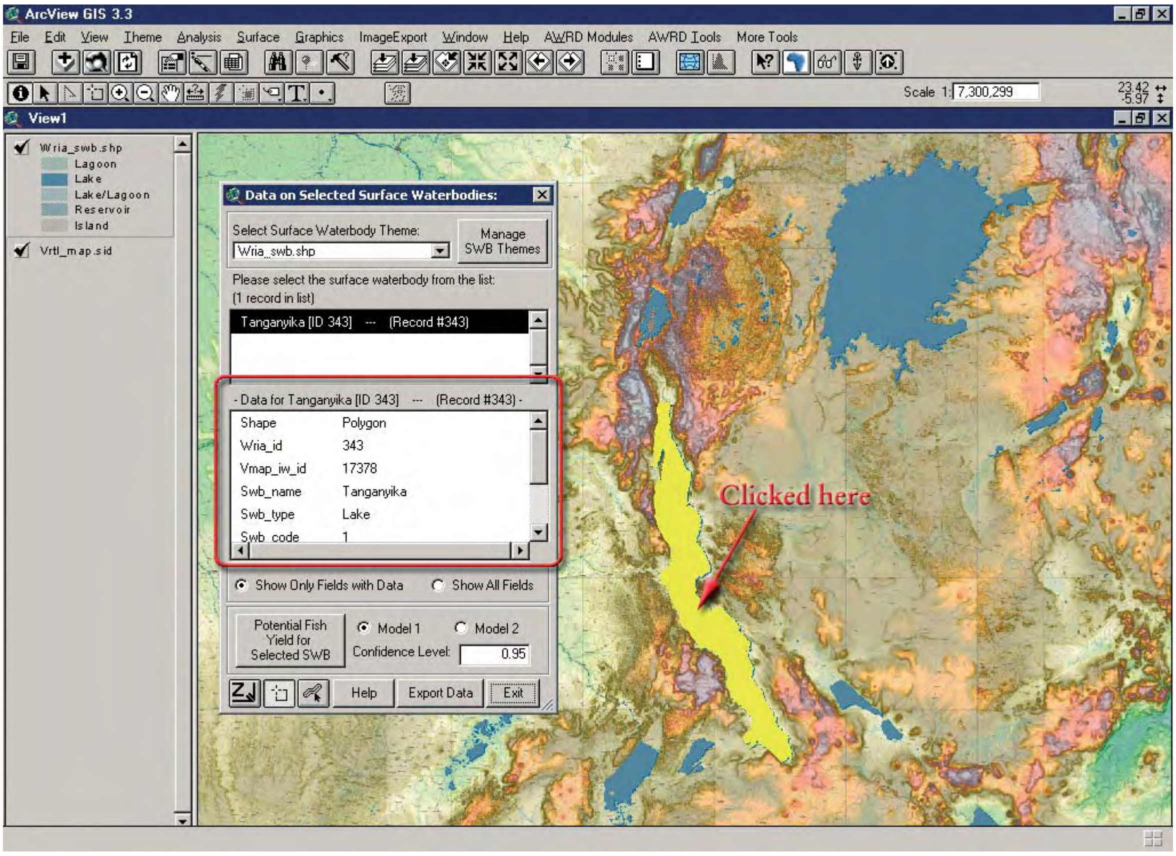
If the waterbody feature is a Polygon feature, then the module will also display the surface area of that waterbody in square kilometres. These surface area values are drawn directly from the attribute table if an "Area" field has been registered with the theme or, in the case of polygons, can be calculated directly from the actual waterbody shape itself if an area field has not been registered.

If the text in a particular box is so long that it will not fit within that box, then the user may resize the dialog by clicking on one of the corners and stretching it to the proper size. This will also stretch out the various boxes and allow the text to be read.
In this example, the shapefile "wria_swb.shp" was "registered" (Figure 1.23), the Lake Tanganyika waterbody was selected, and the Surface Waterbodies viewer is then used to provide statistics on Lake Tanganyika (Figure 1.24).

1. Click on the "Add Basemap Image to View" tool  to load one of the image backgrounds (e.g. "Vrtl_Map.sid") from the image database component folder. This background image is not necessary for proper functioning of the SWB Viewer, but it makes it easier to locate your area of interest in the view.

2. Click on the "Data Inventory" button [Data Inventory] to load one of the surface waterbody themes (e.g. "wria_swb.shp") from the Surface Waterbodies database component.
3. In this example, Lake Tanganyika was selected with a mouse click. The statistics derived from this selection for Lake Tanganyika include Id's and surface areas and are shown in Figure 1.24.

FIGURE 1.24
Surface waterbody attribute report associated with the selected waterbody (e.g. Lake Tanganyika)



The complete statistics depicted in Figure 1.24 include:

Shape: Polygon; Wria_id: 343; Vmap_iw_id: 17378; Swba_name: Tanganyika; Swb_type: Lake; Swb_code: 1; Hyd_code: 1; Laea_ha: 3284471.75; Laea_acres: 8115929.7; Laea_prmtr: 1878035.7; Laea_sqmi: 12681.4; Laea_sqkm: 32844.7; Rec_num: 342

Note The new fieldname "Laea", means that these values are based on the Lambert Equal Area Azimuthal projection.

"Show Only Fields with Data" or "Show All Fields" options

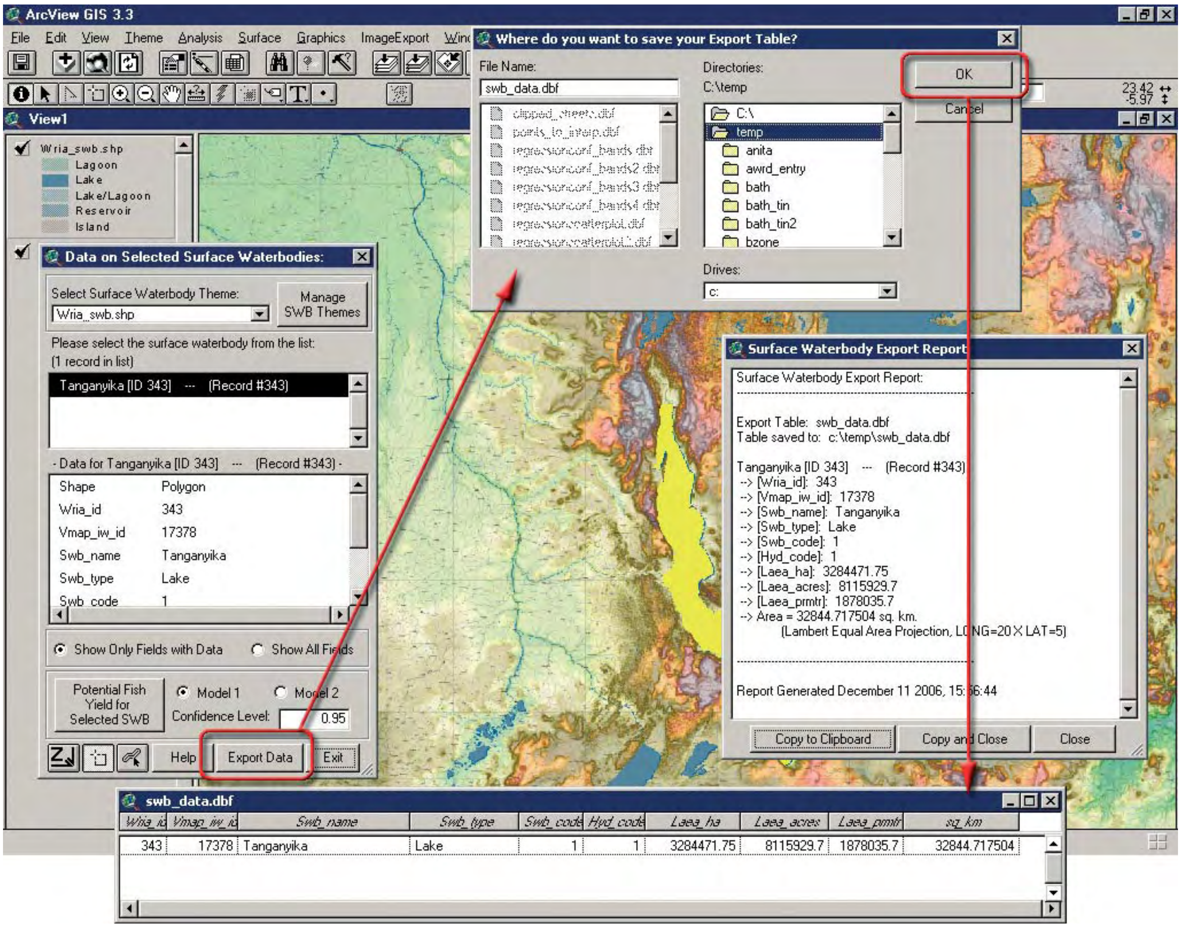
Some surface water body themes contain a very large number of fields of data, but many of the actual records have no data recorded for those fields. Therefore this module provides the option to show either just those fields with data or all fields. If a particular waterbody has data for all fields, then either option will show the full set of data.

Export Data

If one or more surface water bodies are currently selected, then a user may export those records to a new table by clicking on the "Export Data" button Export Data. During any export, the user will be prompted to specify where to save the data and the module will then generate a new table based on only those selected waterbodies. If the selected SWBs are polygon features, then the module will also generate surface area values (in square kilometres) for each of the waterbodies.

1. With at least one surface waterbody selected, click the "Export Data" button on the SWB Viewer dialog.
2. Type a name for file you are exporting and then select a location to store it in your hard drive. Click "OK". After any data have been exported to a new table, that new table will automatically be added to the ArcView project (Figure 1.25).

FIGURE 1.25
Saving the new Export Table in an ArcView Project



Report GeoStats for surface waterbodies polygon themes

Due to the tight integration of tool-sets between the modules of the AWRD, users can also access tools which may have applications outside of a particular module. One such tool is the Report GeoStats tool, which reports geostatistics for any active SWB Polygon theme in a view, when the user clicks on any SWB polygon on the map.

Users can calculate or update the area values for any polygon theme using also the "*Calculate/Update GeoStats in Polygon Themes Tables...*" option in the AWRD

Tools menu. This tool will calculate/update the area for each polygon in square kilometres, hectares, square miles and/or acres, and/or the perimeter in metres, based on the Lambert Equal Area Azimuthal projection centred at 20° longitude and 5° latitude. This function is described in more detail in Section 1.7, “Additional Tools and Customization Module”.

Locate surface waterbodies by name or coordinate references

Another tool included in the SWB Module is the Find Location tool, which is available by clicking on the  button.

This will open the Find Location by Theme tool dialog, which provides a wide variety of options for finding a surface water body given specific coordinates or a name.

Predict potential fish yield

The potential fish yield prediction functions provide users of the AWRD with the ability to estimate the potential annual fish yield of a particular surface water body, in tonnes per year, based on two regression models developed by Halls (1999). The first model is based entirely on the surface area of the waterbody and does not consider any outside influences on that waterbody. The second model incorporates the mean air temperature of the waterbody drainage basin.

Halls (1999) fitted linear models to estimates of potential yield and various hydrological, morphological and other hypothesised explanatory variables for 94 African waterbodies using simple linear regression and backwards stepwise multiple linear regression methods. More than 30 explanatory variables were examined in relation to estimates of potential yield (PY) and potential yield per unit area (PYPUA) including:

- Surface area of the waterbody
- Drainage basin area of the waterbody
- Shoreline length of the waterbody
- Human population density in the catchment area
- Mean annual precipitation over the waterbody and over the catchment area
- Mean annual air temperature over the waterbody and over the catchment area
- Total length of six categories of roads over the catchment area
- Density of six categories of roads over the catchment area
- Total density of all roads in the catchment area
- Mean soil fertility index
- Amount and density of catchment area containing planted crops
- Amount and density of catchment area containing natural vegetation mosaic
- Amount and density of catchment area containing either planted crops or natural vegetation mosaic
- Total population number within the catchment
- Shoreline development index
- Drainage basin area as a proportion of waterbody area.

Halls found that that Surface Area of the waterbody was the best predictor of potential fish yield with an $R^2 = 0.804$ (Halls, 1999), meaning that approximately 80.4% of the variation in potential fish yield among surface water bodies could be explained by the surface area of those waterbodies.

$$\text{Model 1: } \text{In}(Y_{new}) = 2.688 + 0.818 \text{ x } \text{In}(Area)$$

When looking at combinations of explanatory variables, Halls found that a model using both Surface Area and Mean Annual Air Temperature within the Catchment Area explained marginally more of the variation in potential yield ($R^2 = 0.817$) than the model containing Surface Area alone (Halls, 1999).

$$\text{Model 2: In}(Y_{new}) = -3.881 + 0.790 \text{ x In}(Area) + 2.221 \text{ x In}(TempDB)$$

The 94 waterbodies examined by Halls (1999) ranged from 1– 69 649 km^2 in size, and from 14.6–27.7 °C in mean annual drainage basin air temperature.

The potential fish yield prediction tools provided in this extension allow users to predict potential fish yield for a selected surface waterbody using either model. Model 1 requires only a measure of the surface area of the waterbody while Model 2 requires both surface area and mean annual air temperature.

Prediction models always have some inherent uncertainty, and therefore these tools also generate a confidence interval around that prediction at a confidence level specified by a user. These confidence levels allow the user to quantify the uncertainty surrounding the model predictions. For example, if a 95 percent confidence level is specified, then the user can say that there is a 95 percent chance that the actual Potential Fish Yield for that surface water body lies within the upper and lower 95 percent confidence levels. This also means that there is a 5 percent chance that the actual Potential Fish Yield lies outside of the confidence levels.

Note If the waterbody surface area is not available for the selected waterbody, then the “Potential Fish Yield for Selected SWB” function will be disabled. If there is no air temperature data available, then the Model 2 option will be disabled.

Potential fish yield report

The Potential Fish Yield reports provide users with detailed information on the model applied, the data and values used to generate the predicted fish yield output, and the results in the original natural log values. The data in the report can easily be saved to the clipboard so it can be pasted it into any text-editing program.

Using the Potential Fish Yield Calculators

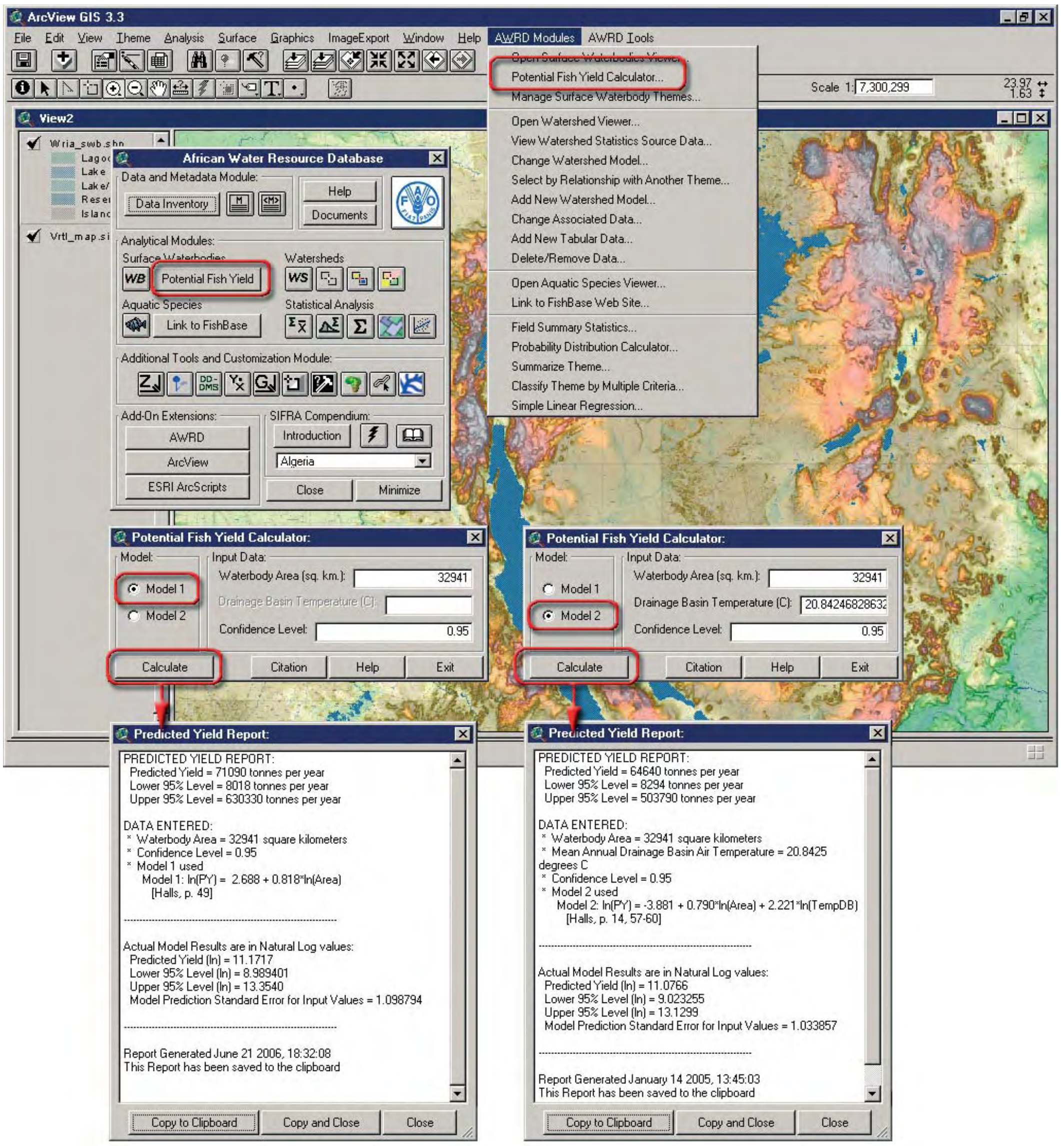
In the following illustration, the potential annual fish yield of Lake Tanganyika is estimated using the Potential Fish Yield Calculator .

1. Click on the button Potential Fish Yield available in the AWRD Interface or the AWRD Modules menu option “*Potential Fish Yield Calculator…*”. Select Model 1 and/or Model 2.
2. Enter an area value of 32 941 km^2 (available from the SWB Viewer statistics on Lake Tanganyika).
3. If using Model 2, enter a drainage basin temperature of 20.8 ºC (available using the Watersheds Module, described in Section 1.4).
4. Click on the “Calculate” button.

According to the **WRIA_SWB** dataset, Lake Tanganyika has a surface area of 32 941 km^2 and a drainage basin mean annual air temperature (CRES dataset) of approximately 20.8 °C. The Predicted Fish Yield Report (Figure 1.26) indicates that the predicted fish yield for this particular surface waterbody, based on Model 1 is 71 090 tonnes per year whilst for Model 2 it is 64 640 tonnes per year, with a 95 percent Confidence Interval of 8 293–503 790 tonnes per year.

The actual fish yield recorded for Lake Tanganyika in Halls’ dataset is 196 570 tonnes per year, which is approximately three times the predicted value but well within the 95 percent confidence interval.

FIGURE 1.26
Potential fish yield prediction for Lake Tanganyika using the general Potential Fish Yield Calculator



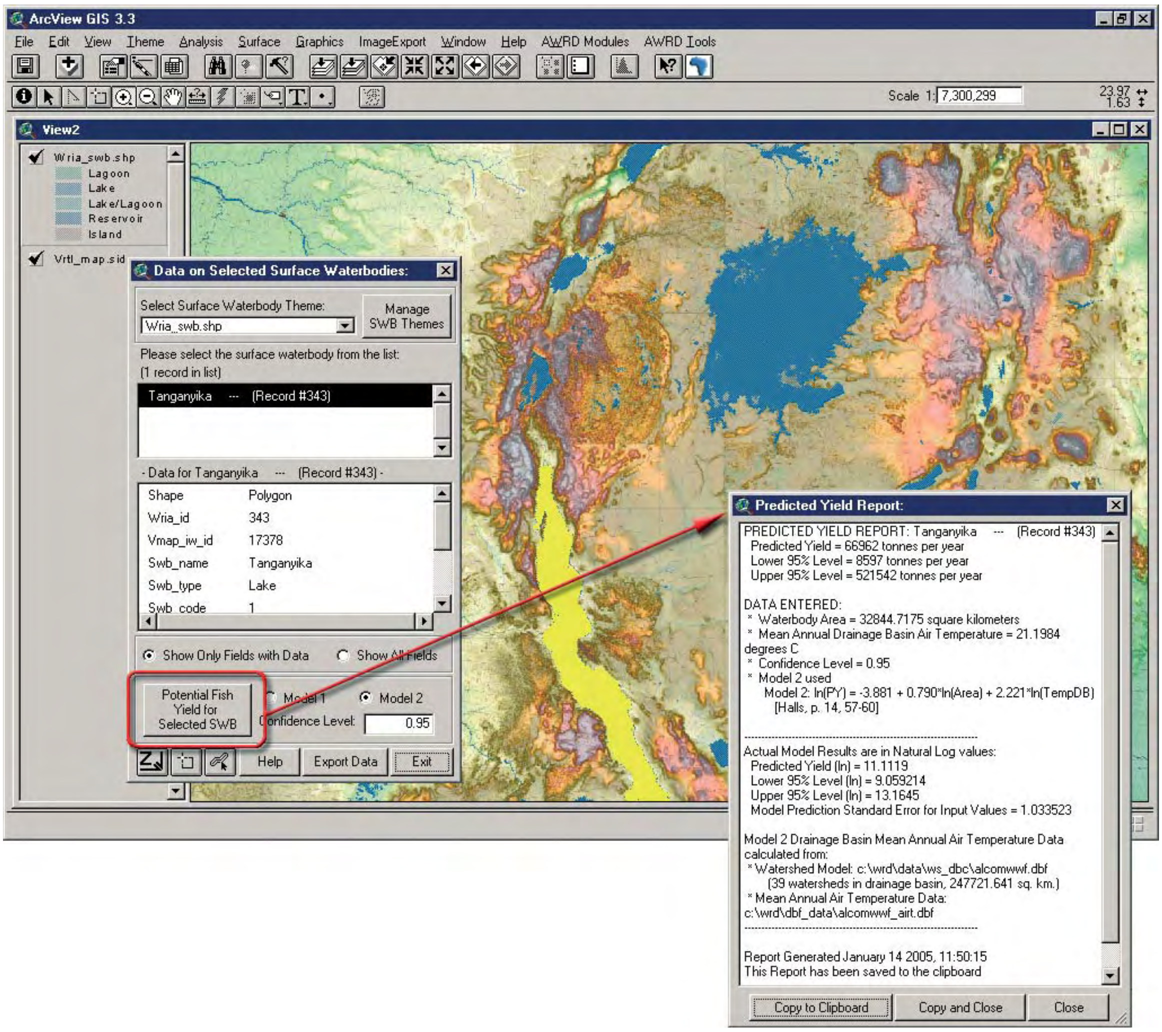
The calculations and output are similar when using the button [Potential Fish Yield for Selected SWB] available in the SWB Viewer, except that the Predicted Fish Yield Report also gives the user extra information on the actual surface waterbody and ancillary air temperature data used. For example, the following illustration (Figure 1.27) again estimates predicted fish yield for Lake Tanganyika, but this time using the actual Lake Tanganyika polygon and derived mean air temperature values.

1. To do this analysis, make sure the WRIA_SWB dataset is available in your view and that the SWB Viewer is open.

2. Select "Tanganyika" from the list on the Surface Waterbodies window, and then click the "Predict Potential Fish Yield" button, selecting Model 2.

In this case, the Predicted Fish Yield Report tells us exactly which surface waterbody was examined, what watershed model was used to identify the drainage basin, how many watersheds were in the drainage basin, how large the drainage basin was and what data source was used to calculate air temperature.

FIGURE 1.27
Potential fish yield prediction for Lake Tanganyika using the "Potential Fish Yield for Selected SWB" in the Surface Waterbodies Module dialog (Model 2)



Prediction precision

The variables used by Halls (1999) explained much of the variation in the estimated potential yield after appropriate log transformations to meet the normality assumptions of the model fitting method.

However, upon back-transforming the confidence intervals, it becomes evident that the predictions of potential yield are imprecise. This imprecision is likely to reflect a number of factors including natural variability among waterbodies unrelated to waterbody area and drainage basin temperature, and imprecise and inaccurate estimates of potential yield used to build the models. Halls (1999) discusses further sources of error. It is important that users are aware of the uncertainty surrounding the model predictions, and users should always consider that the model prediction is only a "best estimate" based on a relatively small set of data. This is why the use of confidence intervals is often considered more accurate and informative than the basic predicted value. A confidence interval provides a more realistic estimate of potential yield by generating a range of values within which there is a specified probability that the true potential yield will be contained. Furthermore, different ranges of values can be generated reflecting different confidence levels, and in general, ranges with high confidence levels will be wider than ranges with lower confidence levels.

To illustrate the uncertainty surrounding the model predictions we compare the predicted potential fish yield for a number of surface water bodies with the actual measured potential fish yield. Table 1.18 shows actual potential fish yield values, predicted values and confidence intervals for 14 of Halls' original 94 waterbodies. These 14 were selected only because they reflected a good range of waterbody sizes.

TABLE 1.18
Original data for 14 sample waterbodies

Waterbody Name	Country	Waterbody area	Drainage basin air temperature	Actual catch	Predicted values (using Model 2)		
					Potential yield *(tonnes/year)*	Confidence intervals *(tonnes/year)*	
		(km²)	*(°C)*	*(tonnes/year)*		**95%**	**90%**
Mgori	Tanzania	1	19.6	43	15	2–117	3–84
Sake	Rwanda	12	19.6	175	109	15–806	20–581
Luhondo	Rwanda	22	15.8	100	109	14–831	20–597
Itasy	Madagascar	30	17.2	990	169	23–1 261	32–908
Kachira	Uganda	46	18.9	1043	288	39–2 132	54–1 538
Burero	Rwanda	50	15.7	100	204	27–1 555	37–1 116
Kitangiri	Tanzania	102	22.1	2 320	771	104–5 703	145–4 112
Nyumba_ YaMungu	Tanzania	155	20.6	6 675	915	124–6 742	172–4 865
Jebel	Sudan	216	24.9	8 108	1 819	241–13 706	336–9 853
Upemba	Zaire	577	21.2	5 479	2 742	370–20 315	513–14 645
Kainji	Nigeria	1 409	27.4	6 628	9 889	1 275–76 725	1 781–54 898
Aswan	International	3 942	25.1	28 993	18 274	2 387–139 925	3 328–100 335
Malawi	International	29 315	20.1	57 900	54 425	6 982–424 214	9 766–303 304
Victoria	International	69 694	19.9	228 571	105 654	13 309–838 726	18 671–597 881

Source: Halls (1999).

Calculating the confidence intervals

The methods described by Neter, Wasserman and Kutner (1990) and Draper and Smith (1998) are used for calculating confidence intervals for new observations. Using the general equation for confidence intervals:

$$Y_{new} \pm t\left(1-\alpha/2; n-2\right) * s\left\{Y_{new}\right\}$$

where:

t = that value from the t-distribution at $\left(1-\alpha/2; n-2\right)$ degrees of freedom

α = 1 – Confidence Level

n = Number of waterbodies used in original model (n = 94)

$s\left\{Y_{new}\right\}$ = Standard Error of a New Observation

The standard error of a new observation varies according to how close the surface area and mean air temperature values of the new observation are to the respective mean values from the original model. For Model 1, the standard error is calculated as:

$$s\left\{Y_{new}\right\} = \sqrt{MSE\left[1+\frac{1}{n}+\frac{\left(X_h-\bar{X}\right)^2}{\sum\left(X_i-\bar{X}\right)^2}\right]}$$

where:

MSE (Mean Square Error) = 1.130623182273 (Original Data; Halls, p. 49)

$n = 94$

X_h = Natural Log of New Observation Surface Area

$\bar{X} = 4.350252361762$ (Original Data)

$\sum \left(X_i - \bar{X}\right)^2 = 640.130871075101$ (Original Data)

For Model 2, the standard error is calculated as:

$$s\left\{\hat{Y}_{new}\right\} = \sqrt{MSE\left(1 + \mathbf{X}_h'\left(\mathbf{X}'\mathbf{X}\right)^{-1}\mathbf{X}_h\right)}$$

where:

MSE = 1.043710232412 (Original Data; Halls, p. 57-60)

$$\mathbf{X} = \begin{pmatrix} 1 & X_{11} & X_{12} \\ 1 & X_{21} & X_{22} \\ \vdots & \vdots & \vdots \\ 1 & X_{n1} & X_{n2} \end{pmatrix}, \quad X_{n1} = \text{Natural Log of Area}, \quad X_{n2} = \text{Natural Log of DBTemp}$$

$$\mathbf{X}_\mathrm{h} = \text{Vector of new observation values for nl-Area and nl-DBTemp} = \begin{pmatrix} 1 \\ X_{h1} \\ X_{h2} \end{pmatrix}$$

Input data must be transformed by taking the natural log, and the output data must be re-transformed by taking *e* to the *z* power according to the definition of the natural logarithm:

$$\text{if } \left[N = e^z\right] \text{ then } \left[z = \ln N\right] \quad \text{(Abramowitz and Stegun, 1972)}$$