10. Many index models use the weighted linear combination method to calculate the index value. Explain the steps one follows in using the weighted linear combination method.
11. What are the general shortcomings of the weighted linear combination method?
12. Provide an example of an index model from your discipline.
13. What kinds of variables can be used in a logistic regression model?
14. What is an environmental model?
15. Provide an example of a process model from your discipline. Can the model be built entirely in a GIS?
16. Go to the SWAT Input web page (**http://www.brc.tamus.edu/swat/swatinp.html**) and examine the inputs to SWAT. Which input data can be prepared or created in a GIS?

## APPLICATIONS: GIS MODELS AND MODELING

This applications section covers four tasks. Tasks 1 and 2 let you build binary models using vector data and raster data, respectively. Tasks 3 and 4 let you build index models using vector data and raster data, respectively. Different options for running the geoprocessing operations are covered in this section. Tasks 1 and 4 use ModelBuilder. Task 2 uses Raster Calculator in the Spatial Analyst extension. Task 3 uses command lines. In Task 4, you also have a chance to examine a Python script, a text file created by exporting the model.

### Task 1: Build a Vector-Based Binary Model

**What you need:** *elevzone.shp,* an elevation zone shapefile; and *stream.shp,* a stream shapefile.

Task 1 asks you to locate the potential habitats of a plant species. Both *elevzone.shp* and *stream.shp* are measured in meters and spatially registered. The field ZONE in *elevzone.shp* shows three elevation zones. The potential habitats must meet the following criteria: (1) in elevation zone 2 and (2) within 200 meters of streams. You will use ModelBuilder to complete the task.

1. Start ArcCatalog, and connect to the Chapter 18 database. Launch ArcMap. Rename the data frame Tasks 1&2. Add *stream.shp* and *elevzone.shp* to Tasks 1&2. Open the ArcToolbox window. Set the Chapter 18 database for the current workspace. Because ModelBuilder is run from a toolbox, you will first create a new toolbox. Right-click ArcToolbox and select New Toolbox. Rename the new toolbox Chap18.

**Q1.** The context menu of the Chap18 toolbox has the selections New and Add. Besides model, what other types of tools can the toolbox handle?

2. Right-click Chap18, point to New, and select Model. Select Model Properties from the Model menu in the Model window. On the General tab, change both the name and label to Task1 and click OK.
3. The first step is to buffer *streams* with a buffer distance of 200 meters. Drag the Buffer tool from the Analysis Tools/Proximity toolset and drop it in the Model window. Right-click Buffer and select Open. In the Buffer dialog, select *stream* from the dropdown list for the input features, name the output feature class *strmbuf.shp,* enter 200 (meters) for the distance, and select ALL for the dissolve type. Click OK.
4. The visual objects in the Model window are color-coded. The input is coded blue, the tool gold, and the output green. The model can be executed one tool (function) at a time or as an entire model. Run the Buffer tool first. Right-click Buffer and select Run. The tool

turns red during processing. After processing, both the tool and the output have the added drop shadow. Right-click *strmbuf.shp,* and select Add to Display.

5. Next overlay *elevzone* and *strmbuf.* Drag the Intersect tool from the Analysis Tools/Overlay toolset and drop it in the Model window. Right-click Intersect and select Open. In the Intersect dialog, select *strmbuf.shp* and *elevzone* from the dropdown list for the input features, name the output feature class *pothab.shp,* and click OK.
6. Right-click Intersect and select Run. After the overlay operation is done, right-click *pothab.shp* and add it to display. Turn off all layers except *pothab* in ArcMap's table of contents.
7. The final step is to select areas from *pothab* that are in elevation zone 2. Drag the Select tool from the Analysis Tools/Extract toolset and drop it in the Model window. Right-click Select and select Open. In the Select dialog, select *pothab.shp* for the input features, name the output feature class *final.shp,* and click the SQL button for the expression. Enter the following SQL statement in the expression box: "ZONE" = 2. Click OK to dismiss the dialogs. Right-click Select and select Run. Add *final.shp* to display.
8. Select Auto Layout from the Model window's View menu and let ModelBuilder rearrange the model diagram. Finally, select Save from the Model menu before closing the window. To run the Task1 model next time, right-click Task1 in the Chap18 toolbox and select Edit.

## Task 2: Build a Raster-Based Binary Model

**What you need:** *elevzone_gd,* an elevation zone grid; and *stream_gd,* a stream grid.

Task 2 tackles the same problem as Task 1 but uses raster data. Both *elevzone_gd* and *stream_gd* have the cell resolution of 30 meters. The cell value in *elevzone_gd* corresponds to the elevation zone. The cell value in *stream_gd* corresponds to the stream ID. You will use Raster Calculator in Spatial Analyst for Task 2 because it is more efficient than other geoprocessing options.

1. Add *stream_gd* and *elevzone_gd* to Tasks 1&2. Make sure that the Spatial Analyst extension is selected and its toolbar is checked. The first step is to create continuous distance measures from *stream_gd.* Click the Spatial Analyst dropdown arrow, point to Distance, and select Straight Line. Make sure that *stream_gd* is the raster to calculate the distance to, enter 30 (meters) for the output cell size, and opt for a temporary output raster. Click OK. *Distance to stream_gd* is the temporary output raster.
2. Now you can query *elevzone_gd* and *Distance to stream_gd* to locate the potential habitats. Select Raster Calculator from the Spatial Analyst dropdown list. Enter the following expression in the expression box: [Distance to stream_gd] <=200 AND [elevzone_gd] = 2. Click Evaluate.
3. *Calculation* shows the potential habitats with the value of 1. Compare *Calculation* with *final* from Task 1. They should cover the same areas.

**Q2.** What tool in ArcToolbox can you use to complete Step 1 of Task 2?

## Task 3: Build a Vector-Based Index Model

**What you need:** *soil.shp,* a soil shapefile; *landuse.shp,* a land-use shapefile; and *depwater.shp,* a depth to water shapefile.

Task 3 simulates a project on mapping groundwater vulnerability. The project assumes that groundwater vulnerability is related to three factors: soil characteristics, depth to water, and land use. Each factor has been rated on a standardized scale from 1 to 5. These standardized values are stored in SOILRATE in *soil.shp,* DWRATE in *depwater.shp,* and LURATE in *landuse.shp.* The score of 9.9 is assigned to areas such as urban and built-up areas in *landuse.shp,* which should not be included in the model. The project also assumes that the soil factor is more important than the other two factors and is therefore assigned a weight of 0.6 (60%), compared to 0.2 (20%) for the other two factors. The index model can be expressed as Index value = 0.6 × SOILRATE + 0.2 × LURATE + 0.2 × DWRATE. In Task 3, you will use a geodatabase, command lines, and attribute data analysis to create the index model.

1. First create a new personal geodatabase and import the three input shapefiles as feature classes to the geodatabase. In ArcCatalog, right-click the Chapter 18 database, point to New, and select Personal Geodatabase. Rename the geodatabase *Task3.mdb.* Right-click *Task3.mdb,* point to Import, and select Feature Class (multiple). Use the browser in the next dialog to select *soil.shp, landuse.shp,* and *depwater.shp* for the input features. Make sure that *Task3.mdb* is the output geodatabase. Click OK to run the import operation.
2. The main part of Task 3 is to overlay all three feature classes. You will use command lines to perform the overlay operations. Click Show/Hide Command Line Window on ArcCatalog's standard toolbar to open the Command Line window. Several features about the use of command lines should be mentioned. One, you can type the command (i.e., tool) or drag and drop the command from ArcToolbox to the Command Line window. Two, a command uses a number of arguments. The Command Line window shows the command syntax; it also highlights the argument to be entered following a space. But the window does not explain the function of each argument. To get the explanation, you can use the ArcGIS Desktop Help document and look for the command line syntax. Three, you can take the default for an argument by entering #. Four, the Command Line window allows you to run one command at a time or several commands together. You can enter two or more command lines by using Ctrl-Enter, and press Enter to execute the commands.
3. Enter the following two command lines in the Command Line window:
```
workspace c:\Chapter18\Task3.mdb
Intersect_analysis depwater;landuse;soil vulner ALL # INPUT
```
   The workspace command assumes that the current workspace is c:\Chapter18\Task3.mdb. If you omit the line, you will get an error message stating that the operation fails to create the overlay output (i.e., *vulner*). The first required argument for the Intersect_analysis command is the names of the input features, separated by semicolons. The second required argument is the name of the output feature class. The three optional arguments relate to the joining of attributes, the cluster tolerance, and the output type. Press Enter.

**Q3.** How many feature classes have you specified for the Intersect operation?

4. The remainder of Task 3 consists of attribute data operations. Preview the attribute table of *vulner.* The table has all three rates needed for computing the index value. But you must go through a couple of steps before computation: add a new field for the index value, and exclude areas with the LURATE value of 9.9 from computation.
5. Open the ArcToolbox window in ArcCatalog. Double-click the Add Field tool in the Data Management Tools/Fields toolset. In the next dialog, select *vulner* for the input table, enter TOTAL for the field name, select DOUBLE for the field type, enter 11 for the field precision, and 3 for the field scale. Click OK. Make sure that TOTAL has been added.
6. Insert a new data frame in ArcMap, and rename it Task 3. Add *soil, landuse, depwater,* and *vulner* from *Task3.mdb* to Task 3. (You will only be working with *vulner*; the other three feature classes are for reference.) Open the attribute table of *vulner.* TOTAL appears in the table with

Nulls. Click the Options dropdown arrow and choose Select By Attributes. Enter the following SQL statement: "LURATE" < > 9.9. Click Apply. Right-click TOTAL and select Field Calculator. Click Yes in the Field Calculator message box. Enter the following expression in the Field Calculator dialog: 0.6 × [SOILRATE] + 0.2 × [LURATE] + 0.2 × [DWRATE]. Click OK to dismiss the dialog. The field TOTAL is populated with the calculated index values. You can assign a TOTAL value of −99 to urban areas. Click the Options dropdown arrow and select Switch Selection. Right-click TOTAL and select Field Calculator. Enter −99 in the expression box, and click OK. At this point, you have completed calculating the index value. Select Clear Selection from the Options dropdown arrow. Close the table.

**Q4.** Excluding −99 for urban areas, what is the value range of TOTAL?

7. This step is to display the index values of *vulner*. Select Properties from the context menu of *vulner* in ArcMap. On the Symbology tab, choose Quantities and Graduated colors in the Show box. Click the Value dropdown arrow and select TOTAL. Click Classify. In the Classification dialog, select 6 classes and enter 0, 3.0, 3.5, 4.0, 4.5, and 5.0 as Break Values. Double-click the default symbol for urban areas (range −99–0) in the Layer Properties dialog and change it to a Hollow symbol for areas not analyzed.

8. Once the index value map is made, you can modify the classification so that the grouping of index values may represent a rank order such as very severe (5), severe (4), moderate (3), slight (2), very slight (1), and not applicable (−99). You can then convert the index value map into a ranked map by doing the following: save the rank of each class under a new field called RANK, and then use the Dissolve tool from the Data Management Tools/Generalization toolset to remove boundaries of polygons that fall within the same rank. The ranked map should look much simpler than the index value map.

## Task 4: Build a Raster-Based Index Model

**What you need:** *soil*, a soils raster; *landuse*, a land-use raster; and *depwater*, a depth to water raster.

Task 4 performs the same analysis as Task 3 but uses raster data. All three rasters have the cell resolution of 90 meters. The cell value in *soil* corresponds to SOILRATE, the cell value in *landuse* corresponds to LURATE, and the cell value in *depwater* corresponds to DWRATE. The only difference is that urban areas in *landuse* are already classified as no data. In Task 4, you will use ModelBuilder to create a model and then export the model to a Python script.

1. Insert a new data frame and rename it Task 4. Add *soil*, *landuse*, and *depwater* to Task 4. If necessary, use Add Toolbox in the context menu of ArcToolbox to add the Chap18 toolbox from My Toolboxes to ArcToolbox. Right-click Chap18, point to New, and select Model. Open the Model Properties dialog and, on the General tab, change both the name and label of the model to Task4.

2. Click the Add Data button, and add *depwater*, *landuse*, and *soil* to the Task 4 window. Drag the Single Output Map Algebra tool from the Spatial Analyst Tools/Map Algebra toolset and drop it in the model window. Right-click the Single Output Map Algebra tool and select Properties. On the Preconditions tab, click the Select All button and then OK. The three input rasters are now connected to the tool. (An alternative is to use the Add Connection tool to connect each input raster to the Single Output Map Algebra tool.) Right-click the Single Output Map Algebra tool and select Open. Enter the following Map Algebra expression in the next dialog: 0.6 * [soil] + 0.2 * [landuse] + 0.2 * [depwater]. Use the browser to specify

*vulner* for the output raster. Click OK to dismiss the dialog.

3. Right-click the Single Output Map Algebra tool and select Run. Then right-click *vulner*, and add it to display. In the table of contents of ArcMap, *vulner* shows a value range from 2.904 to 5.0.
4. This step is to reclassify *vulner* so that the output shows 1 (<= 3.00) for “very slight,” 2 (3.01–3.50) for “slight,” 3 (3.51–4.00) for “moderate,” 4 (4.01–4.50) for “severe,” and 5 (4.51–5.00) for “very severe.” Drag the Reclassify tool from the Spatial Analyst Tools/Reclass toolset and drop it in the model window. Right-click the Reclassify tool and select Properties. On the Preconditions tab, check *vulner* and click OK. *vulner* is now connected to the Reclassify tool. Right-click the Reclassify tool and select Open. In the Reclassify dialog, select *vulner* for the input raster and then click the Classify button. In the Classification dialog, select 5 classes, enter 3, 3.5, 4, 4.5, and 5 for the break values, and click OK. In the Reclassify dialog, enter *reclass_vuln* for the output raster and click OK.
5. Right-click the Reclassify tool and select Run. Then right-click *reclass_vuln*, and add it to display. Right-click *reclass_vuln* in the table of contents, and select Properties. On the Symbology tab, change the label of 1 to Very slight, 2 to Slight, 3 to Moderate, 4 to Severe, and 5 to Very severe. Click OK. Now the raster layer is shown with the proper labels.

**Q5.** What percentage of the study area is labeled “Very severe”?

6. Select Save from the Model menu to save the Task4 model. Then click the Model menu again, point to Export, point to To Script, and select Python. Save the script as *Task4.py* in the Chapter 18 database.
7. Use Notepad or any other word processing software to open *Task4.py*. The script should look as follows:

```
# ---------------------------
# Task4.py
# (time and date)
# (generated by ArcGIS/ModelBuilder)
# ---------------------------
# Import system modules
import sys, string, os, arcgisscripting
# Create the Geoprocessor object
gp = arcgisscripting.create ()
(“esriGeoprocessing.GpDispatch.1”)
# Check out any necessary licenses
gp.CheckOutExtension(“spatial”)
# Load required toolboxes...
gp.AddToolbox(“C:/Program Files/ArcGIS/
ArcToolbox/Toolboxes/Spatial Analyst
Tools.tbx”)
# Local variables...
landuse = “C:/chap18/landuse”
depwater = “C:/chap18/depwater”
soil = “C:/chap18/soil”
vulner = “C:/chap18/vulner”
reclass_vuln = “C:/chap18/reclass_vuln”
# Process: Single Output Map Algebra...
gp.SingleOutputMapAlgebra_sa(“0.6*[soil] +
0.2*[landuse] + 0.2*[depwater]”, vulner,“”)
# Process: Reclassify...
gp.Reclassify_sa(vulner, “Value”,
“2.9040000438690186 3 1;3 3.5 2;3.5 4 3;4
4.5 4;4.5 5 5”, reclass_vuln, “DATA”)
```

*Task4.py* is a text file that documents every command you have used in Task 4. The line that starts with # is a comment line. The gp object is the geoprocessing object. And sa at the end of each tool name stands for Spatial Analyst. Otherwise, the lines in *Task4.py* are self-explanatory.

8. To run *Task4.py* with changes of the input raster or the computational formula for the index model, you can do the following:
   a. Right-click Chap18 in ArcToolbox, point to Add, and select Script. The dialogs that follow allow you to specify *Task4.py* for the script.

**b.** After Script is added to the Chap18 toolbox, right-click Script and select Edit. PythonWin opens with *Task4.py* in the window. You can make changes in the command lines and then click the Run tool to run the script.

## Challenge Task

**What you need:** *soil, landuse,* and *depwater,* same as Task 4.

The Spatial Analyst Tools/Overlay toolset has a tool called Weighted Sum, which can overlay several rasters, multiply each raster with a given weight, and sum the rasters. This challenge task asks you to use this tool and the ModelBuilder to create a raster-based index model similar to that in Task 4.

**Q1.** What cell values are in the output raster?

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