

GY461 Computer Mapping & GIS Technology

Lost Creek Mine GIS Project

I. Introduction

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For your Geographic Information System (GIS) project, you will determine the economic viability of the Lost Creek Mine claim that has been purchased by a major mining corporation. The ArcGIS 9.1 GIS software will be used to analyze and solve the assigned problems. The base maps containing the raw data will be available on the following web site:

http://www.usouthal.edu/geography/allison/gy461/gy461_project_resources.htm

or at an alternative location designated by your course instructor. Look for the “LostCreek.exe” link to download the self-extracting ZIP file. This project is intended to teach and reinforce the capability of a GIS system to analyze data that is attached to digital maps. In this project, the worth of the mine property is a function of the abundance of the three ore minerals: Chalcopyrite (CuFeS_2), Galena (PbS), and Sphalerite (ZnS). Because the base elements in each mineral have different market values, and because the ore minerals vary in abundance throughout the ore deposit independently, the calculation for net worth over the entire claim is rather complex. Additional complications include the fact that overburden must be removed at significant cost. Because the ore body underlies a road system and processing plant, the strip mine cannot effectively extract any ore closer than 50 meters to the plant or roads. Strip mine operations closer than this distance could undermine the plant or road.

The capability of the GIS to track polygon data and calculate values using attributes makes this project practical on the computer workstation, whereas it would be extremely time consuming with manual methods (and much more error prone). After completion of the project you will be familiar with fundamental GIS concepts, and you will have successfully solved a complex economic geology problem that is based on drill core data from a Colorado massive sulfide deposit. Note that although the data that this project is based on is actual data, the location of the mine has been modified to obscure the true location.

II. Raw Data, Constants, and Other Constraints

You should first create a subdirectory folder using your initials under the $C:\text{ArcGIS_Data}\text{XXX}$ subdirectory. Then create a “LostCreek” child directory under your initials. For the rest of these instructions, the initials “XXX” will be used in examples – these should be replaced by your own initials when you work through the project. Download the starting files from the web site (or alternative location if so instructed) as the raw data for the problem. Note that in the “real world”, you would probably have to create these files from scratch:

Border.shp, Border.shx, Border.dbf, Border.prj
CuFeS2.shp, CuFeS2.shx, CuFeS2.dbf, CuFeS2.prj

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PbS.shp, PbS.shx, PbS.dbf, PbS.prj
Plant.shp, Plant.shx, Plant.dbf, Plant.prj
Roads.shp, Roads.shx, Roads.dbf, Roads.prj
Topography.shp, Topography.shx, Topography.dbf, Topography.prj
ZnS.shp, ZnS.shx, ZnS.dbf, ZnS.prj

The above maps contain the topography of the mine area, volume percent ore mineralogy for three ores, roads, and the plan of the processing plant structure. Note that the (x, y) coordinate system of the mine area is the UTM system, zone 14, NAD27, therefore, (x, y) units are in meters. The topographic contour interval value units are feet. The contours of the volume percent abundance of the three ore minerals are based on thin section petrography from drill cores. The ore body structure consists of a tabular horizontal granite porphyry sill that underlies the entire area. The drilling program that the mining corporation just completed has determined that the top and bottom of the sill are relatively horizontal and planar, therefore, you can assume that the structure is tabular and laterally continuous throughout the mine area. The elevation of the top of the sill is 3400 feet above sea level. The base of the structure is 3072 feet above sea level, therefore, the sill thickness is 100 meters. You also can assume that the contours in **Figures 1-3** of mineral volume percent is representative of the entire ore body from top to bottom. In other words, the drill cores were sampled from top to bottom, with each sample depth counted for volume percent of the three ore sulfide minerals. Therefore, the contour values on the base maps are assumed to represent averages of the entire drill hole. **Figure 4** displays the topography, road system, and processing plant on the mine property. Note that the values for each polygon defined by the contours in **Figures 1-4** are labeled with the appropriate values.

For all four of the contour maps you should consider contour lines as being the bounding limits of polygons with the interior of the polygon possessing a value that falls at one half the contour interval between the adjacent contour lines. If the adjacent contour lines are equal in value you should estimate the value of the polygon based on whether or not the contours represent a "hill" or "valley" trend. In addition to the data maps, use the following definitions/data in your calculations:

Ore Body: includes both the ore minerals and the host granite sill.

Ore minerals: Chalcopyrite (CuFeS_2), Sphalerite (ZnS), and Galena (PbS) are sulfide minerals that form this particular massive sulfide ore deposit.

1 meter = 3.28 feet.

Density Values:

Overburden rock: 2.90

Ore Rock: 2.95

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CuFeS ₂ :	4.20
ZnS:	4.00
PbS:	7.50

Weight % element in mineral:

Cu in CuFeS ₂ :	34.6%
Zn in ZnS:	67.0%
Pb in PbS:	86.6%

Commodity values for pure element per metric ton:

Cu:	\$2,360
Zn:	\$1,300
Pb:	\$790

Cost of overburden removal per metric ton:
\$1465

The provided CuFeS₂, PbS, ZnS, and Topography shape files (.shp) consist of polygon topologies with each polygon already labeled with appropriate numerical values. The Plant, Roads, and Border shape files consist of arc (network) topologies with Roads have attached attributes for primary and secondary roads.

III. Tasks

The primary task is to evaluate the economic viability of this mine given the above raw data. This is a task normally given to staff geologists of a mining company before a mining company invests the huge amount of funds necessary to develop a mining property. To accomplish this task you should attack to problem in the following steps.

STEP 1: The first step will import the various shape files (.shp) into a geodatabase file within ArcGIS. This is important because the geodatabase format automatically keeps track of the area of each polygon, and that will be needed for subsequent calculations.

Start ArcCatalog from the desktop or start menu (you can also start it from within ArcMap). From the "File" menu select "New" and then "Personal Geodatabase". Name the new file "LostCreek". **Figure 5** contains an example of the resulting file in the ArcCatalog window. Note that the downloaded shape files appear in the folder along with the new, blank geodatabase file. The geodatabase file is in fact a Microsoft Access© format file with an "mdb" extension. Files of this type may contain more than one table.

STEP 2: The next step will import the various starting shape files into the personal geodatabase.

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After the shape files have been imported they can be discarded since the entire project will consist of ArcGIS project file (LostCreek.mxd) and the Access database file (LostCreek.mdb).

While in ArcCatalog or ArcMap start the ArcGIS toolbox (red toolbox icon) to begin the import process. In this example the toolbox is opened from ArcCatalog. Look for the toolbox folder “Conversion Tools” > “To Geodatabase” > “Feature Class to Geodatabase” option. Double-click on this icon to run the utility. Import all of the shape files into the LostCreek geodatabase.

Figure 6 displays the setup for the ArcToolbox import step. Select the “OK” button to process the import step.

Now the various layers can be added to a ArcMap project file. Start ArcMap from the desktop or start menu. Select a “New empty map” option in the opening dialog. In the upper button bar select the “add data” button (black plus mark on yellow diamond). Select the LostCreek.mdb geodatabase, and then the layers stored in the geodatabase. Save the project file as LostCreek.mxd to your LostCreek folder. Right-Click on the “Layers” word in the left layer window and select properties. For coordinate system select predefined UTM NAD27 zone 14 north. Save the project at this point.

Make the CuFeS₂ layer the active layer by left-clicking on it in the layer control window (left window). Turn off the other polygon layers by un-checking their names. Select the information icon (i) from the button bar. Left click on a polygon. You should see the numeric value of the polygon (wt. % of CuFeS₂) and the area (shape_area) of the polygon listed. If not, have the instructor check your project.

Modify the symbol property of the Roads layer by right-clicking on the “Roads” name in the layer window and then select properties. Select the “Symbology” tab. Select “Categories” and “Unique Values” and then “Add all values” to the legend. Change the “Primary” and “Secondary” road categories to a thick black line and a thin black line respectively. Do this by double-clicking on the line symbol and modifying the symbol. You project should now appear as in **Figure 7**.

STEP 3: The next step is a series of polygon overlay operations that will ultimately combine all of the data layers into a single polygon layer. In this layer each polygon will contain values of CuFeS₂, PbS, ZnS, Elevation and Area. The overlay module in ArcGIS can only “union” together 2 polygon layers at one time, therefore, the strategy for producing the final polygon topology will be:

1. Union CuFeS₂ and Topography to create Union1.
2. Union Union1 and PbS to create Union2.
3. Union Union2 and ZnS to create Union3.

Union3 will therefore contain all of the data layers in a single polygon topology.

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To begin the process double-click the toolbox icon in ArcMap. From the toolbox window expand the “Analysis Tools” > “Overlay” > “Union” utility. Double-click on the icon to start the union operation and specify “Topography” and “CuFeS2” as the 2 input layers. In addition, specify the output as a geodatabase named “Union1” stored in “LostCreek” geodatabase. Select the optional “No FID” option to avoid conflicting field names in future union operations. **Figure 8** displays the setup of the union dialog- note that the “No_FID” option of the join attributes list box should be selected. **Figure 9** displays the ArcMap arrangement of the project after the union operation. The figure also displays the results of the “information” tool after clicking on a polygon. Note that “Elevation” and “CuFeS2” fields contain numeric data, and that the area of the polygon is contained in “Shape_Area”.

Continue using the same overlay union tool to create “Union2” and “Union3”. **Figure 10** contains the layout of this combination of all 4 data layers. Be sure to check the results of Union 3 with the information icon. All 4 data layers should be represented in each polygon. The info tool (dark blue circle with white “i” in the center) should be used to verify this before proceeding to the next step. If you have problems getting to this point seek help from your instructor.

STEP 4: The next step involves creating buffer zones around the road system and processing plant that are located on the mine property. The ore cannot be strip-mined closer than 50 meters to any of these features because of the danger of rock slides undermining them. To make allowances for this problem a 50 meter “buffer” zone will be created around the roads and processing plant. This will be done in 2 independent steps. These 2 buffers will then be merged into a single buffer zone, and then “unioned” with the Combo3 topology to mark the portions of polygons that cannot be mined.

To begin creating the buffer zones double-click on the toolbox icon to open the toolbox window if it is not already open. Expand the tools hierarchy until you can find “Analysis Tools” > “Proximity” > “Buffer”. Double-click on the Buffer icon to start the utility. Indicate “Roads” as the input topology, “RoadBuf” as the output topology, and 50 meters as the buffer distance. Name the new buffer as “RoadBuf”. **Figure 11** displays the dialog window setup for the buffer operation. Note that the dissolve_type is set to all so that the result is one continuous polygon buffer.

Your ArcMap project should appear as **Figure 12** at this point. Create a buffer of 50 meters around the processing plant using the same method just described. Call this buffer polygon “PlantBuf”.

Start the overlay union utility to union together “RoadBuf” and “PlantBuf”. Call the result “Buffer”. In the union dialog window set “JoinAttributes” list box to “No_FID”. The results should appear as in **Figure 13**.

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STEP 5: In this step the Union3 and Buffer polygon topologies will be combined with another union operation. Use the overlay union tool with Union3 and Buffer as the input topology, and Union3Buf as the output topology. Set the “JoinAttributes” list box to “ALL”. With the info tool you can now verify that the Union3Buf polygon topology inherited all of the attributes of Union3, but also the field “FID_Buffer”. Any polygons that fall outside the buffer zone will have this field set to -1, all polygons inside the buffer will have a value of 1. We can use this fact to extract all of the polygons inside the buffer zone out of the polygon topology.

Open the toolbox window and select “Analysis Tools” > “Extract” > “Select”. Double-click to run the utility. Setup the dialog window as in **Figure 14**. Note that the field name “FID_Buffer” must be enclosed in square brackets in the expression edit box. The results of the extraction of the buffer zone can be seen in **Figure 15**. Note that the ArcMap project has the buffer zone removed, and that each polygon has the 4 data layer values attached to it. Make sure you save your project at this time.

The next series of steps will be processed as calculations within the attribute table of the “Results” layer. Right-click on the “Results” layer, and select “Open Attribute Table”. You should see the attribute table in a separate window at this time. You should note that each row in the table represents a single polygon, and you will also see the values for CuFeS₂, PbS, ZnS and Elevation.

Using the “Options” button, and then the “Add Field” option, add the following fields to the attribute table:

OBT	(Overburden tonnage per polygon)
ORT	(Ore rock tonnage per polygon)
Cu	(Copper tonnage per polygon)
Zn	(Zinc tonnage per polygon)
Pb	(Lead tonnage per polygon)
Ore_Value	(Dollar value per polygon)

Use the precision and scale settings indicated in **Figure 16** for all of the new fields. Next set ArcMap in “Edit” mode by selecting “Start Editing” from the Editor button bar. Edit mode allows you to discard changes to the attribute table if your calculations go awry. Right-click on the “OBT” field name in the attribute table. Select “Calculate Values”, and enter the calculation for OBT as indicated in **Figure 17**.

Proceed to calculate the ORT, Cu, Zn, Pb, and Ore_Value fields using field calculations based on the below equations. As with the OBT calculation, play it safe by putting ArcMap into edit mode before typing in the calculation equation. If the results are reasonable in the attribute table then select the “Save Edits” from the editor drop-down list. When you are done with the

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calculations be sure to select “Stop Editing” from the editor drop-down list.

A) Overburden tonnage per polygon:

$$[\mathbf{OBT}] = [\text{Shape_Area}] * ([\text{Elevation}] - 3400) * 0.3048 * 2.90$$

The 0.3048 converts feet to meters. Overburden rock density is 2.90.

B) Ore rock tonnage per polygon:

$$[\mathbf{ORT}] = [\text{Shape_Area}] * (100) * (2.95)$$

Use the item name [ORT] to hold this value. Note that the sill thickness is 100 meters, and the ore rock density is 2.95.

C) element tonnage per polygon:

$$= [\text{ORT}] * (\text{vol. \% mineral}_x) / 100 * (\text{density mineral}_x / \text{density ore}) * (\text{wt. \% element}_x) / 100$$

$$1. [\mathbf{Cu}] = [\text{ORT}] * [\text{CuFeS}_2] / 100 * 4.20 / 2.95 * 34.6 / 100$$

$$2. [\mathbf{Pb}] = [\text{ORT}] * [\text{PbS}] / 100 * 7.50 / 2.95 * 86.6 / 100$$

$$3. [\mathbf{Zn}] = [\text{ORT}] * [\text{ZnS}] / 100 * 4.00 / 2.95 * 67.0 / 100$$

Create the items [Cu], [Zn], and [Pb] respectively to hold the calculated values of metric tonnage of a specific element on a per polygon basis.

D) Value of commodities per ton mined:

$$[\mathbf{Ore_Value}] = [\text{Cu}] / [\text{ORT}] * (2360) + [\text{Zn}] / [\text{ORT}] * (1300) + [\text{Pb}] / [\text{ORT}] * (790)$$

[Ore_Value] will hold this calculation. Market prices for each commodities are volatile, therefore, different values may be assigned compared to those given in this handout. In this example Cu=\$2,360, Zn=\$1,300, and Pb=\$790.

STEP 6: This step composes a final map product with legend information. The goal is to visually display levels of color indication the economic worth of each polygon based on all the relevant factors. Start the ArcMap application and load the LostCreek project. Use the identity tool on the FinalResults layer to make sure that all calculations are “seen” by ArcGIS. If you cannot find the “Ore_Value” calculation see your instructor at this time.

Right-click on the “Results” layer in the layer control window, and then select “Properties”. Then select the “Symbology” tab. Select “quantities” on the left side of the dialog window, and “Graduated colors”. For the value field select “Ore_Value” with no normalization. Under “Classification pick 6 classes and use the “Classify” button to choose equal intervals. Next right

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click on one of the legend labels and select “format labels”. Set the format of the labels to “currency”. Now select the “General” tab to change the title of the layer to “Ore Value per Metric Ton”. Use the same method to edit the other layer titles to match **Figure 18**. **Figure 18** displays the project map as it should appear before designing the layout. Make sure that your project appears like this map before proceeding further.

In the ArcMap main menu select “File” then “Page Setup”. Set the parameters of this dialog to those of **Figure 19** except for the printer, which your instructor will indicate. Now select “View” and then “Layout View” from the main menu. The display will now change to indicate the edges of the 8.5 x 11 size media with the map set inside a re-sizeable frame. If the frame does not match the media orientation modify it to take up the left 3/4 of the media. Right-click on the map frame, select “properties”, and then select “Data Frame”. Set a fixed scale of 1:8000 for the map. From the “Insert” menu add these items:

1. North Arrow
2. Scale Bar
3. Relational fraction text (scale text)
4. Legend
5. Title

When inserting the legend add only the Border, Roads, Plant, and Results layers to the legend. Otherwise accept the default settings.

Position elements of the map layout to match **Figure 20**. Print a hard copy of the map using “File” and “Print” from the main menu

STEP 7: The last step produces a report of the economic potential of the mine in Excel. Start Excel from the desktop. Use “File” > “Open” to open the “Results” table within the “LostCreek.mdb” file in the “\ArcGIS_Data\XXX\LostCreek\” folder. Immediately save this file to your directory as “Results.xls” type. Pay attention to the file type list box in this dialog!

Format the spreadsheet layout so that all fields are visible and that all tonnage and dollar amounts are rounded to 0 decimal places. Use commas to separate thousands from hundreds, etc. Position the cursor in cell A2. Use the menu sequence “Window” > “Freeze Panes” to make the headers of the columns visible no matter where you scroll to in the spreadsheet. Now scroll to last rows of the spreadsheet. Use the sum function {=sum()} to calculate the sum of the Cu, Zn, and Pb tonnage columns. Do the same for the overburden tonnage (OBT) column. In a cell several rows below the last row calculate:

Mine net worth = $\sum[\text{Cu}] \times (\text{Cu price per ton}) + \sum[\text{Zn}] \times (\text{Zn price per ton}) + \sum[\text{Pb}] \times (\text{Pb price per ton}) - \sum[\text{OBT}] \times (\text{price of overburden removal per ton})$.

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Note that the above summation symbols (“ Σ ”) denote the sum of the entire column of values for a specific field. Use the above mine net worth equation to calculate the net worth of the mine as indicated in **Figure 21**. Print the spreadsheet with headers and page numbers for a final report hard copy.

Summary

The below items should be turned in to your instructor for this project:

1. A hard copy print out of the spreadsheet file with the net worth calculations.
2. A hard copy plot of the Final Results map at a plot scale 1:8,000.
3. All files generated during this project should be located on C:\ArcGIS_Data\XXX\LostCreek\ unless otherwise advised by your instructor.