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Laboratory Exercise – Calculating Runoff Over Land Parcels

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Laboratory Exercise 13 – Calculating Runoff Over Land Parcels

Background:

When developing land, most municipalities will require that all runoff from the site be retained on site or flow into a storm water conveyance system. In the near future, new regulation will require that all runoff be retained on site. For this reason, it is important to know how much runoff can be expected to flow over a potential development site. In this lab, you will use ArcMap ModelBuilder to predict the amount of flow which can be expected over a land parcel in a storm event.

Problem Statement:

You are seeking to develop land in Bluffdale, Utah. The city is beginning to require Low Impact Development (LID) practices and will require all runoff to be retained on site. For this reason, you need to know the amount of runoff that can be expected at undeveloped sites in Bluffdale. In this lab, you will use soil data, precipitation data, and elevation data to calculate the total amount of overland flow expected on each parcel of land in a storm event where 1 inch of precipitation occurs on the valley floor. Note that this lab calculates the total amount of water flowing over the parcel during the entire storm, which tells us how much water we will need to retain in a storm. You will use this information to determine proper measures to take in order to retain all runoff.

You will use ArcMap Model Builder to complete this task. You will build a model that will use soil, precipitation, elevation, and parcel data to calculate the average runoff expected to flow over each undeveloped parcel in the city of Bluffdale. Your model will also display the location of streams in the Bluffdale area. Your final product will be a color coded map displaying the total amount of runoff expected to pass over each parcel in a storm event.

Data:

<http://gis.utah.gov/data/elevation-terrain-data/10-30-meter-elevation-models-usgs-ned/> NED 10m: You will need to download several small DEM's which you will combine in your model. Using the interactive map, define the area of interest (Bluffdale, just North of the point of the mountain). Then click the option "10 Meter NED" and select the download button. Download the NED's named q1518 and q1519.

<https://gis.utah.gov/data/boundaries/citycountystate/> Municipalities Data: Scroll down and download the file called Municipal Boundaries: Shapefile.

<https://gis.utah.gov/data/cadastre/parcels/> Parcel Data: Scroll down to the Salt Lake County Section and download the Salt Lake County October 2017 Shapefile.

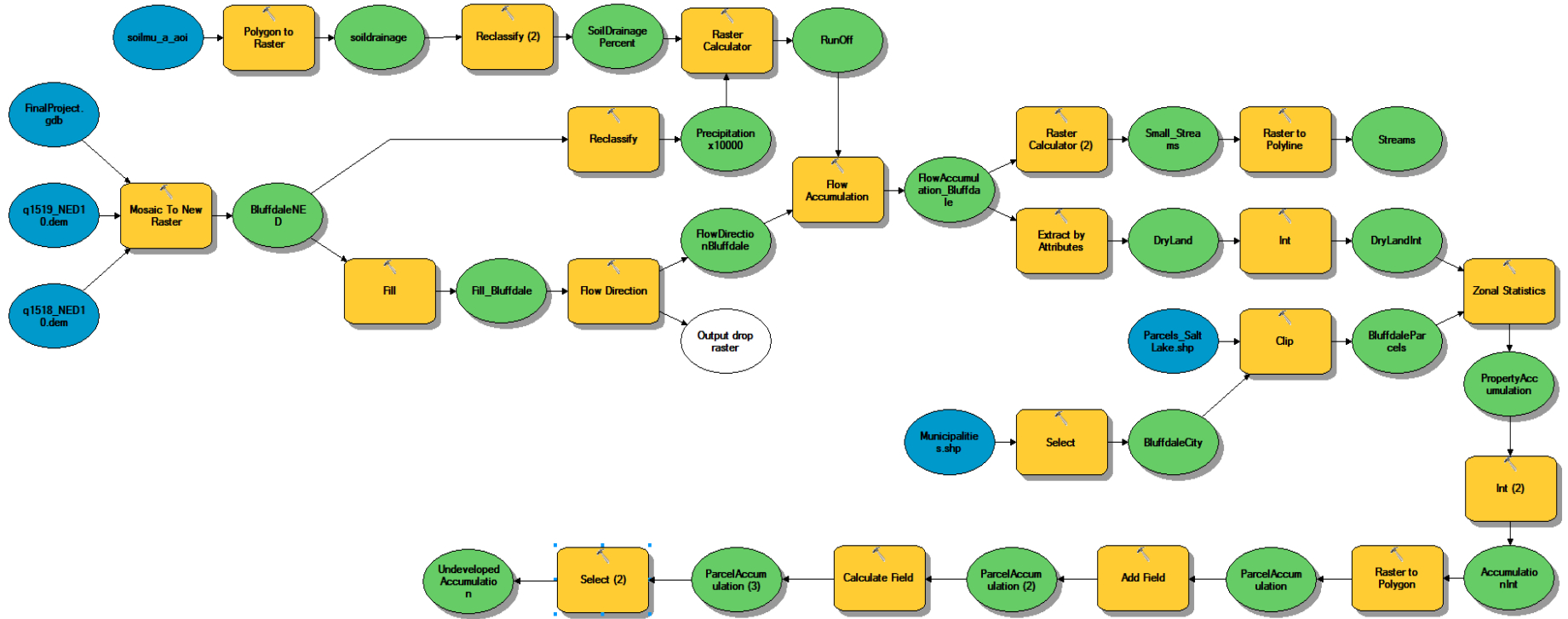
wss_aoi_2017-12-01_09-38-52 Soil Data: Download the wss_aoi_2017-12-01_09-38-52 file from Learning Suite. Unzip to your project folder. You will use the shapefile located in the spatial folder named soils_mu_a_aoi.

ModelBuilder Tools:

In this exercise, you will use the following tools:

- Mosaic to New Raster – Combines multiple raster datasets together into one new dataset of a specified cell size and projection.
- Fill – Fills in areas that are called pits in a raster. A pit is one or more cells which has no downstream cells. This may reflect either what is actually occurring on the ground or it is artificially created by the software. This model assumes that all water will drain from the raster and thus, fills all pits.
- Flow Direction – Computed at each cell as the direction to the neighboring cell with the greatest slope.
- Flow Accumulation – Measures the drainage area in units of grid cells. In this model, each grid cell will be weighted using the weight grid option, which will allow the flow accumulation to measure the amount of runoff passing through a particular cell.
- Raster to Polyline / Polygon – Creates a polyline or polygon feature based on raster cells with similar values or values within certain ranges.
- Reclassify – Reclassifies the values in a raster.
- Raster Calculator – Performs map algebra on a raster dataset or set of datasets.
- Extract by Attributes – Extracts the cells of a raster based on a logical query.
- Int – converts a raster to integer type.
- Clip – Extracts input features that overlay clip features.
- Zonal Statistics – Calculates statistics on values of a raster within the zones of another dataset.
- Add Field – Adds a new field to a table of the table of a feature class.
- Calculate field – Calculates the values of a field for a feature class.
- Select – Extracts features from an input feature class using a Structures Query Language (SQL) expression and stores them in an output feature class.

Example Model



Step by Step Solution

You will first use the Mosaic to New Raster tool to create elevation data for the site. You will then use the fill and flow direction tools. You will classify the soil data using the polygon to raster and reclassify tools. You will create precipitation data using the reclassify tool on the elevation data. You will combine the soil and precipitation data into runoff data using the raster calculator. You will then calculate flow accumulation using the flow direction raster and using the runoff data as a weight grid. You will then use the raster calculator and raster to polyline tool to display the streams in Bluffdale.

You will use the Extract by Attributes tool to extract areas of dry land from the flow accumulation raster. You will use the Int tool to convert this dry land raster to integer format. You will use the Zonal Statistics tool to calculate the average runoff over each parcel in the city of Bluffdale. You will then use the Int tool to transform this raster data into an integer type so that it can be converted to polygon data through the raster to Polygon tool. You will then add a field to the polygon parcel data for runoff accumulation. You will then select the parcels of undeveloped sites and display their runoff amounts as your final product.

Step 1

The Mosaic to New Raster tool is used to combine multiple DEM data sets into one set in the NAD 1983 UTM Zone 12N projection with a cell size of 10 meters. The settings for this tool are displayed below in Figure 1. The tool is shown in Model Builder in Figure 2.

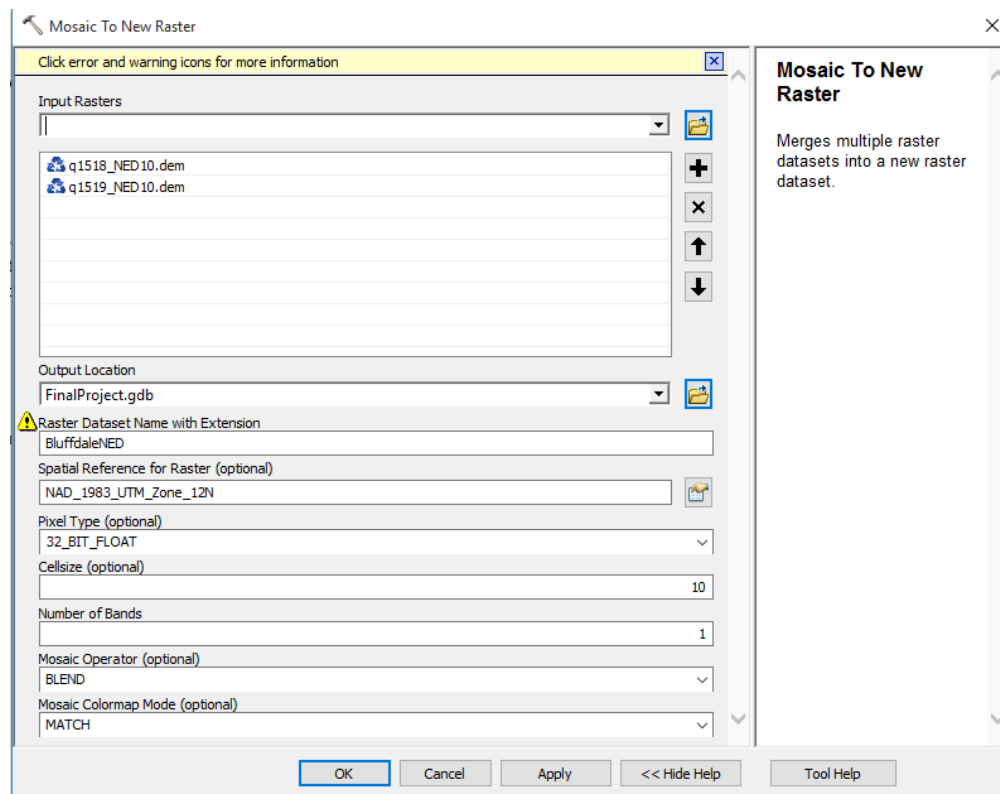


Figure 1- How to Configure the Mosaic to New Raster Tool for an Elevation Raster.

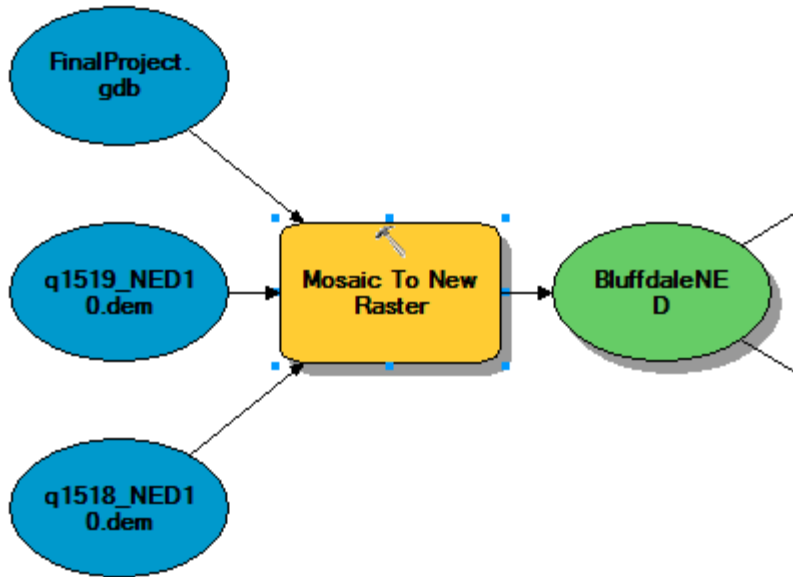


Figure 2 - Using the Mosaic to New Raster Tool in Model Builder.

Step 2

The “Fill” tool is used to fill in the pits in the raster so that all the water doesn’t get stuck. This tool is shown in Figure 3.

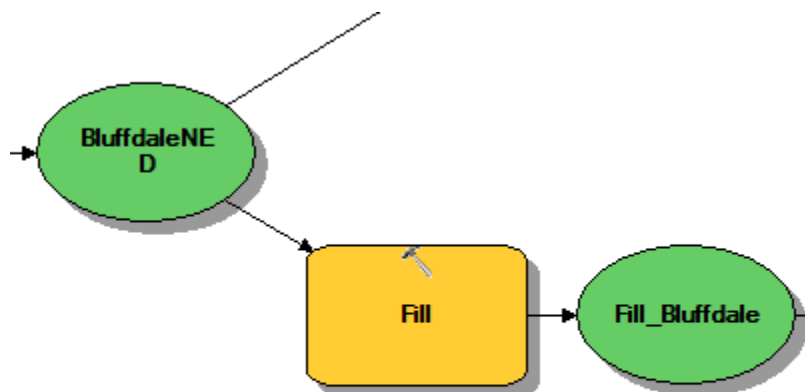


Figure 3: The Fill Tool in Model Builder.

Step 3

To determine the flow direction from cell to cell, you will need to use the Flow Direction tool. You will need to use the output raster from the filled raster you created in the last step. For this lab, you will not need the output drop raster, so just leave that option blank. This is shown in Figure 4.

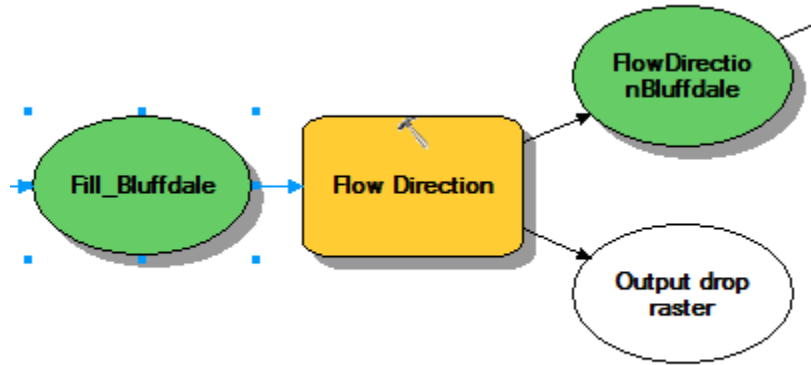


Figure 4 - The Flow Direction Tool in Model Builder.

Step 4

The Reclassify tool will be used to create precipitation data for the case of 1 inch of rainfall on the valley floor. Areas of higher elevation will receive more precipitation in this case. The precipitation rate will be scaled by elevation according to the reclassify tool. Values of the elevation raster should be reclassified as shown in Table 1. The inputs for the Model Builder tool are shown in Figure 5. The tool is shown in Model Builder in Figure 6.

Table 1 - Reclassification Values for Precipitation Raster.

Given Value	Reclassified Value
1300-1400	0.0256
1400-1500	0.0265
1500-1600	0.0278
1600-1700	0.0289
1700-1800	0.0298
1800-1900	0.0310
1900-2000	0.0321
2000-2100	0.0330
2100-2200	0.0340
2200-2300	0.0348

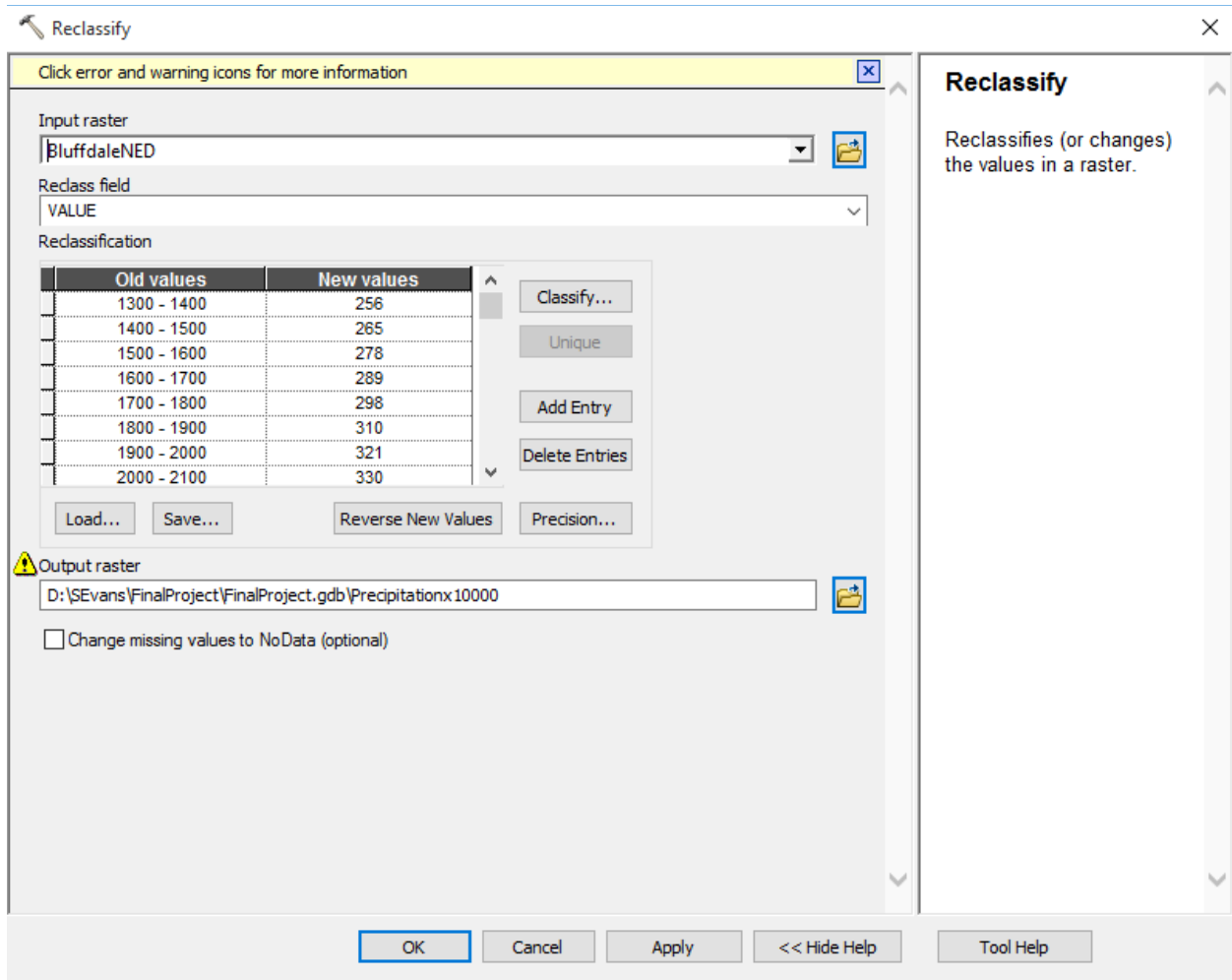


Figure 5 - How to configure the Reclassify tool for Precipitation

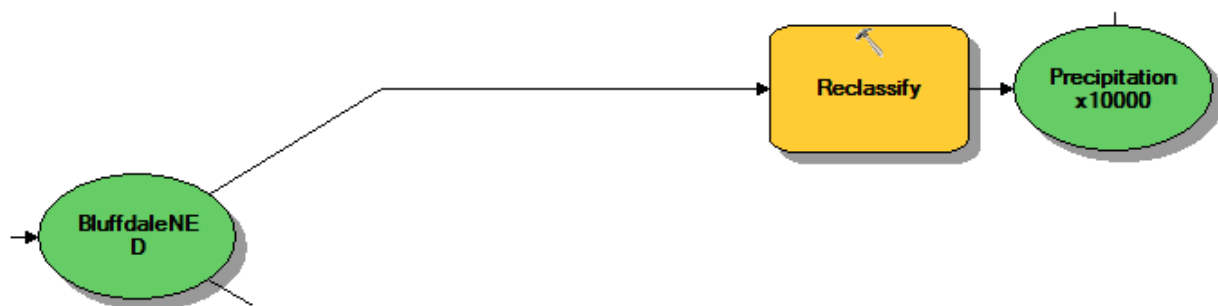


Figure 6 - The Reclassify Tool in Model Builder.

Step 5

To make our downloaded soil data usable for our purposes, we need to use the Polygon to Raster tool. Use the wss_aoi_2017-12-01_09-38-52 file downloaded from learning suite and convert it to a raster data with a cell size of 10 meters. This is shown in Figure 7.



Figure 6 - The Polygon to Raster Tool in Model Builder.

Step 6

Use the Reclassify tool to reclassify the soil data according to the values shown in Figure 8. The output of this tool is the percent drainage for the soil type. For example, a well-drained soil will be assigned a value of 12, meaning 12% of the water will percolate down into the soil. The tool is shown in Figure 9.

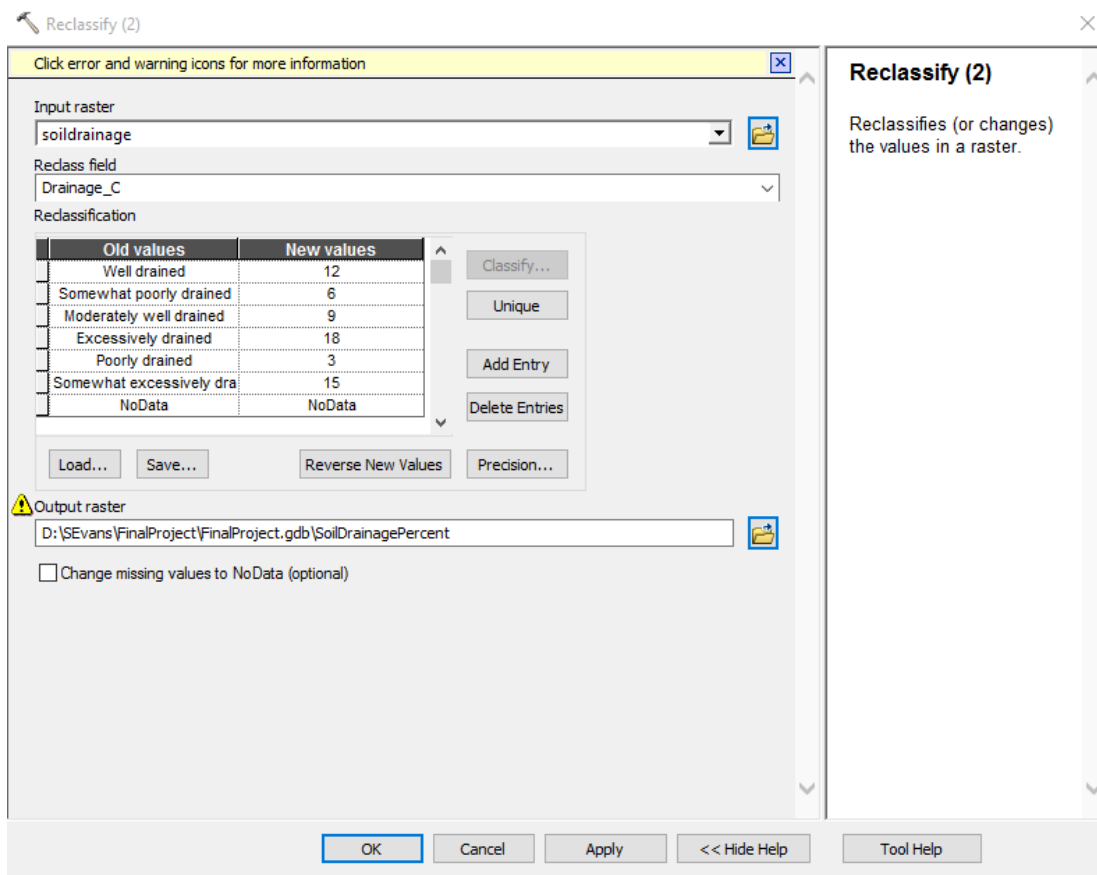


Figure 7 - Configuring the Reclassify Tool for Soil Drainage.



Figure 8 - The Reclassify Tool in Model Builder.

Step 7

Use the Raster Calculator Tool to combine the precipitation and soil data together to calculate the run off for each cell as shown in Figure 10. Use the following expression in the Raster Calculator:
"%Precipitationx10000%"*(100-"%SoilDrainagePercent%")/100.0

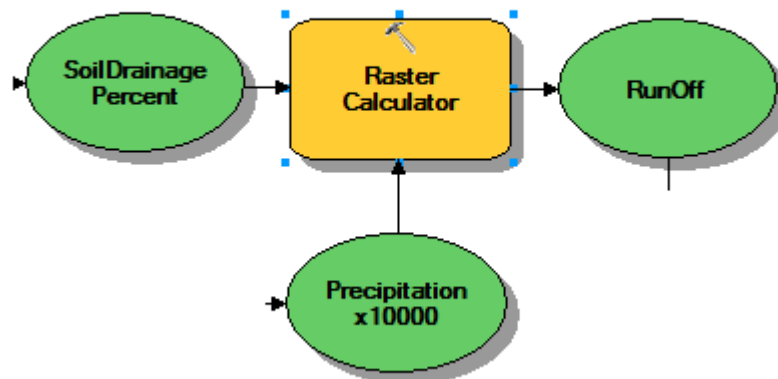


Figure 9 - The Raster Calculator Tool in Model Builder.

Step 8

The Flow Accumulation tool is used to calculate the flow accumulation in each cell based on the flow direction from step 3 and using the runoff raster created in step 7 as the input weight raster. Use FLOAT as the output data type. This tool is shown in Figure 11.

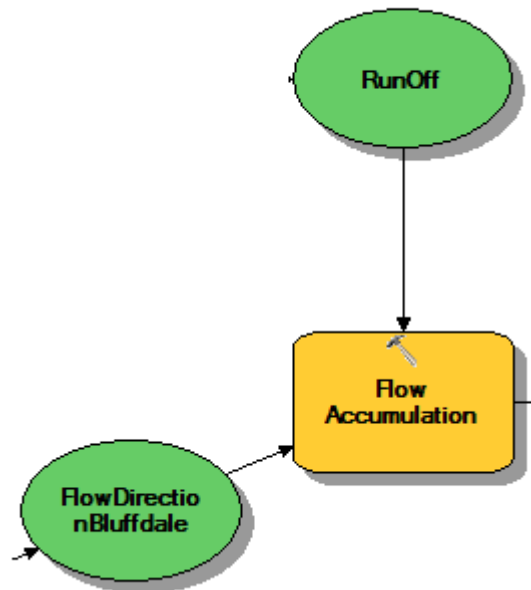


Figure 10 - The Flow Accumulation Tool in Model Builder.

Step 9

The Raster Calculator is used to determine the location of streams in Bluffdale with the following expression: `"%FlowAccumulation_Bluffdale%">1000000`. The tool is shown in Figure 12.

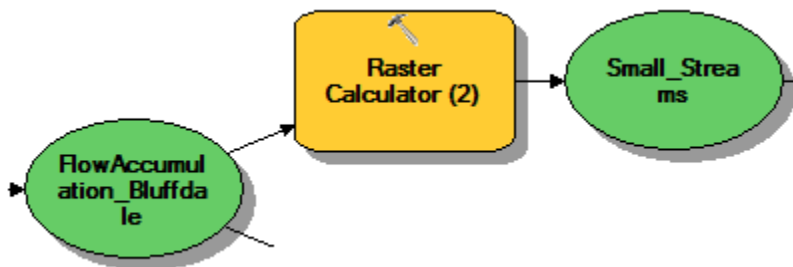


Figure 11 - The Raster Calculator Tool in Model Builder.

Step 10

The Raster to Polyline tool is used to convert the pixels that have been defined as a stream to a polyline shapefile. This is shown in Figure 13. The output of this tool provides us with the streams for the Bluffdale area. Add this output layer to your final map.



Figure 12 - The Raster to Polyline Tool in Model Builder.

Step 11

The Extract by Attributes tool is used to extract values from the Flow Accumulation raster corresponding to dry land. The tool settings will use the flow accumulation raster from step 8 as the input raster and a where clause of **VALUE<10000**. This tool is shown in model builder in Figure 14.

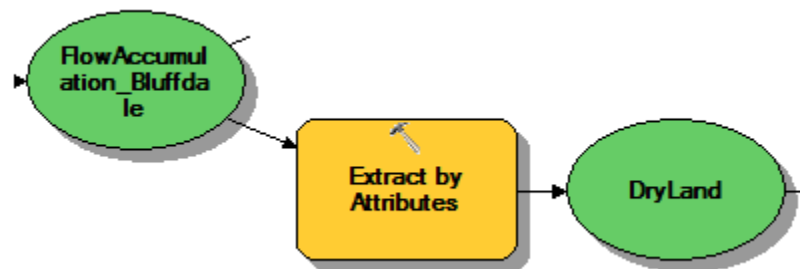


Figure 13 - The Extract by Attributes Tool in Model Builder.

Step 12

The Int tool is used to convert the extracted dry land raster to an integer type so that zonal statistics may be performed. This is shown in Figure 15.



Figure 14 - The Integer Tool in Model Builder.

Step 12

The parcel data for the city of Bluffdale will be created by first using the Select tool to select Bluffdale's boundaries from the municipalities polygon shapefile downloaded from gis.utah.gov using the query "**NAME**" = '**Bluffdale**'. The Clip tool is then used to remove all parcel data outside of Bluffdale, giving the Bluffdale Parcels dataset. This is shown in Figure 16.

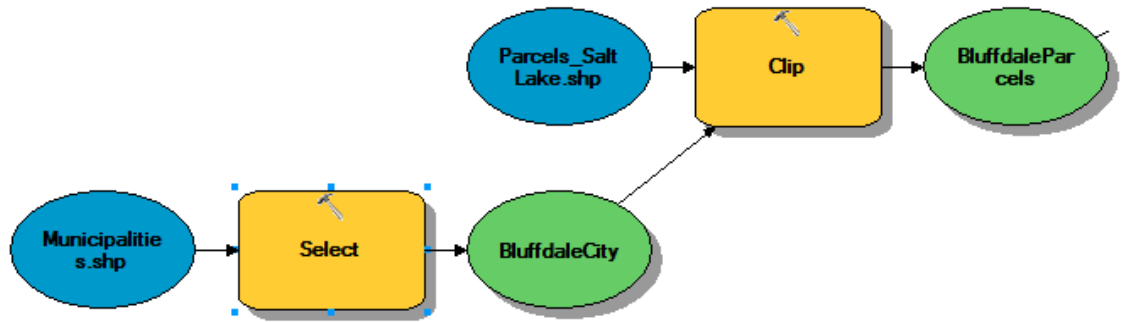


Figure 15 - Clipping Parcel Data to the City of Bluffdale.

Step 13

The Zonal Statistics tool is used to calculate the average dry land flow accumulation for each parcel in the city of Bluffdale. Formulate the Zonal Statistics tool according to Figure 17. This is shown in Model Builder in Figure 18.

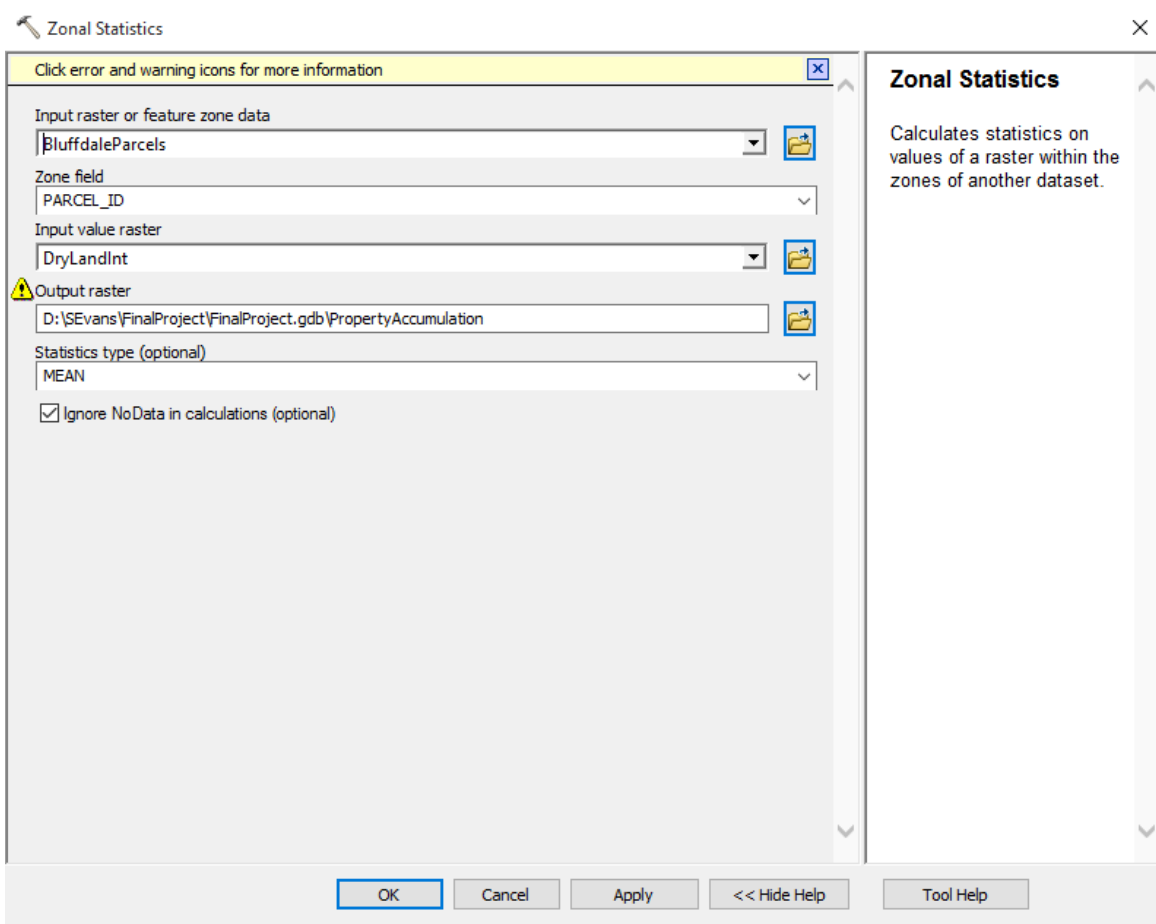


Figure 16 - Settings for the Zonal Statistics Tool.

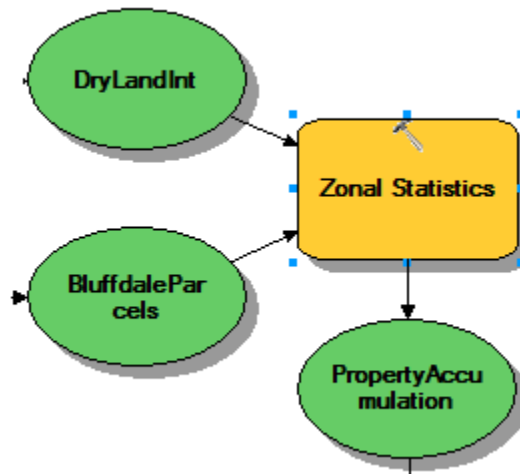


Figure 17 - The Zonal Statistics Tool in Model Builder.

Step 14

The Int tool is again used on the output of zonal statistics in order to convert the average accumulation raster to an integer form, so it can later be converted to a polygon data type. This is shown in Figure 19.

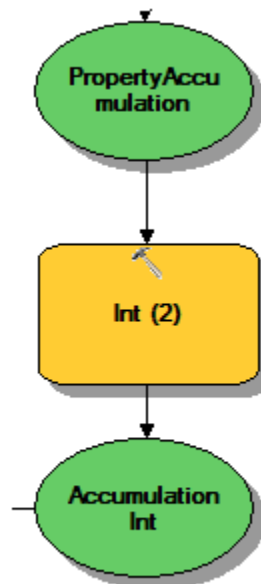


Figure 18 - The Integer Tool in Model Builder.

Step 15

The Raster to Polygon tool is used to convert the average accumulation raster to polygons. These polygons represent the parcels of land in Bluffdale with an attribute for runoff accumulation called gridcode. This is shown in Figure 20.

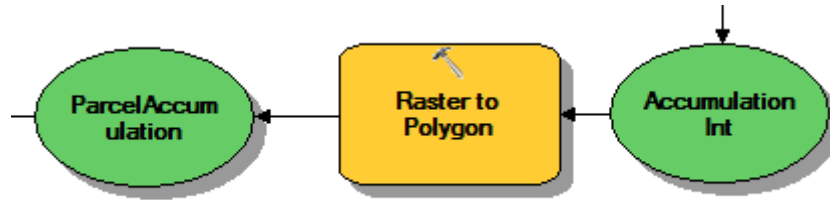


Figure 19 - The Raster to Polygon Tool in Model Builder.

Step 16

The Add Field tool is used to add a field called “WaterAccumulation” of type FLOAT to the Parcel Accumulation polygon dataset created in step 15. This is shown in Figure 21.



Figure 20 - The Add Field Tool in Model Builder.

Step 17

The Calculate Field tool is used to calculate the average amount of water (in inches) that can be expected to flow over the parcel as a result of the storm event. Calculate values for the field called WaterAccumulation by selecting WaterAccumulation as the Field Name and entering the following expression: $[gridcode]/10000.0*100.0/2.54$. This tool is shown in Figure 22.

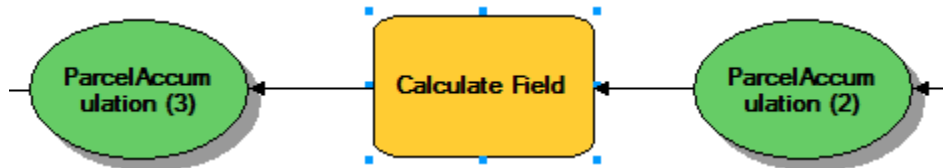


Figure 21 - The Calculate Field Tool in Model Builder.

Step 18

The Select tool is used to select the undeveloped parcels in Bluffdale to display as final results. Undeveloped parcels will typically be larger than developed parcels or roads, so we will eliminate small developed parcels and road parcels and select only undeveloped parcels by using the following query in the Select tool: $(Shape_Area/Shape_Length)>20$. This tool is shown in Figure 23.

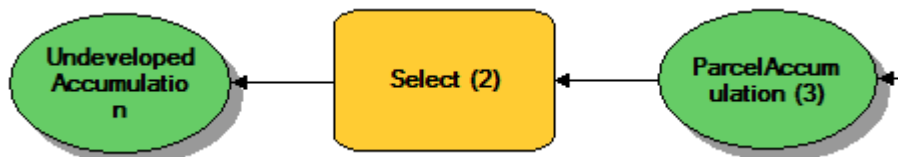


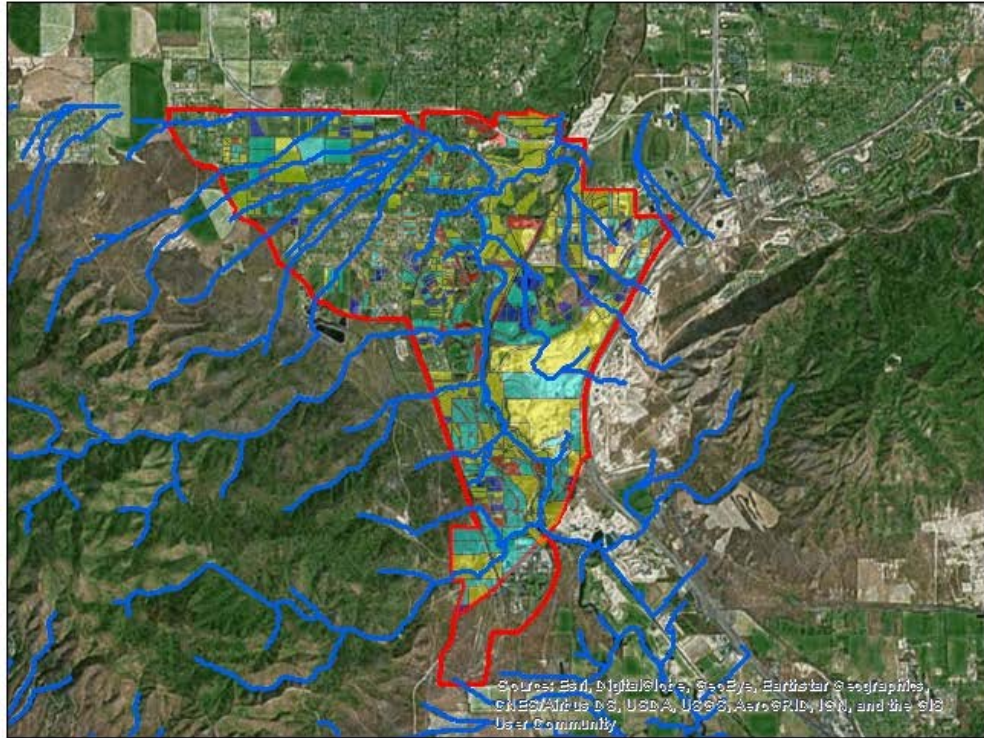
Figure 22 - The Select Tool in Model Builder.

Deliverables:

After constructing the model following the directions given above, run the model and add the undeveloped parcels accumulation shapefile to the map. Next, right click on the Undeveloped Parcels Accumulation shapefile and open the properties window. Open the Symbology tab. On the left side of the menu, select the Quantities option and select Graduated Colors. Set the value to WaterAccumulation and select a color ramp. This will format the polygon data for undeveloped parcels so that it will display different colors for different amounts of runoff. Then adjust the transparency so that underlying imagery is still visible. Your final map should show these color coded parcels and should show the locations of streams in Bluffdale. Prepare a report that contains your model, a list of steps that you have taken in the Model-building process, describe your results for the project, and a final map of your results. Make sure to review over the rubric at the end of this chapter for the full requirements for this laboratory exercise.

Example Map:

Bluffdale Runoff Analysis



0 0.5 1 2 Miles

Bluffdale Boys
Lab 13
Runoff Analysis
12/7/2017
NAD 1983 UTM Zone 12N

Legend

— Streams

Runoff Accumulation

Water Accumulation

Less than 4 inches

4 - 7 inches

7 - 10 inches

10 or more inches

BluffdaleCity



Rubric for Calculating Total Runoff Over Land Parcels

Item	Points
Assignment Title, Author Name, Date, Course Name	/5
Brief summary of the requirements of the project and why this might be useful	/5
Describe your model <ul style="list-style-type: none"> • List each of the tools used: (2 pts) • List tool settings applied for the analysis (2 pts) • List all input, intermediate, and output datasets (2 pts) • Describe each input dataset including type (point, line, polygon, raster) and the source of the data (2 pts) • Describe each output dataset (point, line, polygon, raster) 	/10
<ul style="list-style-type: none"> • One or more full pages (8.5x11) showing your model (5 pts) • All text is readable (10 point font minimum) (3 pts) • All tools and data sets are shown (2 pts) 	/10
<ul style="list-style-type: none"> • Which areas of Bluffdale seem dryer and which areas seem to accumulate more water during storm events? 	/5
Make a full page (8.5x11) map showing the results of your runoff analysis. <ul style="list-style-type: none"> • Map Title: (1 pt) • Neat Line: (1 pt) • North Arrow: (1 pt) • Scale Bar: (1 pt) • Text box with author name, date, map projection: (1 pt) • Streams are visible and undeveloped parcels are displayed so that runoff data can be obtained easily for each parcel through color coding (6 pts). • Each data set clearly symbolized: (1 pt) • Visible basemap showing underlying terrain data: (1 pt) • Zoomed to an appropriate scale for viewing analysis results: (1 pt) • All text is legible on printed map: (1 pt) 	/15
Bonus Task: Repeat the lab exercise with a different set of data. Include in your report what data you used, how you acquired it, what, if anything, you changed to complete the exercise work. Also include an additional full page map showing your results.	Instructor's Discretion