Exercise 5- Watershed and Stream Network Delineation from DEMs

GIS in Water Resources Fall 2014

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This exercise illustrates watershed and stream network delineation using digital elevation models (DEM) using the Hydrology tools in ArcGIS and online services for Hydrology and Hydrologic data. In this exercise, you will develop a stream basin by selecting a stream gage location (the USGS discharge gauge (USGS station ID 06793000) on the Loup River near Genoa, Nebraska) and using the ArcGIS online tools to delineate the watershed draining to the gage. National Hydrography (NHD flowline) and Digital Elevation Model (NED30m) data will be retrieved for the Loup River Basin from online services. You will then perform drainage analysis on a terrain model for this area.

The ArcGIS Hydrology tools will be used to derive several terrain parameter data sets that describe the drainage patterns of the basin. Geoprocessing analysis is performed to fill sinks (pits) and to generate data on flow direction, flow accumulation, catchments, streams, stream segments, and watersheds. These data are then used to develop a vector representation of catchments and drainage lines from selected points that can then be used in network analysis.

This exercise shows how connectivity between the landscape and streams can be developed starting from raw digital elevation data, and that this enriched information can be used to compute watershed attributes commonly used in hydrologic and water resources analyses.

Background on the Loup River

From Wikipedia: The Loup River is a tributary of the Platte River, approximately 68 miles (109 km) long, in central Nebraska. The river drains a sparsely populated rural agricultural area on the eastern edge of

the Great Plains southeast of the Sandhills. The name of the river means "wolf" in French, named by early French trappers after the Skidi band of the Pawnee, whose name means "Wolf People," and who lived along its banks. The river and its tributaries, including the North Loup, Middle Loup, and South Loup, are known colloquially as "the Loups", comprising over 1800 mi (2900 km) of streams and draining approximately one-fifth of



Nebraska. A diversion dam southwest of Genoa diverts water to the Loup Canal to hydroelectric facilities in Monroe and then in Columbus. The canal then runs into the Platte a short distance below its confluence with the Loup.

¹ Some of the materials and structure for this exercise originated from Dr. David Tarboton, Utah State University.

Learning Objectives

The objectives of this exercise are to delineate the watershed and stream network for a selected basin using DEM and spatial analyst tools in ArcGIS. We will also delineate the watershed using online delineating tools. The processing will include:

- 1. Downloading and Importing Gauge station location (Point Data)
- 2. Downloading the DEM and NHD data from ESRI Online Sources
- 3. Extracting the DEM data
- 4. Delineating the Watershed from DEMs
- 5. Network Delineation
- 6. Network Analysis

Special requirements for the Exercise

We need to activate the Spatial Analyst extension before we proceed with the exercise. Once you have activated it on your computer you do not need to repeat this step again

Select Customize -> Extensions

Customize	Windows	Help
Toolbars		•
Extensi		
Add-In	Manager	

Select 3D Analyst and Spatial Analyst extension. We will be using these during the exercise.



You also need to be subscribed to the ArcGIS online services. This is done by obtaining an invitation from the administrator of the UNL account. This invitation will be arranged by the instructor. You will need to activate the invitation.

Part 1: Online Watershed Delineation and Data Retrieval from ESRI

A watershed is the total drainage area upstream of a point. For this exercise we will delineate the watershed upstream of the USGS Stream Gauge site 06793000 on the Loup River near Genoa, Nebraska.

1.1 Adding the USGS Gauge station to the Map

We need to add the Gauge Station's coordinates to ArcMap. Information about the gauge station can be found at the USGS water data website, map viewer:

http://maps.waterdata.usgs.gov/mapper/index.html

Zoom in to the area and locate the gauge station. Otherwise, you can search for the station ID number 06793000.



Click on the Access Data to get location information.

USGS 06793000 Loup River near Genoa, Nebr.

Available data for this site SUMMARY OF ALL AVAILABLE DATA . GO

Stream Site

DESCRIPTION:

Latitude 41°25'07", Longitude 97°43'25" NAD83 Nance County, Nebraska, Hydrologic Unit 10210009 Drainage area: 14,320 square miles Contributing drainage area: 5,620.00 square miles, Datum of gage: 1,540.13 feet above NGVD29.

Transfer the geographical information into an excel spreadsheet and convert the latitude/ longitude from degrees, minutes, seconds to decimal degrees. (Decimal Degrees = degree + minutes/60 + seconds/3600).

Α	В	С	D	E	F	G	Н	I.
SiteID	Lat Deg	Lat Min	Lat Sec	Long Deg	Long Min	Long Sec	Lat DD	LongDD
6793000	41	25	7	97	43	25	41.41861	-97.7236

Following the steps from previous exercises, add the spread sheet to ArcMAP and display XY data based on the LAT DD (for Y) and Long DD (for X) columns. You will want to make sure you select NAD83 as the coordinate system (see below). Right click on this spreadsheet layer and select **Display XY data**.



Set the X and Y fields. Recall that the USGS NWIS website indicated a NAD83 coordinate system. Click **Edit** to edit the coordinate system

	Display XY Data	×
A table containi map as a layer	ing X and Y coordinate data can be added to the	
Choose a table	from the map or browse for another table:	
Sheet1\$	v	2
Specify the fi	elds for the X, Y and Z coordinates:	
X Field:	LongDD	
Y Field:	Lat DD 🗸	
Z Field:	<none></none>	
Coordinate Sy Description:	ystem of Input Coordinates	
Geographic Name: GC	Coordinate System: S_North_American_1983	
Show Det	ails Edit]
✔ Warn me if t	the resulting layer will have restricted functionali	ty
About adding X	Y data OK Cancel	

Locate **Geographic Coordinate Systems** \rightarrow **North America** \rightarrow **NAD1983** in the Spatial Reference Properties window and click OK.

Spatial Reference Properties	×
XY Coordinate System	
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County Systems County Systems Decean Indian Ocean Alaskan Islands American Samoa 1962 Ammassalik 1958	

Now you have the Gauge station in NAD83 coordinate system in the map.

Let's now add a topographic base map to serve as a background in the viewer, so that we have some frame of reference where our gauge is.



You can see our gauge station is on the Loup River near Genoa.

We should export the data as a feature dataset or a shape file. However, before we do that, let's open Arc Catalog and create a folder and a geodatabase to store your files. You are going to be creating a lot of files from terrain preprocessing. It is important that you create a Geodatabase to store and organize output files. In addition, some of the terrain processing tools will give you error or will not run without the output location set into a Geodatabase.



Now let's set up a folder and geodatabase for your work. First create a folder (for instance, for the instructor: C:\Ayse\Ex5\Sol1). Then, save the map document in this folder (Ex5.mxd). This serves to

establish a place on disk where temporary files can be written and a Home location in Catalog. Now, create a new Geodatabase and name it **Loup.gdb.** Inside the Loup.gdb, create a feature data set and name it **Basedata** and set its Projection coordinates as Albers Equal Area Conic. The Albers Equal Area Conic is usually the best projection system for preserving area.



Click Next, Next and Finish.

Now let's export the data, Right click on the Events layer



Save the file as **Gauge** in the **BaseData** Feature dataset under your Loup GDB. Placing the Gauge feature inside the BaseData feature will automatically adopt the Albers projection of the BaseData feature. This serves to project the geographic coordinates of this site feature class to the North America Albers coordinate system of the BaseData feature dataset and make it a permanent feature class. Remove Sheet1\$ Events.

	Export Data	×
Export:	All features	~
Use the s	same coordinate system as:	
🔵 this la	ayer's source data	
O the da	ata frame	
the fe (only a	eature dataset you export the data into applies if you export to a feature dataset in a geodatabase)	
Output fe	eature class:	
C:\Ayse	e\Exe5\sol1\Loup.gdb\BaseData\Gauge	2
	OK Cancel	
🗆 🚞 Exe5	5	
	dummy sol1	
	Loup.gdb	
6	🖃 🖆 BaseData	

Online watershed Delineation and Data Retrieval

😳 Gauge

Sol1.mxd

1.2. Elevation Data

To do any kind of watershed or water flow analysis you need to have Elevation information. The next step is to add Elevation data to the map.



Open ArcCatalog. Double Click on Add ArcGIS Server. Select **Use GIS Services**, the first option.

	Add ArcGIS Server
	This wizard guides you through the process of making a connection to an ArcGIS Server. You can create a connection to use, publish, or administer GIS services.
 ↓ 1 	What would you like to do? Use GIS services Publish GIS services Administer GIS server
	< Back Next > Cancel

Enter the Server URL <u>http://elevation.arcgis.com/arcgis/services</u>

and your ArcGIS.com user name and password. Note that **username and password** are case-sensitive.

	General	×
Server URL:	http://elevation.arcgis.com/arcgis/services	
	ArcGIS Server: http://gisserver.domain.com:6080/arcgis	
Authentication (O	ptional)	
User Name:	akilic_UN1	
Deserved		
Password:		
	Save Username/Password	
About ArcGIS Serve	er connections	
	< <u>B</u> ack Finish Ca	ancel

You should see ARCGIS on elevation.arcgis.com displayed in your Catalog under GIS Servers.



Expand the tool to see the services available



NED30m is the USGS National Elevation Dataset digital elevation model. Drag and drop NED30m from ArcCatalog onto your ArcMap to add this data to the ArcMap data frame. Close the coordinate systems warning. You may have to try this a few times before the NED30m shows up in ArcMap. Make sure you have both windows for Arc Catalog and ArcMap is open.



The first view in ArcMap look like the following. You can then zoom in to the gage for the Loup River.



1.3. Watershed tool in the Hydrology toolbox

Now we are going to add the Watershed tool in the Hydrology toolbox. The server url is at

http://hydro.arcgis.com/arcgis/services

Add ArcGIS Server	×
This wizard guides you through the process of making a connection to an ArcGIS Server. You can create a connection to use, publish, or administer GIS services.	
What would you like to do? Use GIS services Publish GIS services Administer GIS server	
 < <u>B</u> ack <u>N</u> ext > Car	ncel

	General	X
Server URL:	http://hydro.arcgis.com/arcgis/services	
	ArcGIS Server: http://gisserver.domain.com:6080/arcgis	
Authoritication (Or	tens	
Authentication (Op	tional)	
User Name:	akilic_UN1	
Password:	••••••	
	Save Username/Password	
About ArcGIS Server	connections	
	< <u>B</u> ack Finish	Cancel

Now locate the watershed tool in the Hydrology toolbox in Arc Catalog. We are going to create a watershed representing all contributing areas above Loop River gage at Genoa.



Click on watershed and set Input Points to Gauge (the Loop River stream site). Set Data Source Resolution to 30 meter. Leave other inputs at their defaults and click OK to run the tool.

₹	Watershed – 🗆 🗙
Input Points	Data Source Resolution (optional)
Gauge 💌 🖻	Keyword indicating the source data that will be used in the analysis. The keyword is an approximation of the spatial resolution of the digital elevation model used to build the foundation hydrologic database. Since many elevation sources are distributed with units of arc seconds, we provide an approximation in meters for easier understanding.
Point Identification Field (optional)	 Blank - The hydrologic source was built from 3 arc second, approximately 90 meter resolution elevation data. This is the default.
Snap Distance (optional) Snap Distance Units (optional) Meters Data Source Resolution (optional)	 FINEST- Finest resolution available at each location from all possible data sources. 30m - The hydrologic source was built from 1 arc second, approximately 30 meter resolution elevation data.
30m ✓ Generalize Watershed Polygons (optional) ✓ Return Snapped Points (optional)	 90m - The hydrologic source was built from 3 arc second, approximately 90 meter resolution elevation data.
	~
OK Cancel Environments << Hide Help	Tool Help

When the tool completes, you should have an Output Watershed that has been delineated using the ESRI online watershed delineation service. It appears in the GPInMemoryWorkspace part of the map document table of contents. You need to have "List by Source" option selected for Table of Contents (TOC). Notice that there are two layers listed: Output Watershed which shows the outline of our watershed boundary of the Loup River above Genoa. The second feature is called Output Snapped Points and contains the outlet point "snapped" or moved to be on the stream. We will use this later on the exercise.



Right click on Output Watershed and select Data and Export Data to export this delineated watershed and name the output feature class as **Basin** in Loup.gdb\BaseData. This saves the Basin feature class on your computer. We will be using this Basin basemap to extract data. This is our study domain.



Likewise, save the Output Snapped Points in Loup.gdb\BaseData\GageSnap feature class. Saving these results "locally" retains them in case you have to restart. If that happens, the GPInMemoryWorkspace would be lost and you would have to repeat this procedure.

	Export Data
Export:	All features
Use the sa	ame coordinate system as:
🔵 this lay	yer's source data
the da	ta frame
the feat (only a contract)	ature dataset you export the data into applies if you export to a feature dataset in a geodatabase)
Output fea	ature class:
C:\Ayse	\Exe5\sol1\Loup.gdb\BaseData\GageSnap
	OK Cancel

Let's zoom in near the outlet of the Loup River basin (Genoa guage). Note whether or not the location of the gauge has been shifted relative to the original location that you used. This is to move the outlet onto the stream flow path in the preprocessed NED30m DEM that underlies the watershed delineation. Estimate the amount of shift and why it occurred. Which location do you conclude is the most accurate and why.



Notice that our watershed boundary has a stair step shape (the green color above) because it is based on DEM grid cells.

Check to make sure that the underlying NED30m DEM coordinate system is the same as the display data frame. If not, you would need to change data frame to the coordinate system of the DEM. Check this by Right clicking on the data frame Layers I Properties and evaluating the projection system. Compare that information with the same thing for the DEM.

Extracting the DEM for the Basin from NED30m

Next we want to extract the DEM for this area. Here we want the DEM over an area slightly bigger than the watershed. Let's use a 1 km buffer.

K Buffer	- 🗆	×	
Input Features			^
Basin	•	2	
Output Feature Class			
C:\Ayse\Exe5\sol1\Loup.gdb\BaseData\Basin_1km_Buffer		2	
Distance [value or field] O[Linear unit]			
1000 Meters		~	
◯ Field			
		\sim	
Side Type (optional)			
FULL		~	
End Type (optional)			
ROUND		\sim	
Dissolve Type (optional)			
NONE		~	
Dissolve Field(s) (optional)			
			~
OK Cancel Environments	Show H	elp >>	

Search for the Buffer (Analysis) tool and set the inputs as follows

This process may take several minutes to complete (watch the lower righthand part of your screen for progress). When finished, the basin will now be outlined by the buffered basin feature that is 1 km larger (see following figure where the basin and buffered basin are viewed with no fill):



Next, we will search for the Extract by Mask (Spatial Analyst) tool and set the inputs as follows

1	Extract by Mask	_ 🗆	×
Input raster			_ ^
NED30m		•	6
Input raster or featur	e mask data		
Basin_1km_Buffer		•	6
Output raster			
C:\Ayse\Exe5\sol1\L	oup.gdb\DEM		6

The result is a DEM over the buffered area of the basin. This DEM is 1 km larger than the Loup River basin so that we have no problems during calculations of terrain parameters including slope and flow direction.



This completes the downloading and extraction of the DEM from the online services. The DEM is now ready for terrain analysis.

To turn in: The number of columns and rows, and grid cell size in the Loup River basin DEM.

The minimum and maximum elevation values in the Loup River basin DEM.

The next step is to bring in the NHD flow line data.

1.4. National Hydrography Data Service (NHDPlusV2).

Next we are going to bring in flowlines that have been preprocessed by ESRI and are made available via ArcGIS server. This product is only available via the online subscription. When possible, it is best to use the online data to save processing, downloading, unzipping time.

In Catalog, under GIS Servers add the http://landscape1.arcgis.com/arcgis/services ArcGIS service as you did before for elevation and hydrology services.

	General	×
Server LIDI •	http://landscape1.arcois.com/arcois/services	
Server OKL.	ArcGIS Server: http://gisserver.domain.com:6080/arcgis	
Authentication (O	ptional)	
User Name:	akilic_UN1	
Password:	•••••	
	Save Username/Password	
About ArcGIS Serve	er connections	
	< <u>B</u> ack Finish C	Cancel

Under "Tools" in the Landscape 1 service, double click on "**Extract Landscape Source Data**" (see image below) and choose **NHDPlus V2 Flowlines** as the Landscape Layer and **Basin** as the study area.

Kernet La	ndscape Source Dat	a —	□ ×
Choose Landscape Laye	r		
Study Area			×
Basin		•	8
Study_Area			

Wait until this message box appears



Open the Geoprocessing Results Window in ArcMAP (in the top menu):



Expand the "current session" and you will see a "NHDPlusv.zip" file appear.



Double Click to open the output zip file and copy the geodatabase folder Landscape.gdb that is inside the zip file into the folder where you are working (for example: C:\Ayse\Ex5\Sol1). (Click on the

Landscape.gdb to select it, right click and select 'copy' and then go to your working folder (for example C:\Ayse\Ex5\Sol1). Do the copy and paste in the same Explorer window):



Add the feature class NHDPlusv from Landscape.gdb (that is in your working folder) to the ArcMap display and symbolize using Gage Adjusted Flow E to give a flow map. Under Symbology, select "Quantities" and "Graduated colors." Ignore warnings. Format the labels.

Layer Properties								×	
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General	Source	Selection	Display	Symbology	Fields	Definition Query	Labels	Routes	Hatches
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	£	Sho <u>w</u> cla	ass ranges u	sing feature value	es		Adva	ance <u>d</u> -	
						ОК	Ca	ncel	Apply



This is now a local set of NHDPlus vector streamlines for the Loup River Basin.

1.5. Main Stream Properties

Let's now identify the main stem of the Loup River, including the Middle Loup River, and determine some of its properties. Open the attribute table for NHDPlusv. Select By Attributes and click on "Get Unique Values" to see the names of the stream. *Note: The hydrographic GNIS names contained in and displayed by the NHD are from the GNIS (Geographic Name Information System) database which holds the Federally recognized name of each feature and defines the location of the feature by state, county, USGS topographic map, and geographic coordinates.*

You need to write a Query to select where

gnis_name = 'Loup River' OR gnis_name = 'Middle Loup River'

	Select by Attributes									
Enter a WHEF	Enter a WHERE clause to select records in the table window.									
Method :	Create a new se	election		~						
OBJECTID comid gnis_name lengthkm reachcode				*						
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SELECT * FR	OM NHDPlusv <u>W</u>	HERE:								
gnis_name =	'Loup River' OR (gnis_name = 'Mi	ddle Loup River'	<						
Cl <u>e</u> ar	Verify	<u>H</u> elp	Loa <u>d</u>	Sa <u>v</u> e						
			Apply	Close						

The query will select both main stem and middle loop rivers and they should display as a highlighted color.



Now we will export the selected Loup and Middle Loup entries. Right click on the NHDPlusv layer and select Data \rightarrow Export Data and save the selected features as LoupMain in the Loup.gdb\Basedata feature dataset. This is a feature that contains only information on the Loup and Middle Loup rivers (but none of their tributaries).

	Export Data							
Export:	Selected features							
Use the same coordinate system as:								
🔵 this lay	this layer's source data							
O the dat	ta frame							
the fea (only a	 the feature dataset you export the data into (only applies if you export to a feature dataset in a geodatabase) 							
Output fea	ature class:							
C:\Ayse	\Exe5\sol1\Loup.gdb\BaseData\LoupMain							
	OK Cancel							

Let's examine the length of the mainstem Loup (and Middle Loup) River from its source to this outlet (Genoa gauge).

In the attribute table of LoupMain locate the column "Length (km)" and Right click on the header and select Statistics



Note the "Sum" value and the units (the length of the Loup and Middle Loup River from its source to this outlet at Genoa gauge).

To turn in. Prepare a layout showing the topography (DEM), Basin Outline, NHDPlusv streams and Loup River Main stem and Middle Loup streams for the Loup River Basin. Include a scale bar and North arrow and appropriate title, labeling and legend so that the map is self-describing.

Part 2. Hydrologic Terrain Analysis

This activity will guide you through the initial hydrologic terrain analysis steps of Filling Pits, calculating Flow Direction, and calculating Flow Accumulation (steps 1 to 3). The resulting flow accumulation raster will allow you to identify the contributing area at each grid cell in the domain, a very useful quantity fundamental to hydrologic analysis.

Next an outlet point will be used to define a watershed as all points upstream of the outlet (step 4).

Focusing on this watershed, streams will be defined using a flow accumulation threshold within the watershed (step 5).

Hydrology functions will be used to define separate links (stream segments) and the catchments that drain to them (steps 6 and 7).

Next the streams will be converted into a vector representation (step 8) and more Hydrology toolbox functionality used to evaluate stream order (step 9) and the subwatersheds draining directly to each of the eight stream gauges in the example dataset (step 10).

The result is a comprehensive set of information about the hydrology of this watershed, all derived from the DEM.

Step 1: DEM Conditioning (Fill Pits)

Search and Run the **Fill tool** – to fill in the Sinks in the DEM. Sinks are the cells that are surrounded by cells all having an elevation higher than it, i.e the water will not flow anywhere from the "pit" cell. Running this tool is very memory and CPU intensive and will take a long time. Save the file into the Geodatabase.

Select Spatial Analyst Tools \rightarrow Hydrology --> Fill. Set the input surface raster as **DEM** and output surface raster as **fill** in Loup.gdb.

ArcToolbox 🗆 ×	<u></u>	
 Analysis Tools Cartography Tools Conversion Tools Data Interoperability Tools Data Management Tools Editing Tools Enear Referencing Tools Multidimension Tools Multidimension Tools Parcel Fabric Tools Parcel Fabric Tools Schematics Tools Schemat	Input surface raster DEM Imput surface raster C:\Ayse\Exe5\sol1\Loup.gdb\Fill Imput surface raster Z limit (optional) Imput surface raster	~

Let's examine the impact of Fill on the DEM. Select Spatial Analyst Tools \rightarrow Map Algebra \rightarrow Raster Calculator and evaluate the differences between FILL and the original DEM by calculating the difference FILL – DEM in Raster Calculator. Save the result as "FillMinusDEM".

Layers and variables								Conditional —	^
 → Fill → DEM 	7	8	9	1	==	!=	8.	Con Pick	
♦ NED30m	4	5	6	*	>	>=	1	SetNull	
	1	2	3	-	<	<=	^	Math	
		0		+	(~	Exp	
								Explu	•
"Fill" - "DEM"									

View this difference map. Comment on the differences, where they occur, and why they occur. You should on an area to make this assessment. If you see lots of pits, especially in the "Sandhills" area, suggest what these pits are, in reality.

To help with your assessment, also create a Contour map from the DEM. Select Spatial Analyst Tools \rightarrow Surface \rightarrow Contour. You can set the Contour interval to 10 m.

An overlay of the Contour lines on top of the FillMinusDEM map, where the map is colorized to show low values as green and large values as blue is shown below:



The above figure on the left is a closeup of the boxed area in the west central part of the Loup River Basin. That figure, with contours and colorized differences (showing filled pits), may give you a better idea of what these features are. (The circled area is commented on later). *Question: what are these, and should they be filled?*

Step 2. Flow Direction

To delineate the Watershed, we should know which way the water is flowing from a cell. To determine this, search for tool **Flow Direction**. This tool compares each cell with its neighboring cells to determine the direction of steepest descent, and therefore, where each cell is draining to.

Flow Direction Tool applied to the "Fill" DEM. Flow direction is saved as "FDR" and the Drop raster is saved as "DRP".



If we zoom in to the same area as above (for the FillMinusDEM), we can see the actual detail for specific slopes:



Note that some of these shapes have straight edges. This occurs because the flowline (direction) has been determined for the pit-filled areas, and these areas are perfectly flat after the filling. Therefore, the direction tool gets 'confused' and assigns a variety of directions.

The following snapshot is along the Middle Loup River and shows the drainage of south-facing slopes and north-facing slopes into the river:



Step 3.Flow Accumulation

Once we know the Flow direction we can ascertain how the flow is getting accumulated and where small groups of cells turn into streams and where streams turn into rivers.

Search for the **Flow Accumulation** tool or Spatial Analyst Tools \rightarrow Hydrology \rightarrow Flow Accumulation. Use the Flow direction as the input raster and save the output in to the Geodatabase as "**FAC**".



0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	Q	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2





5	Flow Accumulation	_ 🗆 ×
Input flow direction raster		_ ^
FDR		▼ 🖆
Output accumulation raster		
C:\Ayse\Exe5\sol1\Loup.gdb\FAC		🖻 👘
Input weight raster (optional)		
		- 🖻
Output data type (optional)		
FLOAT		~

The Flow Accumulation tool is a very CPU and Memory intensive process. You will need to be patient. Have some coffee. Watch an old episode of "Friends" and relax. This tool will take substantially more time than it took to make the Flow Direction raster (it may take about 1 hour).

The initial result in the viewer will look like the following:


The result initially looks like just a black screen because all values close to zero are colored black, but there are some cells in the main river having high values for accumulated cells. Therefore, the "color stretch" shows most cells as black.

If you zoom in you will see some of the stream structure. Adjust the symbology of the Flow Accumulation layer to a classified scale with **multiplicatively increasing breaks** that you type in, to illustrate the increase of flow accumulation as one descends through the grid flow network. In symbology, use 8 classes and select the "Classify" Button and choose the "Manual" method to type in your class breaks in the window in the lower right hand corner of the menu window.

Classification		×
Classification	- Classification Statistics	
Method: Manual V	Count:	39112009
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	Maximum:	37,477,444
Data Exclusion	Sum:	286,142,783,436
E <u>x</u> clusion Sampling	Mean:	7,316
	Standard Deviation:	331,439
Columns: 100 - Show Std. Dev. Show Mean		
44		Brea <u>k</u> Values %
400000 20		3,000
20°, 1, 00°, 4, 7%		5,000
3000000		10,000
		30,000
2000000		50,000
2000000		100,000
		1,000,000
1000000		57,77,77
0		
0 9,369,36118,738,72:28,108,08:37,477,	44	
		ОК
Snap breaks to data <u>v</u> alues		Cancel

	Laye	er Properties	×
General Source Exten	t Display Symbology		
Show: Unique Values Classified	Draw raster grouping val	lues into classes	3
Stretched Discrete Color	Fields Value <value></value>	Vormalization <none></none>	¥
	Classification Manual	Classes 8 V Classif	ÿ
	Color Ramp		v
	Symbol Range	Label	^
	0 - 3,000	0 - 3,000	
	3,000 - 5,000	3,000.000001 - 5,000	
	5,000 - 10,000	5,000.000001 - 10,000	
	10,000 - 30,000	10,000.00001 - 30,000	
	30,000 - 50,000	30,000.00001 - 50,000	
	50,000 - 100,000	50,000.00001 - 100,000	~
F- 485	Show class breaks using c	ell values Display NoData as	
About symbology	Use hillshade effect	Z: 1	
		OK Cancel	Apply



Turn off the unnecessary layers and pan and zoom to the outlet of the outlet of the basin, which is at the Genoa Gaging Station. This location is indicated in the following figure. Use the identify tool to determine the value of "FAC" at the outlet.



The value obtained represents the drainage area in number of 30 x 30 m grid cells. Calculate the drainage area in km².

Turn in the drainage area into the gauge station in both number of 30 m grid cells and as km² as estimated by the flow accumulation tool. Compare this to the area of the basin, as a 'check' where the area of the basin is obtained from two different sources: a) from the attribute table for the basin, and b) from the USGS properties menu for the Genoa gage as shown below. Also, determine why the "Drainage area" in the USGS Description has a different value than the "contibuting drainage area" for this particular basin(think about what we have dicussed under the flow direction analysis).

USGS 06793000 Loup River near Genoa, Nebr.

Available data for this site SUMMARY OF ALL AVAILABLE DATA • GO

Stream Site

DESCRIPTION:

Latitude 41°25'07", Longitude 97°43'25" NAD83 Nance County, Nebraska, Hydrologic Unit 10210009 Drainage area: 14,320 square miles Contributing drainage area: 5,620.00 square miles, Datum of gage: 1,540.13 feet above NGVD29.

Step 4: Watershed

We will run the Watershed tool twice. The first time we run it, we will ask for delineation of all of the watershed above the Genoa gauge. This will give us a single 'watershed' unit. The second time through, we will run the Watershed tool using stream segments (links) to delineate small catchments throughout the basin. Note that we already have the entire 'watershed' via the watershed tool from the ESRI online watershed delineation service that was run earlier. But it is a good check to do it again, plus to see the outcome.

Before we can use a 'single point' as the "pour point" in the Watershed tool, we need to 'snap' the gauge location to the 30 m cell that has the highest FAC, and we turn that location into a 30 m equivalent size. We do this using the Snap Pour Point tool:

~	Snap Pour Point –	- 🗆 ×
Input r	aster or feature pour point data	
Pour p SiteII	oint field (optional)	~
Input a	accumulation raster	▼ 200
Output C:\Av	raster se\Exe5\sol1\Loup.gdb\Snap_to_FAC	
Snap o	listance	30
	OK Cancel Environments	Show Help >>

The result of the Snap Pour Point will be a single raster layer that has the value of the maximum FAC and it will be the size of one 30 m cell (the red cell in the following screenshot, where the "blue" symbol is the original location of the gauge and the "green" cell is the location when previously snapped to the ESRI online watershed tool) :



For the first time through: Search and run the **Watershed** Tool using the Snap_to_FAC as the feature pour point data and FDR as input:

~	Watershed	– 🗆 ×
In	put flow direction raster	
In	put raster or feature pour point data	
19	Snap_to_FAC	⊻ 🖻
P(our point field (optional) /alue	~
0	utput raster	
(C:\Ayse\Exe5\sol1\Loup.gdb\Watershed_FAC	2
		~
	OK Cancel Environments	Show Help >>

Use the Flow direction raster (FDR) for Input flow direction and the Snap_to_FAC for feature point data. It is important to use the "30 m" Snap_to_FAC raster point to make sure that the Watershed tool 'sees'

that the outlet cell is located on the maximum accumulation cell. The result should be a Watershed raster that has the value 1 over the area upstream from the outlet point. The following is a result (in green) when using the filled DEM-based flow direction and flow accumulation tools. The purple line is the basin boundary derived from the online Watershed tool. Notice that there is some disagreement at a few locations along the edge.



Step 5. Delineating the Stream Network

Stream networks can be delineated from a Digital Elevation Model (DEM) using the output from the FLOWDIRECTION and FLOW ACCUMULATION tools. Flow accumulation, in its simplest form, is the number of upslope cells that flow into a particular cell. By applying a threshold value to the values of FLOWACCUMULATION, a stream network can be defined that is comprised of catchments that are of the size of the threshold value. For this exercise we will explore the effect of using a thresholds of 5,000 (a standard value) and 30,000 cells.

Search and open the **Raster Calculator** and apply the query of FAC > 5000 and Watershed_FAC > 0. The "Watershed_FAC > 0" will cause the accumulation to apply only to our watershed. Save the result as STR5000. Run the Calculator a second time and apply the query of FAC > 30000. Save the result as STR30000.

("FAC" > 5000) & ("Watershed_FAC" > 0)

≺	Raste	er Ca	lcul	ator					- 🗆 ×
Map Algebra expression									/
Layers and variables Vatershed_FAC Snap_to_FAC FAC FAC FII Fill ("FAC" > 5000) & ("Watershed_FAC" > 0)	~	7 4 1	8 5 2	9 6 3	/ * +	=== > < (!= >= <=)	& ^	Conditional ^ Con Image: Conditional of the second sec
Output raster C:\Ayse\Exe5\sol1\Loup.gdb\STR5000			OF	(Cancel		Enviror	nments Show Help >>

The result is a raster representing the streams delineated over our watershed that have flow accumulation > 5000 and that are inside the watershed boundary.



The raster image shows the Streams (Blue color) where the flow accumulation is more than 5,000 grid cells within the watershed. Now let's change the color of 0 Values (Cells with Flow Accumulation < 5,000) to no color, you can zoom and see the layout of various streams.

For the 30,000 threshold (results below), the streams are much shorter and less dense. This makes sense, since 30,000 cells must accumulate before we call something a stream.



Step 6. Stream Links

The Stream Link function creates a grid of stream links (or segments) that have a unique identification. A link may be a head link, or it may be defined as a link between two junctions. All cells in a particular link have the same grid code that is specific to that link.

Search and run Stream Link Tool

~	Stream Link	_ 🗆 🗙
Input stream raster		^
STR5000		▼ 🖻
Input flow direction rast	er	
FDR		▼ 🖻
Output raster		
C:\Ayse\Exe5\sol1\Lou	p.gdb\StrLnk5000	🖻 🗸
ОК Са	ancel Environments	Show Help >>

The result is a grid with unique values for each stream segment or link. Symbolize StrLnk5000 with unique values so you can see how each link has a separate value. The streams look like the results from the raster calculator above. Run the same Stream Link tool for the 30,000 cell threshold and call the results StrLnk30000.



Catchments

The Watershed function provides the capability to delineate unique catchments upstream of discrete links in the stream network. Run the **Watershed** tool again but this time use the input raster as the strlnk. Run this tool twice, once using StrLnk5000 and once using StrLnk30000.

47

🔨 Watershed 🗕 🗖 🗙
Input flow direction raster
FDR 🗹 🖻
Input raster or feature pour point data
StrLnk5000 💌 🖻
Pour point field (optional)
Value
C:\Ayse\Exe5\sol1\Loup.gdb\Catchment5000
OK Cancel Environments Show Help >>

The result is a Catchment grid where the subcatchment area draining directly to each link is assigned a unique value that is the same as the link it drains to. This allows a relational association between lines in the StrLnk grid and Area's in the Catchments grid. Symbolize the Catchments grid with unique values so you can see how each catchment has a separate value.



Catchments when threshold is set to 5000.



Catchments when threshold is set to 30000.



Closeup view of catchments and streams when threshold is set to 5000.



Closeup view of catchments and streams when threshold is set to 30000.

Questions: Compare the two catchment grids (based on 5000 and 30,000 thresholds). Which one appears to present the best representation of catchments for purposes of hydrologic modeling? Justify your answer. Based on the close ups, what are the primary differences between the two catchment maps?

Step 7. Conversion to Vector

Let's convert the raster representation of streams derived from the DEM to a vector representation. This is useful to reduce disk storage requirements and to create a continuous vector or each stream segment that can identified in a hydrologic model and that is independent of the raster grid. Search and Run **Stream to Feature** tool for the 30000 threshold data. Remember that the vector result is a feature and should be saved under the feature class **Basedata** that we created earlier. Also make sure to uncheck the Simplify Polylines checkbox.

Stream to Feature 🛛 🗕 🗡
Input stream raster
StrLnk30000 💌 🖻
Input flow direction raster
FDR 🗹 🔁
Output polyline features
C:\Ayse\Exe5\sol1\Loup.gdb\BaseData\DrainageLines_30000
Simplify polylines (optional)
OK Cancel Environments Show Help >>

The "simplify polygons" option can cause streams to "cut corners" that will result in errors when they are later matched with values on an underlying stream order grid during the process of determining stream order.

The result is a linear feature class "DrainageLines_30000" that has a unique identifier associated with each link.

Similarly convert the Watershed and Catchments into polygons by using **Raster to Polygon** tool

🔨 Raster to Polygon — 🗖 🗙
Input raster
Catchment30000 💌 🖻
Field (optional)
Value
Output polygon features
C:\Ayse\Exe5\sol1\Loup.gdb\BaseData\Catchment_30000_poly
Simplify polygons (optional)
✓
OK Cancel Environments Show Help >>
Raster to Polygon — — X
Input raster
Watershed_FAC 🗾 🖻
Field (optional)
Value
Output polygon features
C:\Ayse\Exe5\sol1\Loup.gdb\BaseData\Watershed_FAC_Poly
Simplify polygons (optional)

The results are a Polygon Feature Class of the catchments draining to each link. The feature classes DrainageLine and CatchPoly represent the connectivity of flow in this watershed in vector form and will be used later for some Network Analyses, that requires having these data in vector form. The following screenshot shows the polygons for the 30000 threshold catchments, with the red boundary the polygon created from the Watershed_FAC feature.



If we turn on the drainagelines_30000 polygons that represent the stream network, we get the following:



Turn in

Screenshots of the last two figures showing the polygons of catchments and then also with overlays of the stream segment lines.

Describe (with simple illustrations) the relationship between StrLnk, DrainageLine, Catchments and CatchPoly attribute and grid values. What is the unique identifier in each that allows them to be relationally associated?

Step 8: Strahler Stream Order

Stream order is used to define stream size based on a hierarchy of tributaries,



Search and run tool Stream Order

6	Stream Order	_ 🗆	×
Input stream raster		_	_ ^
STR30000		•	2
Input flow direction raste	r		
FDR		-	2
Output raster			
C:\Ayse\Exe5\sol1\Loup	o.gdb\StreamOrder30000		2
Method of stream orderi	ng (optional)		
STRAHLER			~
			\sim
	OK Cancel Environments	Show He	lp >>

The result is a Raster StrahlerOrder that holds Strahler Order values for each grid cell. Let's now associate these with the streams represented by DrainageLine.

Locate the Zonal Statistics as Table (Spatial Analyst) tool and run it with inputs as follows

🔨 🛛 Zonal Statistics as Table 🚽 🗖 🗙	
Input raster or feature zone data	~
StrLnk30000 💌 🖻	
Zone field	
Value	
Input value raster	
StreamOrder30000 💌 🖻	
Output table	
C:\Ayse\Exe5\sol1\Loup.gdb\OrderTable	
✓ Ignore NoData in calculations (optional)	
ALL V	
	\checkmark
OK Cancel Environments Show Help >>	

The result is a Table "OrderTable" that has zonal statistics from the StrahlerOrder grid corresponding to each link in the StrLnk grid. Open the **DrainageLine** attribute table. Select Table Options \rightarrow Add Field. Specify the name StrahlerOrder and leave other properties at their default. (Strahler Orders are small integer numbers that should fit in a Short Integer data type)



2 Ŧ Yes OK Cancel

х

Select Table Options → Joins and Relates → Join, then specify the Join data as follows

Table						Join Data 🛛 🕰
ii - Ma	- 🔁 - 🏪 👧 🖾 🚑 🗙 Find & Replace	_				Join lets you append additional data to this layer's attribute table so you can, for example, symbolize the layer's features using this data.
	Select By Attributes Clear Selection Switch Selection Select All Add Field Turn All Fields On Show Field Aliases		id_code from_node to 1 1 1 2 2 2 3 3 3 4 4 4 5 5 5 6 6 6 7 7 8 8 8 9 9		What do you want to join to this layer? Join attributes from a table	
	Arrange Tables Restore Default Column Widths Restore Default Field Order Joins and Relates	10 11 Widths 12 14 der 13 22 14 14 14	11 13 14 22 45		Show the attribute tables of layers in this list Ghoose the field in the table to base the join on: VALUE	
	Related Tables	•	Ren	nove Join(s)	۲	Join Options <u>K</u> eep all records All records in the target table are shown in the resulting table.
						Unmatched records will contain null values for all fields being appended into the target table from the join table. Keep only matching records If a record in the target table doesn't have a match in the join table, that record is removed from the resulting target table. Validate Join

About joining data

OK

Cancel

The DrainageLine table now displays many more columns because it has included all the columns from OrderTable. Since the Strahler Order is the same for each link, the fields MIN, MAX, MEAN, MAJORITY, MINORITY, MEDIAN all hold the same value, the stream order and any one of these can be copied into the StrahlerOrder field we just created.

Right Click on the StrahlerOrder field header and select Field Calculator. Click Yes to the warning about working outside an edit session, then double click on the OrderTable. MIN field so that the Field Calculator displays as follows and click OK.



Notice that the StrahlerOrder field is now populated with the minimum OrderTable. MIN values. Remove all Joins from the DrainageLine table.

4	Find and Replace							
	Select By Attributes	-	StrahlerOrder		OBJECTID *	Value *	COUNT	
5	Clear Selection	.5179	49	1	1	1	282	
3	Switch Selection	.2588	18	1	2	2	211	
-	Switch Selection	.7147	'18	1	4	4	409	
	Select All	.9089	57	3	6	6	463	
	Add Field	1.589	65	3	8	8	35	
-	Turne All Fields On	.5901	49	2	12	12	32	
	Turn All Fields On	.0434	20	1	5	5	2/9	
	Show Field Aliases		:65	2	16	16	101	
	Arrange Tables	2 777	37	1	10	10	123	
Alla	Analige Tables	6316	81	2	11	11	95	
	Restore Default Column Widths	.4474	.67	1	18	18	49	
	Restore Default Field Order	.8106	26	1	19	19	43	
_		6066	01	2	10	10	405	
	Joins and Relates		Join		21	21	60	
	Related Tables	•	Remove Join(s)	•	OrderTable	22	218	
	Caracter Caracte				D 41	9	571	
U	Create Graph		Relate		Remove Al	I Joins 26	356	
	Add Table to Layout		Remove Relate(s)	•	24	24	784	
	Reload Cache	7020	900		20	20	300	
	Reload Cache	1230	24	2	7	15	192	
þ	Print	6303	132	1	13	13	371	
	Reports	- COAC	100	2	13	13	571	
	Francis							
	Export	53 Se	elected)					
	Appearance							

Symbolize the DrainageLine feature class using Strahler Stream Order for color and line width.

					Layer	Properties				×
General	Source	Selectio	n Display	Symbology	Fields	Definition Query	Labels	Joins & Relates	Time	HTML Popup
Show:			D			I		h		1
Feature	s		Draw quar	itities using	j symdo	I SIZE TO SNOW (exact va	iues.	mpoπ	
Catego	ries		Fields				Data			
Quantit	ies		Value:	StrahelrC	order	~	[1	
Grad	uated col uated syn	ors nbols	Normalizatio	n: none		~		Exclude		
Charts	ortional sy	mbols	المعا	Helenour	lleite			B + 11		
Multiple	e Attribut	tes	JENE.	UNKNOW	TOHILS	*		Rotation		
			Min Value	mbols to disp	Value	Legend: 1	~			
								OK Ca	ancel	Apply

Turn In: A layout showing the stream network and catchments attractively symbolized with scale, title and legend. The symbology should depict the stream order for each stream.



Part 3. Network Analysis

3.1. Creating a Geometric Network

Some of the real power of GIS comes through its use for Network Analysis. A Geometric Network is an ArcGIS data structure that facilitates the identification of upstream and downstream connectivity. Here we step through the process of creating a geometric network from the vector stream network representation obtained above, and then use it to determine some simple aggregate information.

Zoom in to near the Outlet. You will see that there is not perfect agreement between the NHDPlus streams and the DrainageLine stream we delineated (see previous screenshots). These are due to differences between the raster DEM and vector mapping of NHD.



The redish line is the primary Loup River from NHD and the thick blue is the Drainageline developed from DEM above.

To perform Network Analysis we need an outlet at the downstream end of our stream. Here we use the point in the **GageSnap** feature class determined from the initial Watershed delineation. This needs to be edited to move right on to the downstream end of the stream network.

Open the Catalog window and right click on Loup.gdb\BaseData \rightarrow New Geometric Network. You may have to first close ArcMap to free up the BaseData.



Click Next on the New Geometric Network screen. Enter the name LoupNet, then click Next

o features within so	crified tolerance:
No	
Yes 0.001	Meters
Line ends and junction connect. If they do i	ons must match up precisely for features to not match up they can be moved within the limits e. The default value is based on the XV tolerance
of the snap tolerand of the feature datas	et.
or the snap tolerand of the feature datas	et.

New Geometric Network	×
Select the <u>f</u> eature dasses you want to build your network fro	m:
Contour10m	Select All
GageSnap	<u>C</u> lear All
Gauge	<u>U</u> navailable
< Back Next :	> Cancel

At the prompt to Select roles for the network feature class, switch the role under Sources and Sinks for Gauge to Yes. This will be used as a Sink for the network. This is a location that receives flow. Click Next.

Feature Class Name	Role	Sources & Sinks
DrainageLines_30000	Simple Edge	<none></none>
🛃 GageSnap	Simple Junction	Yes

Do not add any weights at the prompt about weights, just click Next. Click Finish at the summary prompt. The result is a Geometric Network LoupNet that can be used to perform network operations.

Open ArcMAP and the project, and bring in the **Utility Network Analyst** by right clicking on the 'grey area' of the ArcMAP toolbar (some empty space near the top).



Utility Network Analyst			- X
LoupNet	Flo	w 🕶 🖳 Analysis 🕶 🏒 🔻 Find Common Ancestors	\checkmark X
		Display Arrows For 🔸	
	∢	Display Arrows	
		Prop Display Arrows	
		Turn flow direction arrows on or off	

The result is a set of black dots on each network link. These indicate that flow directions for the network **are not assigned**.



To assign network flow direction, the Outlet needs to have a property called AncillaryRole set to be the encoding for Sink.

Open the Editor Toolbar and select Start Editing (Click Continue if there is a warning). You may need to right click on the same 'grey area' near the top in ArcMAP to make the Editor tool bar visible:

	Sol1_v2.mxc	d - ArcMap	
Geoprocessing Customize Windows Help :1.220,263 ✓ ✓ 💭 🕞 🕞 🖕 ③ ● Ø ● Ø 🕞 🕞 👘 🁘 👘 🁘 👘 🆿 👘 👘 👘 👘 🁘 🁘 🆿 🁘 🆤 🁘 🁘 🁘 🁘 🁘 🁘 🁘 🁘 🁘 🁘 <td></td> <td>: Drawing • 🕅 🕤 🐨 🖪 🗌 • 🗛 • 🖄 🖗 Ar</td> <td>rial</td>		: Drawing • 🕅 🕤 🐨 🖪 🗌 • 🗛 • 🖄 🖗 Ar	rial
	Start E	diting ×	
	This map contains data from more than one di Please choose the layer or workspace to edit.	atabase or folder.	
	Source C:\ayse\exe5\sol1 C:\Ayse\Exe5\sol1\Landscape.gdb C:\Ayse\Exe5\sol1\Loup.gdb	Type ArcInfo Workspace File Geodatabase File Geodatabase	N N
	About editing and workspaces	OK Cancel	4

Use the Editor Edit Tool to select the **GaugeSnap** symbol and move it to the intersection of the watershed and the DrainageLine. You may have to 'work a little' to get the gauge symbol highlighted. There may be a little 'dropdown box' next to the symbol that shows up to help you select only the gauge. Once selected, you can move the gauge up to the outlet and on the drainage line.



After moving the gauge, click on the Attributes button on the Editor Toolbar to open the attributes



display panel.

The panel should show that the AncillaryRole for this point is "None". Change it to Sink.

Attributes	□ ×
GageSnap ■ 1	
	&l
OBJECTID	1
PourPtID	1
Enabled	True
AncillaryRole	Sink 🗸 🗸
AncillaryRole	
Short Integer	Û
Create Features	ibutes

Next, click on the Set Flow Direction Tool on the Utility Network Analysts toolbar

Utility Network Analyst		\frown		- X
LoupNet	✓ Flow	· 4 ₂	Analysis 🔻 夫 🔻 Find Common Ancestors	\checkmark \times
	· · · ·		l I	

You should see the black dots switch to arrows indicating that Flow in the network is now set towards the designated Sink at the outlet. This network is now ready for Analysis.

Stop Editing by **Stopping the Editor** (using the Editor menu), saving edits and preventing anything else from getting changed.



3.2. Analysis Using a Geometric Network

Geometric Network analysis can be used to identify the number of stream links upstream of a point, the total length of the upstream stream links, the total upstream area, drainage density (total length/total area), number of downstream links along path to outlet, and distance to the outlet along the streams.

Let's identify one location of interest as a point on the Middle Loup River about ½ way up the basin (see image below), **just above** the entry of Victoria Creek, a large side tributary. A close-up snapshot of location is below.

Zoom to the vicinity of that location (see location below) and place an edge flag using the Utility Network Analyst **Add Edge Flag Tool**. You may want to add US Topo map to identify the location of interest.



If you place the edge flag on a wrong stream, or put more than one edge flag, you can **clear the flags** located under **the Analysis** tab of **Utility Network Analyst.**

LoupNet	v Flow ◄ طي Ar	nalysis 🕶 💐 👻 Find Common Ancestc 🗸 🗸 🗸
		Disable Layers 🔸
		Clear Flags
		Clear Flags
		Clear Opti Clears the flags from the current network





The above is "zoomed in" of the Victoria creek confluence with the Middle Loup River. Overlying the topo map. The edge flag is shown as green symbol and it is placed on the Middle Loup above the confluence with Victoria Creek. Notice, that drainage lines do not agree perfectly with the topo map.

The topo map is older, but it shows more meandering of the streams which is real and **is missed by the steepest descent rule!!** This could have serious impact in models that estimate velocities and erosion of streams, transit times, and environment characteristics such as fish habitat (pools and riffles). Please always remember this!

You can bookmark this zoomed in view so that you can come back to it later. You can do this by creating the bookmark and giving it a name:

2											
File	Edit	View	Воо	kmarks	Insert	Selection	Geoproc	essing	Customize	Windows	Help
	2 🖬	8	<u>a</u>	Create I	Bookmar	k				🗉 🇊 🐻	N
•	I . (191	03		Manage	e Bookm	arks		Create	Bookmark		
	D (9	8 6		Edge Fl	ag for Mi	iddle Loup n	ear Victor	Create new b	e a spatial boo	kmark. Your	
Table	e Of C	ontent	S					currer	nt extent of yo	ur map and	
°:: () 😞	🗳 🗄						extent	s it easy to get t after navigati	back to that ng away.	3
+) 🗹 D	rainag	eLin	es_300	00			Book	marks are liste	d in the	60
-		ontour	10m	I				in you	ir map docum	ient.	35
									185-175-	4500	
Now that we placed the edge flag on our location, we can Set the Trace Task to Trace Upstream and press Solve.

LoupNet	v Flow ◄ 🖧 Analysi	s 🔸 🕹 Find Common Ancestc 🗸 🧹 🕫	
		Find Common Ancestors	
	1. m	Find Connected	
		Find Loops	
		Find Disconnected	
		Find Path	
		Trace Downstream	
		Find Upstream Accumulation	
		Trace Upstream	
10			
-			
	I de		

Next click on the Solve button (see below).

Flow • 🖕 Analysis • 🔀 • Trace Tas	Trace Upstream	÷ 🔀 ÷
		Solve

The result is a "red" highlighting of the link that has the edge flag and all links upstream.



Now we can create a table of segment lengths, etc. in the reaches upstream of our point. Go to **Select Analysis** and then **Options**



Switch the Results format to **Selection**. Select **Analysis Clear Results** and **run the trace again**.

Analysis Options	Flow 🕶 🚔 🛛 Analysis 🕶 💐 🔹 Trace Ta
General Weights Weight Filter Results	Disable Layers 🕨
	Clear Flags
Results format	Clear Barriers
Drawings	Clear Results
Draw individual elements of complex edges	Options
Trace task result color	
Selection	
Results content	
Results include:	
All features	
Features stopping the trace	
Of these results include:	
✓ Edges	
✓ Junctions	
OK Cancel Apply	

Now Open the **Attributes table** for the **DrainageLine** (the one with 30,000 threshold) feature and see the selected records

able 🗄 • 🔁 • 🏪 👧	🖸 🚑 🗙 🖣) ¶) @ >	<					□ ×
rainageLines_	30000						Sele	ction Statistics of DrainageLines_30000
OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length		
13	Polyline	13	19	19	21	1498.810626	Field	
15	Polyline	15	21	23	21	2107.740189	Shape Length	
29	Polyline	29	34	33	39	3069.809594	ondpe_cengu	Frequency Distribution
30	Polyline	30	39	34	39	12126.338192	Statistics:	40 61
36	Polyline	36	27	21	44	20676.546786	Count 169	
37	Polyline	37	41	40	44	1361.21524	Minimum: 258.631139	30 -
38	Polyline	38	49	50	51	930.503594	Maximum: 62030.706992	20
39	Polyline	39	40	39	51	3587.338494	Sum: 2073844.445818	
43	Polyline	43	50	44	54	4012.211184	Mean: 12271.26891	
50	Polyline	50	51	51	60	4449.515533	Standard Deviation: 10762.323294	
51	Polyline	51	54	60	54	3882.840597	Nulls: 0	258.6 20801.9 41345.2 61888.5
52	Polyline	52	62	61	60	11822.799909		10530.3 31073.6 51616.9
66	Polyline	66	55	54	76	9594.478996		
72	Polyline	72	79	71	76	6764.009951		
80	Polyline	80	85	85	94	4046.319594	<	
85	Polyline	85	69	76	98	62030.706992		
86	Polyline	86	72	69	98	24907.832814	1 Irue	
88	Polyline	88	76	77	101	22854.544526	1 True	
89	Polyline	89	101	99	101	5011.951589	2 True	
90	Polyline	90	95	103	94	6691.821726	2 True	
91	Polyline	91	96	101	103	8414.134649	2 True	
92	Polyline	92	97	96	99	25967.064068	1 True	
94	Polyline	94	102	108	99	6048.218513	1 True	
95	Polyline	95	100	98	109	3696.39804	3 True	
96	Polyline	96	94	94	109	46163.377204	2 True	
97	Polyline	97	105	112	103	9547.373957	1 True	v 7
1 101	Debulies	404	110	100	110	2000 207722	0 Trus	
• • •		/ (169 out	or opd Selected)					
PrainageLines_300	000							
								(*

Right click on column header Shape_Length and see the Statistics

These records will differ based on where you put your **Edge** Flag and in how the various catchments were created (5000 vs. 30000 etc).

Question: Record the total length and number of stream links upstream of your flag.

Switch the Trace Task to **Trace Downstream** and press **Solve** again. Notice how the selected stream links switch to those downstream from the flag.



The following is the view of the entire basin showing downstream of our edge flag highlighted until the outlet.



Question: Determine the total length of these links as an estimate of the distance along the rivers from your Flag edae to the downstream outlet.

Join the **Catchment30000** attribute table into the **DrainageLine**30000 table (operate on the Drainageline feature and click join) using the **Grid_Code** for a field that join will be based on (see below). This provides access to the area draining directly to each stream link.

Join Data ×
Join lets you append additional data to this layer's attribute table so you can, for example, symbolize the layer's features using this data.
What do you want to join to this layer?
Join attributes from a table
1. <u>Choose the field in this layer that the join will be based on:</u>
grid_code V
2. Choose the table to join to this layer, or load the table from disk:
🗞 Catchment_30000_poly
\checkmark Show the attribute tables of layers in this list
3. Choose the field in the table to base the join on:
gridcode
Join Options
All records in the target table are shown in the resulting table. Unmatched records will contain null values for all fields being appended into the target table from the join table.
◯ Keep only <u>m</u> atching records
If a record in the target table doesn't have a match in the join table, that record is removed from the resulting target table.
<u>V</u> alidate Join
About joining data OK Cancel

×	×										30000	inageLines
		C 1 A	Shape	Shape Length	gridcode *	ld	OBJECTID *	Enabled	StrahlerOrder	Shape Length	to node	from node
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	scending	Sort De	2158	13049.1178	369	448	448	True	5	2526.287193	371	370
	ed Sorting	Advand	16049	36364.367	374	453	453	True	5	1748.83989	372	371
	arize	Summa	45815	55226.8368	373	472	472	True	5	6343.265852	382	372
		Caratina	1550 📡	35993.3008	389	492	492	True	5	2790.867183	386	382
	2011	Statisti	9614	29499.6654	388	496	496	True	5	2499.760201	387	386
_	alculator	Field C	8679	70564.1882	391	499	499	True	5	11762.509252	392	387
	Statistics	Calcul	4385	15151.8196	399	479	479	True	5	2017.815242	395	392
t of stati	Generates a report or	Turn F	5680	16079.482	412	487	487	True	5	3195.051978	408	395
es in this	the selected values in	Tunn	15693	39580.2634	416	498	498	True	5	5357.777107	414	408
and is dis	field. This command	Freeze	35560	58566.42	420	509	509	True	5	5701.027941	426	414
imeric. If	this field is not nume	Delete	15198 🗙	29561.509	440	523	523	True	5	4814.897663	441	426
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	records.	177609	40639353.	57082.162	471	595	595	True	5	4863.933668	484	469
-		917513	7530834.	19666.4434	482	575	575	True	5	3146.015832	491	484
		113651	35029474.	59741.4596	497	607	607	True	5	5022.029039	503	491
	260938	5260875.	18676.9366	503	601	601	True	5	2074.35416	508	503	
		995982	3735775.	14286.0012	523	617	617	True	5	1929.067209	523	522
		160964	47930188.	52629.3806	513	627	627	True	5	11819.503263	510	523
		617663	41138476.	51825.4064	516	625	625	True	5	7549.226352	528	508
		176268	956.	123.6884	526	631	631	True	5	7325.268987	522	529
		396232	39848596.	46197.5888	530	643	643	True	5	6487.265106	541	528
		352537	1912.	185.5326	529	621	621	True	5	20329.811454	529	558
	~	335022	394900.	4514.624	558	662	662	True	5	1192.242502	558	559
		<u> </u>		70050 054		000		-	-	0000 700705	500	

Evaluate the total area upstream of the Flag edge using Shape_Area Statistics.



You can also, by placing a flag at an upstream link, determine the flow path (and its length) from any distant link to the outlet.

Now, evaluate the length of the longest flow path by choosing a link that appears to have the longest flow path (a bit of trial and error may be necessary) (see screenshot below).



Prepare a layout that illustrates the longest flow path in the Loup River Basin

Turn In:

A table and screen shots of an Edge Flag Point for the longest flow line, showing the number of upstream stream links, the total length of upstream stream links, the total upstream area, drainage density (total length/total area), number of downstream links along path to outlet, distance to outlet along the streams.

A layout illustrating the longest flow path in the Loup River watershed and giving the length in km.

Summary of Items to turn in: **PART 1**

- 1.3. The number of columns and rows, and grid cell size in the Loup River basin DEM. The minimum and maximum elevation values in the Loup River basin DEM.
- 1.5. Note the "Sum" value and the units of the length of the Loup and Middle Loup River from its source to this outlet at Genoa gauge.
- 1.5. Prepare a layout showing the topography (DEM), Basin Outline, NHDPlusv streams and Loup River Main stem and Middle Loup streams for the Loup River Basin. Include a scale bar and North arrow and appropriate title, labeling and legend so that the map is self-describing.

PART 2

- **Step 1:** The above figure on the left is a closeup of the boxed area in the west central part of the Loup River Basin. That figure, with contours and colorized differences (showing filled pits), may give you a better idea of what these features are. (The circled area is commented on later).
 - Question: what are these, and should they be filled?
- **Step 3:** Turn in the drainage area into the gauge station in both number of 30 m grid cells and as km2 as estimated by the flow accumulation tool. Compare this to the area of the basin, as a 'check' where the area of the basin is obtained from two different sources: a) from the attribute table for the basin, and b) from the USGS properties menu for the Genoa gage as shown below. Also, determine why the "Drainage area" in the USGS Description has a different value than the "contributing drainage area" for this particular basin(think about what we have discussed under the flow direction analysis).
- **Step 6:** Questions: Compare the two catchment grids (based on 5000 and 30,000 thresholds). Which one appears to present the best representation of catchments for purposes of hydrologic modeling? Justify your answer. Based on the closeups, what are the primary differences between the two catchment maps?
- Step 7:
 - Turn in screenshots of the last two figures showing the polygons of catchments and then also with overlays of the stream segment lines.
 - Describe (with simple illustrations) the relationship between StrLnk, DrainageLine, Catchments and CatchPoly attribute and grid values. What is the unique identifier in each that allows them to be relationally associated?
 - A layout showing the stream network and catchments attractively symbolized with scale, title and legend. The symbology should depict the stream order for each stream.

PART 3

3.2.

- Question: Record the total length and number of stream links upstream of your flag.
- Question: Determine the total length of these links as an estimate of the distance along the rivers from your Flag edge to the downstream outlet.
- A table and screen shots of an Edge Flag Point for the longest flow line, showing the number of upstream stream links, the total length of upstream stream links, the total upstream area, drainage density (total length/total area), number of downstream links along path to outlet, distance to outlet along the streams.
- A layout illustrating the longest flow path in the Loup River watershed and giving the length in *km*.