Exercise 4. Watershed and Stream Network Delineation GIS in Water Resources, Fall 2014 Prepared by David G Tarboton and David R. Maidment

Purpose

The purpose of this exercise is to illustrate watershed and stream network delineation based on digital elevation models using the Hydrology tools in ArcGIS and online services for Hydrology and Hydrologic data. In this exercise, you will select a stream gage location and use online tools to delineate the watershed draining to the gage. National Hydrography and Digital Elevation Model data will be retrieved for this area (Logan River Basin) from online services. You will then perform drainage analysis on a terrain model for this area. The Hydrology tools are used to derive several data sets that collectively describe the drainage patterns of the basin. Geoprocessing analysis is performed to fill sinks and generate data on flow direction, flow accumulation, 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 detailed information on the connectivity of the landscape and watersheds 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.

Learning objectives

- Do an online watershed delineation and then extract the data for that watershed to perform a more detailed analysis.
- Identify and properly execute the sequence of Hydrology tools required to delineate streams, catchments and watersheds from a DEM.
- Evaluate and interpret drainage area, stream length and stream order properties from Terrain Analysis results.
- Develop a Geometric Network representation of the stream network from the products of terrain analysis.
- Use Network Analysis to select connected catchments and determine their properties.

Computer and Data Requirements

To carry out this exercise, you need to have a computer which runs ArcGIS 10.2 or higher and includes the Spatial Analyst extension. No data is required to start this exercise. All the necessary data will be extracted from ArcGIS.com services. To use these services you need an ArcGIS.com account that has been linked to an ArcGIS license.

The exercise is divided in to the following activities that each comprise a sequence of steps

- 1. Online Watershed Delineation and Data Retrieval.
- 2. Hydrologic Terrain Analysis
- 3. Network analysis

Before we start

In ArcMap select **Customize** → **Extensions**

Customize		Windows	Help	
	Toolba	rs	+	
	Extensions			
	Add-In	Manager		

Select the Spatial Analyst extension. We will be using this during the exercise.

Extensions	×
Select the extensions you want to use.	
Description:	
3D Analyst 10.2 Copyright ©1999-2013 Esri Inc. All Rights Reserved	
Provides tools for surface modeling and 3D visualization.	
	Close

The USGS NWIS website for the Logan River:

<u>http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=10109000</u> gives the following information about the Logan River Stream Site.

USGS 10109000 LOGAN RIVER ABOVE STATE DAM, NEAR LOGAN, UT

	Available data for this site	SUMMARY OF ALL AVAILABLE DATA	•	GO	
S	tream Site				
	DESCRIPTION: Latitude 41°44'36", Longitude 111° Cache County, Utah, Hydrologic Unit	46'55" NAD27 16010203			
	Drainage area: 214 square miles Datum of gage: 4,680.00 feet above	NGVD29.			

Note the Latitude, Longitude and geographic coordinate system (NAD27). Note also the drainage Area.

Compute the latitude and longitude in decimal degrees in an Excel Spreadsheet.

	Α	В	С	D	E	F	G	Н	I	
1	SiteID	LatDeg	LatMin	LatSec	LongDeg	LongMin	LongSec	LatDD	LongDD	
2	10109000	41	44	36	111	46	55	41.74333	-111.78194	
-										

Online Watershed Delineation and Data Retrieval

1. Watershed draining to a stream gage

Open ArcMap. Click on the arrow part of the **bound** icon to **Add Basemap** and select **Topographic**. You should see a display of the World_Topo_map.

Click on the control of the Logan River Stream Gage.

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 NAD27 coordinate system. Click **Edit** to edit the coordinate system

Display XY Data		×				
A table containing map as a layer	g X and Y coordinate data can be added to	the				
Choose a table fr	rom the map or browse for another table:					
Sheet1\$	<u> </u>	- 6				
Specify the field	ds for the X, Y and Z coordinates:					
X Field:	LongDD	•				
Y Field:	LatDD	•				
<u>Z</u> Field:	<none></none>	•				
Coordinate Sys	tem of Input Coordinates					
Description:						
Name: WGS	Projected Coordinate System: Name: WGS_1984_Web_Mercator_Auxiliary_Sphere					
Geographic C	oordinate System:					
Name, GC3						
		Ŧ				
	•					
Show <u>D</u> etai	ls Edit.					
Warn me if the resulting layer will have restricted functionality						
About adding XY	data OK Car	icel				

Locate **Geographic Coordinate Systems** \rightarrow **North America** \rightarrow **NAD1927** in the Spatial Reference Properties window and click OK.

5	Spatial Reference Properties	×
	XY Coordinate System	
l	🏹 🔻 🛛 Type here to search 🔹 🍳 🔊 🖗 🖛 🔆	
l		*
L	🖃 🗁 Geographic Coordinate Systems	
	🗄 🔚 Africa	
L	🗄 🚞 Antarctica	
	🗄 🧮 Asia	



Click OK again to Display XY data and OK to acknowledge that the table will not have an Object-ID field. A dot should appear on your map showing you where the Logan River stream site is.



Zoom in on this to get a sense for the topography near Logan. I also changed the symbology of the point to make it easier to see.



Open ArcCatalog. Double Click on Add ArcGIS Server



At the prompt check that Use GIS services is checked and click Next

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
	< Back Next > Cancel

Enter the Server URL <u>http://elevation.arcgis.com/arcgis</u> and your ArcGIS.com user name and password. (with an older version of ArcGIS you may need to enter <u>http://elevation.arcgis.com/arcgis/services</u>)

General	The second second	×
Server URL:	http://elevation.arcgis.com/arcgis	
	ArcGIS Server: http://gisserver.domain.com:6080/arcgis	
Authentication (Opt	ional)	
User Name:	dtarb	
Description		
Password:		
	Save Username/Password	
About ArcGIS Server	connections	
	< <u>B</u> ack Finish	Cancel

Note that your user name and password needs to have been associated with an ESRI license as arranged by one of the instructors. Click Finish. You should see arcgis on elevation.arcgis.com displayed in your Catalog under GIS Servers.



Expand the tool to see the services available



In a similar manner add the service <u>http://hydro.arcgis.com/arcgis</u>. After expanding the tools you should see the Watershed and TraceDownstream tools



In elevation.arcgis.com **NED30m** is the USGS National Elevation Dataset digital elevation model. Drag and drop this onto your map to add this data. Close the coordinate systems warning.



The initial appearance is rather dark. Open Properties and Symbology. Change the color ramp and using the slider bar to expose the bottom of the Symbology Window set the Statistics to "From Current Display Extent" so that you get more differentiation within the display.

L	ayer Properties								x
	Selection	Fields	Def	inition Query	C. and	St	atus	Time	
L	General Source	Key Metadata	Extent	Display	Sync	Joiogy	Server Functi	ons Mos	aic
	Show: Classified Stratched	Stretch values alo	ng a color r	amp			Ē	3	
L	Discrete Color		-85.6	Low :	-85.608	8		•	
l		Color Ramp:					-]	
l		Display Backg	round Value:	0			as 🗾 ,		
		Use hillshade	effect	Z: 1		Display N	loData as 🗾	•	
l		Type: Mir	nimum-Maximu	um	•		listograms	=	
L						V I	nvert	_	
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	About symbology	Max:						-	
						ОК	Cancel	Арр	bly

And here is the result, a fairly nice color shaded terrain map display.



Now let's set up a folder and geodatabase for our work. First create a folder (e.g.

C:\Users\dtarb\Dave\Ex4). Save the map document in this folder (Ex4.mxd). This serves to establish a place on disk where temporary files can be written and a Home location in Catalog. Without this some of the geoprocessing tools fail.

Right click in Catalog Home and create a New File Geodatabase



Set the name to **Logan.gdb**.

Right click Logan.gdb to create a new Feature Dataset

Catalog			Ψ×	
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Location: 间 Logan.gdb			-	
🗉 ன Home - Scratch\Ex4				
■ Logan.gdb ● ~\$LoganGa ● Ex4.mxd ● ● ● ● ● ● ● ● ● ● ● ● ● ○ ● ○ ● ○ ● ○ ○ ○ ● ○ ○ ○ ● ○ ● ○ ● ○ ● ○ ● ○ ● ○ ● ○ ● ○ ○ ○ ● ○ ○ ○ ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● <td>Copy Paste Delete Rename Refresh Make Default Geodatabase</td> <td></td> <td></td> <td></td>	Copy Paste Delete Rename Refresh Make Default Geodatabase			
Database Conr Add Databa	Distributed Geodatabase		b Feetur	- Dataset
Add ArcGIS	Import Export Share as Geodata Service	•	Feature FNew	r Feature Dataset

Set the name to **Basemap**. Click Next.

New Feature	Dataset	
Name:	Basemap	
		<back next=""> Cancel</back>

For the coordinate system scroll to the bottom and expand the Layers folder. Select

North_America_Albers_Equal_Area_Conic. This is the coordinate system of NED30m, so we choose to use this for our work here. Click Next.

New Feature Dataset
Choose the coordinate system that will be used for XY coordinates in this data. Geographic coordinate systems use latitude and longitude coordinates on a spherical model of the earth's surface. Projected coordinate systems use a mathematical conversion to transform latitude and longitude coordinates to a two-dimensional linear system.
🏹 👻 Type here to search 🔹 🍳 🔬 🕼 👻 🔆
Current coordinate system:
North_America_Albers_Equal_Area_Conic WKID: 102008 Authority: ESRI Projection: Albers False_Easting: 0.0 False_Northing: 0.0 Central_Meridian: -96.0 Standard_Parallel_1: 20.0 Standard_Parallel_2: 60.0 Latitude_Of_Origin: 40.0 Linear Unit: Meter (1.0)
< <u>B</u> ack <u>N</u> ext > Cancel

Click Next at the vertical coordinate system. We do not need to set a vertical coordinate system. Click Finish at XY Tolerance leaving the defaults. Now you have a feature dataset Basemap in the Logan geodatabase.

Right click on Sheet1\$Events (the XY events layer from the gage site spreadsheet) and select Data / Export Data.



Set the Output feature class to **Gage** in the Basemap feature dataset and click OK.

Export Dat	a 🛛 🔍		
Export:	All features		
Use the s	ame coordinate system as:		
🔘 this lay	ver's source data		
🔘 the da	🔘 the data frame		
 the feature dataset you export the data into (only applies if you export to a feature dataset in a geodatabase) 			
Output fe	ature dass:		
C:\Users	s\dtarb\Dave\Ex4\Logan.gdb\Basemap\Gage		
	OK Cancel		

This serves to project the geographic coordinates of this site feature class to the North America Albers coordinate system of the Basemap feature dataset and also to make it a permanent feature class. Add it as a layer and remove the spreadsheet and XY Events layer (Sheet1\$ Events).

Now locate the Watershed tool in the Hydrology toolbox as part of hydro.arcgis.com in Catalog.



Open the **Watershed** tool and set Input Points to **Gage** (the Logan River stream site) and Data Source Resolution to FINEST. Leave other inputs at their defaults and click OK to run the tool.

₹ Watershed	
Input Points	Data Source Resolution (optional) 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 burdencies database. Since many
Point Identification Field (optional) Snap Distance (optional)	elevation sources are distributed with units of arc seconds, we provide an approximation in meters for easier understanding.
Snap Distance Units (optional) Meters Data Source Resolution (optional)	• <i>Blank</i> - The hydrologic source was built from 3 arc second, approximately 90 meter resolution elevation data. This is the default.
Generalize Watershed Polygons (optional) Return Snapped Points (optional)	 FINEST- Finest resolution available at each location from all possible data sources.
OK Cancel Environments << Hide Help	Tool Help

When the tool completes you should have an Output Watershed that has been delineated using the online watershed delineation service. Notice that it appears in the GPInMemoryWorkspace part of the map document table of contents. Notice also that there is an Output Snapped Points feature class that contains the outlet point "snapped" or moved to be on the streams. We will use this later on. Note also that this tool does not use the DEM layer that we added. It operates on its own internally processed DEM and can in fact be run without a DEM layer in the map.



Right click on **Output Watershed** and select **Data** \rightarrow **Export Data** to export this delineated watershed and set the output feature class as **Basin** in **Logan.gdb\Basemap**.



This saves the Basin locally on your computer. I symbolized this with a red outline.

Similarly save the Output Snapped Points in Logan.gdb\Basemap\GageSnap feature class. Saving these results locally retains them in case you need to restart ArcMap in which case the GPInMemoryWorkspace is lost.





Note that the GageSnap point is shifted slightly from the Gage point. This is to move it onto the stream flow path in the preprocessed NED30m DEM that underlies the watershed delineation. Note also that the watershed boundary has a stair step shape as it is based on DEM grid cells but that these are skewed relative to the map display. This is because the underlying NED30m DEM coordinate system is different from the display data frame. Let's re-orient the data frame to the coordinate system of the DEM. Right click on the data frame Layers \rightarrow Properties



Select the **Coordinate System** tab and scroll to the bottom. Under Layers select North_America_Albers_Equal_Area and click OK.

Data Frame Prop	erties					X
Feature Cache	Annotation Gro	ups E	Extent Indicators	Frame	Size an	d Position
General	Data Frame	Coord	inate System	Illumina	tion	Grids
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+ (NAD 1983 Cont North_America	iquous Albers_B	ISA Albers qual_Area_Co	nic		
	 ↔ Gage ♦ Basin 					
Current coo	WICS 1094 Wab rdinate system:	Morent	se Anniliser C	abara		Ŧ
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Projection: False_East False_Nort Central_Me	Albers ting: 0.0 thing: 0.0 eridian: -96.0					
Standard_ Standard_ Latitude_C Linear Unit	Parallel_1: 20.0 Parallel_2: 60.0)f_Origin: 40.0 : Meter (1.0)					Ŧ
Transform	nations					
			ОК	Cance		Apply

Click Yes to the warning. The DEM edges should now be aligned vertically. Remove the GPMInMemoryWorkspace layers as we have them saved locally and save the map document.

2. National Hydrography Data Service (NHDPlusV2)

In **Catalog** \rightarrow **GIS Servers** add the <u>http://landscape1.arcgis.com/arcgis</u> ArcGIS service as you did before for elevation services.

General	×						
Server URL:	http://landscape1.arcgis.com/arcgis/services						
	ArcGIS Server: http://myserver:6080/arcgis/services Spatial Data Server: http://myserver:8080/arcgis/rest/services						
Authentication (Optional)							
User Name:	dtarb						
Description of the second s							
Password:							
Save Username/Password							
About ArcGIS Server connections							
About Spatial Data Server connections							
	< Back Finish Cancel						

Add USA_NHDPlusV2 service layer to see the NHDPlus streams. You may need to expand the display to maximum extent and zoom in for the streams to appear.



Under "Tools" in the Landscape 1 service, use "Extract Landscape Source Data" (see image above) and choose NHDPlus V2 Flowlines as the Landscape Layer and Basin as the study area.

Ktract Landscape Source Data	Y Standard		
Choose Landscape Layer NHDPlus v. 2 Flowlines Study Area Basin Study_Area			Extract Landscape Source Data This geoprocessing service extracts data from one of the Landscape Analysis Layer's source datasets based on a study area to a file geodatabase that is delivered in a ZIP file
	OK Cancel Environments << H	Hide Help	Tool Help

Wait until this message box appears.

Extract Landscape Source Data

Open the Geoprocessing Results Window



Identify the Output File NHDPlusv.zip.

Results
🖃 🖫 Current Session
🖃 🖉 - Extract Landscape Source Data [231153_09292013]
Output File: NHDPlusv.zip
🗄 🗸 mputs
🕀 🚰 Environments
🕀 🤑 Messages
🕀 🔨 Watershed [225205_09292013]
n Shared

Double Click to open the output zip file and copy the geodatabase folder **Landscape.gdb** to the folder where you are working (e.g. C:\Users\dtarb\Dave\Ex4). In Catalog right click on your working folder and Refresh so that the Landscape.gdb is visible.



Right click on the NHDPlusv in Landscape.gdb and select **Export → To Geodatabase (single)**

😑 ன Home - Dave	e\Ex4	*		
	liger -			
🕀 🚺 Log	Сору			
💽 Ex4 🗙	Delete			
🕀 🖻 Log	Rename			
🖃 🔂 Folder (Create Lawar			
🗉 🖾 C:\ 🗸	Create Layer			
	Manage	►		
E S Toolbo	Export	•		To CAD
🕀 🛐 My	Load	•		To Coverage
🕀 🐼 Syst	Review/Rematch Addresses			To Geodatabase (single)
🕀 🛱 Databa: 📄	Item Description			To Geodatabase (multiple)
🗆 🛐 GIS Ser 🛴	Properties			To Sha Export To Geodatabase (single)
Add 🛄	Properties	_		To Shar Convert this feature class or
Add ArcIMS Server				shapefile into a feature class.
Add WCS Server			33	
Add WMS Server			÷3	XML Recordset Document

Set the Output Location to Logan.gdb\Basemap and Output Feature Class to NHDPlusv. Leave other inputs at their defaults.

	Ш	The name of the output feature class
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		·

This serves to move the NHDPlusv features into our Basemap feature class converting the projection to be North_America_Albers_Equal_Area_Conic consistent with the rest of our data.



Symbolize **NHDPlusv** from **Logan.gdb** using Gage Adjusted Flow E to give a flow map.

Turn off the NHDPlusv2 service. This is now a local set of NHDPlus vector streamlines for the Logan River Basin.



3. Main Stream Properties

Let's now identify the main stem of the Logan River and determine some of its properties.

Open the attribute table for NHDPlusv. Select By Attributes



Configure the Query to select where gnis_name = 'Logan River'

Select by Attributes
Enter a WHERE clause to select records in the table window.
Method : Create a new selection
OBJECTID comid gnis_name lengthkm reachcode
= 2<> ike 'Chicken Creek' 'Hodge Nibley Creek' 'Hodge Nibley Creek' 'Logan River' 'Logan River' 'Right Fork Logan River' 'Right Tony Grove Creek' Is Get Unique Values on To: SELECT * FROM NHDPlusv WHERE:
gnis_name = 'Logan River'
Cl <u>e</u> ar Verify <u>H</u> elp Loa <u>d</u> Sa <u>v</u> e Apply ⁵ Close

The Logan River main stream should be selected. Close the attribute table.



Right click **NHDPlusv** layer and select **Data** \rightarrow **Export Data** and save the selected features as LoganMain in the Logan.gdb\Basemap feature dataset.

Export Dat	a			
Export:	Selected features			
Use the same coordinate system as:				
🔘 this layer's source data				
🔿 the data frame				
the fe (only a)	 the feature dataset you export the data into (only applies if you export to a feature dataset in a geodatabase) 			
Output fe	Output feature dass:			
C:\Usen	C:\Users\dtarb\Dave\Ex4\Logan.gdb\Basemap\LoganMain			
	OK Cancel			

This is a feature representing just the Logan River. Let's examine its length. Open the attribute table of LoganMain. Note that there are multiple columns that give length. Length (km) is length in km from the NHD. Shape_Length is the far right column and is the length evaluated by ArcGIS when the data was loaded into the geodatabase. All geodatabase features have geometry measures (e.g. length or area). The units of Shape_Length are the units of the feature dataset coordinate system, which are meters in this case. You should note consistency between Length (km) and Shape_Length once units are converted. There is also a column Shape_Leng. This also came from NHDPlus and is incomplete. You can ignore this. Right click on the column header "Shape_Length" of the far right column and select Statistics.

Ta	ble					
0	- B	- 🖫 👧 🕅	⊕ [™] ×			
Lo	ganMain					×
Г	TRASH	TURBIDITY	Impairments_Number	Impairments_String	Shape_Length	
	<null></null>	<null></null>	<null></null>	<null></null>	2932.: 🐂	Sort Ascending
	<null></null>	<null></null>	<null></null>	<null></null>	87.: 🛒	Sort Descending
	<null></null>	<null></null>	<null></null>	<null></null>	2703.	Advanced Serting
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	<null></null>	<null></null>	<null></null>	<null></null>	2550	Statistics
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	<null></null>	<null></null>	<null></null>	<null></null>	507.	Turr the selected values in this numeric
	<null></null>	<null></null>	<null></null>	<null></null>	3143	Free field. This command is disabled if
	<null></null>	<null></null>	<null></null>	<null></null>	1032.	this field is not numeric. If any of
	<null></null>	<null></null>	<null></null>	<null></null>	4173. 🗙	Dele the records in the table are
	<null></null>	<null></null>	<null></null>	<null></null>	802.	currently selected, statistics will
			ar.m.	ar.m.	2025	only be generated for the selected
E						records.
1	• •	0 + +	• 🔲 💻 🛛 (0 out of 47 S	elected)		
N	HDPlusv	LoganMain				

The following Statistics report is generated.

Statistics of LoganMain	
Field	
Shape_Length	Frequency Distribution
Count: 47	15
Minimum: 87.597863 Maximum: 4173 551034 Sum: 53109 683852	10
Mean: 1129.993273 Standard Deviation: 1022.861757	
Nulls: 0	
	87.6 976.5 1865.4 2754.2 3643.1

Note the value of **Sum**. This is the length of LoganMain (the Logan River main stream) in meters.

Now switch to the NHDPlusv tab in Table and click Clear Selection to clear the selection of Logan River main stream segments.

Table				x
🗄 • 🖶 • 🖫 🔂 🖉 🗶 🖂				
NHDPlusv Clear Selection				×
Feature Code	Shape_Leng	Enabled	Stream Lev	*
Stream/River: Hydrographic Category = Perennial	0.036081	True		
Artificial Path	0.001106	True		
Stream/River: Hydrographic Category = Perennial	0.031874	True		
Stream/River: Hydrographic Category = Perennial	0.001285	True		
Artificial Path	0.00454	True		
Stream/River: Hydrographic Category = Perennial	0.028341	True		
Stream/River: Hydrographic Category = Perennial	0.029877	True		
Stream/River: Hydrographic Category = Perennial	0.00622	True		
Stream/River: Hydrographic Category = Perennial	0.02426	True		
Stream/River: Hydrographic Category = Perennial	0.013305	True		
Stream/River: Hydrographic Category = Perennial	0.004626	True		Ŧ
			4	
14 4 0 → →1 📄 🔲 (47 out of 203 Selected)				
NHDPlusv LoganMain				

Locate the column **Shape_Length** (far right), right click and select **Statistics** noting the value of Sum. This is the total length of streams in the Logan River Basin.

Open the attribute table for Basin and look for the far right column **Shape_Area**. This is the Basin area in m². Drainage density is (Total Channel Length)/(Basin Area).

To turn in. Report the main stream length, total stream length, basin area and drainage density for the Logan River Basin as determined from NHDPlus flowlines.

4. Digital Elevation Model

So far we have delineated the watershed and extracted NHDPlus streams for this watershed. 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.

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

K Buffer	
Input Features	Buffer
Basin 🔽 🚰	Creates buffer polygons around input features to a
C: \Users\dtarb\Dave\Ex4\Logan.gdb\Basemao\BasinBuffer	specified distance.
Distance [value or field]	Ξ
Linear unit I000 Meters	INPUT
© Field	•
Side Type (optional)	•
FULL T	
End Type (optional)	DISSOLVE TYPE:
ROUND	NONE
Dissolve Type (optional)	
NONE	
Dissolve Field(s) (optional)	-
OK Cancel Environments << Hide Help	Tool Help

Next search for the **Extract by Mask (Spatial Analyst)** tool and set the inputs as follows. Save the output raster in **Logan.gdb\dem**.

K Extract by Mask			
Input raster NED30m	• 🖻	Extract by Mask Extracts the cells of a raster that correspond to the	^
BasinBuffer Output raster C:\Users\dtarb\Dave\Ex4\Logan.gdb\dem	- 🖻	areas defined by a mask.	
OK Cancel Environments	<< Hide Help	Tool Help	-

The result is a DEM just over the buffered area.



At this point you have extracted all the data you need locally and are ready to begin Hydrologic Terrain Analysis.

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

To turn in. The number of columns and rows, grid cell size, minimum and maximum elevation values in the Logan DEM.

Remove the NED30m and USA_NHDPlusV2 layers as these are no longer needed and save your map document.

Hydrologic Terrain Analysis

This activity will guide you through the initial hydrologic terrain analysis steps of Fill Pits, calculate Flow Direction, and calculate Flow Accumulation (steps 1 to 3). The resulting flow accumulation raster then allows you to identify the contributing area at each grid cell in the domain, a very useful quantity fundamental to much 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 this 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 quite a comprehensive set of information about the hydrology of this watershed, all derived from the DEM.

1. Fill

This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill function modifies the elevation value to eliminate these problems.

Select **Spatial Analyst Tools** \rightarrow **Hydrology** \rightarrow **Fill**. Set the input surface raster as dem and output surface raster as fel in Logan.gdb.

Press **OK**. Upon successful completion of the process, the "fil" layer is added to the map.

Let's examine the impact of Fill on the DEM. Select **Spatial Analyst Tools** \rightarrow **Map Algebra** \rightarrow **Raster Calculator** and evaluate **fil - dem**.

* Raster Calculator	and the second second	Theories of the		
Map Algebra expression	on		*	Map Algebra expression
Layers and v fil dem	7 8 9 / == != & 4 5 6 * >>= 1 2 3 - <=	Conditional A Con Pick SetNull Math Abs Exp Even10		The Map Algebra expression you want to run. The expression is composed by specifying the inputs, values, operators, and tools to use. You can type in the expression directly or use the buttons and controls to help you create it.
"fil" - "dem" Output raster C: \Users\dtarb\Dave	≥\Ex4\Logan.gdb\filminusdem OK Cancel Environ	ments)	Ŧ	 The Layers and variables list identifies the datasets available to use in the Map Algebra expression. The buttons are used to

Select **Spatial Analyst Tools** \rightarrow **Surface** \rightarrow **Contour**. Set the inputs as follows to determine 20 m contours of the original DEM, **dem**.

Contour		
Input raster	^	Contour
dem 🔽 🛃		Creates a line feature class of
C:\Users\dtarb\Dave\Ex4\Logan.gdb\Basemap\Cont20m		contours (isolines) from a raster surface.
Contour interval		
20 Base conteur (optional)		
Z factor (optional)		
1		
	Ŧ	T
OK Cancel Environments << Hide Help		Tool Help

Symbolize the fil - dem and contour layers similar to



and zoom in on the deepest Sink. The image below shows the deepest sink, with topographic map background.



This is Peter Sink. It is a real topographic feature, not an artifact, so it is a bit erroneous to fill it. Nevertheless for the sake of a complete watershed we fill it. The website <u>http://twdef.usu.edu/Peter_Sinks/Sinks.html</u> gives details on the record low temperatures that have been recorded here. Peter Sinks Air Temperatures - Year's Record Low



To turn in. A layout showing the deepest sink in the Logan River basin. Report the depth of the deepest sink as determined by fil-dem.

2. Flow Direction

This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

Select Spatial Analyst Tools → Hydrology → Flow Direction.

🔨 Flow Direction		
Input surface raster	Flow Direction	*
fil	Creater a raster of flow di	raction
Output flow direction raster	from each cell to its steep	est
C: \Users\dtarb\Dave\Ex4\Logan.gdb\fdr	downslope neighbor.	
Force all edge cells to flow outward (optional)		
Output drop raster (optional)		
C:\Users\dtarb\Dave\Ex4\Logan.gdb\drp		
	~	-
OK Cancel I	nvironments) << Hide Help Tool Help	

Set the inputs as follows, with output "fdr" and "drp".

Press OK. Upon successful completion of the process, the flow direction grid "fdr" and percentage drop grid "drp" are added to the map.



To turn in: Make a screen capture of the attribute table of fdr and give an interpretation for the values in the Value field using a sketch.

3. Flow Accumulation

This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

Select Spatial Analyst Tools \rightarrow Hydrology \rightarrow Flow Accumulation.

Set the inputs as follows

K Flow Accumulation	
Input flow direction raster	Flow Accumulation
fdr	
Output accumulation raster	flow into each cell. A weight factor
C: Users (ataro (Dave (Ex4)Logan.gdb (rac	can optionally be applied.
Output data type (optional)	
FLOAT	•
	v
OK Cancel E	vironments << Hide Help Tool Help

Press OK. Upon successful completion of the process, the flow accumulation grid "fac" is added to the map. This process may take **several minutes** for a large grid, so take a break while it runs! Adjust the symbology of the Flow Accumulation layer "fac" to a classified scale with multiplicatively increasing breaks that you type in, to illustrate the increase of flow accumulation as one descends into the grid flow network. Use 8 classes and hit the "Classify" Button to enable you to select "Manual" method and to type in your class breaks into the window in the lower right hand corner.

Classification		×
Classification	Classification Statistics	
Method: Manual	Count:	723104
Classes: 8	Minimum:	585 705
Data Exclusion	Sum:	579,282,916.9
Exdusion Sampling	Mean:	801.1059501
	Standard Deviation:	17,593.63986
Columns: 100 🚔 🔲 Show Std. Dev. 🗍 Show Mean]
8000(;888 ;288 600000 400000 200000	585,705	Break Values % 30 100 300 1,000 3,000 10,000 30,000 585,705
0 146,426.25 292,852.5 439,278.7	5 585,705	ОК
Snap breaks to data <u>v</u> alues	1325 Elements in Class	Cancel

Layer Properties			1	X
General Source Extent	Display	Symbology		
Show: Unique Values Classified	Draw ra	ster grouping values in	to classes	
Stretched Discrete Color	Fields <u>V</u> alue	<value></value>	✓ Normalization	<none></none>
	Classific	ation Manual	Classes 8	✓ Classify
	Color Ram	ip		■ 111111111111111
	Symbol	Range	Label	A
		0 - 30	0 - 30	
		30 - 100	30.0000001 - 10	00 📃
		100 - 300	100.0000001 - 30	0 0
		300 - 1,000	300.0000001 - 1,	000
		1,000 - 3,000	1,000.000001 - 3	,000
		3,000 - 10,000	3,000.000001 - 1	.0,000 +
	Show	class breaks using cell value		Display NoData as
About symbology	🔲 Use hi	llshade effect	Z: 1	
			ОК	Cancel Apply

After applying this layer symbology you may right click on the "fac" layer and Save As Layer File

🖃 🗹 🖬]	🕀 🗞 Versio
	P	Сору
	×	Remove
		Open Attribute Table
		Joins and Relates
		Zoom To Layer
	5	Zoom To Make Visible
	•	Zoom To Raster Resolution
🖃 🗹 🖬	·	Visible Scale Range
	1	Data 🔸
		Edit Features
	\diamond	Save As Layer File
		Create Layer Package
	1	Properties

The saved Layer File may be imported to retrieve the symbology definition and apply it to other data.

Pan and zoom to the outlet where the river leaves the watershed. Turn off unnecessary layers and arrange layer order so that you can see the Basin feature class on top of the fac layer. Use the identify tool to determine the value of "fac" at the point where the main stream exits the area defined by the Basin polygon. This location is indicated in the following figure.



The value obtained represents the drainage area in number of 30.92 x 30.92 m grid cells. Calculate the drainage area in km². Compare this drainage area to the drainage area reported by the USGS at the Logan River stream site (214 mi²) and to the area of the Basin feature class obtained from the online service watershed delineation.

To turn in: Report the drainage area of the Logan River basin in both number of 30.92 m grid cells and km^2 as estimated by flow accumulation. Report the area of the Logan River basin in km^2 as calculated by the arcgis.com watershed function. Report the area of the Logan River basin in km^2 as reported by the USGS for the Logan River stream site. Discuss reasons for any differences.

4. Stream Definition

Let's define streams based on a flow accumulation threshold within this watershed.

Select **Spatial Analyst Tools** \rightarrow **Map Algebra** \rightarrow **Raster Calculator** and enter the following expression, using the name **Str** for the output raster.

Raster Calculator	The Dealer		
Map Algebra expression		^	Map Algebra expression
Layers an \uparrow \diamondsuit fac 7 \diamondsuit drp \diamondsuit fdr \blacklozenge filminusdem \diamondsuit fil \diamondsuit dem \checkmark \bigcirc dem \checkmark \bigcirc \bullet	Conditional A Con Pick SetNull Math Abs Exp Evp 10		The Map Algebra expression you want to run. The expression is composed by specifying the inputs, values, operators, and tools to use. You can type in the expression directly or use the buttons and controls to help you create it.
"fac" > 5000 Output raster C: \Users\dtarb\Dave\Ex4\Logan.gdb\Str		Ŧ	 The Layers and variables list identifies the datasets available to use in the Map Algebra expression. The buttons are used to enter numerical values and operators into the
OK Cancel Environ	ments) << Hide Help		Tool Help

The result is a raster representing the streams delineated over our watershed.



This extends across the buffer area at the downstream end. To ensure that our streams are within the watershed we want lets clip this. Locate the **Extract by Mask (Spatial Analyst)** tool and set the inputs as follows

K Extract by Mask	Sufficient suffer Spin-or and			
Input raster		^	Extract by Mask	*
Str	_			
Input raster or feature mask data			correspond to the areas defined	
Basin	_		by a mask.	
Output raster				
C: \Users \dtarb \Dave \Ex4\Logan.gdb \Strc				
		Ŧ		-
ОК	Cancel Environments << Hide Help		Tool Help	

The result is a stream raster entirely within the Logan River Basin.



5. Stream Links

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

Select **Spatial Analyst Tools** → **Hydrology** → **Stream Link.** Set the inputs as follows and click OK.

* Stream Link	N. San Dantes		
Input stream raster		*	Stream Link
Strc	☑ 🔁		Assigns unique values to sections
Input flow direction raster			of a raster linear network between
Output raster	- <u>-</u>		intersections.
C:\Users\dtarb\Dave\Ex4\Logan.gdb\Strlnk			
		-	
ОК	Cancel Environments		Tool Help

The result is a grid with unique values for each stream segment or link. Symbolize **StrLnk** with unique values so you can see how each link has a separate value.

	(2
$\sim \mathcal{A}$	ا کمپ	7
	$\frac{1}{2}$	}
\sim	vir >	ی لر

6. Catchments

The Watershed function also provides the capability to delineate catchments upstream of discrete links in the stream network.

Select **Spatial Analyst Tools** \rightarrow **Hydrology** \rightarrow **Watershed.** Set the inputs as follows. Notice that the Input raster or feature pour point data is the StrLnk grid. This results in the identification of catchments draining to each stream link. Click OK.

Natershed		
Input flow direction raster	^	Watershed
fdr Imput raster or feature pour point data		Determines the contributing area
Strink 💌 🖻		above a set of cells in a raster.
Pour point field (optional) Value		
Output raster		
C: \Users\dtarb \Dave\Ex4\Logan.gdb \Catchment	-	~
OK Cancel Environments << Hide Help		Tool Help

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



7. Conversion to Vector

Let's convert this raster representation of streams derived from the DEM to a vector representation.

Select **Spatial Analyst Tools** \rightarrow **Hydrology** \rightarrow **Stream to Feature.** Set the inputs as follows. Note that I named the output **DrainageLine** in the **Logan.gdb\BaseMap** feature class.

Notes and the second se	1			٢
Input stream raster		^	Stream to Feature	*
Strink	🗔 🔁			
Input flow direction raster			Converts a raster representing a linear network to features	
fdr	I 🖻		representing the linear network.	
Output polyline features				
C:\Users\dtarb\Dave\Ex4\Logan.gdb\Basemap\DrainageLine				
Si plify polylines (optional)				
		Ŧ		-
OK Cancel Environments	<< Hide Help		Tool Help	

Note here that we uncheck the Simplify polylines option. The simplification can cause streams to "cut corners" that can result in errors.

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

Select **Conversion Tools** \rightarrow **From Raster** \rightarrow **Raster to Polygon**. Set the inputs as follows again avoiding simplification of polygons

🔨 Raster to Polygon		
Input raster	*	Simplify polygons
Catchment 🗾 🚰		(optional)
Field (optional) Value		Determines if the output polygons
Output polygon features C:\Users\dtarb\Dave\Ex4\Logan.gdb\Basemap\CatchPoly		shapes or conform to the input raster's cell edges.
Splify polygons (optional)	-	 Checked—The polygons will be smoothed into
OK Cancel Environments << Hide Help		Tool Help

The result is a Polygon Feature Class of the catchments draining to each link.

Due to the geometry of grid cells in Catchment, you may get multiple polygons for a single Catchment grid code value. Locate the **Dissolve (Data Management)** tool and set the following inputs.

N Dissolve	
Input Features	Dissolve
CatchPoly	
Output Feature Class	Aggregates features based on specified attributes
C:\Users\dtarb\Dave\Ex4\Logan.gdb\Basemap\CatchPolyDissolve	specified attributes.
Dissolve_Field(s) (optional)	
OBJECTID	INDUT
	INFOI
Shape_Length	
Shape_Area	
OK Cancel Environments << Hide Help	Tool Help

This merges all polygons with the same gridcode value and results in a one to one association between DrainageLine features and CatchPolyDissolve reatures.

The feature classes DrainageLine and CatchPolyDissolve represent the connectivity of flow in this watershed in vector form and will be used later for Network Analysis, that is enabled by having this data in vector form.



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

Network Analysis

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.

1. Creating a Geometric Network

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. These are due to differences between the raster DEM and vector mapping of NHD.



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.

Select Start Editing on the Editor Tool. You may get a window that indicates that the map contains data from more than one database of folder. This will occur if you have not removed the unnecessary layers along the way. If this occurs select the layer "GageSnap" as indicated below and click OK.

Q Ex4.mxd - ArcMap	
File Edit View Bookmarks Insert Selection Ge	oprocessing Customize Windows Help
i 🗋 📸 🔚 🥼 % 🏥 🖺 🗙 ᠫ (* 🔶 🛛 1:7.25	• 🗸 🖬 🗊 🗊 🖉 🐌 🚽 🖄 🕾 🦛
i 🔍 🔍 🖉 🎱 X 🖞 53 🗲 🔶 🕅 - 🖾 🔈	🖉 💷 🏭 👫 🚜 💭 💿 💽 🖕 🗄 Drawing - 🖒 💮 🚳 🗔 - A - 🖄
Table Of Contents 🛛 🕂 🗙	
🗞 🧕 🐟 📮 🗉	Editor 🗸 🗙
Gage	Editor▼ トトレノア 毎~ 米I 宮山中× 및 III 西 I III
Output Snapped Points [225205 09292013]	Start Editing
•	Start Editing
🖃 🗹 Basin	Save Edi
	Move edit features or attributes.
□ 🗹 NHDPlusv	Split
Gage Adjusted Flow E	Constru

Select GageSnap as the Layer to edit

Start Editing		×	
This map contains data from more than one database Please choose the layer or workspace to edit.	e or folder.		
📝 🚸 Basin 1kmBuffer			
🛛 😥 🕸 CatchPoly			
🔰 🔗 DrainageLine			
🔰 😥 😳 Gage			
GageSnap			
🗾 💓 LoganMain			
🗾 🔗 Logan Single		=	
NED 30m			
VED30m			
MHDPlusv			
U WOutput Snapped Points [225205_09292013]			
U Voutput Watershed [225205_09292013]	Output Watershed [225205_09292013]		
WAT_Catchment			
		-	
Source	Туре		
C:\Users\dtarb\Scratch\Ex4\Landscape.gdb	File Geodatabase		
C:\Users\dtarb\Scratch\Ex4\Logan.gdb	File Geodatabase		
GPInMemoryWorkspace:{AA9DB0C5-7AD6	In Memory Workspace		
About editing and workspaces	ОК	Cancel	

You may encounter a warning that certain layers are not editable. This can be ignored since the layer GageSnap is not on the list of not editable layers. Click Continue at the warning (if you get it). Click on

the GageSnap point and drag it until it lines up with the DrainageLine Endpoint as shown below. It should snap right on. You may need to turn some other layers off and zoom in to control the snapping.



Select Stop Editing and Save on the Editor.

Now open the Catalog window and right click on Logan.gdb\BaseMap \rightarrow New Geometric Network



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

Vew	v Geometric Network
E	Enter a <u>n</u> ame for your geometric network:
	LoganNet
5	Snap features within specified tolerance:
(No
(⊙ <u>Y</u> es
	0.001 Meters
	Line ends and junctions must match up precisely for features to connect. If they do not match up they can be moved within the limits of the snap tolerance. The default value is based on the XY tolerance of the feature dataset.
	< <u>B</u> ack <u>N</u> ext > Cancel

Select the features **DrainageLine** and **GageSnap**. These will be used to create a Geometric Network. Click Next.

New Geometric Network	×
Select the <u>f</u> eature classes you want to build your network fro	m:
Cont20m	Select All
🔽 🛨 DrainageLine	Clear All
Gage	
GageSnap	Unavailable
< <u>B</u> ack <u>N</u> ext	> Cancel

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

New Geometric Network				
Select <u>r</u> oles for the the netwo	ork feature classes:			
Feature Class Name	Role	Sources & Sinks		
😁 DrainageLine	Simple Edge	<none></none>		
GageSnap	Simple Junction	Yes		
	< <u>B</u> ack	Next > Cancel		

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 LoganNet that can be used to perform network operations



Note that multiple instances of GageSnap and DrainageLine may have been added to your display. Remove the extras to avoid confusion.

Select **Customize** → **Toolbars** → **Utility Network Analyst** from the main menu to activate the Utility Network Analyst toolbar

Utility Network Analyst		- ×
LoganNet 🗸	Flow • 🖕 Analysis • 📌 • Find Common Ancestors	-X

Click on **Flow** → **Display Arrows** on the Utility Network Toolbar



The result is a set of black dots on each network link. These indicate that flow direction for the network is 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. Select layer GageSnap if prompted and click Continue if there is a warning. Use the Editor Edit Tool to select the point at the outlet in the GageSnap Feature Class (There is only one point) and select it in the dropdown that appears



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 4 ×					
🖃 🚸 GageSnap					
🖸 1					
	<u> </u>				
OBJECTID	1				
PourPtID	1				
Enabled	True				
AncillaryRole	None 🔹				
	<null></null>				
	None				
	Source				
	Sink				

Click on the Set Flow Direction Tool on the Utility Network Analysts toolbar.



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, saving edits.



2. Analysis using a Geometric Network

Zoom to a tributary of interest, say right hand fork, just up Logan Canyon and place an edge flag near the junction with the main stem using the Utility Network Analyst Add Edge Flag Tool.



Set the Trace Task to Trace Upstream and press Solve.

LoganNet	Flow ▼ 🚑 An	nalysis 🕶 💐 🕇 Trac	e Upstream	- × × -
FIREN, ENALYON	Wilderbess Area			Solve Perform trace task

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



Select Analysis \rightarrow Options



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

Analysis Options	Flow - 🖣 Ana	Ilysis 🔹 🥇 👻 Trace Ta
Consert Weights Weight Eller Regulte		Disable Layers 🔹 🕨
		Clear Flags
Results format		Clear Barriers
Return results as: Orawings		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 the upstream features are selected. Open the Drainage Line feature class attribute table and show selected records

Table						□ ×			
0	🗉 - 🖶 - 🖫 🍢 🖸 🚭 🗶 🕾 💀 🛷 🗙								
Dra	DrainageLine						×		
	OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length	Enabled	•
F	62	Polyline	62	64	65	63	2005.917086	1	
	63	Polyline	63	62	62	66	1589.568019	1	E
	64	Polyline	64	67	66	65	759.333361	1	
	66	Polyline	66	70	68	66	1014.21305	1	
	67	Polyline	67	65	64	69	1236.616596	1	
	68	Polyline	68	71	69	68	1192.242461	1	
	71	Polyline	71	73	74	69	3563.008909	1	
	72	Polyline	72	77	72	74	306.568182	1	-
ŀ	• •	1 > >		(13 out of 81 S	elected)				
D	rainageLine								

Right click on column header **Shape_Length** → **Statistics**



Record the total length (sum) and number of stream links in the Logan River Right Hand Fork. Switch the Trace Task to **Trace Downstream** and press **Solve** again. Notice how the selected stream links switch to those downstream from the flag. Select **Clear Selection** and **Analysis Clear Flags** to remove the trace results. Three tributaries of interest in the Logan River Watershed are indicated:

- Right Hand Fork
- Franklin Basin
- Beaver Mountain





Use Flags and the Trace tool to determine the total length of streams in each of these tributaries. Also determine the distance from the junction of these tributaries with the main stem downstream to the outlet.

Join the CatchPolyDissolve attribute table to the DrainageLine table.

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. Choose the field in this layer that the join will be based on:					
grid_code 🔹					
2. Choose the <u>t</u> able to join to this layer, or load the table from disk:					
🗞 CatchPolyDissolve 🔽 🖆					
✓ Show the attribute tables of layers in this list					
3. Choose the <u>fi</u> eld in the table to base the join on:					
gridcode 🗾 👻					
Join Options					
<u>Keep all records</u>					
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>matching</u> 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					

This provides access to the area draining directly to each stream link. Use Trace Upstream to select all the links in a tributary and evaluate the total area upstream of each using **Shape_Area** \rightarrow **Statistics**.

For example based on a Trace Upstream from the Flag at the Franklin Basin Tributary the area draining Franklin Basin is determined to be 89.897 km² in the following figure.



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. 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). Prepare a layout that illustrates the longest flow path in the Logan River basin.



To turn in: A table giving for each of the tributaries identified above 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 Logan River Basin and giving the length in km.

OK. You are done!

Summary of Items to turn in.

1. Report the main stream length, total stream length, basin area and drainage density for the Logan River Basin as determined from NHDPlus flowlines.

- 2. Prepare a layout showing the topography, Basin Outline, NHDPlusv streams and Logan River Main stem stream for the Logan River Basin. Include a scale bar and North arrow and appropriate title, labeling and legend so that the map is self-describing.
- 3. The number of columns and rows, grid cell size, minimum and maximum elevation values in the Logan DEM.
- 4. A layout showing the deepest sink in the Logan River basin. Report the depth of the deepest sink as determined by fil-dem.
- 5. Make a screen capture of the attribute table of fdr and give an interpretation for the values in the Value field using a sketch.
- 6. Report the drainage area of the Logan River basin in both number of 30.92 m grid cells and km² as estimated by flow accumulation. Report the area of the Logan River basin in km² as calculated by the arcgis.com watershed function. Report the area of the Logan River basin in km² as reported by the USGS for the Logan River stream site. Discuss reasons for any differences.
- 7. Describe (with simple illustrations) the relationship between StrLnk, DrainageLine, Catchment and CatchPoly attribute and grid values. What is the unique identifier in each that allows them to be relationally associated?
- 8. A table giving for each of the tributaries identified above 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.
- 9. A layout illustrating the longest flow path in the Logan River Basin and giving the length in km.