GLS210 Geomorphology
Fluvial Geomorphology of the Upper Yellowstone River Drainage Basin
Using Google Earth to Analyze Rivers

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Goal: Upon completion of this lab you will know and be able to analyze various parameters of a stream system using Google Earth, Excel, and NIH ImageJ.

Objectives
You will:
1. identify fluvial features on a topographic map.
2. learn how to retrieve and overlay topographic maps onto Google Earth.
3. read and interpret topographic maps.
4. measure and plot profile data and calculate vertical exaggeration
5. use spreadsheets to record and graph data, and make calculation.
6. determine geomorphic parameters such as sinuosity ratio and gradient.
7. define the drainage area of a basin in Google Earth and calculate it using ImageJ.

Lab Time Required: 6 hours

Introduction to the Grand Canyon of the Yellowstone, Yellowstone National Park, WY

Figure 1. Grand Canyon of the Yellowstone River, Yellowstone National Park, WY. The bright colors displayed along the canyon walls are the product of oxidation. (Image taken by Fort Photo, available through [Creative Commons/Flickr])

As it cascades off the Yellowstone Plateau, the Yellowstone River carves a deep canyon through a thick succession of pyroclastic and effusive rhyolites that were variably weakened by hydrothermal alteration (fig. 1). The uppermost and least altered rhyolite exposed at Upper Falls creates a resistant caprock that locally controls the river's depth of erosion. The Grand Canyon of the Yellowstone developed where the caprock was breached, allowing the river to rapidly slice through the underlying altered rhyolites. Erosion is slowed where a more resistant layer is encounter such as the rhyolite that holds up the Lower Falls (fig. 1).

During the Pleistocene the Yellowstone Plateau was occupied by an ice cap fed by alpine glaciers, streaming onto the plateau from the neighboring highlands. Although it is conceivable that a tongue of ice could have extended from the Plateau into the canyon there is no evidence that ice carved the canyon. However, outbursts from glacial lakes trapped on the Plateau's surface during deglaciation may have aided in the canyon's formation.

Throughout this lab you will study various aspect of the Yellowstone River as it makes it's transition from the Yellowstone Plateau into the Grand Canyon. In the process you will learn how to work with Google Earth, topographic maps, and spreadsheets.

Part I: Introduction: Adding content to Google Earth

Google Earth offers several ways to add content that can increase your viewing experience. As geomorphologists we might like to view an area through a photographer's lens to obtain a more personal view of the landscape, or add content that would allow us to measure and evaluate various landscape parameters. I will briefly introduce you to loading images, and finding topographic maps for overlays. Although I will provide the overlay for this exercise, feel free to download, overlay, and explore other topographic maps discussed as in Step 3 and outlined in the Appendix.

A: **Choosing content: images.** (To reduce clutter, deselect everything in the "Layers" pane.) Open the "Geographic Web" folder and check "Panoramio". This photo-sharing file allows you to view photos taken from locations around the world. You can also view and add your own photos by visiting the Panoramio Website (http://www.panoramio.com/). One word of caution however, images are not always located properly. With Panoramio open go to Yellowstone National Park and explore some of its features. Other photo-sharing options are available. However, Panoramio is the one of the best, and already loaded in Goggle Earth's primary database. Continue on to learn how to find and load content outside the primary database.

B: **Adding content:** Click on "Add Content" on the right side of the "Places" pane. If your version of Google Earth is missing the button then access the KML Gallery directly through your browser. Scroll through the subjects for files of interest or use the Earth Finder search box to locate files. There is additional content available on the Internet that you can locate by searching the web. For example, do the following search: "topographic maps for Google Earth," and you will come up with "MapFinder" discussed below. Any new files are loaded into your "Temporary Places." You can choose to save or remove these at the end of the session.

C. **Loading files: topographic maps.** Once you've located a kmz or kml file of interest selecting it will automatically start Goggle Earth and load the file's content. USGS (24k) topographic maps are available for free from MapFinder. Click on "MapFinder for Google Earth" and a folder labeled "USGS 24k Topographic Index" will load into your Goggle Earth Temporary Places column. This file contains all the 24k index maps for the U.S. You can download any map from this file and load it as a layer in Google Earth. (See Appendix regarding how to create overlays.) The Yellowstone River overly created for this lab is a partial composite of two quadrangles downloaded from this file.

Part II: Working with topographic maps on Google Earth

A. Locating and retrieving map info. Load the Yellowstone River kmz file created for this lab. You are going to locate the maps used for this overlay. Go to the "USGS 24k Topographic Index" and complete the following steps:

Step 1. Open the file by clicking on the arrow next to the filename. **Do not check the box**, which will load the entire file. Doing so will slow down Google Earth and may cause your computer to hang up if memory is low. For this reason never load unnecessary files.

Step 2. Open but don't load the subfolder "Topo Index States T-W." Scroll down and load Wyoming by marking the checkbox. The index maps for the entire state will appear. Find the two quadrangles of interest and select their info markers. (You will not need to download the maps.)

Step 3. Answer the following:

a. Locate and identify the two maps used for this exercise:

Answer: Crystal Falls and Canyon Village

b. What is the relative fraction scale *1:24,000* and contour interval *20 feet* of these maps.

Step 4. Deselect *Wyoming* and continue on with the exercise.

B. Becoming familiar with the map and local topography:

Select the Yellowstone River layer containing the topographic map. By adjusting the opacity of the overlay you can toggle back and forth between the satellite image and the contour map. Answer the following questions:

1. From the topographic map determine the following:
   a. Contour interval: *20 feet* every 5th (dark) contour is: *100 feet*.
   c. Highest elevation: *8695 feet* Quadrant located: *SE*
   d. Lowest elevation: *6740 feet* Quadrant located: *NE*
   b. Relief of map area: *8695-6740 feet=1955 feet*

2. Note that in this area Yellowstone River has both mature and youthful reaches. Which section is mature and which is youthful? Describe the characteristics of each. *The canyon extending below the upper falls is youthful, having a narrow, deep V-shaped valley, several rapids, and no flood plain. The river above the fall is mature. Here the river is sinuous, the valley broad with an oxbow lake and looping cutoff meanders.*

3. What is the explanation for these extreme differences in character?
Variations in rock resistance. The upper part is a graded reach--graded to a resistant volcanic layer forming a temporary and local base level. The lower reach is rapidly down-cutting through altered volcanic rocks.

4. A **hanging valley** is characterized by a steep falls where a tributary enters the main valley. They develop where a glacial or stream tributary lacks the erosive power required to keep pace with the more rapid down-cutting of the main channel. Yosemite National Park is noted for its glacially carved, U-shaped valleys and dramatic hanging valleys. (Click on the placemarker and explore Yosemite in Google Earth.). There are several hanging valleys entering the Grand Canyon of the Yellowstone. Approximately how many lie along this stretch of the canyon? *8*

5. Structure and drainage patterns:
   a. Describe the drainage pattern in the southeast corner of the topographic map.
   Valleys are perpendicular to regional slope – somewhat rectangular.

   b. Develop a hypothesis explaining the pattern.
   Most likely structurally controlled

   c. Study the geologic map (Christainsen, 2001) provided by the link below. Evaluate your hypothesis. Was it correct? What is (are) responsible for the drainage pattern? *Valleys are controlled by faults.*

C: Profiling using Google Earth and spreadsheets

1. Construct cross-valley profiles (cross sections) along A-A' and B-B'. Complete the following steps:

   Step 1. Use the slider to make the topographic map opaque.

   Step 2. Take and record measurements: On the map are two profile lines A-A' and B-B' across the valley of the Yellowstone River. Use Google Earth's measuring (path or line) tool to obtain the distance and elevation of points along each profile line. ***Recommendation:*** *Use the* *line tool. Measure in miles. Keep one end of the line at the origin. Select and stretch the other end as you progress along the profile line. Also, when using any measuring tool use the arrow keys on your keyboard to move the map.*

While you're measuring enter the data into an Excel worksheet. *If you don't have Excel use Open Office (PC and Mac) or NeoOffice (Mac), which are both free and work just as well.*

For each profile the first column in the worksheet is always the **x data** (cumulative distance from start) and the second column is the **y data** (elevation of each point). Maintaining this structure is important in order to correctly graph the data.

Step 3. After the data is entered use the chart tool (scatterplot) to graph each profile.

Format your graph accordingly: Click on the plot points to bring up the "format point" window. Reduce the point size to 2 and connect the lines. Double-click on the axes of your plot to bring up the "format axis" window and set the scale as follows: Y axis; minimum=6600, maximum=8600, Major units=100. For the X axis; mimimum = 0 and maximum is 2. Eliminate the legend and stretch the side borders to the edge of the paper. The vertically each chart should span approximately 18 lines. Label the axes (under Chart Options).

Step 4. Print and calculate the vertical exaggeration for each chart: VE = horizontal scale / vertical scale. You will need a ruler to measure the length of each axis and will have to convert miles to feet. Show all values, units and calculations:

A-A': VE =

B-B': VE=

Answer should be approximately 2X for both graphs, but may vary depending on the sizing each person's chart.

2. Construct a longitudinal profile of the river. Using the same method draw a longitudinal profile of the river from points E to E'. Record the distance in miles. Don't reformat the plot. *See attached file.*

3. Using the spreadsheet calculate the following gradients: *See attached file*

Region	Gradient (ft/mile)	% slope (**y** in ft/**x** in ft*100)
Entire River		
Reach above Upper Falls		
Falls reach		
Reach below Lower Falls		

4. Review your map, the satellite image, and your profiles. Compare and contrast the two segments of the Yellowstone River. Include: valley W/D ratio; relief; gradient, flood plain; youthful and mature, cut-off meander, sand bars, rapids, mass wasting etc. *(Remember you can change the opacity of the overlay by using the slider bar above the layer window on the left.)*

5. From the satellite imagery (terrain option selected) compare and contrast the region in and around Yosemite Valley with that of the Grand Canyon of the Yellowstone River. What is similar? What is different?

6. What principal characteristic supports the argument that the Grand Canyon of the Yellowstone has a fluvial and not glacial origin?
Glacial valleys are U or parabolic in valley profile. The canyon is clearly V-shaped.

Part III: Determining the perimeter and area of a drainage basin.

Google Earth's polygon tool can be used to delineate watersheds. Unfortunately you cannot calculate the area without buying the $400 Professional version. However, we can perform such measurements by saving our working window as a jpeg file and importing it into ImageJ (http://rsb.info.nih.gov/ij/) -- a free, java-based, PC and Mac compatible, image processing software program from the National Institute of Health.

1. Procedure:

Step 1. **Reveal topographic map:** Make the topographic map overlay fully opaque. Center your screen on the drainage basin surrounded by box C. Zoom in until the eye altitude, displayed on lower right corner of window, is around 4.25 km (13,950 feet).

Step 2. **Save Image:** In the menu bar go to File > Save > Save Image, and save the image to your computer.

Step 3. **Download and install ImageJ** on your computer. Open ImageJ and import your saved Google Earth image. (In ImageJ go to *File >Open* and select your file.)

Step 4: **Selecting parameters to be measured**: In the ImageJ menu go to *Analyze > Set Measurement* and check "area" and "perimeter".

Step 5. **Set watershed boundary:** With the polygon tool delineate the watershed by outlining the drainage divide around the basin. Imagine the direction that water falling on the surface would flow. Water flows in opposite directions from a divide, which typically follows a series of ridges and highlands. Streams and gullies will not cross a divide, but may begin slightly down slope from it. When crossing contours the divide must be drawn perpendicular to the contour lines. Tweak your polygon by selecting and adjusting the point handles. Review your outline, then **make it permanent by pressing Control+D.** Once the outline is permanent you can easily retrace it. *See attached image*

Step 6. **Set the scale.** Draw a horizontal line across two complete UTM grid squares with the line tool. (UTM gridlines are 1km apart.) In the ImageJ menu select *Analyze > Set Scale*. Type "2" for know distance and "km" for units. Record the number of pixels in question 2b below. Now you're set to obtain your measurements.

Step 7. **Analyze:** Accurately retrace your drainage line with the polygon tool. Upon completion go to the menu and choose *Analyze* > *Measure* and the area and perimeter will be displayed. Check to make you're your answer makes sense!! If not then you have to reset your scale by repeating steps 5 and 6.

2. Answer the following questions:

   a. Is the watershed boundary (Step 5) entirely contained within the red square? Explain. No, the eastern tip of the drainage system is outside the box.

   b. What is the scale obtained in Step 6? *529* pixels equals 2 kilometers.

   c. What is the perimeter and area of the drainage basin in kilometers (Step 7)? *7.56 km* / *2.65 square km*.

   d. Convert to miles (.62 miles/km) *4.69 miles /1.64 square miles*

Part IV: Sinuosity Ratio (channel length/valley length)

Sinuosity ratio is a quantifiable aspect of channel pattern that can be measured from maps and air photos. The classification by Brice (1975) defines sinuosity as follows: For any given reach the value of sinuosity is the ratio of the stream length as measured along the stream centerline to valley length as measured along the valley centerline. Reaches are straight (SR=1-1.05), sinuous (SR=1.06-1.5) and meandering (SR=1.5). Sinuosity reflects proximity to baselevel, stream gradient, channel composition and sediment load. A highly sinuous or meandering single-channel stream is typically near or at baselevel, has a low gradient, and contains predominantly fine-grain sediment.

Return to the Yellowstone River map in Google Earth and complete the following:

1. Determine the sinuosity ratio and classify the reach outlined (C) on Trout Creek located in the Hayden Valley. In Google Earth select the *measure* > *polygon* tool to measure the stream and valley lengths. *Answer: SR = 1.28 miles/.79 mile = 1.6 this reach is meandering*

2. Identify the baselevel for Trout Creek and approximate gradient. (Given: the elevations for the upper and lower ends of the reach are 7715 ft and 7695 ft respectively.) *Yellowstone River/ gradient = 16 feet/mile*

3. Identify the most probably channel composition and sediment load for Trout Creek: silt and clay, coarse sand, gravel (circle one) *silt and clay - the river is cutting through glacial lake sediments*

4. Is there any evidence from the Panoramio photos that the water level in the Hayden Valley was higher? *Yes, there are terraces (of glacial lake sediments) along the sides of the stream.*

Useful sites:

Brice, 1975, Airphoto Interpretation of the Form and Behavior of Alluvial Rivers: Final Report for U.S. Army Reasearch Office.
Christiansen, Robert L., 2001,The Quaternary and Pliocene Yellowstone Plateau Volcanic Field of Wyoming, Idaho, and Montana: U. S. Geological Survey Professional Paper 729-G, URL http://pubs.usgs.gov/pp/pp729g/
Map URL: http://pubs.usgs.gov/pp/pp729g/plate1.pdf

Love, J.D. and others, Reconnaissance Study of Pleistocene Lake and Fluvial Deposits In and Near Ancestral Yellowstone Lake, Wyoming: in Morgan, Lisa, Ed., Integrated Geoscience Studies in the greater Yellowstone Area, volcanic, tectonic, and hydrothermal processes in the Yellowstone geoecosystem, U.S.G.S. professional paper 1717.
URL: http://pubs.usgs.gov/pp/1717/downloads/pdf/p1717C.pdf

State University of New York College of Environmental Science and Forestry (SUNY ESF). Fluvial Geomorphology Training Module, URL: http://www.fgmorph.com/menu.php

Website and file links

Gimp

Gimp Download: http://www.gimp.org/
Users Manual (pdf): http://gimp.org/docs/

Google Earth

Goggle Earth Download: http://earth.google.com/download-earth.html
Goggle Earth User Guide: http://earth.google.com/userguide/v4/
Google Earth Gallery: http://earth.google.com/ig/directory?synd=earth&pid=earth&cat=featured
Designing and Creating Earth Science Lessons with Google Earth: http://stevekluge.com/projects/dlesege/dlesegemanual/manual.html (Steve Kluge and others - Delese GE online manual)

ImageJ

ImageJ Download and Documentation: http://rsb.info.nih.gov/ij/
Quick Guide to ImageJ (pdf): http://www.medizinischeinformatik.fh-aachen.de/downloads/service/ImageJQuickGuide.pdf (Prof. W. Hillen, Medical Informatic, University of Applied Sciences Aachen/Julich)

Yellowstone River KMZ file used for this lab:
http://w3.salemstate.edu/~lhanson/gls210/GLS210_Labs/GLS210_YellowstoneLab/YellowstoneRiverLab.kmz

Appendix

How to overlay topographic maps in Google Earth:

Topographic maps for Google Earth can be found at [Mapfinder for Google Earth] ([kmz file]). This file allows you to view state index maps for the entire U.S.

Step 1: Choose and download the map(s) you want to overlay.

Step 2: Reducing the file size
Layers can slow down the interface. So before loading a map into Google Earth open the original tiff file in an image processing program such as Photoshop (Mac/pc $$$), Graphic Converter ($, Mac http://www.lemkesoft.com/) or Gimp (free for Mac/pc; http://www.gimp.org/) and reduce the file size, by cropping the image or removing the white border to include only what you are interested in. Change the format to a jpeg file at 70% quality. Make sure to keep one or more of the original edges of the quadrangle for registration purposes.

Step 3: Preparing to overlay
Make visible the Index from which you obtained the map. You will use this to register the overlay. Turn off "terrain" in the bottom of the layers pane or your map will be distorted and hard to register.

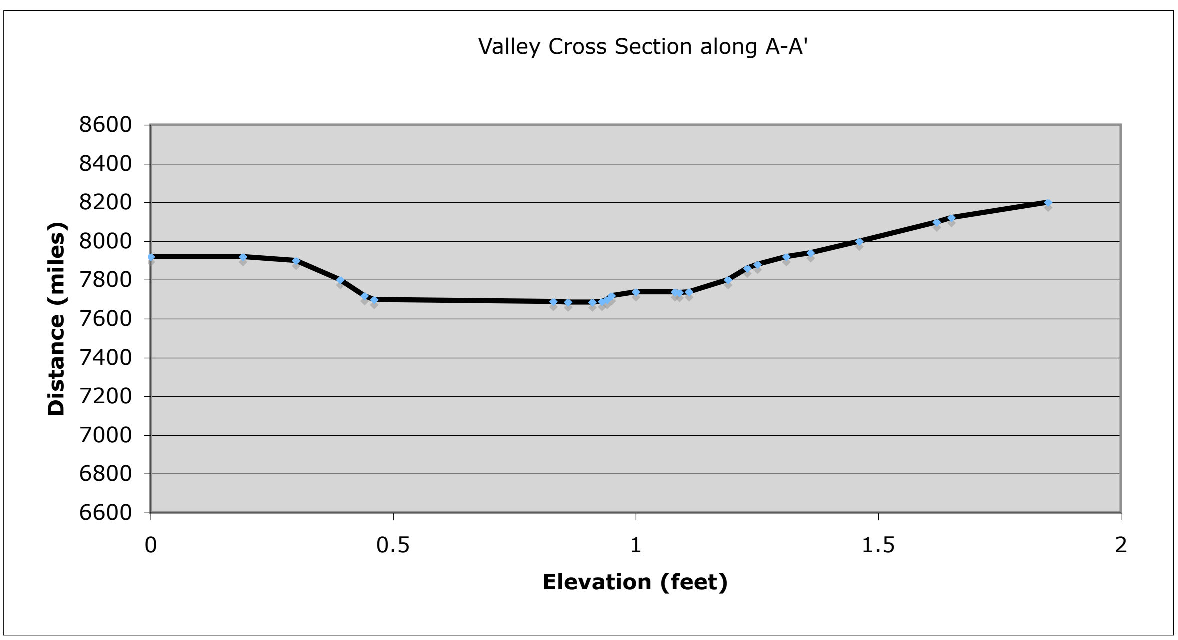
Step 4: Adding and adjusting the overlay
Click on the overlay button in Google Earth, scroll to the map location on your hard drive, and select the file. The overlay will appear in Google Earth. Move (select center cross), resize (select corner or edge handles) and rotate (diamond handle on left) to properly register the map over the terrain. Start by aligning the edges of the map with that of the original Index Map. Rotating should not be necessary if you did not rotate the map during editing.

Step 5: Check for distortion.
Check to make sure your map is not distorted. Otherwise your measurements will not be accurate. Use Google Earth's measuring tool to check the distance between UTM gridlines.

Cross section A-A'

Distance	Elevation	
0	7920	
0.19	7920	
0.3	7900	
0.39	7800	
0.44	7720	
0.46	7700	
0.83	7690	
0.86	7685	River Channel
0.91	7685	
0.93	7690	
0.94	7700	
0.95	7720	
1	7740	
1.08	7740	
1.09	7735	gully
1.11	7740	
1.19	7800	
1.23	7860	
1.25	7880	
1.31	7920	
1.36	7940	
1.46	8000	
1.62	8100	
1.65	8120	
1.85	8200	

VE=2

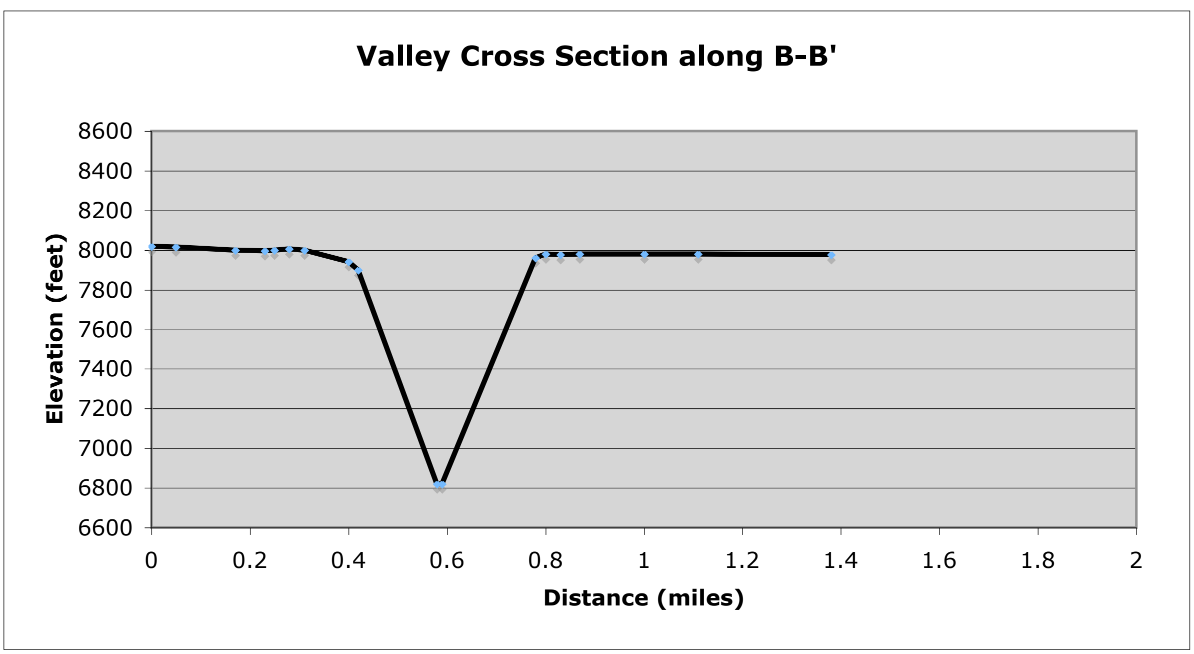


Valley Cross Section along B-B'

Distance	Elevation	
0	8020	
0.05	8015	stream
0.17	8000	
0.23	7995	
0.25	8000	
0.28	8005	
0.31	8000	
0.4	7940	
0.42	7900	
0.58	6820	nw bank
0.59	6820	se bank of Yellowstone River
0.78	7960	
0.8	7980	
0.83	7975	
0.87	7980	
1	7980	
1.11	7980	
1.38	7976	

VE= ((5280*2)/13)/(2000/5)

VE=2

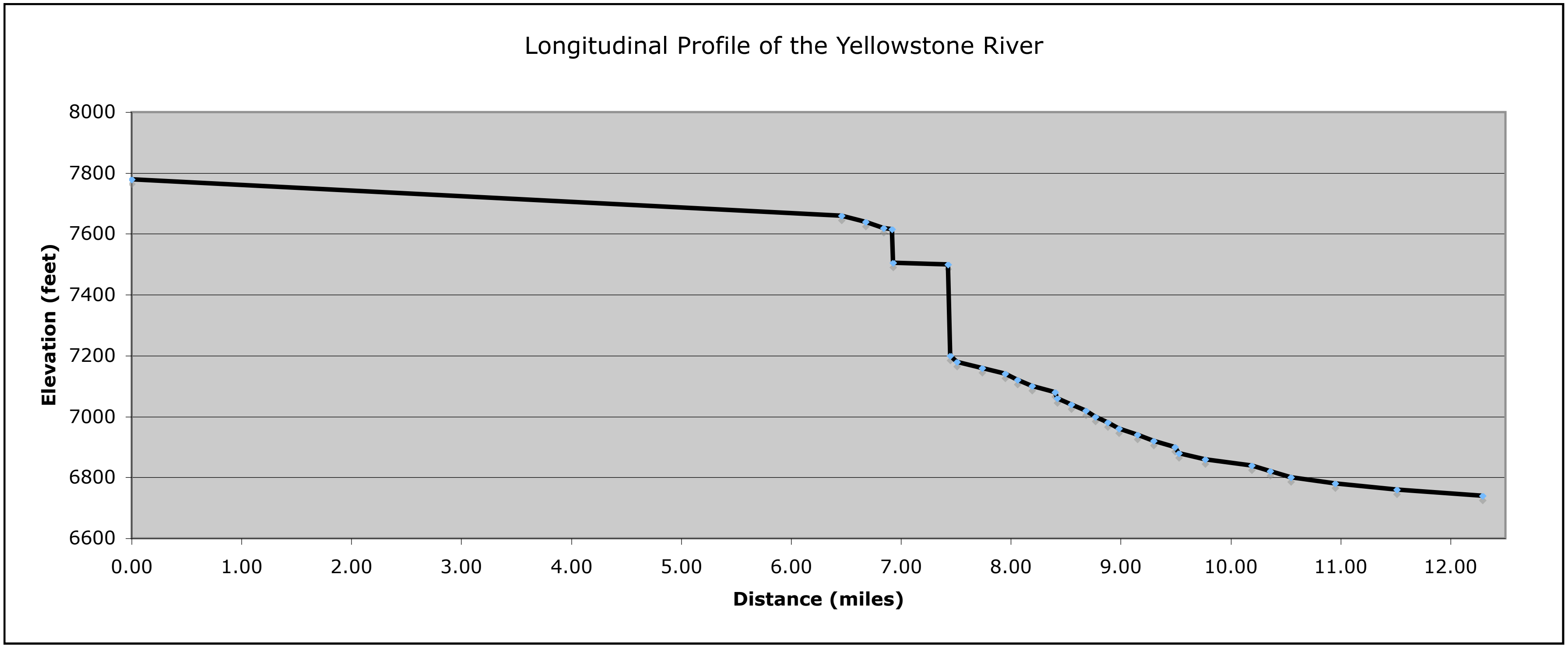


Yellowstone River Valley -- longitudinal profile from E to E'

	Distance (miles)	Elevation (feet)	
0.00	0.00	7780	
6.46	6.46	7660	
	6.68	7640	
	6.84	7620	
	6.92	7615	Upper Falls
	6.93	7505	base
	7.43	7500	Lower Falls
	7.45	7200	base
	7.51	7180	
	7.74	7160	
	7.95	7140	
	8.06	7120	
	8.19	7100	
	8.4	7080	
	8.42	7060	
	8.55	7040	
	8.68	7020	
	8.77	7000	
	8.88	6980	
	8.98	6960	
	9.15	6940	
	9.3	6920	
	9.49	6900	
	9.53	6880	
	9.77	6860	
	10.19	6840	
	10.36	6820	
	10.55	6800	
	10.95	6780	
	11.51	6760	
	12.29	6740	

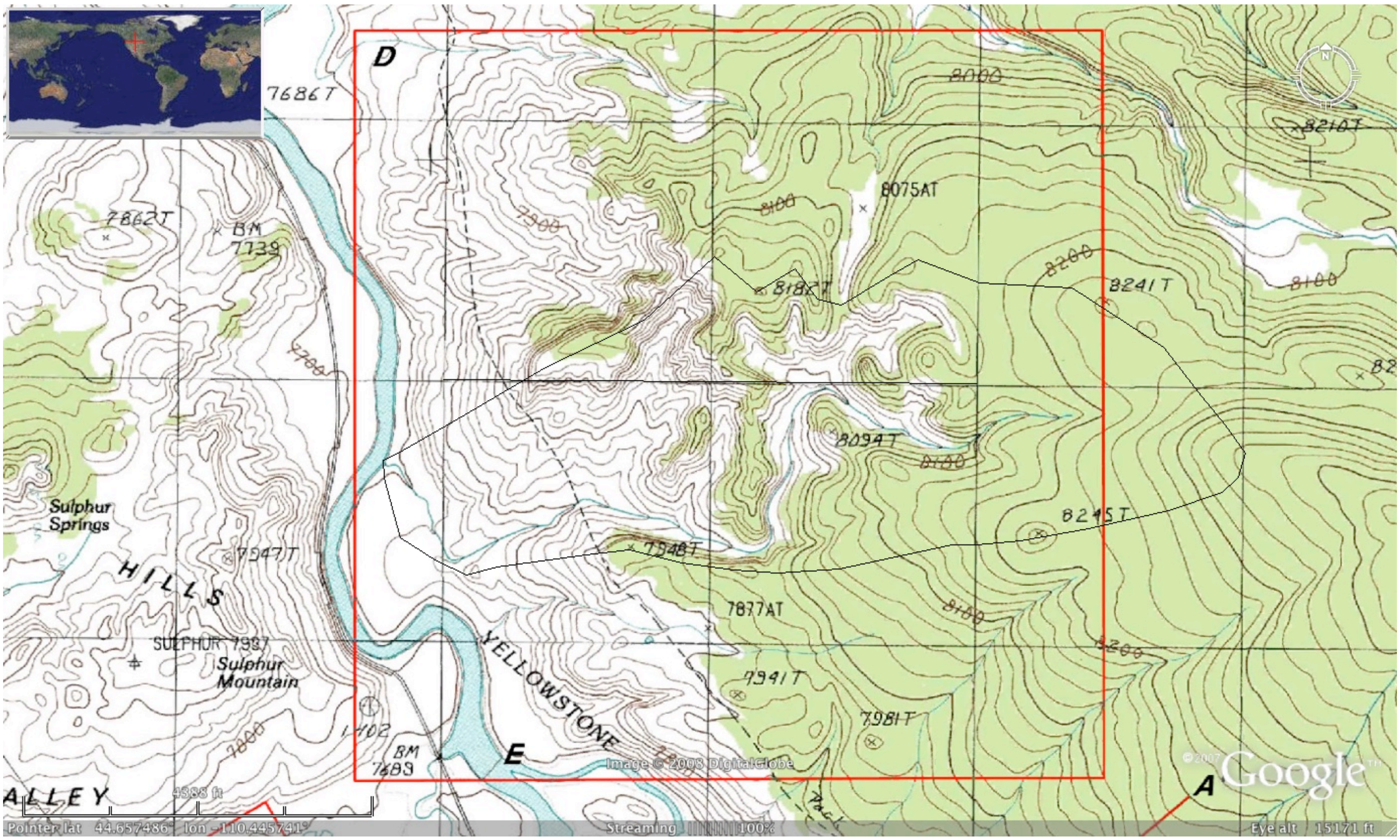
				miles	ft/mile	%
Gradients	High	Low	relief(h-l)	Distance	Gradient (r/d)	
Entire River	7780	6740	1040	12.29	85	1.6
Above falls	7780	7615	165	6.92	24	0.5
Falls region	7615	7200	415	0.53	783	14.8
Below falls	7200	6740	460	4.84	95	1.8

%= r/(d*5280)*100



Vertical scale 1400 feet=6.5 cm
Horizontal scale 5280=1.7 cm

VE=(5280/1.7)/(1400/6.5) = 14


D
E
A
7686T
7862T
BM 7739
8075AT
8000
8100
8182T
8200
8241T
8210T
8094T
8245T
7548T
7877AT
7941T
7981T
Sulphur Springs
HILLS
SULPHUR 7987
Sulphur Mountain
BM 7683
YELLOWSTONE
ALLEY
Image © 2008 DigitalGlobe
Google
Pointer lat 44.657486° lon -110.445741°
Streaming 100%
Eye alt 15171 ft