Lab 2 Landsat Multispectral Processing

Utilizes Textbook's Remote Sensing Digital Database: Chapter 3 data.

The objectives of this lab are to learn the processing tools on ENVI's main display window that are used to interrogate, display, and display multispectral data.

Evaluate individual bands
Quick stats (overview of dataset statistics)
Compare an enhanced image with original USGS data
Spectral profile
Evaluate different color composites in four display Views
Regions of Interest (ROIs)
Scatter plots (feature space)

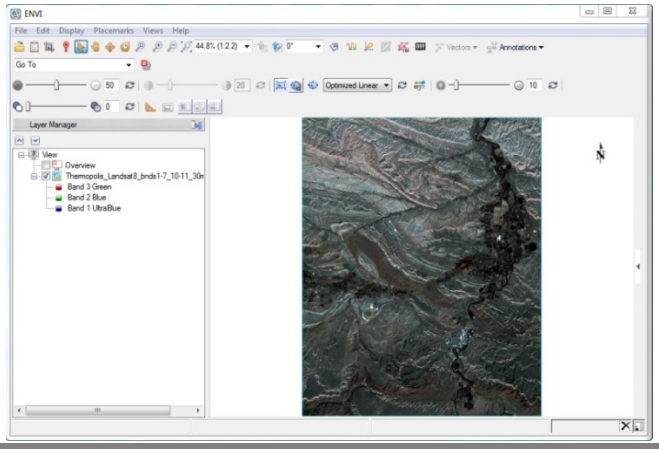
Eight questions are asked during this lab – you are to write your answer on the sheet that is at the end of this handout. Two files are to be uploaded to the instructor.

1) Open the Remote Sensing Digital Database chapter 3 folder named "Plates_7 and 27_Thermopolis". You can see that all the Landsat 8 bands and derived images that are explained in the textbook are contained within this folder. Also there is a folder named **Lab_2_Data** that has other data used in this lab.

Open ENVI (the GIS-look option) and load the 9-band Landsat data in ENVI format named: "Thermopolis_Landsat8_bnds1-7_10-11_30m_ENVI_".

NOTE: The ENVI file has more information compared with the GeoTIFF because the wavelength (blue, NIR, Thermal IR, etc.) can added to the band number and displayed in the Layer Manager and Data Manager.

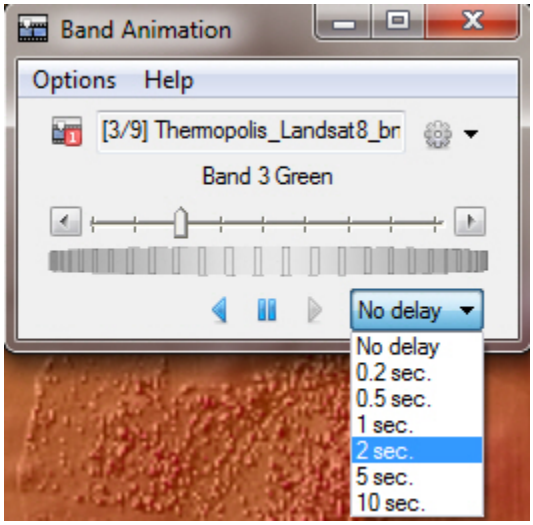
Zoom to full extent. Note that the first 3 bands are automatically displayed by the ENVI software based on the default Preferences. To see what bands are displayed you have to click on the "+" sign to the left of the file name (see below).



File > Data Manager Lists all 9 bands in this Landsat dataset

Look at Figure 3-11 A-G in the textbook. The geologic map is Figure 3-11H. Also look at Plate 7. We'll examine the spectral characteristics of the Red Rose Anticline and the agricultural fields in the upper right along the Wind River.

2) Let's examine each of the 9 bands. *Right-click* on the file name in the Layer Manager > *Band Animation.* ENVI flickers through the 9 bands rapidly(!) by default.



Slow down ENVI….Use the dropdown menu in the lower left of the Band Animation tool to choose 2 seconds or 5 seconds.

Question 1: Which band is most unlike the other 8 bands?

3) Let's load 7 of the individual bands. Open the "Bands" subfolder that is in the Remote Sensing Digital Data chapter 3 folder named "Plates_7and27_Thermopolis".

Landsat OLI bands 2-7 and 10 are available for loading into ENVI.

Highlight the seven TIFF images with the *Control (Ctrl) Key down* and click *Open*

Turn-off all the bands in the View except "Band 10 Thermal_tif.tif" in the Layer Manager View

Right-click on Band 10 in the Layer Manager and *View Metadata.*

What is the pixel size of this thermal IR band? _____

Right-click on Band 6 in the Layer Manager and *View Metadata.*

What is the pixel size of this SWIR1 band? _____

The Landsat 8 TIR sensor acquires thermal IR bands 10 and 11 with 100 x 100 m pixels. The Landsat 8 OLI sensor acquires VNIR-SWIR bands 1 to 7 with 30 x 30 m pixels. The USGS resamples the thermal IR bands to 30 x 30 m pixels for delivery to users.

Question 2: Why are the Landsat 8 thermal IR bands collected with pixels that cover an area more than 100 times larger than the VNIR-SWIR 30 x 30 m pixels?

(see Equation 1-2 and Table 3-1 in the textbook)

4) Turn on Landsat OLI band 5 NIR. *Right click* > *Quick Stats*

Select Plot > *Histogram Band 1* (Drop-down menu in upper left of Quick Stats)

This Landsat band was resampled to 8-bit from the original data delivered by the USGS and contrast-stretched for the textbook figure. You are viewing a contrast-stretched grayscale image (you would not know this unless the remote sensing analyst documented the radiometric change in the metadata).

Question 3: A. What is the Mean and Standard Deviation of all the pixels in the grayscale Band 5 NIR?

B. What percentage of pixels have values within one standard deviation of the mean? (see textbook Figure 9-3 for explanation)

C. What digital number (DN) is displayed by the most pixels (Data Value on the horizontal axis of the histogram)? How many pixels have that DN ("Count" value)? What percentage of the 256 DNs is contained by this largest DN?

5) Let's zoom into the area shown in the textbook's Figure 9-2. Turn on Landsat band 5 NIR. Load the UTM Zone 13 vector polygon shapefile named "Textbook Fig 9-2 Thermopolis.shp" that is in the **Lab_2_Data** folder.

File > *Open* > "Textbook Fig 9-2 Thermopolis.shp" (the type of file to load is designated "SHP". Many files are required to support a shapefile(!)

Right click on the shapefile in the Layer Manager > *Properties* > *change* "Line Thickness" to *3* > *Change* "Line Color" to black so that the rectangular polygon is displayed more clearly.

We want to replicate some of Figure 9-2. Turn-off all images and bands except Band 5 NIR. Display the band 5 with "No Stretch". You have to keep highlighting "Band 5 NIR" in the Layer Manager while the vector shapefile is

turned-on to use tools and to see information about the raster band 5.

Zoom-in so the polygon fills your View

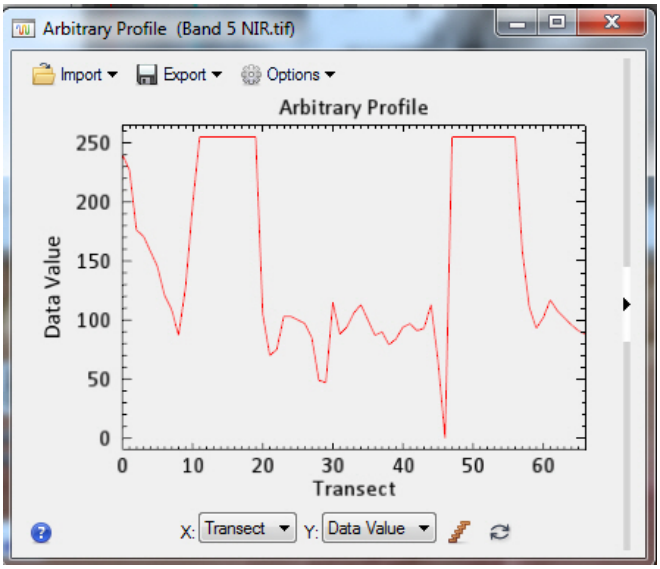
Display > Cursor Value Move the crosshairs around the image with the Select tool (arrow)

What is the brightest DN value for band 5? What is the darkest DN value for band 5?

Turn-off the shapefile. *Highlight* Band 5 NIR in the Layer Manager

Display > Profiles > Arbitrary

Draw a profile that mimics a – a' on Figure 9-2A (keep clicking until the profile pops up in a window). What do you see as the high and low DNs (see figure below).



a- a' profile of Band 5 NIR

6) Let's look at band 5 in the 9-band dataset (Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_). Highlight this color composite in the Layer Manager. Change the band combination to a 7-5-2 as red-green-blue.

Right-click the 9-band Landsat dataset in the Layer Manager > *Change RGB Bands…* The bands in this dataset have the original DNs delivered by the USGS.

Right click on the 9—band Landsat dataset > *Quick Stats*

Select Plot > Histogram Band 5

Question 4: A. What is the Mean and Standard Deviation of all the pixels in the 9-band Landsat dataset's Band 5 NIR?

B. Scroll down (or use the "Locate Stat" dropdown menu) and select Band 5. Computer screens can typically only display 256 levels (DNs) of brightness. So each DN on the histogram and your computer screen contains many DNs from the original USGS data. How many original DNs are contained within each DN displayed in the histogram and on the computer screen (look for "binsize =….")

C. What range of original USGS digital numbers (DN) have the highest count in band 5?

D. How many pixels (the "Count" value) in band 5 have the highest DN?

E. The USGS delivers Landsat 8 OLI and TIR bands with 16-bit radiometric resolution! How many levels of brightness is available with 16-bit data?

NOTE: The Landsat 8 system collects the data with 12-bit radiometric resolution (see Textbook Table 3-3).

7) Let's examine a color IR image generated from the "Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_" dataset. The area we are evaluating continues to be within the shapefile and the textbook Figure 9-2.

Right-click on the file name in the Layer Manager and *Change RGB bands…*

Generate a color IR image (Bands 5-4-3 or NIR-red-green in R-G-B). To see what bands are displayed you have to click on the "+" sign to the left of the file name.
Zoom to Full Extent

Contrast-stretch the color IR image – use the "Linear 2%" stretch

Display > Cursor Value Move the crosshairs around the image with the Select tool (arrow). The DNs for the 3 bands are displayed in the "Data:" field.

What is the approximate brightest DN value for band 5 NIR? What is the approximate darkest DN value for band 5 NIR?

Turn-on the shapefile. *Zoom-in* to the shapefile polygon. *Highlight* the 9-band Landsat dataset in the Layer Manager

Display > Profiles > Arbitrary

Draw a profile that mimics a – a' on Figure 9-2A. Where do you see the high and low DNs for Band 5?

Question 5: A. How is the DN profile from the enhanced grayscale Band 5 NIR (shown above) compare with the DN profile from the original USGS data for Band 5 NIR (seen as a red line in the profile (not shown))?

B. What is different about the profiles? (Do not include the difference in the "Data Value" on the vertical axis)

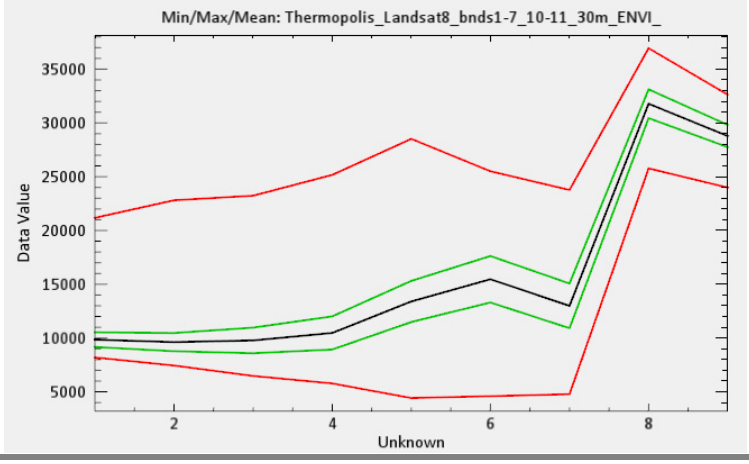
C. Why the difference in the profiles? (Hint: what is different in the image processing?)

Question 6: Reflected near IR light is very bright (high Data Value) over irrigated agricultural fields on your Arbitrary Profile across the original USGS Landsat data. On this same plot, what happens to the reflected red light (band 4) over irrigated agricultural fields in comparison to reflected green light (band 3)? Any idea why this occurs?

8) Let's look at the brightness values of the 9 bands in the "Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_" dataset. Highlight the color IR image in the Layer Manager. The bands in this dataset have the original DNs delivered by the USGS.

Right click on the 9—band Landsat dataset > *Quick Stats*

The horizontal axis labelled "Unknown" represents the band number. The visible bands are 1-4, the NIR band is 5, the SWIR bands are 6 and 7, and the thermal IR bands are 8 and 9 on the horizontal axis. The "Data Value" vertical axis represents the 16-bit DNs (brightness value) that are delivered with Landsat 8 radiance data. See below.



Question 7: A. Explain the statistical plot above. (also look at the metadata table)

B. What band has the highest mean DN?

C. What band has the highest DN range?

D. What band has the largest standard deviation?

9) Zoom out on the color IR image so that you see the Red Rose Anticline and the agricultural fields (perhaps with a map scale of 1:100,000). Let's look at a spectral profile at individual pixels.

Display > *Profiles* > *Spectral*

Move the crosshairs around with the select arrow and click on different pixels.

Examine the profile at the following features:

Irrigated agricultural field
Wind River
Airport
Different color geologic outcrops

What band varies the most? What bands vary the least?

10) Let's change the Color IR image in our View to a natural color image.

Right-click on 9-band Landsat data set in Layer Manager > *Change RGB Bands* > *Select* Band 4 - Band 3 - Band2 as R-G-B > *OK* > *Zoom to Full Extent* > *Contrast Stretch* to "Linear 2%"

Now let's generate 4 Views and load three other band combinations in each one, then link the four views so we can pan and zoom in and out and easily compare the different colors composites.

Views > *2 X 2 Views* We'll load the empty Views using the Data Manager.

Highlight View 2 (upper right) with your cursor. *Data Manager* > *Select* Band 5 – Band 4 – Band 3 as R-G-B in the 9-band Landsat data set > *Load Data* > *Zoom to Full Extent* > *Contrast Stretch* to "Linear 2%"

Highlight View 3 (lower left) with your cursor. *Data Manager* > *Select* Band 7 – Band 5 – Band 2 as R-G-B in the 9-band Landsat data set > *Load Data* > *Zoom to Full Extent* > *Contrast Stretch* to "Linear 2%"

Highlight View 4 (lower right) with your cursor. *Data Manager* > *Select* Band 7 – Band 6 – Band 5 as R-G-B in the 9-band Landsat data set > *Load Data* > *Zoom to Full Extent* > *Contrast Stretch* to "Linear 2%"

To see what bands are displayed you have to click on the "+" sign to the left of the file name.

Turn-off all other images and shapefile in the Layer Manager . Each View should only have the color composite checked in the Layer Manager and displayed.

Now we will *link* the four Views.

Views > *Link Views* > GeoLink *active* > *Link All* > *OK*

Pan around *Zoom in & out*

Question 8: List the colors displayed with the different color composites in the agricultural fields along the Wind River. Zoom in on a field with much irrigation and vigorous crops and a field with limited irrigation and less vigorous crops to fill in the blanks on the table.

a) natural color (red-green-blue in R-G-B),

b) color IR (NIR-red-green in R-G-B)

c) enhanced color (SWIR2-NIR-blue in R-G-B)

d) total IR (SWIR2-SWIR1-NIR in R-G-B)

11) Close 3 of the 4 Views.

Right-click on "View" in the Layer Manager > *Remove View*

In the remaining View > *Zoom to Full Extent*

We will now examine the correlation between the different bands using the Scatter Plot Tool. We will be working with the same

"Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_" dataset.

Change RGB Bands > *5-4-3* as red-green-blue (color IR)

Turn off other layers in your Layer Manager.

You will be doing statistical analysis using all the pixels in each band.

Display > *2D Scatter Plot* (Picture below)

Press the "Toggle Density Slice" tool (upper center) to see the pixel density scaled to color.

Click the "Full Band" box.

Change the Class 1 color from default red to yellow.

White areas in the scatterplot show where the highest number of pixels overlap between the two bands while black areas have the least number of overlapping pixels.

Start with bands 1 versus 2, and work your way through band combinations. Ignore the thermal bands (# 8 and 9 in the Scatter plot)

Note how band 5 NIR is significantly different from the other VNIR-SWIR bands

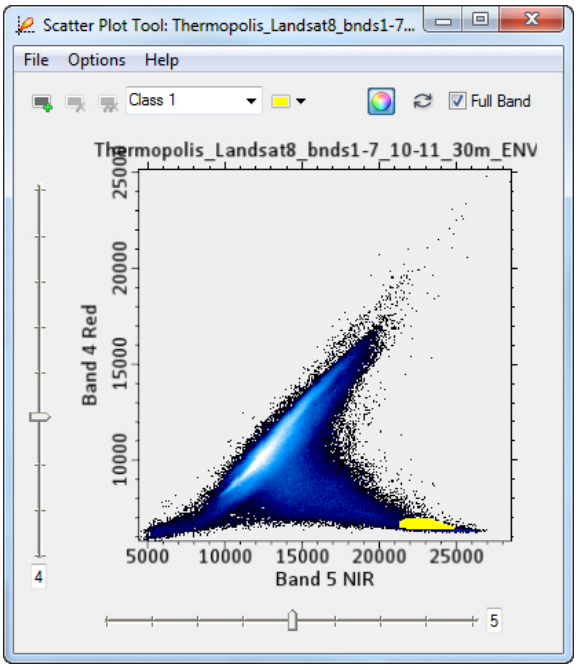
Display Band 5 NIR versus Band 4 Red in the color Scatter plot (see picture below). On the image in the ENVI View, as you move your mouse around you should see a small square.

If you don't, close the scatter plot tool, highlight the 9-band Landsat dataset in the Layer Manager and reopen the 2D scatterplot display

Display > 2D Scatterplot

As you move your mouse over irrigated agricultural fields – you will see the color IR red pixels display where the Band 5 NIR have high DN values and the Band 4 Red have low DN values in the scatterplot. The image is connected to the Scatter plot!

On the scatter plot, draw a polygon around the pixels with high Band 5 NIR DNs and low Band 4 Red DNs. This is "Class 1". (see below). You will see those pixels that have band 5 and band 4 pixels within your polygon light up on the color IR image! You have identified vigorous vegetation in the agricultural fields.



Let's upload the Landsat color image with the Class 1 pixels highlighted to the instructor as a "geospatial pdf".

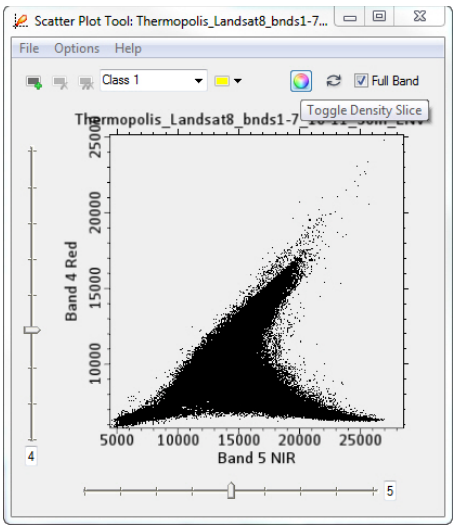
File > Export View To > GeoSpatial pdf (the pdf has coordinates!)

Briefly fill in the blanks on the form (this is metadata!)

Name the pdf "Your Name_Landsat_vig_veg"

12) Now we will use the scatter plot tool to display the spectral characteristics of select features that you will map with ENVI's ROI (region of interest) tool.

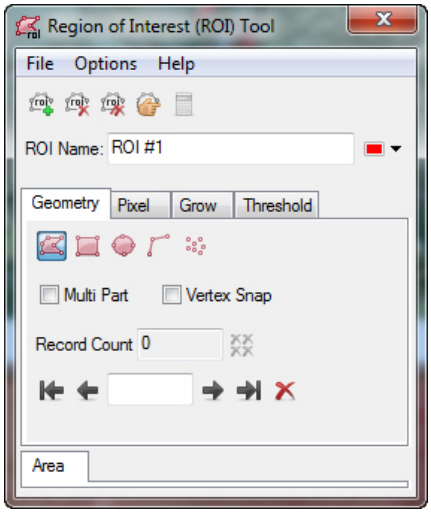
Clear the yellow Class 1 on the scatterplot. *Options > Clear Class*



Use the Toggle Density Tool (upper center) to change to a Black pattern for the pixel distribution.

Go to the main ENVI display to access the ROI tool.

File > New > Region of Interest The Region of Interest (ROI) Tool pops up



We will create 4 ROIs using the default *Geometry > polygon tool* in the menu above. The ROIs will represent:

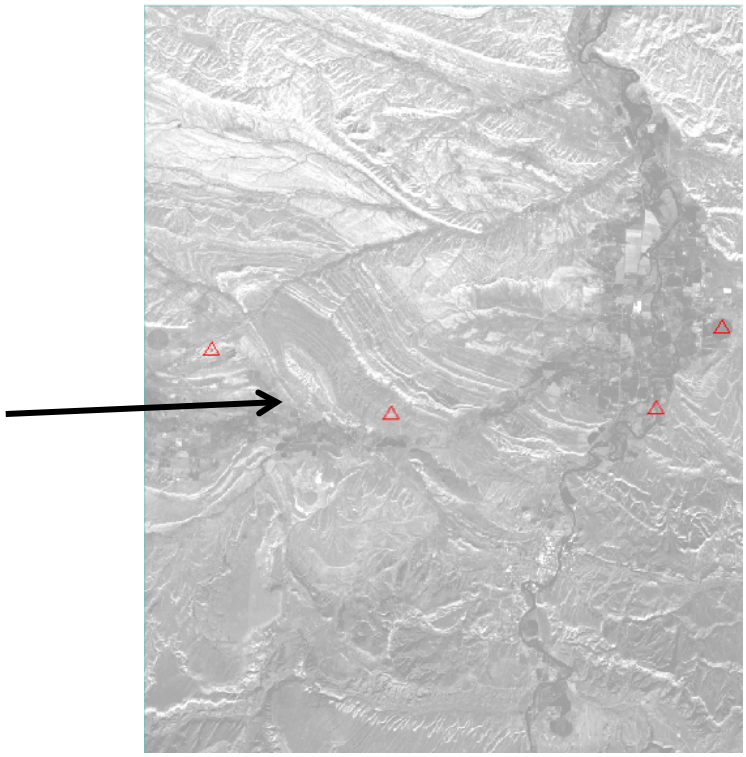
Irrigated vigorous vegetation
Water in the Wind River
Outcrop of the Chainman Shale
Airport tarmac (asphalt?)

We will display the Landsat as a 7-5-2 as R-G-B color image. Use a Linear 2% stretch.

We will use a GIS vector shapefile that has each of the four features above mapped as points. Draw your ROI polygon around those pixels near the shapefile point that are "pure" pixels for the feature of interest. Don't mix other pixels as that will degrade the spectral signature of our four features of interest.

File > Open open the "Lab_2_Data" folder and select the "ROI_sites on Thermopolis Landsat.shp" file. (the SHP File).

The four points will display on the ENVI view. The points are located across the center of the image. They are difficult to see! *Right-click* on the ROI sites shapefile in the Layer Manager and *change* the Properties – *enlarge* the "Point Size" to "20". Maybe *change* the color to "Black".



Location of shapefile points

If you can't see the shapefile points clearly, the longitude and latitude coordinates are provided below. Drive your *Zoom tool* (enables zooming in with a rectangle area of interest) to each point, zoom-in, and create a polygon ROI.

Feature of Interest	Longitude	Latitude
Irrigated Vegetation	-108.1263	43.7313
Chainman Shale	-108.2886	43.6956
Airport tarmac asphalt	-108.3788	43.7161
Water	-108.1574	43.7012

a) *Zoom* into the vigorous agricultural field and draw a ROI polygon within the bright green pixels. *Double-click* at the end of your polygon line to close the polygon and create the ROI

Rename the ROI #1 to "Irrigated vegetation".
Click-on the upper left icon "New ROI" to create a new ROI.

b) *Zoom* into the Chainman Shale outcrop and draw a ROI polygon within the yellow-orange to orange pixels.

Rename the ROI #.. to "Chainman Shale".
Click-on the upper left icon "New ROI".

NOTE: the polygons and ROIs can get mixed up. You may have to delete an ROI, edit the name (*right-click* on the ROI in the Layer Manager), and redo an ROI. Look at the Layer Manager and Data Manager to see if you are correctly making four ROIs over four areas on the Landsat image. If you get two polygons in your ROI, just use the Record Count at the bottom of the ROI Tool and delete the incorrect polygon. *PATIENCE!!*

c) *Zoom* into the Airport tarmac and draw a ROI polygon within the darkest pixels. (*change* the shapefile color from black to yellow so you can see it…)

Rename the ROI #.. to "Airport tarmac".
Click-on the upper left icon "New ROI".

d) Zoom into the Wind River water and draw a ROI polygon within the darkest pixels.

Rename the ROI #.. to "Water".

You should see the four ROIs under a folder named "Regions of Interest" in the Layer Manager. Let's rename this folder

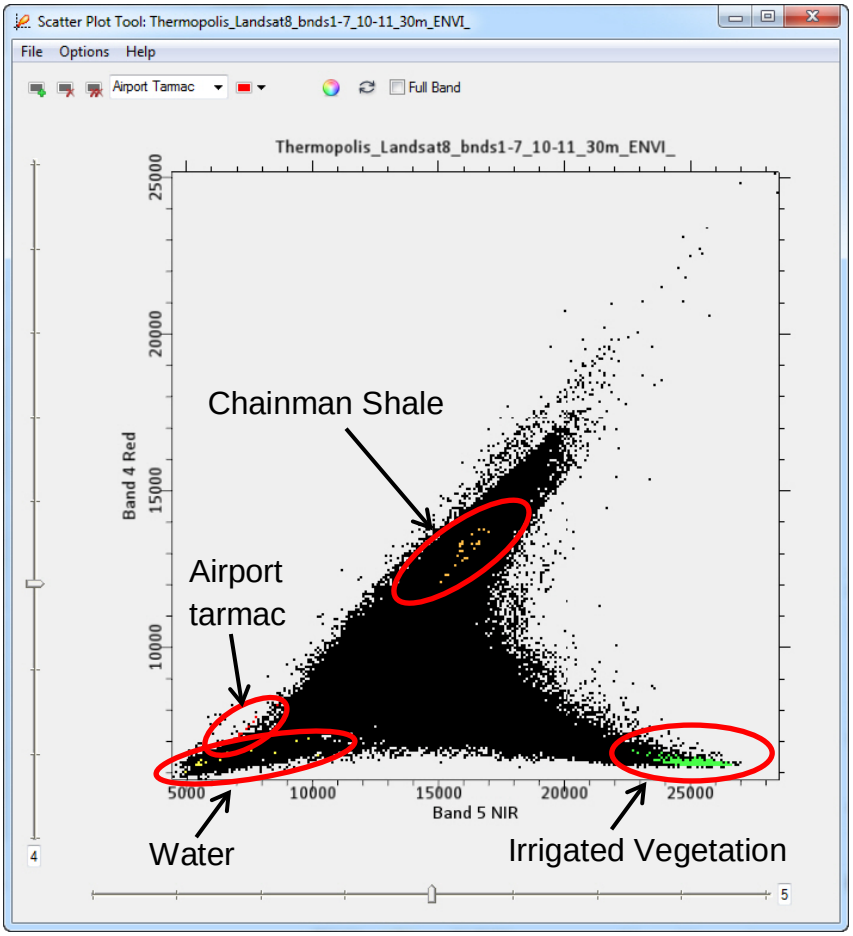
Right-click "Regions of Interest" folder > *Save As*
"Your Name_ROIs_for_ScatterPlot"

NOTE: You can also save the four ROIs using the Regions of Interest (ROI) Tool. File > Save As *Click-on* the "Select All Items" button.

13) Now let's see where these four ROIs are located on our scatter plot.
First you have to *highlight* the 9-band Landsat data in the Layer Manager!
Display > 2D Scatter Plot (if not already opened)
Choose band 4 on the vertical axis and band 5 on the horizontal axis.

Use the *Toggle Density Slice* to make the scatter plot black.

On the Scatter Plot Tool *File > Import ROIs*
You should see the 4 ROIs you just created(!)
Push the "Select All Items" button.
You will the pixels that match your ROI spectral signatures show up on the black scatter plot with default colors. Let's change the colors to brighter shades.



The ROIs reveal that each of the classes has a unique spectral signature that is differentiated on the band 4 (red) versus band 5 (NIR) scatter plot! You also see the same-color pixels on the image in the ENVI view. There are few asphalt pixels and no (?) water pixels outside the Wind River with the same spectral characteristics as our ROIs.

Save the scatter plot as an image *File > Save Plot As > Image.*

Name the plot "Your Name_Scatterplot_with_ROIs"

Upload the .jpg or .png image to the instructor

Lab 2 Multispectral Landsat Processing Name:

Upload the following files to the instructor:

(11) “Your Name_Scatterplot_map.pdf”

(13) “Your Name_Scatterplot_with_ROIs.png”

Question 1: Which band is most unlike the other 9 bands?

Question 2: Why are the Landsat 8 thermal IR bands collected with pixels that cover an area more than 100 times larger than the VNIR-SWIR 30 x 30 m pixels?
(see Equation 1-2 and Table 3-1 in the textbook)

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Question 4: A. What is the Mean and Standard Deviation of all the pixels in the 9-band Landsat dataset’s Band 5 NIR?

B. Scroll down (or use the “Locate Stat” dropdown menu) and select Band 5. Computer screens can typically only display 256 levels (DNs) of brightness. So each DN on the histogram and your computer screen contains many DNs from the original USGS data. How many original DNs are contained within each DN displayed in the histogram and on the computer screen (look for “binsize =….”)

C. What range of original USGS digital numbers (DN) have the highest count in band 5?

D. How many pixels (the “Count” value) in band 5 have the highest DN?

E. The USGS delivers Landsat 8 OLI and TIR bands with 16-bit radiometric resolution! How many levels of brightness is available with 16-bit data?

Question 5: A. How is the DN profile from the enhanced grayscale Band 5 NIR (shown above) compare with the DN profile from the original USGS data for Band 5 NIR (seen as a red line in the profile (not shown))?

B. What is different about the profiles? (Do not include the difference in the "Data Value" on the vertical axis)

C. Why the difference in the profiles? (Hint: what is different in the image processing?)

Question 6: Reflected near IR light is very bright (high Data Value) over irrigated agricultural fields on your Arbitrary Profile across the original USGS Landsat data. On this same plot, what happens to the reflected red light (band 4) over irrigated agricultural fields in comparison to reflected green light (band 3)? Any idea why this occurs?

Question 7: A. Explain the statistical plot. (also look at the metadata table)

B. What band has the highest mean DN?

C. What band has the highest DN range?

D. What band has the largest standard deviation?

Question 8: List the colors displayed with the different color composites in the agricultural fields along the Wind River. Zoom in on a field with much irrigation and vigorous crops and a field with limited irrigation and less vigorous crops to fill in the blanks on the table.

Features of Interest / OLI Bands__	Agriculture fields with much irrigation and vigorous crops	Agriculture fields with limited irrigation and less vigorous crops
Natural Color OLI 4-3-2 as R-G-B		
Color IR OLI 5-4-3 as R-G-B		
Enhanced Color OLI 7-5-2 as R-G-B		
Total IR OLI 7-6-2 as R-G-B		