Field Spectroscopy Facility
NATURAL ENVIRONMENT RESEARCH COUNCIL

Guidelines for Importing & Re-Sampling Spectra Reflectance Data for ENVI[1] Spectral Libraries

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[1] ENVI Image Analysis Software from ITT Visual Information Solutions

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Introduction

ENVI, from ITT Visual Information Solutions is a visualisation software platform for viewing and analysis of hyper spectral images.

The application includes a number of mineral and vegetation spectral libraries which can be used for spectrum identification, feature extraction, anomaly detection, target finding and material mapping. The *Spectral Library Builder* within ENVI allows for your specific field spectral reflectance data files to be added to these data bases and re-sampled to match the hyper spectral or multi-bands of the airborne or satellite images.

The aim of this guide is to provide step by step instructions for creating your ENVI spectral library with you spectral reflectance data from a Spectra Vista HR-1024™ / HR-768™ field spectroradiometer. The guide will include information on the spectral resolution of the instruments and data re-sampling.

HR-1024™ & HR-768™ Spectral File Format

Data files from the HR-1024™ / HR-768™ include a file header and four columns of data from each pixel in the V-NIR, SWIR-1 and SWIR-2 detector arrays. The spectral file format for either instrument is more generally called "Signature" or "SIG" format. The first column contains the centre wavelength of the detector pixels, the second and third columns contain the Reference & Target Radiance or Raw DN data with the final column the calculated relative or absolute Reflectance values (ref *Figure 1*).

Within the SIG format file there are small regions of spectral overlap between the three detector arrays (ref *Figure 2*).

It is essential that the data in this overlap region has been removed before importing into the ENVI spectral library.

Open the SIG data file and confirm *Overlap: Remove* is listed in the file header as highlighted in *Figure 1*.

```
/*** Spectra Vista HR-1024 ***/
name= gr121610_003.sig
instrument= HR: 0811011
integration= 90.0, 26.4, 8.0, 90.0, 26.4, 8.0
scan time= 1, 1
scan settings= AD, AI, AD, AI
external data set1= 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
external data set2= 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
external data dark= 0,0,0,0,0,0,0,0
external data mask= 0
optic= LENS 4(1), LENS 4(1)
temp= 29.7, -0.2, -5.3, 29.7, -0.1, -5.3
battery= 6.61, 6.62
error= 0, 0
units= Radiance, Radiance
time= 16/12/2010 17:09:53, 16/12/2010 17:09:59
longitude= ,
latitude= ,
gpstime= ,
comm=
memory slot= 0, 0
factors= 0.992, 0.988, 1.000 [Overlap: Remove @ 980/NIR-SWIR
On, Matching Type: Radiance @ 966 - 1000]
data=
348.1  3024.17  3139.00  103.80
349.7  3204.62  3239.88  101.10
351.3  3447.46  3490.95  101.26
352.9  3703.79  3719.06  100.41
354.5  3869.02  3907.04  100.98
356.1  4063.36  4139.79  101.88
```

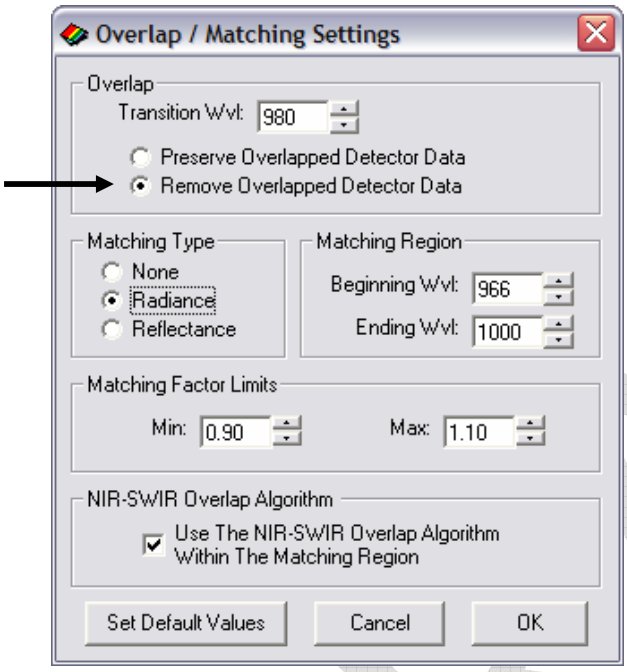
Figure 1 HR-1024 Signature Data File

™ HR-1024 and HR-768 are trademarks of Spectra Vista Corporation

Data Acquisition – PC Mode

Prior to acquiring the spectral data the simplest method for ensuring all the SIG data files exclude the overlapped data is to check the *Remove Overlapped Detector Data* in the HR-1024/768 PC Data Acquisition Software menu:-

Control_Setup Overlap/Matching…



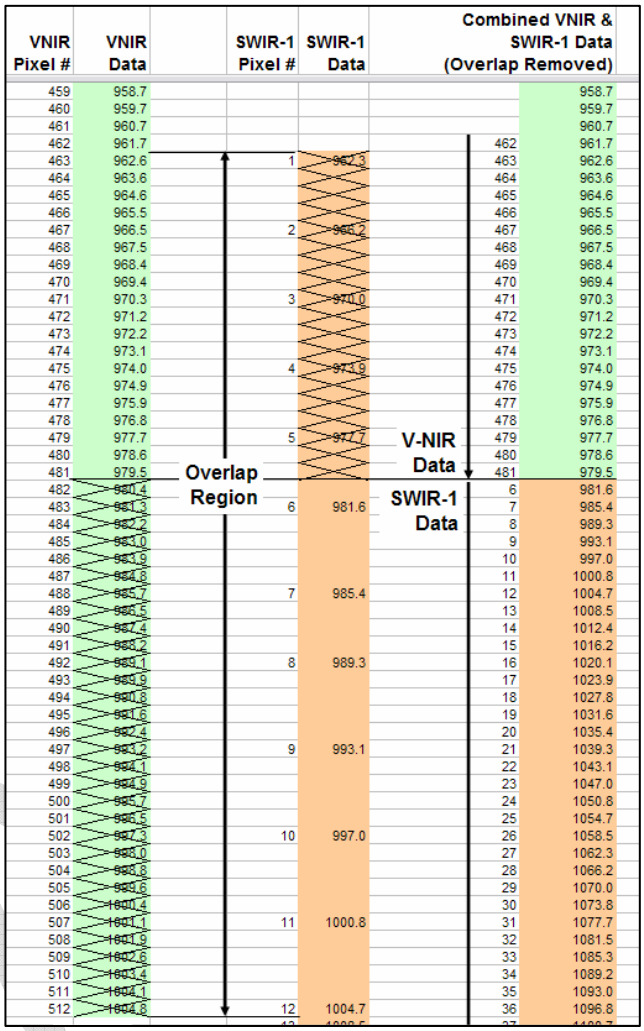


Figure 2 Overlapping VNIR & SWIR-1 regions

Removing Overlapped Detector Data

Data files which contain the Overlapped Detector Data can be processed to remove the overlap using the HR-1024 Tool – Scan Matching/Overlap Correction, ref *Figure 3*.

Note all the spectral data files captured with the *PDA* or in *Stand-Alone* data acquisition modes will require to be processed as shown to remove the overlap data.

Refer to the User Manual for further details on this tool.

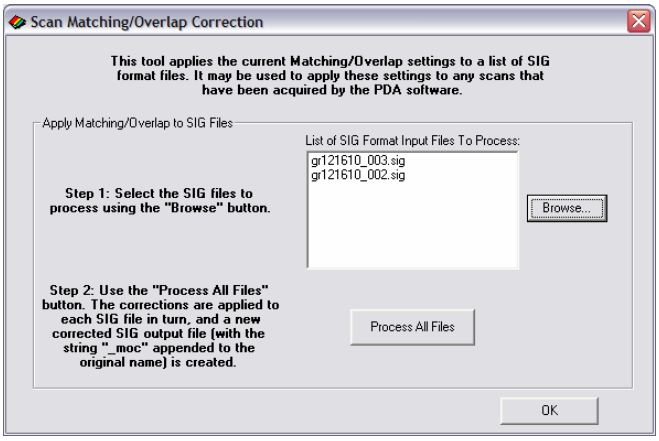


Figure 3 HR-1024 Overlap Removing Tool

Spectral Resolution[2] – FWHM

ENVI will retrieve the wavelength data from the spectral reflectance files and append this to the header file it creates for each spectral library. However if you wish to include the spectral resolution (FWHM) within the library database it will be necessary to create a separate file with wavelength and FWHM data which is imported prior to the spectral reflectance data. Note if the FWHM data is omitted from the library header file, ENVI will assume a spectral resolution equal to the sample interval, reference *Footnote 8 on page 6*. This can lead to some divergence in spectral features between library and high resolution hyper spectral data.

Creating a Pixel Centre Wavelength & Spectral Resolution File

The pixel centre wavelength and spectral resolution file contain two columns of data which match the measurement properties of the field spectroradiometer. The following information will be required:-

- The pixel centre wavelengths for each sample point in the data file
- The switching points between the arrays in multi-spectrometers instruments such as the HR-1024.
- The spectral resolution across each array / spectrometer

The complete range of pixel centre wavelengths can be captured from any of the reflectance data files with the overlapped data removed. We will use the sample interval to identify the switching points and assume the manufactures specification for spectral resolution applies to all points in each detector array[3].

1. Start Excel and open a typical Signature data file from your SVC spectroradiometer. Use the space delimiter to ensure the columns of data are correctly separated. Note this file must have the overlap data removed.
2. Delete all the rows with the file header data.
3. Delete all the columns of data except column A with the wavelength values.
4. In cell C2 calculate the wavelength interval between cells A2 and A1. Repeat for all the wavelength values.

	A	B	C	D
1	348.1	3.5		
2	349.7	3.5	1.6	
3	351.3	3.5	1.6	
4	352.9	3.5	1.6	
5	354.5	3.5	1.6	
6	356.1	3.5	1.6	
7	357.6	3.5	1.5	
8	359.2	3.5	1.6	
9	360.8	3.5	1.6	
10	362.4	3.5	1.6	
11	363.9	3.5	1.5	
12	365.5	3.5	1.6	
13	367.1	3.5	1.6	
14	368.7	3.5	1.6	
15	370.2	3.5	1.5	

[2] Referred to as "spectral bandwidth" in ENVI, with the sampling interval referred to as band spacing

[3] In some spectroradiometer the spectral resolutions can change dramatically across the each detector array.

5. Copy the FWHM value for your VNIR spectroradiometer[4] into cell B1

6. Highlight the first discontinuity step in the wavelength interval. This marks the point where the data changes from the VNIR (silicon) spectrometer to the SWIR-1 (InGaAs) spectrometer.

7. Copy the FWHM value down for all values of the VNIR spectrometer.

8. Copy the FWHM value for your SWIR-1 spectroradiometer[5] into the next cell in column B.

9. Highlight the second[6] discontinuity step in the wavelength interval. This marks the point where the data changes from the SWIR-1 spectrometer to the SWIR-2 spectrometer.

10. Copy the FWHM value down for all values of the SWIR-1 spectrometer.

11. Copy the FWHM value for your SWIR-2 spectroradiometer[7] into the next cell in column B.

12. Copy this FWHM value down for all the remaining wavelength values in your worksheet..

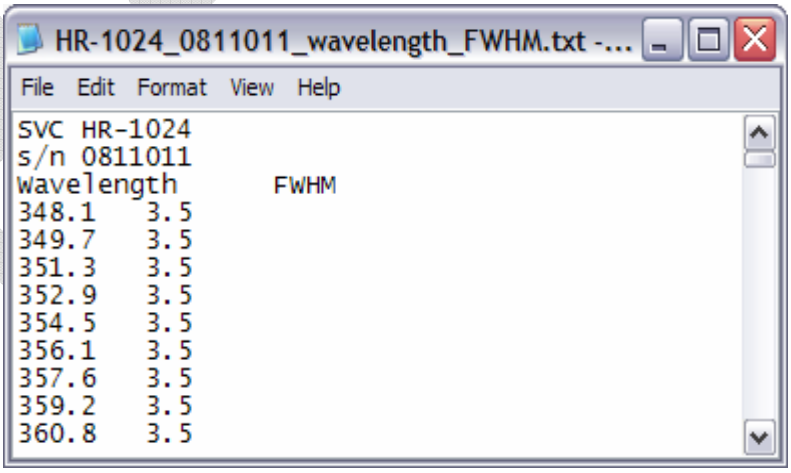
13. Delete column C.

14. Add a text header and column titles is desired.

15. Save the files as a TAB delimited text file.

	A	B	C	D
476	974.9	3.5	0.9	
477	975.9	3.5	1.0	
478	976.8	3.5	0.9	
479	977.7	3.5	0.9	
480	978.6	3.5	0.9	
481	979.5	3.5	0.9	
482	981.6	9.5	2.1	
483	985.4	9.5	3.8	
484	989.3	9.5	3.9	
485	993.1	9.5	3.8	
486	997	9.5	3.9	
487	1000.8	9.5	3.8	
488	1004.7	9.5	3.9	
489	1008.5	9.5	3.8	
490	1012.4	9.5	3.9	

	A	B	C	D
726	1862.7	9.5	3.2	
727	1865.9	9.5	3.2	
728	1869	9.5	3.1	
729	1872.2	9.5	3.2	
730	1875.3	9.5	3.1	
731	1878.5	9.5	3.2	
732	1881.6	9.5	3.1	
733	1881.7	6.5	0.1	
734	1884.5	6.5	2.8	
735	1887.2	6.5	2.7	
736	1890	6.5	2.8	
737	1892.8	6.5	2.8	
738	1895.5	6.5	2.7	
739	1898.3	6.5	2.8	



[4] For the HR-1024 this is typically 3.5nm in the VNIR range.

[5] For the HR-1024 this is typically 9.5nm in the SWIR-1 range.

[6] Note there are only two spectrometers in the HR-768 and therefore only two sets of FWHM values.

[7] For the HR-1024 this is typically 6.5nm in the SWIR-2 range.

ENVI Spectral Libraries

Information, text & images courtesy of ITT Visual Information Solutions

ENVI typically includes a list of mineral and vegetation spectral libraries form institutions such as USGS, JPL and IGCP. Information on sample and measurement protocols and some spectral resolution (FWHM) for each of these libraries is contained in a readme.txt file with each library directory. Each *.sli file is accompanied with it ENVI header file *.hdr containing wavelength data.

Viewing ENVI spectral Libraries

16. From the ENVI main menu bar, select **Spectral→ Spectral Libraries→ Spectral Library Viewer**. The Spectral Library Input File dialog appears.
17. Click **Open→ Spectral Library** and search for the directory **spec_lib** in the **products** directory of the program. From the list of *_lib directories select the JPL SL directory and **Open** the spl1.sli .
18. Highlight the file jpl1.sli and click OK to open the Spectral Library Viewer as shown in **Error! Reference source not found.**.
19. Click on any of the minerals listed to open the spectral reflectance plot.

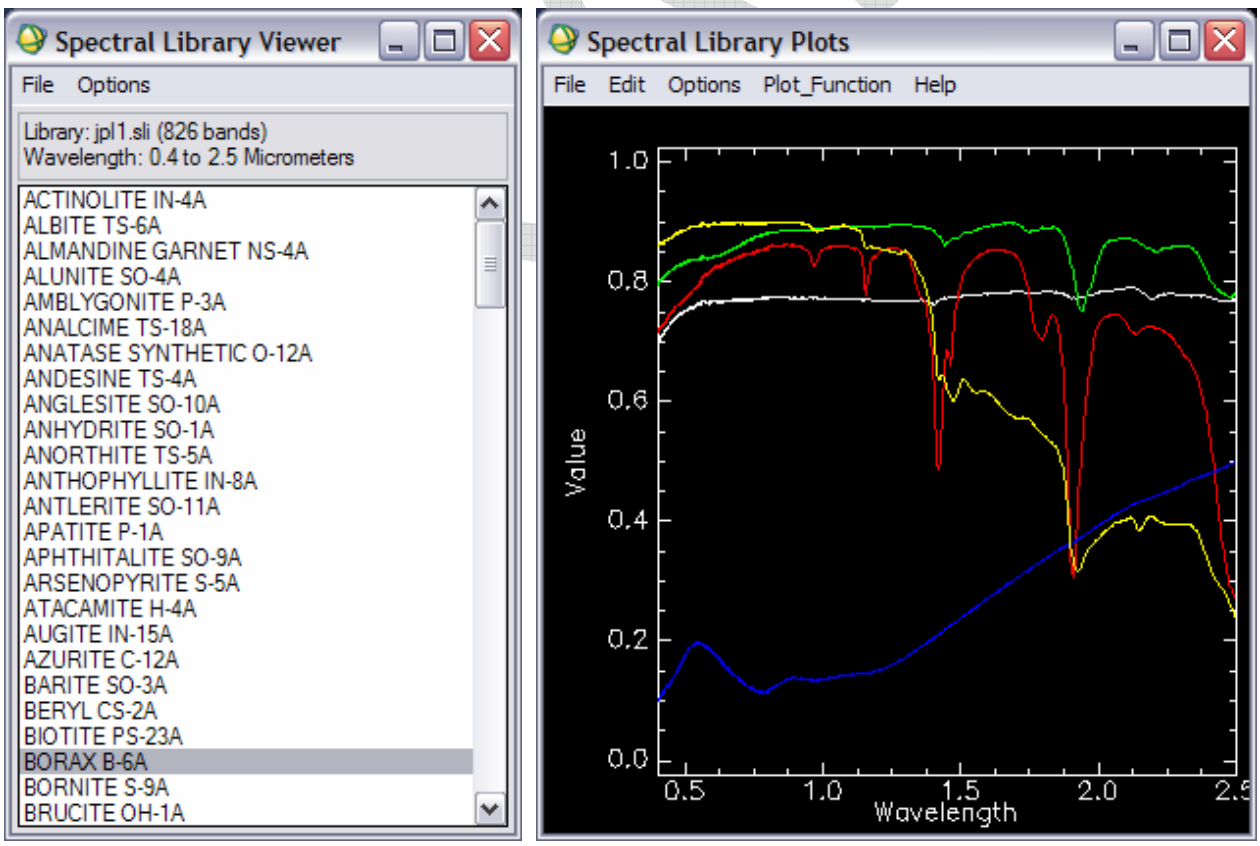


Figure 4 Spectral Library Viewer

20. From the **Edit** menu on the above Plot select **Data Values** .. and then **BORAX B-6A** from the list to open the Edit Plot dialog shown in **Error! Reference source not found.**

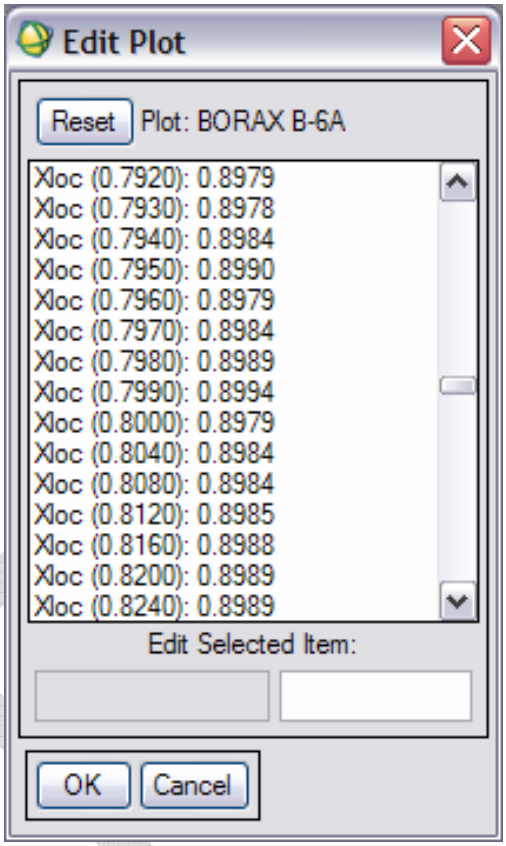


Figure 5 Data Values for BORAX B-6A

From the ***Spectral File Viewer*** ref *Figure 4* the wavelength range is 0.4 to 2.5µm with 826 bands in this range. Scrolling up and down the data within ***Edit Plot*** it can be seen that the reflectance data is sampled with a 0.001 µm (1 nm) interval from 0.4 to 0.8 µm (400 to 800 nm) and with a 0.004 µm (4 nm) interval from 0.8 to 2.5 µm.

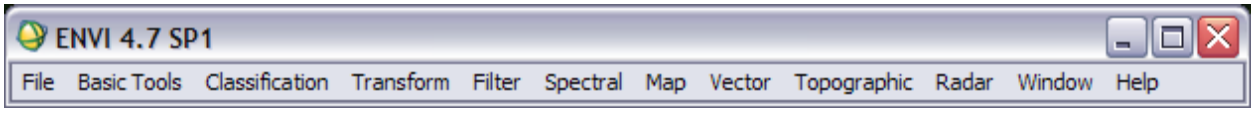
From the Readme.txt file the optical "bandwidth" () for this data set is:-

Spectral Region	Bandwith (FWHM)
0.4 - 0.8 µm	1 – 4 nm
0.8 – 2.2 µm	< 20 nm
2.2 – 2.5 µm	20 – 40 nm

This information may be useful when comparing data sets or re-sampling to other "bandwidths".

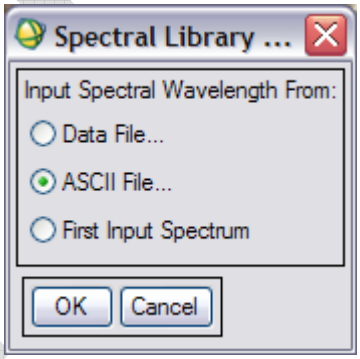
Building Spectral Libraries in ENVI (4.6 or 4.7)

Information, text & images courtesy of ITT Visual Information Solutions



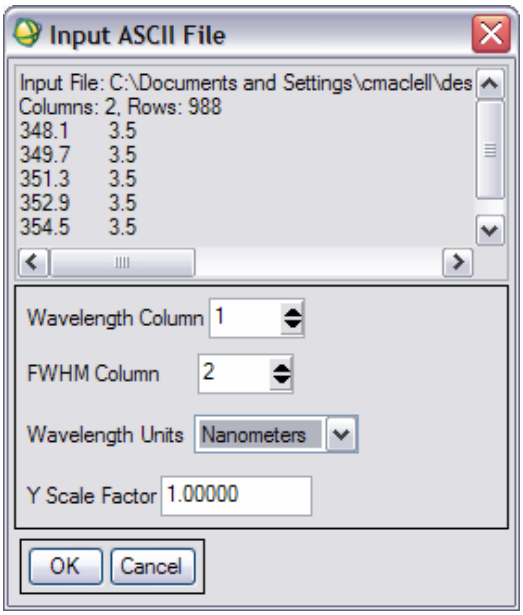
Use the **Spectral Library Builder** to create ENVI spectral libraries from a variety of spectra sources, including ASCII files, other spectral libraries, ROI means, and spectral profiles and plots. The collected spectra are automatically resampled to an input wavelength space using FWHM information, if available[8].

Adding Wavelength, FWHM & Reflectance Data



21. From the ENVI main menu bar, select **Spectral→ Spectral Libraries→ Spectral Library Builder**. The Spectral Library Builder dialog appears.
22. Select **ASCII File** and click OK.
23. Use the ***Enter File Containing Output Wavelength*** dialog to select the Spectra Vista HR-1024 *wavelength & spectral resolution (FWHM)* file created for your spectroradiometer.

    The ***Input ASCII File*** dialog appears.



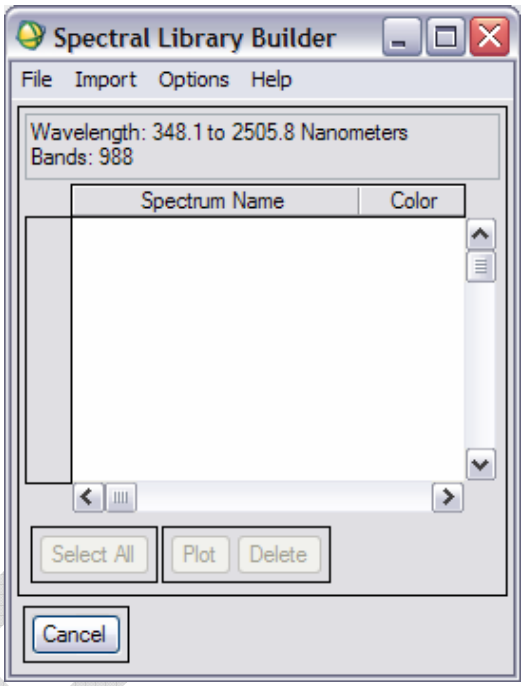
24. Specify the **Wavelength Column** as **1** and select from the drop down list the **Wavelength Units** as **Nanometers**.
25. The ASCII file also contains FWHM values, specify the **FWHM Column** as **2**.
26. Leave the Y scale at 1.00000

[8] If you only provide wavelengths (band centers), ENVI assumes critical sampling and uses a Gaussian model with an FWHM equal to the band spacings. If you provide wavelengths and FWHM information, ENVI uses a Gaussian model with FWHM spacings. If you provide a filter function, ENVI uses that for the resampling.

27. Click **OK.** The ***Spectral Library Builder*** dialog appears with the wavelength range and number of spectral bands listed.

    Note 7.1: If you select **Data File**, in step #1 above the wavelength data is acquired from an ENVI vector file, region of interest (ROI) or other spectral library file.

    Note 7.2 : If you select **First Input Spectrum**, in step #1 above the Spectral Library Builder dialog appears without the option for inserting a wavelength and FWHM data table.



28. Use the ***Import → from ASCII file..***to open the file dialog and select the SIG file(s) with reflectance data. Select the file and click **OK**.

    The ***Input ASCII File*** dialog appears as shown in *Figure 7*

    Note the four columns of data (wavelength, reference, target & reflectance) are shown but the file header has been removed.

    Since the wavelength data has been previously entered above only the reflectance values need to be selected at this stage.

29. Highlight only **Column 4** and select Nonometers from the Wavelength Units drop down list.

30. Click **OK** to open the ***Spectral Library Builder***

31. Use the mouse to expand the width of the dialog to view all the file information as shown in *Figure 8*.

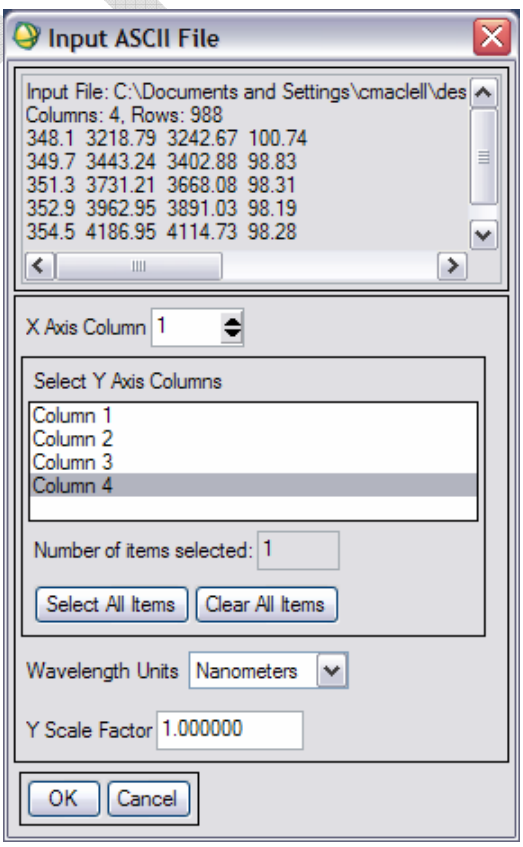


Figure 7 SIG Data in ENVI Input ASCII File dialog

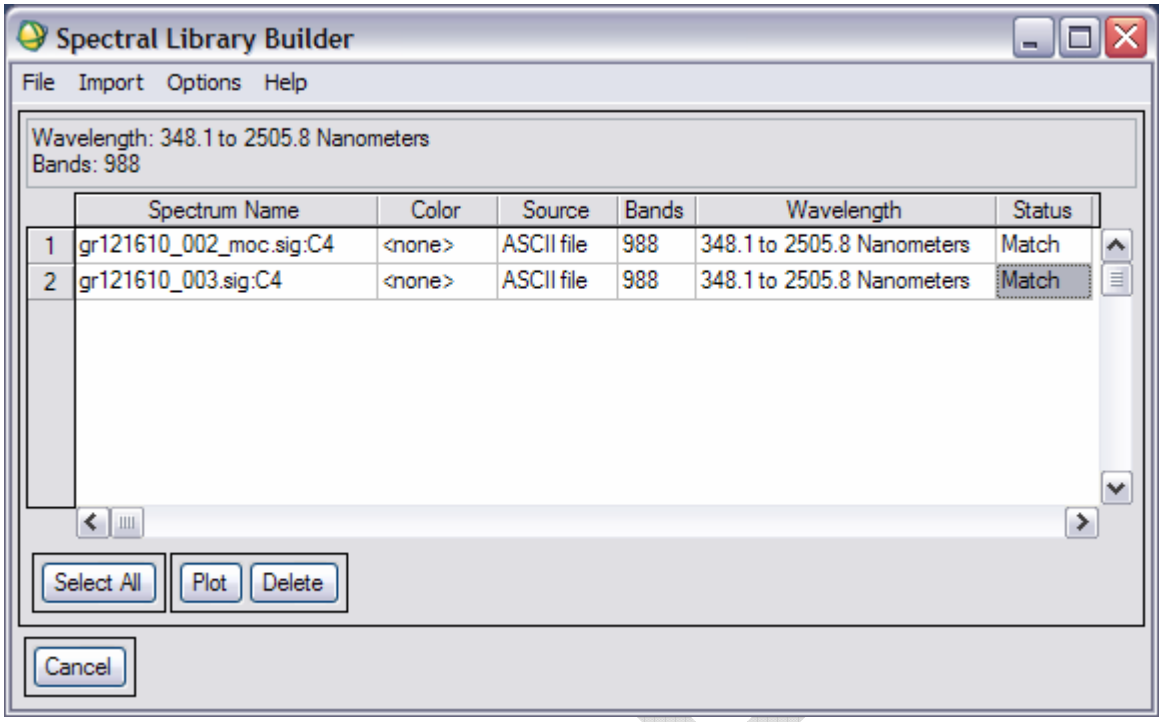


Figure 8 Spectral Library Builder showing two SIG files /

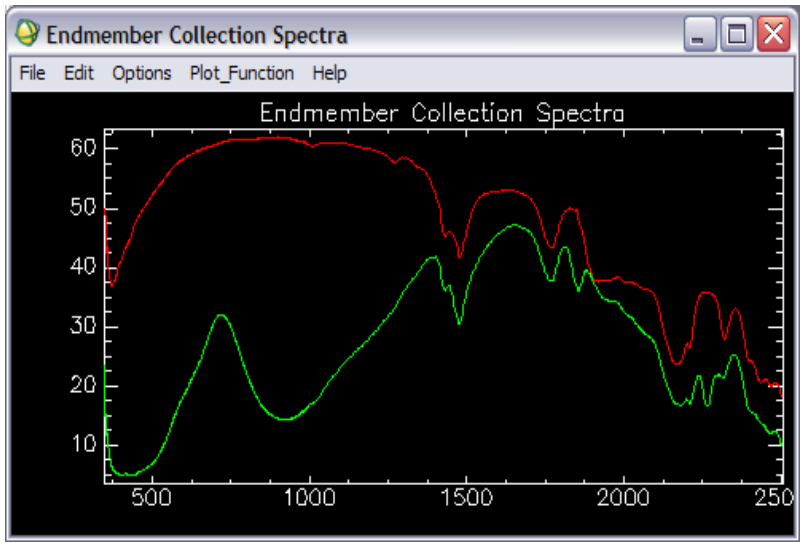
Notes:

- The first file on the list has the extension **_moc** to indicate that it was re-processed to match and remove the overlap data.
- The Spectrum filenames have **C4** appended to indicate that data is from column 4.
- The Color used for plotting can be selected by right clicking on <none> for each file.
- Status indicates the wavelength range and number of bands **Match** the wavelength range etc of the reference file imported above. Data files are re-sampled when number of bands differs.

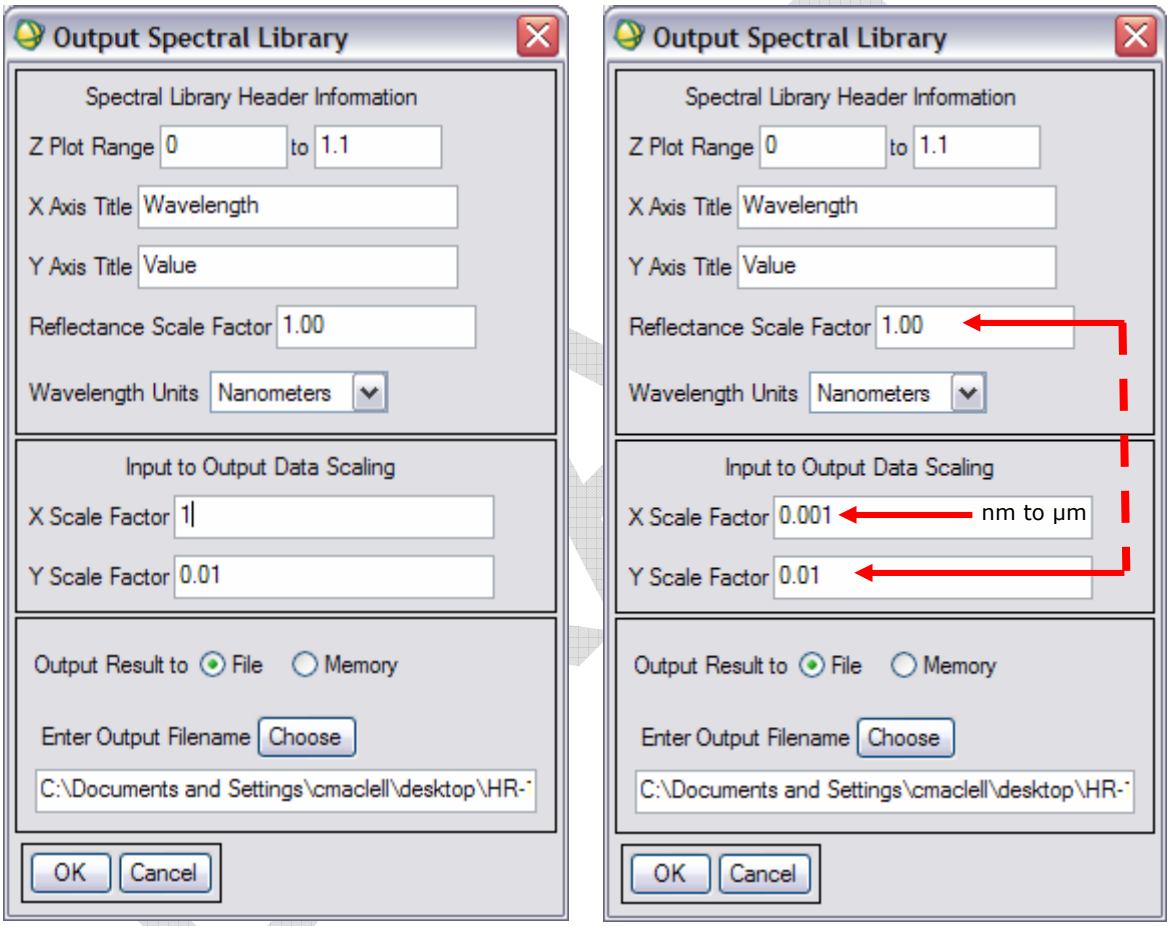
32. Use the **Select All** button and click on the **Plot** button display the imported reflectance spectra.

    Plot parameters and settings are available through the menu bar.

    Close the Plot window.



33. After collecting your spectra, select File-> Save spectra as -> Spectral Library file… to build the spectral library
34. Set the Z Plot Range 0 to 1.1, or other scale is required
35. Add axis titles
36. Typically the Signature reflectance scale is percentage 0 – 100%. This can be normalized to 1 using a Y scale factor of 0.01
37. The wavelength scale can be set to nanometers with an X Scale factor of 1 or microns with a Scale factor of 0.001.



38. Click on Choose to select a filename and path to save your new Spectral Library.

The header (.hdr) files for the spectral libraries can be viewed in a text editor program. *Figure 9* shows the header file with the wavelength scale in nanometers, followed by the FWHM values. *Figure 10* shows an alternative library header with the wavelength scale in microns.

HR-1024.HDR - Notepad

File Edit Format View Help

```
 2322.000000, 2324.500000, 2326.899902, 2329.300049, 2331.800049, 2334.199951,
 2336.600098, 2339.000000, 2341.399902, 2343.899902, 2346.300049, 2348.699951,
 2351.100098, 2353.500000, 2355.899902, 2358.300049, 2360.699951, 2363.100098,
 2365.500000, 2367.899902, 2370.300049, 2372.699951, 2375.000000, 2377.399902,
 2379.800049, 2382.199951, 2384.600098, 2386.899902, 2389.300049, 2391.699951,
 2394.000000, 2396.399902, 2398.800049, 2401.100098, 2403.500000, 2405.800049,
 2408.199951, 2410.500000, 2412.899902, 2415.199951, 2417.600098, 2419.899902,
 2422.199951, 2424.600098, 2426.899902, 2429.199951, 2431.600098, 2433.899902,
 2436.199951, 2438.600098, 2440.899902, 2443.199951, 2445.500000, 2447.800049,
 2450.100098, 2452.399902, 2454.699951, 2457.000000, 2459.300049, 2461.600098,
 2463.899902, 2466.199951, 2468.500000, 2470.800049, 2473.100098, 2475.399902,
 2477.699951, 2479.899902, 2482.199951, 2484.500000, 2486.800049, 2489.000000,
 2491.300049, 2493.600098, 2495.800049, 2498.100098, 2500.300049, 2502.600098,
 2504.800049}
fwhm = {
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
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 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
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 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000, 3.500000,
```

Figure 9

HR-1024-micron.hdr - Notepad

File Edit Format View Help

```
ENVI
description = {
  New spectral library file [Thu Dec 23 17:10:38 2010]}
samples = 991
lines   = 5
bands   = 1
header offset = 0
file type = ENVI Spectral Library
data type = 5
interleave = bsq
sensor type = Unknown
byte order = 0
wavelength units = Micrometers
reflectance scale factor = 1.000000
z plot range = {0.00, 1.10}
z plot titles = {Wavelength, Value}
band names = {
 Spectral Library}
spectra names = {
 alunite1024-1010.sig:C4, jarosite 1024-1010.sig:C4,
 kaolinte1024-1010.sig:C4, mylar 1024-1010.sig:C4,
 polyester 1024-1010.sig:C4}
wavelength = {
 0.346700, 0.348300, 0.349800, 0.351400, 0.352900, 0.354500, 0.356100,
 0.357600, 0.359100, 0.360700, 0.362300, 0.363800, 0.365400, 0.366900,
 0.368400, 0.370000, 0.371600, 0.373100, 0.374600, 0.376200, 0.377700,
 0.379300, 0.380800, 0.382400, 0.383900, 0.385500, 0.387000, 0.388500,
 0.390100, 0.391600, 0.393200, 0.394700, 0.396200, 0.397800, 0.399300,
 0.400900, 0.402400, 0.403900, 0.405500, 0.407000, 0.408500, 0.410100,
 0.411600, 0.413100, 0.414700, 0.416200, 0.417700, 0.419300, 0.420800,
 0.422300, 0.423900, 0.425400, 0.426900, 0.428400, 0.430000, 0.431500,
 0.433000, 0.434500, 0.436100, 0.437600, 0.439100, 0.440600, 0.442100,
 0.443700, 0.445200, 0.446700, 0.448200, 0.449700, 0.451200, 0.452800,
```

Figure 10