User Guide to the ESG ColorEnhance Wizards

for ER Mapper 6

Release 1.1 – January 2001

This document is a user guide to running the "ESG ColorEnhance Wizards" plug-in for ER Mapper. These wizards are developed, maintained and supported by Earthstar Geographics (ESG). This document is organized into the following sections:

■ Overview of wizards and installation

■ Details and tips on running each wizard

Notes: This document is not intended as a user guide for the ER Mapper software. You should be familiar with ER Mapper to gain full benefit from using these wizards. Earth Resource Mapping does *not* provide support for these wizards, so you should read this document thoroughly before contacting Earthstar Geographics if you have support questions.

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Wizards and User Guide written by Earthstar Geographics, San Diego, CA (www.es-geo.com)

Wizard Overview and Installation

The ESG ColorEnhance Wizards for ER Mapper are designed to be fast, interactive tools to help you take full advantage of advanced image enhancement and processing techniques available within ER Mapper. Those new to image processing will find them valuable for experimenting with and learning about various techniques. Advanced users will gain "power tools" to quickly apply and modify their favorite techniques. All wizards provide immediate access to change any option, and quickly refresh the image to view the effects.

Colordrape Wizard–Lets you create several different types of colordrape images (combined color and shaded relief), typically used for DEMs, geophysical, seismic, or similar data types. You get fast access to many different combinations and options, including the Shiny and Wet Look colordrapes.

Color Enhancement Wizard–Lets you perform several different types of color space enhancements on an RGB image, such as Landsat, SPOT, color airphotos, or other similar data. Enhancement types include Hue Saturation Intensity (HSI), Brovey Transform, Direct Decorrelation Stretch (DDS), and more.

Resolution Merge Wizard–Lets you merge or "fuse" a lower resolution multispectral image (such as Landsat TM) with a higher resolution panchromatic image (such as SPOT Pan). Techniques include Hue Saturation Intensity (HSI), Brovey Transform, Smooth Filter Intensity Modulation (SFIM), HPF Additive, and more.

Natural Color Wizard–Lets you transform false color infrared images with red vegetation to "simulated natural color" with green vegetation. Typical data types include SPOT XS, Landsat MSS, and color IR airphotos. Also provides vegetation masking, and Brovey Transform and DDS color enhancement options.

System requirements

To run these wizards, you must have a licensed copy of ER Mapper.

ER Mapper version required: 6.0 or higher
Disk space required: approx. 1 MB

Using the wizards as templates

The wizards are written in ER Mapper's batch scripting language. Users with some programming aptitude may want to use the wizards as templates to help create your own wizards that perform similar functions. For this reason, the wizard script files contain detailed comments to help you understand their design and logic.

To modify a wizard, open the ".erb" file in a text editor and resave it under a different name. (Be sure to do this immediately to avoid overwriting the original wizard.) Then make your modifications and resave it. You can run your new wizard by selecting **View/Batch Engine Script Control**, then clicking the **Run Script** button. You can also create your own toolbar and run them from there. See the ER Mapper documentation for details on creating batch scripts and wizards.

Installing the wizards

Important: You must have the password supplied at the time of sale to run this installation procedure.

1) Close all ER Mapper applications.
2) Copy the file "esgcewiz11.exe" into a temporary directory on your hard drive.
3) Double-click on the "esgcewiz10.exe" file icon in the Windows Explorer. The **WinZip Self Extractor** dialog displays.
4) Click the Browse… button, then select the directory containing ER Mapper on your system (typically ERMAPPER60, ERMAPPER61, etc.). Be sure the "Overwrite Files Without Prompting" option is selected.
5) Click the "Unzip" button to display the password dialog.
6) Enter the password supplied to you, then click **OK** to unzip and copy the files into the appropriate ER Mapper directories.
7) Click **Close** on the **WinZip Self Extractor** dialog when finished.
8) Restart ER Mapper, then select **ESG ColorEnhance** from the **Toolbars** menu to display the ColorEnhance wizards toolbar.

Notes: The installation only adds new files, it does *not* replace any files that ship standard with ER Mapper. (Any custom ER Mapper files you have added are also not disturbed.) If you do not see the ColorEnhance toolbar after installation, you probably selected the wrong directory location for ER Mapper in step 4. (Verify the location and perform the installation again.)

Accessing the wizards within ER Mapper

The wizards are setup as a "toolbar" inside ER Mapper. To gain access to them, select **ESG ColorEnhance** from the **Toolbars** menu on the main ER Mapper menu bar.

The **ESG ColorEnhance** toolbar is setup with four buttons; each starts up a wizard with a graphical interface. If you point the mouse to a button, the name of the wizard appears next to it (the "tool tip"). Wizards are referred to by these names in the rest of this document.

Filter files added during installation

In addition to wizard script and graphic files, the installation procedure adds several filter files to your ER Mapper installation. These are needed to run some of the options on the Resolution Merge Wizard.

Installed into the ERMAPPER6x/kernel directory:

```
filters_lowpass/avg9.ker
filters_lowpass/avg11.ker
filters_high_pass/Sharpen_5x5.ker
filters_high_pass/Sharpen_7x7.ker
filters_high_pass/Sharpen_9x9.ker
```

Uninstalling the wizard files

There is no "uninstall" utility. However, the wizard files take up very little disk space (less than 1MB) and will not impact other software products.

## How to tell your wizard version

To determine which version of the ESG ColorEnhance Wizards you have installed, click the 'Help' button on the first page of any wizard. The version described in this document is 1.1.

Rescaling Non-8-Bit Datasets

Some techniques available in the "Resolution Merge Wizard" and "Color Enhancement Wizard" require that one or both input datasets be in 8-bit data format. (That is, they must have a data range between zero and 255.) This means that image types such as 11-bit IKONOS images cannot be used directly as input. Both wizards will warn you of this condition as you are running them, and let you know if the technique requires 8-bit data ranges.

You can, however, use non-8-bit images by rescaling them into an 8-bit data range, then saving them as a Virtual or Raster Dataset. As an example, following are some general steps for rescaling an 11-bit IKONOS 3-band color image in ER Mapper:

1) Open the image file in ER Mapper (**File/Open**).
2) Open the **Algorithm** dialog box, and setup the algorithm so that each band in your input dataset has a layer. Make sure you label each layer with the description you want to use for "band labels" in your output Virtual or Raster Dataset. In the example below, an IKONOS color infrared image is setup to be saved as a 3-band Virtual or Raster Dataset:
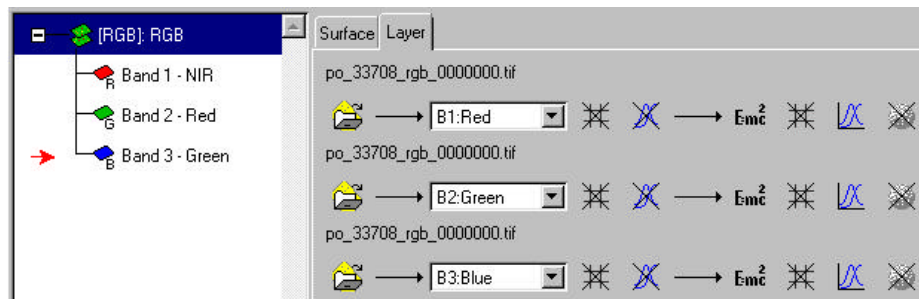
3) Open the post-formula transforms for each layer, reset the transform line to the default ( ), and select the **Limits to Actual** menu option. Your transforms for each layer should look similar to this (but with different data ranges of course):
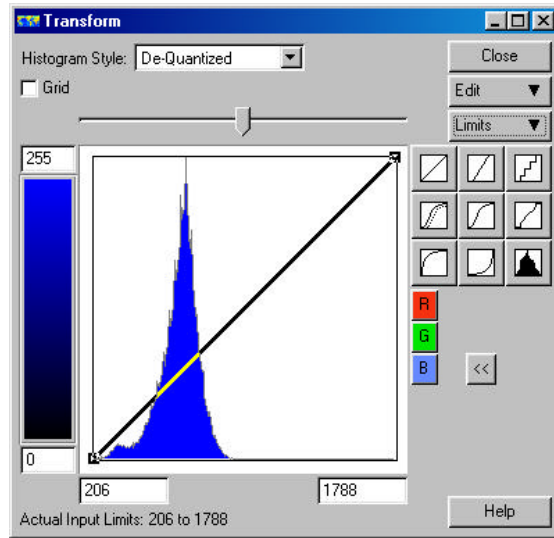
Note: If you like, you can apply a clip ( ) to each layer to stretch the contrast a bit, but you will lose some of the dynamic range.

4) Select **File/Save As**, and select to save as either a Virtual Dataset or Raster Dataset file type:

Virtual Dataset–Use this option to avoid creating a new disk file (however processing will be slower than when using a Raster Dataset). When prompted to delete the output transforms, select **No**.

Raster Dataset–Use this option to save a copy of the data in a new disk file in ER Mapper Raster format. On the **Save As ER Mapper Dataset** dialog, be sure to select the "Unsigned 16-bit Integer" data type, and uncheck (turn off) the "Delete output transforms" checkbox.

After saving, use the Virtual or Raster Dataset as input to the wizard.

Colordrape Wizard
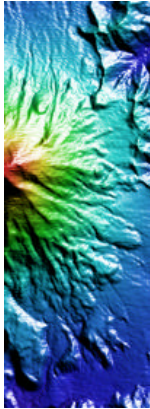
The Colordrape Wizard lets you create several different types of colordrape images, or images that combine color with shaded relief. ER Mapper is world famous for the ease with which it creates colordrape images, and this wizard gives you fast access to many different combinations and options. You can specify the sun shading angle (azimuth) and elevation, the color set used to display the image and various contrast enhancements, filter the data to smooth out noise, and invert the values if needed. You can also use two different datasets for color and shaded relief if desired (just make sure they at least partially overlap and have the same datum and projection).

Following is an overview of each of the image type options. (Details on controls and options that apply to all techniques is contained in a following section.)

Standard Colordrape
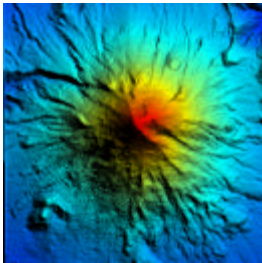
As implied, the Standard Colordrape option makes a standard ER Mapper colordrape image with one Pseudocolor layer and one Intensity layer. The Intensity layer has sun angle shading turned on to create the shaded relief effect. Both layers are adjustable independently, so the image color table or transform can be modified independent of the image shading, and vice versa.

The image on the left is the Mt. St. Helens volcano "before" dataset supplied with ER Mapper. Sun shading is from the northeast at 55 degrees elevation. Color enhancement is a linear contrast stretch (limits to actual).

Softened Colordrape
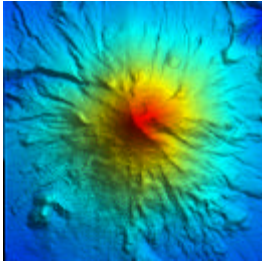
The Softened Colordrape creates a colordrape with a "softer" shading effect, so the color can be seen better in shadowed areas. This may be a better choice than the Standard colordrape if you want to deemphasize the topography or surface detail and increase the image color (especially in shadowed areas). The image on the left has a 30% transparency applied compared to the previous Standard example.

This image is created by using two surfaces in the algorithm. The top surface is a standard colordrape, the lower surface contains only the Pseudocolor layer. The top surface is then set to a degree of transparency so more of the pure image color from the lower surface is blended into the overall image to soften the shading effect.

The wizard offers several pre-defined settings for transparency (percent softening) on the Color Properties page. After creating the image, you can manually adjust the transparency of the top surface to modify the amount of softening. (Higher transparency reduces shadowing, lower gets closer to a standard colordrape.)

Shiny Look Colordrape

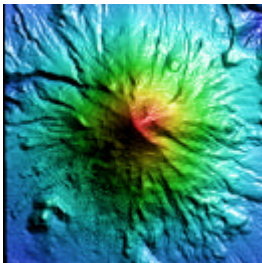The Shiny Look creates an image that adds "highlights" (the illusion of reflected light) to the image, so it looks like a plastic raised relief map. The Shiny look is a two-stage process that is created by first making a standard colordrape image, saving it as an algorithm, then loading it into a Hue Saturation Intensity (HSI) algorithm. The "color" layer (band) of the standard drape algorithm is loaded into the Hue layer, and the Saturation and Intensity layers contain the "shaded" layer (band).

To create the shiny effect, the shaded relief data in the Saturation layer is first inverted (using the "255-I1" formula) so that the most brightly illuminated pixels are the lower data values. Then a logarithmic-type transform line is applied to set these areas to very low saturation values. This strongly decreases the strength of colors in brightly illuminated areas (desaturates them), so they look greyish or white and thus "shiny."

Note that when using HSI algorithms, you are limited to a fixed set of colors (the same colors you see in the "hue" color table). Because of this, your options for coloring the image are limited (i.e., you cannot pick any color table as you could if using a standard or softened colordrape). To make more color set variations, the wizard offers options that let you include or exclude certain hues. (It does this by changing the Y axis transform limits for the Hue layer.) A few more variations are added by inverting the hue data (255-I1), then setting specific output (Y axis) transform limits.

Wet Look Colordrape
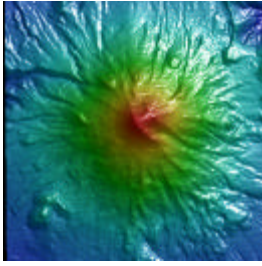
The Wet Look is a variation of the Shiny Look that creates a more glossy looking image. It is created in basically the same way, except that the Intensity layer of the HSI algorithm has a special transform line that looks similar to a Gaussian Equalize transform. This flattens out the contrast in the mid-range brightness, makes the shadowed areas lighter and makes the shiny "highlight" areas much brighter, so they almost appear to be glossy or wet.

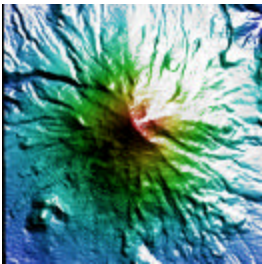The Wet Look has an additional 'Add more wetness to image' option that appends a second transform to the Saturation layer that clips the X-axis limits to a range of 40-255 (instead of 0-255). This simply sets more of the highlight areas to the maximum brightness value, so you get a little more "wetness."

Metallic Look Colordrape

The Metallic Look is simply an extreme version of the Shiny Look, and is really just a special effect that you would not normally use. This is created by making a Shiny look image, but setting the Saturation layer's X-axis transform range to 60-255 (instead of 0-255). This causes all the saturation to be removed from most highlighted areas, thus turning them entirely grey or white (giving the overall image a very grey or metallic look). This look removes much of the color, so it is not recommended for image interpretation.

General Controls and Options

General wizard controls and options that apply to all image types are explained in detail below:

- **Input images**–You can the same image or two different images or bands for input (for example, magnetics data for color and a DEM for shaded relief). If using two different images, they must be in the same datum and projection, and cover at least some common area. Unless you choose to define an image subset, the colordrape image will show the full extents of the shaded relief image.

- **Inverting data values**–This option designed for datasets such as seismic two-way time or bathymetry where smaller data values are actually structurally higher features than the larger values. Inversion adds a "-input1" formula that "flips" the data histogram, so the structurally higher features are displayed on the right side of the histogram. This usually allows more natural manipulation and presentation of the data. It is not essential to use this (so it is an option), and you would not normally not use it on DEMs, aeromagnetics, gravity, etc.

- **Filtering to reduce noise**–This option applies a 3x3 median filter to the shaded relief (intensity) layer to smooth out spikes or reduce gridding noise in the colordrape image. It is not applied to the color layers(s).

- **Defining an image subset**–This option lets you process only a portion of the input image's geographic area. Color/contrast stretching is applied only to the data range of the subset area. Click the 'Define image subset (zoomed area)' button to display an image of your shaded relief data, then zoom into the area you want to process. To proceed and use this area, check the 'Process only this subset' button and click Next>. (If 'Process only this subset' is off, the entire area of the shaded relief image is processed.) For Shiny, Wet and Metallic Look images, the extents are saved in an intermediate algorithm (so you cannot zoom out to the full extents of the dataset later).

  Note: If using the Wet, Shiny or Metallic Look image type, areas of the shaded relief image that extend outside the color image are displayed in red. You may therefore want to define a subset to exclude these areas from the image. (If using Standard or Softened colordrapes, areas of the shaded relief image that extend outside the color image are displayed in greyscale.)

- **Setting custom shade parameters**–The Shading Properties page lets you select a predefined sun elevation and azimuth, or define your own custom settings. To define your own, first check the 'Use current custom shade setting' box, then click the 'Set custom shading parameters' button. Use the Edit Sun Angle dialog to set the desired shading for the image, then close Edit Sun Angle dialog (do not close the shaded image) and click Next>. Your custom setting is used as long as the 'Use current custom shade setting' box is checked. (To use the current menu selections instead, turn off 'Use current custom shade setting'.)

- **Color table/color set**– If using Standard or Softened colordrapes, you can select any color table currently installed in ER Mapper to create the image colors. The Wet, Shiny or Metallic Look image types do not use a color table, so you are limited to a fixed set of predefined options. (See the "Shiny Look" section earlier for more information.)

Color Enhancement Wizard

The Color Enhancement Wizard lets you perform several different types of color space enhancements on an RGB image. These enhancements are typically designed to make the image more pleasing to the eye or enhance the overall information content to aid analysis and interpretation.

Most of these techniques are standard in the remote sensing industry, and some references are listed that provide more technical detail that is beyond the scope of this document. Please consult these references for details on the specific techniques.

Following is an overview of each of the techniques:

Hue Saturation Intensity (HSI)

This technique allows separate adjustments to hue, saturation and intensity (HSI) components of an image. The three bands of RGB data are transformed into H, S and I components using formulas, then you can select various options to modify or enhance each component. Some basic definitions of Hue, Saturation and Intensity:

- **Hue**–The wavelength of reflected light, or commonly identified by the name of the color such as red, cyan, or green. Hue is measured as a location on the standard color wheel (left) and is expressed as a degree value between 0° and 360°. Red is zero or 360, green is 120, cyan is 180, and so on.

- **Saturation**–The strength or purity of the color (sometimes called chroma). Saturation represents the amount of gray in proportion to the hue and is measured on the scale 0 (gray) to 1 (fully saturated). Dull or pastel colors have low saturation values; vivid or pure colors have high saturation. For a hue of red, for example, low saturation produces a pinkish color, and high saturation produces a vibrant red color.

- **Intensity**–The relative brightness (lightness or darkness) of a color.

The wizard offers the following choices for HSI enhancement:

■ **Rotate hue–**This lets you shift all colors in the image by rotating them around the 360 degree color wheel. All colors will be rotated clockwise by the amount you specify. Application examples include rotating red hues in a color infrared image to become green (a simple vegetation 'natural color' technique). Or, shift the color of a specific feature of interest to another color (useful with RGB band ratios, Principal Components, or similar images).

■ **Stretch saturation–**Saturation stretching increases the contrast of the saturation component to make all image colors more pure or vivid. It is commonly used to increase color contrast in highly correlated band combinations such as Landsat TM RGB=321 that often produce "bland" images. The effect of different saturation stretch options varies from image to image, so experiment for best results.

■ **Stretch or sharpen intensity–**One of the advantages of HSI over other enhancement techniques is the direct control of the image intensity (brightness/contrast) separate from the color (hue and saturation). You can contrast stretch the intensity using several predefined options. You can also apply a high pass (sharpening) filter to add"crispness" to the image. (1987).**Tip:** If your input data is not already contrast stretched, best results are usually achieved by contrast stretching the data in RGB space before conversion to HSI. (This is recommended for most satellite imagery, but may not be needed for TIFF airphotos or other data with good contrast.) This option is provided on the wizard's RGB Bands page.

Reference: Gillespie, A., A. Kahle and R. Walker, 1986. "Color Enhancement of Highly Correlated Images. I. Decorrelation and HSI Contrast Stretches." *Remote Sensing of the Environment*, 20, pp. 209-235 (1987).

Direct Decorrelation Stretch (DDS)

The Direct Decorrelation Stretch (DDS) is a form of decorrelation stretching that increases color saturation by reducing the achromatic component of the RGB image. It is computationally much simpler than HSI conversion, and thus faster for simply increasing color saturation. It also allows saturation enhancement while working in RGB color space. So you could, for example, save the color enhanced image as an RGB Virtual Dataset for further use in data fusion or other processing.

DDS has a "k" factor that controls the amount of saturation increase (ranging from 0.0 to 0.99). Start with 0.2 to 0.5 (depends on the image) and increase or decrease the value until color saturation is at the desired level. The wizard implements the DDS technique using formulas as follows:

```
Red layer = R-(k*(MIN(R,G,B)))

Green layer = G-(k*(MIN(R,G,B)))

Blue layer = B-(k*(MIN(R,G,B)))
```

where "MIN" is the minimum value of the current pixel in the 3 RGB bands selected, and "k" is an achromatic factor between 0.0 and 0.99. (Effects of the "k" factor vary with different types of images, so experiment for best results.)

Tip: If your input data is not already contrast stretched, best results are usually achieved by contrast stretching the data in RGB space before DDS transformation. (This is recommended for most satellite imagery, but may not be needed for TIFF airphotos or other data with good contrast.) This option is provided on the wizard's RGB Bands page.

Reference: Guo, L. J. and J. McM. Moore, 1996. "Direct decorrelation stretch technique for RGB colour composition." *Int. Journal of Remote Sensing*, Vol 17, No. 5, pp. 1005-1018 (1996).

Intensity Conservation Direct Decorrelation Stretch (ICDDS)

Intensity Conservation Direct Decorrelation Stretch (ICDDS) is similar to DDS, but may preserve the original RGB image intensity more than DDS. ICDDS also has a 'k' factor that works the same way as DDS. The difference between DDS and ICDDS may not be noticeable on some images, but you should experiment with them to find out. The wizard implements the ICDDS technique using formulas as follows:

```
Red = (R-(3k*MIN(R,G,B)))*(R,G,B)/(R,G,B-3k*MIN(R,G,B))

Green = (G-(3k*MIN(R,G,B)))*(R,G,B)/(R,G,B-3k*MIN(R,G,B))

Blue = (B-(3k*MIN(R,G,B)))*(R,G,B)/(R,G,B-3k*MIN(R,G,B))
```

where "MIN" is the minimum value of the current pixel in the 3 RGB bands selected, and "3k" is an achromatic factor 3 times the value of "k" in the DDS formula. (Effects of the "k" factor vary with different types of images, so experiment for best results.)

Tip: If your input data is not already contrast stretched, best results are usually achieved by contrast stretching the data in RGB space before ICDDS transformation. (This is recommended for most satellite imagery, but may not be needed for TIFF airphotos or other data with good contrast.) This option is provided on the wizard's RGB Bands page.

Reference: Guo, L. J. and J. McM. Moore, 1996. "Direct decorrelation stretch technique for RGB colour composition." *Int. Journal of Remote Sensing*, Vol 17, No. 5, pp. 1005-1018 (1996).

Brovey (Chromaticity) Transform

Also known as the "chromaticity" or "color normalize" transform, this technique separates the image into color and brightness components, then stretches the image colors in RGB space. (It was popularized by R. L. Brovey, so it sometimes called the Brovey Transform.) It works by normalizing the band to be displayed by the intensity of the RGB image (the sum of R, G and B). It then multiplies the result by an image band or the overall image Intensity to add the brightness (shadows or albedo information) back into the color image that was removed by the normalization/ratioing. In addition to color enhancement, this technique is commonly used to merge two images as well (so it is also used in the Resolution Merge Wizard). The wizard implements the Brovey Transform technique using formulas as follows:

```
Red = R/(R+G+B)*Intensity

Green = G/(R+G+B)*Intensity

Blue = B/(R+G+B)*Intensity
```

where "Intensity" can be one of the image bands, or the overall image intensity derived from the three RGB bands (or any other set of RGB bands).

When you select to derive intensity from three RGB bands, you can select from the following ways to convert RGB to Intensity. Results can be fairly similar, but some may be preferable to others. The formulas used to do the conversions are as follows:

Maximum value of RGB: `MAX(R,G,B)`

Average of RGB min and max: `(MAX(R,G,B)+MIN(R,G,B))/2`

Average of sum of RGB: `(R+G+B)/3`

RGB to greyscale conversion: `(R*0.28)+(G*0.59)+(B*0.13)`

Results of the Brovey/Chromaticity technique are not as easy to predict as the others, and can produce both beautiful and strange results. (This usually depends on your Intensity data and the contrast enhancement technique.) Start with using one of the image bands as Intensity, then try the RGB Intensity options. Note that the wizard lets you create the Intensity component from *any* three bands in your image, not just the three you selected for RGB. (For example, you could choose Landsat TM bands 742 for your color image, but use the intensity generated from bands 321.)

Often best results are achieved by multiplying by a visible wavelength band, such as bands 1 or 2 or 3 of Landsat TM or band 1 or 2 of SPOT XS or Landsat MSS. The following combinations usually produce nice enhancements (and enhance detail in water areas):

SPOT XS (RGB=321)–use XS1 or RGB Intensity for brightness

Landsat MSS (RGB=321 or 421)–use MSS1 or RGB Intensity for brightness

Landsat TM RGB=321–use TM1, TM2 or RGB Intensity for brightness

Landsat TM RGB=542–use TM1, TM2, TM3 or RGB Intensity for brightness

For RGB Intensity, try different band combinations other than the ones you are using for the RGB image. For an RGB=321 Landsat TM image, for example, intensity from 741, 432 or other combinations can sometimes produce interesting results (depending on the image characteristics).

Reference: Gillespie, A., A. Kahle and R. Walker, 1987. "Color Enhancement of Highly Correlated Images. II. Channel Ratio and "Chromaticity" Transformation Techniques." Remote Sensing of the Environment, 22, pp. 343-365 (1987).

Hybrid Contrast Stretch

The Hybrid Contrast Stretch is a simple technique that lets you combine the characteristics of two different types of standard contrast stretches into a single image. Different types of stretches enhance different sets of features, and combining two types sometimes creates a better overall image than either stretch by itself. For example, combining a 99% clip linear stretch with a Gaussian Equalization can add some detail in the brightest and darkest areas that may be lost by the clipping. This technique is designed primarily for contrast enhancement, and does not enhance or modify image color as much as the other techniques. (The center image at the left is a 50/50 hybrid of a 99% linear stretch and histogram equalization.)

The image is created by splitting the RGB image into two surfaces, then applying a separate type of stretch to each surface. The surfaces are then re-combined into one image by setting the top surface to be partially transparent.. This creates a weighted average between the two images and adds in a proportional amount of the image in the lower surface. Best results are usually achieved by combining a linear (clip) stretch with Histogram or Gaussian Equalization. (This technique could also be implemented in a single surface using weighted average formulas, but can be fine tuned interactively with the Transparency control when using two surfaces instead.)

Tip: The wizard offers a set of predefined weighting percentages between the two surfaces. You can fine tune this yourself to any percentage by opening the

Algorithm dialog, selecting the upper surface and adjusting the transparency slide bar.

Note: One limitation of this technique is that the image cannot be saved as a 3-band Raster or Virtual Dataset for further use. (This is because the image has two surfaces, so each layer in each surface is saved a separate band in the output dataset.) If you want to save the image into a 3-band file for further processing or use, save it as a GeoTIFF instead.

General Controls and Options

General wizard controls and options that apply to all techniques are explained below. (Some techniques have separate options not listed here; see the section on each technique for those.)

■   **Input image**–The input image must contain at least three bands to create an RGB image. Many images merged with the Resolution Merge Wizard can be saved as a Virtual Dataset, then loaded into the Color Enhancements Wizard for further adjustments and processing.

  Note: The HSI, DDS and ICDDS options require 8-bit image files as input because the formulas are designed to operate only on 8-bit (0-255) data ranges. If you have a 16-bit image (IKONOS for example), rescale it to 0-255, save it as a Virtual Dataset (VDS), then load the VDS into the wizard. (See the section "Rescaling Non-8-Bit Datasets" for more information.) The Brovey Transform and Hybrid Stretch options can be used directly on 16-bit image files.

■   **Defining an image subset**–This option lets you process only a portion of the area covered by the input image. Image processing and contrast stretching is applied only to the data range of the selected subset area. Click the 'Define image subset (zoom area)' button to display your image data in RGB, then zoom into the area you want to process. To proceed and use this area, check the 'Process only this subset' button and click Next>. (If 'Process only this subset' is off, the entire area of the image is processed.) For techniques that require an intermediate Virtual Dataset, the subset area is saved as the Virtual Dataset extents (so you cannot zoom out to the full extents later).

Resolution Merge Wizard

The Resolution Merge Wizard lets you merge or "fuse" an RGB image with a panchromatic image. This creates a hybrid image that has the color characteristics of the RGB image and the spatial resolution of the panchromatic image. A typical example is merging Landsat TM 30-meter data with SPOT Panchromatic 10-meter data, SAR imagery, or another data type. Most of these techniques are standard in the remote sensing industry, and some references are listed that provide more technical detail that is beyond the scope of this document.

When merging optical imagery, best results are usually achieved when the spectral qualities of the intensity data match (or are similar to) the spectral qualities of the RGB data. For example, SPOT Panchromatic data tends to be relatively dark in vegetated areas, and thus may make vegetated areas in the merged image appear darker than in the original RGB image. The techniques here respond differently to these qualities, and some (such as RGBI and HSI) require more manipulation of the intensity data than others to create a pleasing overall result.

In addition, some techniques are designed to preserve the original RGB image colors more than others (for example, SFIM and HPF Additive). Others may cause color shifts or stretches (for example, HSI or Brovey Transform), but these can be positive results in many cases depending on your goals.

Following is an overview of each of the techniques:

Red Green Blue Intensity (RGBI)

The Red Green Blue Intensity (RGBI) technique uses intensity substitution to replace the intensity (brightness) component of the RGB image with the panchromatic image data. The wizard creates an RGB algorithm containing the multispectral image, then adds an Intensity layer containing the panchromatic image. This technique allows separate adjustments of the color (RGB layers) and intensity components of the merged image, so you can easily fine tune the result.

With this technique, ER Mapper does a "behind the scenes" conversion of the RGB data into Hue Saturation Intensity color space, substitutes the panchromatic data for the RGB intensity, then converts back to RGB space for the image display. (This operation is automatic in ER Mapper any time you add an Intensity layer to an RGB algorithm.)

With this technique, the wizard provides two additional options designed to help the merged image color better match the original multispectral image, and to compensate for differences in the spectral qualities of the two input images. One is histogram matching the pan data to the intensity of the RGB image, and the other allows the intensity component to be a weighted average of the pan data and an infrared band from the multispectral image. Both of these are described in more detail later in the General Controls and Options section.

Hue Saturation Intensity (HSI)

The Hue Saturation Intensity (HSI) technique also uses intensity substitution to replace the intensity (brightness) component of the RGB image with the panchromatic image data. In this case, the wizard creates a Hue Saturation Intensity algorithm so the image color saturation can be controlled directly (as opposed to RGBI). The Hue and Saturation layers contain the multispectral image data with formulas that convert from RGB to hue and saturation respectively. The Intensity layer contains the panchromatic image, which in turn controls the brightness of the merged image. This technique allows separate adjustments of the hue, saturation and intensity components of the merged image, so you can easily fine tune the result. (For basic definitions of Hue, Saturation and Intensity, see the section HSI section for the Color Enhancements Wizard.)

This technique can be especially good for modifying color saturation while also merging with a higher resolution image. A good example is merging Landsat TM bands 321 with SPOT Panchromatic. Since 321 typically creates a somewhat "bland" image, you can increase the saturation to add more color to the merged image.

With this technique, the wizard provides two additional options designed to help the merged image color better match the original multispectral image, and to help compensate for differences in the spectral qualities of the two input images. One is histogram matching the pan data to the intensity of the RGB image, and the other allows the intensity component to be a weighted average of the pan data and an infrared band from the multispectral image. Both of these are described in more detail later in the General Controls and Options section.

Tip: If your input data is not already contrast stretched, best results are usually achieved by contrast stretching the data in RGB space before conversion to HSI. (This is recommended for most satellite imagery, but may not be needed for TIFF airphotos or other data with good contrast.) This option is provided on the wizard's RGB Bands page.

Reference: Carper, W. J., T. M. Lillesand and R. W. Kiefer, 1990. "The Use of Intensity-Hue-Saturation Transforms for Merging SPOT Panchromatic and Multispectral Image Data." *Photogrammetric Engineering & Remote Sensing*, Vol. 54, No. 4, April 1990, pp. 459-467.

Brovey (Chromaticity) Transform

Also known as the "chromaticity" or "color normalize" transform, the Brovey Transform technique separates the multispectral image space into color and brightness components. (It was popularized by R. L. Brovey, thus the name Brovey Transform.) It works by first normalizing the band to be displayed by the intensity of the RGB image (the sum of R, G and B). It then multiplies the result by the panchromatic image data to add the brightness (shadows or albedo information) of the higher resolution image back into the color image that was removed by the normalization/ratioing.

In addition to image merging, this technique is commonly used for color enhancements of single images as well (so it is also used in the Color Enhancements Wizard). The wizard implements the Brovey Transform technique using formulas as follows:

```
Red = R/(R+G+B)*Intensity

Green = G/(R+G+B)*Intensity

Blue = B/(R+G+B)*Intensity
```

where "Intensity" is the panchromatic image data.

Results of this technique can be very good, especially with uncorrelated band combinations. It tends to accentuate color in the image, which can create a nice color enhancement in addition to the merge. Since it does shift colors somewhat, it may not be the best choice if the primary intent is to match the original colors of the multispectral image. (Try SFIM or HPF Additive instead.) The color normalization also tends to compensate for differences in the spectral properties of the pan and multispectral images, so darkening of vegetated areas in a Landsat TM/SPOT Pan merge is not a problem (as it sometimes is with RGBI or HSI).

The Brovey Transform technique also has an option to Gaussian Equalize the Pan data before performing the merge. This can dramatically brighten the merged image and bring out subtle detail in the Pan data. However, the effect may be too strong in many cases, in which case you simply turn the option off.

References: Vrabel, J., 2000. "Multispectral Imagery Advanced Band Sharpening Study." Photogrammetric Engineering & Remote Sensing, Vol. 66 No. 1, pp. 73-79 (2000).

Hallada, W. and S. Cox, 1983. "Image sharpening for mixed spatial and spectral resolution satellite systems." International Symposium on Remote Sensing of the Environment, 9-13 May, 1983, Ann Arbor, Michigan. Smooth Filter Intensity Modulation (SFIM)

Smooth Filter Intensity Modulation (SFIM)

The Smooth Filter Intensity Modulation (SFIM) technique is designed to merge imagery while minimizing color distortion if the spectral range of the intensity replacement (or modulation) image is different from the spectral range covered by the three bands used in the RGB color composite. Other techniques, such as the Brovey Transform and HSI, can cause noticeable color distortions or shifts, so that the merged image colors look different than the original multispectral RGB image with the same contrast enhancement applied. Considering that the main purpose of image merging is to aid visual analysis, the spectral distortion introduced by other techniques may result in unreliable interpretation for some applications. The wizard implements the SFIM technique using formulas as follows:

```
Red layer = R * Pan / PanAvg

Green layer = G * Pan / PanAvg

Blue layer = B * Pan / PanAvg
```

where "PanAvg" is the panchromatic data with a smoothing (low pass averaging) filter applied.

SFIM has a control for the size of the smoothing filter used to calculate the local average of the panchromatic data during processing. The selection of filter size is important to obtaining the optimal result. For example, to merge a 30-meter resolution Landsat TM image with a 10-meter resolution SPOT Pan image, the minimum smoothing filter size for calculating the local average of the SPOT Pan image pixels is 3x3 (30/10). However, it was found that edge blurring caused by misregistration between the two images can sometimes be minimized by using different filter sizes, for example a 5x5. See the reference article below for complete details on this technique.

Note: The contrast stretch options for SFIM force the output data range of the RGB layers to 0-255. This was found to give a better overall result than Limits to Actual which is used for the other techniques. .

Reference: Guo, L. J., 1999. "A Spectral Preserve Image Fusion Technique for Improving Spatial Details." Presented at the Thirteenth International Conference on Applied Geological Remote Sensing, Vancouver, British Columbia, Canada, 1-3 March 1999.

High Pass Filter (HPF) Additive

The HPF Additive technique merges the multispectral and panchromatic images by adding the R, G and B multispectral image band values to the values of the pan data with a high pass filter applied. The results of the high pass filter contain most of the high frequency information that is related mostly to spatial information, and removes spectral information. By adding the HPF results to the RGB bands, a merged image is created. The wizard implements the HPF Additive technique using formulas as follows:

```
Red layer = R + PanHPF

Green layer = G + PanHPF

Blue layer = B + PanHPF
```

where "PanHPF" is the panchromatic image data with a 3x3 high pass sharpening filter applied.

The HPF Additive technique is good at preserving the spectral character of the original multispectral data, and in this way is similar to SFIM. You may need to apply a fairly strong contrast stretch to get the best result (a 98, 97 or 95% linear clip for example).

HPF Additive has a control for the size of the high pass (sharpening) filter used to extract the high frequency information from the panchromatic data during processing. The selection of filter size is important to obtaining the optimal result. Some studies have found the optimal filter size is approximately twice the ratio of the spatial resolutions of the multispectral and panchromatic data. For example, to merge a 30-meter resolution Landsat TM image with a 10-meter resolution SPOT Pan image (30/10=3), the optimal filter size is 7x7 (3 * 2 rounded up to nearest odd number). See the reference article below for complete details on this technique.

Reference: Chavez, P. S. Jr., S. J. Sides and J. A. Anderson, 1991. "Comparison of Three Different Methods to Merge Multiresolution and Multispectral Data: Landsat TM and SPOT Panchromatic." *Photogrammetric Engineering & Remote Sensing*, Vol. 57, No. 3, 1991, pp. 295-303.

Transparency Merge

The Transparency Merge technique merges the multispectral and panchromatic images by mathematically averaging them. The wizard creates a two-surface algorithm, loading the contrast stretched multispectral image into the upper surface, and the stretched Pan image into the lower surface. Then the upper surface transparency is set to a user selected percentage, thereby creating a weighted average of the two images (surfaces).

This is a simple technique that does not carry through the detail inherent in the pan data as well as the other techniques, so the merged image does not look as crisp or sharp. It is more appropriate for merging a color image and a scanned map, for example, where a simple combination of the two and the ability to quickly adjust the percentage of each is most important.

The wizard provides predefined 20, 30, 40 and 50% transparency settings, but you can easily adjust this to any setting. After creating the image, click Finish to close the wizard. Then select the upper surface in the **Algorithm** dialog box, click the **Surface** tab, and adjust the 'Transparency' slide bar to the desired level.

Tip: Any data, such as a sun shaded DEM or scanned map, can be used as the Panchromatic image. For example, sun shade a DEM, save it a Virtual Dataset (VDS), then load the VDS as the Panchromatic image in the wizard. In this case, select the contrast option 99% (or reset to default later) to avoid changing the appearance of the shaded DEM.

General Controls and Options

General wizard controls and options are explained below. (Some techniques have separate options not listed here; see the section on each technique for those.)

■ **Input images**–The multispectral image must contain at least three bands, and the panchromatic image should generally be higher resolution than the multispectral image. (This is not strictly a requirement, for example you could merge 50-meter SAR imagery as panchromatic with 30-meter multispectral data if desired.) If your panchromatic image contains multiple bands, you will be prompted to select which band you want to use. The images must have the same datum, projection and rotation and cover at least partially overlapping geographic areas. Unless you choose to define an image subset, the merged image will show the full extents of the panchromatic image data.

Note: In some cases you may want to merge two images with different data types (for example 8-bit Landsat with 16-bit IKONOS Pan or SAR). This is not possible with some techniques that use mathematical combinations (but a future release of the wizard will handle the necessary adjustments automatically). The wizard currently will attempt to analyze your input image type(s) and notify you if techniques or options are not available, but may not flag all possible cases. You can, however rescale 16-bit images into a Virtual Dataset with an 8-bit data range and use that as input. (See the section "Rescaling Non-8-Bit Datasets" for more information.) All options and techniques are available when both images are in 8-bit format.

■ **Defining an image subset**–This option lets you process only a portion of the area covered by the input images. Image processing and contrast stretching is applied only to the data range of the selected subset area. Click the 'Define image subset (zoom area)' button to display your panchromatic image data in greyscale, then zoom into the area you want to process. To proceed and use this area, check the 'Process only this subset' button and click Next>. (If 'Process only this subset' is off, the entire area of the panchromatic image is processed.) For techniques that require an intermediate Virtual Dataset, the subset area is saved as the Virtual Dataset extents (so you cannot zoom out to the full extents later).

■ **Match pan intensity to RGB intensity**–(Available with RGBI and HSI options only.) When selected, this option histogram matches the intensity of the panchromatic data to match the intensity of the multispectral RGB image. This may help make the overall brightness/contrast of the merged image better match the brightness/contrast of the original RGB image before merging.

If "Match pan" is selected, the "Int. contrast" menu selection lower on the same page is ignored, and the histogram matching is performed instead. Also, the RGB intensity is calculated using the RGB to intensity "Method" menu selection. If "Match pan" is *not* selected, the contrast of the image intensity component is controlled by the "Int. contrast" menu selection, and the setting for RGB to intensity "Method" is not used.

- **Average Pan and IR band for intensity**–(Available with RGBI and HSI options only.) When selected, this option lets you create the intensity component from a weighted average of the pan data and one of the infrared bands of the RGB data (instead of the intensity data alone). This may be helpful, for example, to brighten vegetated areas in the merged image that would otherwise be darker if using the panchromatic data only.

  When you select this option, you will be prompted to select one of the infrared (IR) wavelength bands from your multispectral image. The wizard does *not* try to guess which band is an IR band, you must make a valid selection yourself. This option is not recommended if your multispectral image does not contain an IR band, but can be used anyway.

  Note: Using this option will slightly degrade the resolution of the merged image because the intensity component is partially derived from the spatial resolution of the multispectral data. The weighted average used is approximately 65% of the pan data and 35% of the IR band data (the formula ((Pan*2) + IR)/3).

- **RGB to intensity conversion**–(Available with RGBI and HSI options only.) This setting only has meaning when the "Match pan" option is selected. It specifies the method (formula) used to convert the three bands of RGB data to intensity so that the pan data can be histogram matched to it. The results are generally similar, but several options are provided in case you have a "preferred" method.

◙ Natural Color Wizard

The Natural Color Wizard lets you convert typical "false color infrared" images into simulated natural color images, so vegetation appears in green instead of red. This can be useful when dealing with clients who are not familiar with interpreting color infrared (CIR) imagery and might be confused by red vegetation.

Typical data types for this transformation include SPOT XS, Landsat MSS, color IR airphotos, and other data types that do not contain a visible blue wavelength band. (To create a true "natural color" RGB image, the data must contain visible blue, green and red wavelength bands, such as Landsat TM or natural color airphotos. There is no real reason to use this wizard on images such as those.)

Following is an overview of each of the techniques:

Simple Weighted Average (WTA)

This technique uses a simple modification of the RGB band combinations and a weighted average formula in the Green layer to transform red vegetation to green. The WTA technique is not perfect, but can often have very nice results with some image-specific adjustments. The usual artifact is the creation of magenta colors in areas that were cyan in the false color IR image. The wizard implements the Simple Weighted Average technique using formulas as follows:

```
Red layer = Red wavelength band

Green layer = (Green band * 3 + IR band) / 4

Blue layer = Green wavelength band
```

The wizard will prompt you to select the Green, Red and Infrared bands from your input image. It makes a simple attempt to guess the correct bands, but you must make sure the correct bands are selected or you will get unpredictable results. For the IR band, any near- or mid-infrared band in the image may be used (near-IR usually gives the best result).

The wizard also provides an option to create a vegetation mask, and apply the natural color transformation only to vegetated areas. (This may help remove or suppress magenta artifacts, for example.) See the general section on wizard controls following for more details on using this option.

Reference: Messina, J, 1996. "Image Utilization: Beginning, Middle and End." *SPOTLight (SPOT Image Corporation Newsletter)*, Fall/Winter issue, 1996, page 19.

Chromaticity Color Enhanced

This technique is an extension of the WTA technique that applies additional color enhancement to the simulated natural color image using the Brovey (Chromaticity) Transform technique. The image is first transformed using the WTA technique, and is saved a Virtual Dataset (VDS). The natural color VDS is then loaded into an algorithm that applies the Brovey (Chromaticity) Transform technique to stretch the image colors. The wizard implements the Brovey Transform technique on the Virtual Dataset using formulas as follows:

```
Red = R/(R+G+B)* B

Green = G/(R+G+B)* B

Blue = B/(R+G+B)* B
```

where "R," "G" and "B" are the virtual Red, Green and Blue bands in the natural color Virtual Dataset. (The Red band actually refers to the red wavelength band and the Blue band to the green wavelength band of the original input image. The Green band is the result of the weighted average of the green and IR wavelength bands.)

This enhancement may look very nice on some images, but not on others. Experiment for best results. For more information on this technique see the Color Enhancements Wizard section and reference papers.

Direct Decorrelation Color Enhanced

This technique (like Brovey) is an extension of the WTA technique that uses the Direct Decorrelation Stretch (DDS) to increase color saturation of the simulated natural color image. The image is first transformed using the WTA technique, and is saved a Virtual Dataset (VDS). The natural color VDS is then loaded into an algorithm that applies the DDS technique to increase color saturation. The wizard implements the Direct Decorrelation Stretch technique on the Virtual Dataset using formulas as follows:

```
Red layer = R-(k*(MIN(B,G,R)))

Green layer = G-(k*(MIN(B,G,R)))

Blue layer = B-(k*(MIN(B,G,R)))
```

where "MIN" is the minimum value of the current pixel in the 3 virtual RGB bands, and "k" is an achromatic factor between 0.0 and 0.99 that controls to amount of color saturation increase. (The Red band actually refers to the red wavelength band and the Blue band to the green wavelength band of the original input image. The Green band is the result of the weighted average of the green and IR wavelength bands.)

The DDS enhancement can make all image colors more vivid, so is good for images that are somewhat bland or desaturated using the Simple WTA technique. You must experiment with the 'k' factor values to determine the best setting for any particular image. (It is easy to increase saturation too much which makes the image look very unnatural.) For more information on this technique see the Color Enhancements Wizard section and DDS reference paper.

General Controls and Options

General wizard controls and options are explained below. (Some techniques have separate options not listed here; see the section on each technique for those.)

■ **Input images and bands**–The input image must be a multispectral image containing red, green and at least one infrared wavelength band. It is up to you to determine this ahead of time, but the transformation will work fine on SPOT XS, Landsat MSS, color IR airphotos, and any other similar data. If using color IR airphotos, you should usually select band 1 for NIR, band 2 for Red, and band 3 for Green when prompted by the wizard. (This is typical of a CIR airphoto in TIFF format for example.)

Tip: If you are not sure you have selected an appropriate band combination, click the 'Preview RGB image or define subset' button. Your current band combination will be displayed. If vegetated areas do not appear red, you have selected the wrong bands or your image may not have the correct wavelength bands.

■ **Defining an image subset**–This option lets you process only a portion of the area covered by the input image. Image processing and contrast stretching is applied only to the data range of the selected subset area. Click the 'Preview RGB image or define subset' button to display your current RGB band combination, then zoom into the area you want to process. To proceed and use this area, check the 'Process only this subset' button and click Next>. (If 'Process only this subset' is off, the entire area of the input image is processed.) For techniques that require an intermediate Virtual Dataset, the subset area is saved as the Virtual Dataset extents (so you cannot zoom out to the full extents later).

■ **Turn on NDVI vegetation mask**–This option lets you apply the natural color transformation only to areas you consider to be vegetation. (If not selected, the color transformation is applied to the entire image.) Applying the mask may help reduce or remove magenta casts or other color effects that may be applied to water or other areas by the natural color transformation (see example on the left). Features within masked areas usually (but not always) appear close to the same colors as in a standard CIR image. If not turned on, the natural color transformation is applied to the entire image.

The mask is calculated by defining a threshold of the Normalized Difference Vegetation Index (NDVI). NDVI is commonly used to indicate the amount and vigor of vegetation in an image, and to differentiate vegetated and non-vegetated areas. NDVI is calculated by the formula:

`(IR-Red)/(IR+Red)`

where "IR" is the image's infrared wavelength band and "Red" is the red wavelength band.

You will be prompted to enter separate threshold values for the Red and Green image layers to control the effect. An NDVI value near zero (0.0) may provide an approximate threshold between vegetated and non-vegetated areas of the image. (However, exact values vary from image to image, so you must experiment.) Valid values are negative 1.0 to positive 1.0.

The mask values also let you adjust the overall color characteristics of the image. In general, values below zero tend to add more green to the image, and values above zero tend to add more red-brown. The separate Red and Green thresholds provide more flexibility in fine tuning the image, but you must experiment to get a feel for their effects. (There is no Blue threshold because the blue band is the same as used in a standard CIR image display, so is not affected.)

Note: The mask can help fix *some* unwanted color shift problems, *but not all*. You may need to try other techniques to fix some problems.

Reporting Problems

Earthstar Geographics provides basic support via email for these ER Mapper wizards. (Please do *not* contact Earth Resource Mapping or their resellers for support.) However, we will *not* answer questions about the theory behind the techniques, what technique is best for your data, and so on. Please consult the references provided and remote sensing and image processing textbooks for answers to these types of questions.

If you have a problem, for example the wizard crashes or creates incorrect results, please follow this procedure:

1) Thoroughly read all the documentation provided with the wizards. *Support will not be provided to those who unlawfully copied the software, and you may be asked to provide proof of purchase if you are not the purchaser of record.* Please do not send questions that you can answer yourself with a few minutes of investigation. (That is why this user guide and wizard online help are provided-please use them!)

2) Try the same operation through the standard ER Mapper interface. For example, build the desired algorithm manually by adding layers, formulas, and so on. If you get incorrect results there as well, it is not a problem with the wizard, but a bug or limitation inherent in ER Mapper.

3) After you have tried 1 and 2 above, email your problem to this address:

   `esgwizards@es-geo.com`

   Be sure to specify the following information in your message:

   ■   Your name, company, telephone number and email address.
   ■   Operating system (Win95, Win98, Win2000 or WinNT).
   ■   Wizard exhibiting the problem.
   ■   Input to the wizard and output you expected to achieve.
   ■   Complete description of the problem *with as much detail as possible, including all options you selected in the wizard and any error messages*. Please avoid simple descriptions like "it doesn't work." Questions cannot be answered unless you clearly define the problem the first time.

All attempts will be made to answer support queries in a timely manner, however it may sometimes require up to 5 working days for a response due to vacations and travel.

Enhancement requests

Feel free to email any enhancement requests to us, or requests for new wizards you would find useful. We will log these and evaluate them for inclusion in future releases of the wizards. (We also perform custom wizard development to your specifications if desired.)

Please send email about enhancements to the following address with the title "CE wizard enhancement request."

```
esgwizards@es-geo.com
```