Community Mapping with GIS & GPS

Lesson prepared by Dan Rosenthal (drosenthal@svsu.org), Mount Anthony Union High School, Bennington, Vt.

This episode of Emerging Science examines remote wireless sensing, a technology that gives one the ability to monitor data without actually being on site. Remote sensing is becoming an important tool for scientists and professionals to study the natural environment and urban areas. There are many useful applications for remote wireless sensing including monitoring the water content of snow in Vermont or California to predict the quantity of spring runoff that will occur, simultaneously monitoring the stress on a bridge and viewing real time images of the traffic that is crossing it, and continuously monitoring volcanoes for seismic activity.

For students, a nice introduction to the world of remote sensing can come through an experience with geographic information system (GIS) and global positioning system (GPS). Students can use this technology to engage in a real scientific research project where the data is meaningful.

Before You Begin

Teaching a lesson that incorporates GIS and GPS can be a daunting task, especially if the teacher and students are not that familiar and comfortable with the technology. Becoming familiar with GIS programs like Google Earth and Google Maps will make learning other GIS programs easier.

Students must first learn basic skills with their GPS units and GIS software before they embark upon a project that utilizes this technology.The most rewarding part of the process is when students can create their own maps to analyze a real world problem and help their community through a service learning project.

Required Technology

GPS units – ideally one per student. I use Garmin GPS units because there is a program called DNR Garmin that allows you to download waypoints into Arc View (a GIS program)
GIS software – I use Arc View because it is a powerful program that professionals use, and it is offered at a reasonable price to public schools
DNR Garmin – a free program, that can be downloaded off the internet, that allows you to download waypoints into Arc View
Garmin Interface Cable – connects the Garmin GPS to a computer's serial port
Digital projector and screen – so you can guide students through the basic tools of Arc View and demonstrate how to do basic tasks in order to create their own maps
GIS Data Layers (available from VCGI – Vermont Center for Geographic Information. Most GIS data is a free download off their website. Some layers like orthophotos must be ordered.)
A computer for every student loaded with Arc View, DNR Garmin and GIS data layers

Since most students are not familiar with this technology, break the content into several lessons.

Lesson 1: The Basics of Arc View

1) What does GIS stand for?

Geographic Information System. A GIS map is like layers of transparencies viewed together.

Typically, the layers are on top of a base map. A base map can be a topographical map or an orthophoto (aerial photograph). Each map layer has tables of information. You can turn map layers on or off. You can click and drag layers on top or underneath other layers.

There are three basic types of layers (points, lines and polygons). An example of a point could be a school, house or waypoint that you take with your GPS. An example of a line could be a road. A polygon is any layer that shows an area like your school's property. On a map, points should be on top of lines and lines should be on top of polygons, otherwise you will not be able to see the layers.

The value of GIS is that it is a tool for spatial analysis and for service learning opportunities.

2) How many of you have used Google Maps before? How many of you have used Google Earth before? How many of you have used a GIS program before?

This is great news. Most of you will learn a new program, but since many of you have experience with programs like Google Maps and Google Earth it will not be quite as difficult for you as some of the tools are similar.

3) Who uses GIS programs?

The list can include cartographers, surveyors, engineers, water quality analysts, town planners, the department of transportation, foresters, conservationists, park rangers, electric utilities, etc. There are many jobs where having GIS skills is an asset.

Next, I demonstrate how to use the basic tools in Arc View using the digital projector and have students follow along.

Afterwards, I have students go through the Arc View Tutorial that I created (see below).

Finally, I have students complete the Arc View Activity that I created (see below). You should adapt the Arc View Activity to your school and surrounding area. The Arc View Tutorial and Arc View Activity reinforce basic GIS skills and introduce students to some of the uses of Arc View.

Lesson 2: The Basics of GPS

1) What does GPS stand for?

Global Positioning System

2) How many of you have used a GPS receiver before? For what purpose?

3) How does a GPS work?

Through 3D trilateration. There is an excellent summary of 3D trilateration on the website below:
http://download.intel.com/corporate/education/emea/eng/za/elem_sec/tools_resources/plans/gps/lessonplans/unit_support/educator_support/How_GPS_works.pdf

You can demonstrate 3D trilateration by having students hold meter sticks and form a circle. The students are satellites and the meter sticks are radio waves. Have the students point their meter sticks towards the center of the circle. Where the sticks overlap would be your location on the surface of the earth. (Note: instead of lines intersecting it would actually be spheres intersecting.)

4) From how many satellites should a GPS receive a signal in order to be accurate?

At least three. It is better if your unit receives a signal from more satellites.

5) How can a GPS unit determine your distance from a satellite?

The GPS unit receives radio waves from satellites. Radio waves are in the electromagnetic spectrum and travel at the speed of light. The distance is determined by the speed (speed of light) times time (the time it takes for radio waves to travel from a satellite to your GPS unit).

6) The clock in a GPS has to be accurate to the fraction of a second. How can a GPS clock be so accurate?

In order to be that precise an atomic clock is necessary. Atomic clocks cost thousands of dollars! GPS units get around this problem by having a quartz clock that constantly resets itself.

Activity

Take students outside with a GPS, school campus grid superimposed on an orthophoto (aerial photo) -- there are directions on how to create grids on the VINS Community Mapping website http://www.vinsweb.org/education/cmp_resources.html -- a clipboard, and a pen or pencil. Have your students turn on their GPS units. After their units are ready to navigate have them determine the accuracy of their GPS unit. The “accuracy” is actually the inaccuracy of the unit. For example, if the accuracy is 20 meters, that means your coordinates can be up to 20 meters away from your actual position on the Earth.

Show students how to navigate through the different pages until they get to the menu page. Show them how to mark a waypoint and how to use the click stick to navigate to mark waypoints.

Have students mark a waypoint and then use the coordinates of the waypoint to plot their position on the school campus grid map by hand. I have a detailed description of how to do this on the MAU Grid map below.

Finally, have students walk a trail on campus and mark waypoints along the route. Students should be careful to take frequent waypoints. When the trail curves, it is good to mark waypoints at the beginning, middle, and end of the curve.

Note: It is good to have all prior waypoints deleted from the GPS units.

Lesson 3: From GPS to GIS

Show students how to download their waypoints into Arc View. In the computer lab, students should have Arc View open. Students should connect their GPS unit to the serial port of their computer and open DNR Garmin. Next students should download the waypoints. There are detailed descriptions on how to do this in my Arc View Tutorial (see below) and on the VINS Community Mapping Website:
http://www.vinsweb.org/education/cmp_resources.html
If you want to have students draw a line that connects their points, you can have them create a new shapefile (line). After they create a shapefile they can use the editor toolbar to draw a line. Make sure they save their edits! Again, see my Arc View Tutorial for detailed step by step directions on how to create and edit a shapefile.

Lesson 4: Create a Map

Now students have a chance to be creative. Have them insert the map essentials (title, legend, scale bar and north arrow). They can also insert text boxes to label features on their map. They can change the color and appearance of their layers. There are step by step directions on how to do this on my Arc View Tutorial.

Lesson 5: Service Learning Project

Now that students have acquired basic GIS and GPS skills, they can embark upon a community mapping project. Be creative! I had students map and remove garlic mustard (an invasive species) at Merck Farm and Forest. The sites are clearly located along a road that traverses Merck’s property. Garlic mustard spread rapidly after a few logging jobs were completed on the property. Often, mustard seeds are transported on the wheels of logging trucks. The maps my students created will become a piece of evidence that suggests that loggers should wash their tires after each logging job. Examples of other projects can be seen at the gallery of community mapping projects: http://www.iftd.org/cmap/ .

Extensions

GIS and GPS works great within the context of a watershed study. Project Wet has directions on how to delineate a watershed and calculate the area of a watershed. In addition you can mark the site where you conduct water quality testing and then analyze potential sources of point source and non-point source pollution upstream from your testing site within your watershed.

On the following pages, I have included resources that can help in your journey to utilize GIS and GPS in the classroom. I have included the Arc View Tutorial, Arc View Activity, and school campus grid. I have also included web-based resources that are useful. It helps to have training with this technology. In the past, I have taught a Community Mapping course with GIS and GPS through my district (Southwestern Vermont Supervisory Union in Bennington, Vt.), and I may offer the course again. Let me know if you are interested in taking the course.

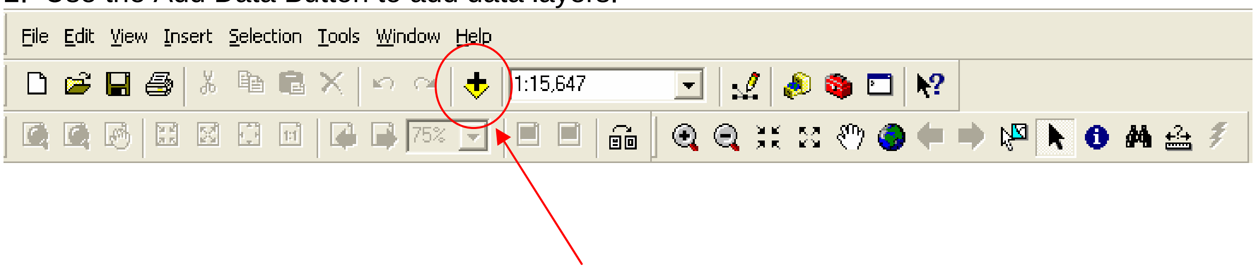
I would like to give thanks and credit to the VINS Community Mapping Program where I received my training through a one-day workshop and a week long intensive summer institute.

ARC VIEW TUTORIAL

Using ARC Map to Add Map Layers

1. Open the program **Arc Map**.

2. Use the Add Data Button to add data layers.



Tips:

a) You can add data layers on top of a *base map* such as a topographical map or an ortho photo (aerial photograph). You can also build your own base map by adding local roads, waterways and contour lines.

b) The order for map layers is:
points
lines
polygons (areas)

You will only see point layers if they are on top of lines or polygons. You will only see line layers if they are on top of polygons.

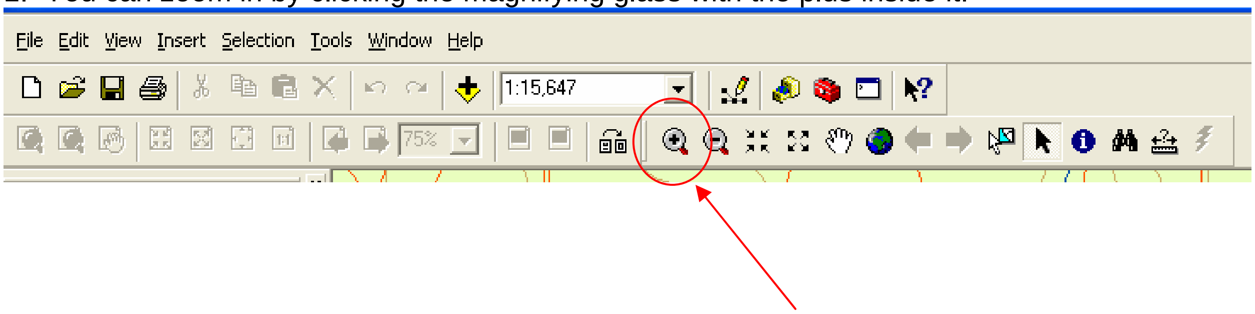
3. Map layers are displayed to the left of your active data frame. You can turn layers on by checking the box. You can turn layers off by removing the check.

Notice that the layers are in order (points, lines and polygons).
Tips: You can *zoom to* a layer by right clicking the layer and selecting zoom to layer.

A random color is assigned to each data layer. You can edit the color and symbol by clicking on it.

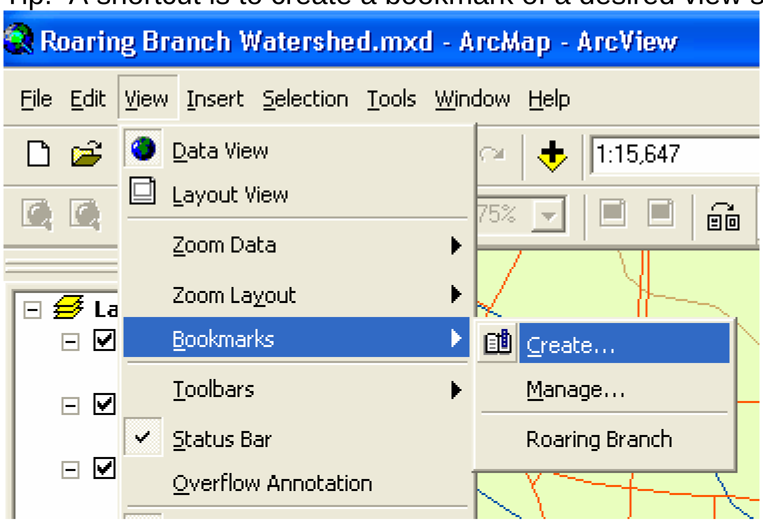
Using Basic Tools in Arc Map

1. You can zoom in by clicking the magnifying glass with the plus inside it.

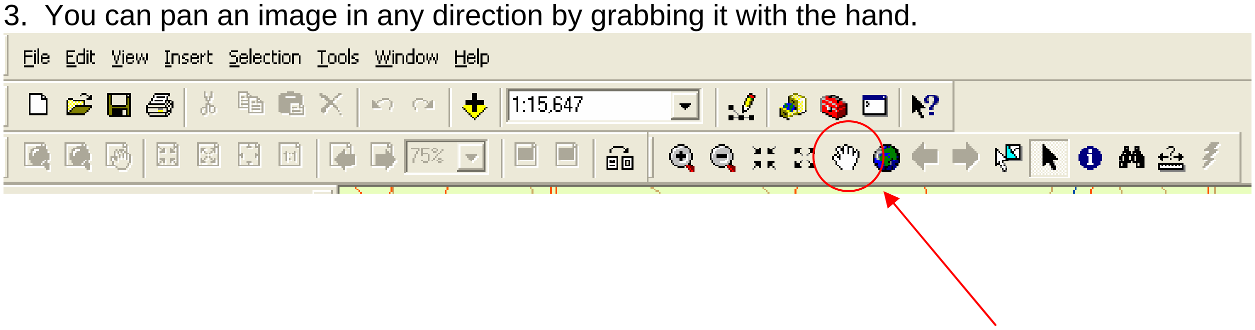


2. You can zoom out by clicking the magnifying glass with the minus inside it.

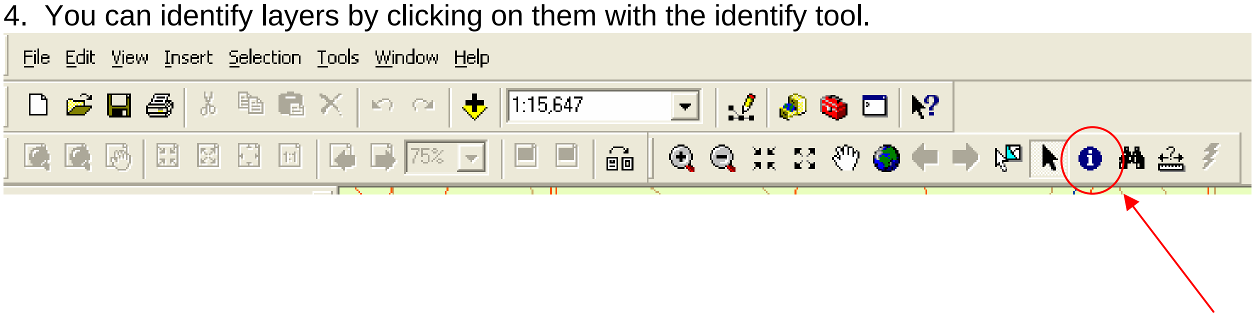
Tip: A shortcut is to create a bookmark of a desired view so you can quickly access it.



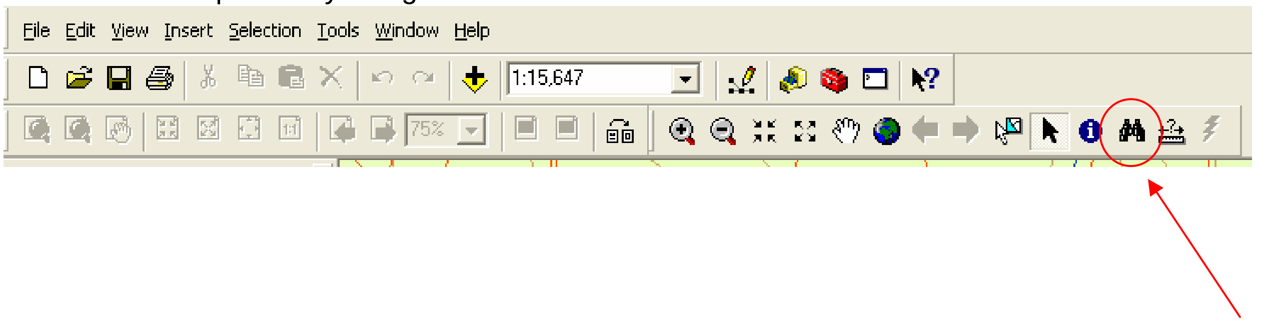
3. You can pan an image in any direction by grabbing it with the hand.



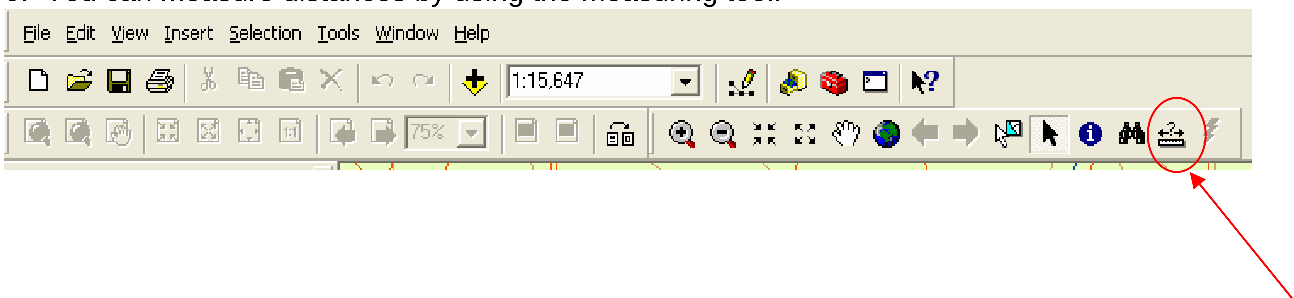
4. You can identify layers by clicking on them with the identify tool.



5. You can find places by using the find tool.



6. You can measure distances by using the measuring tool.



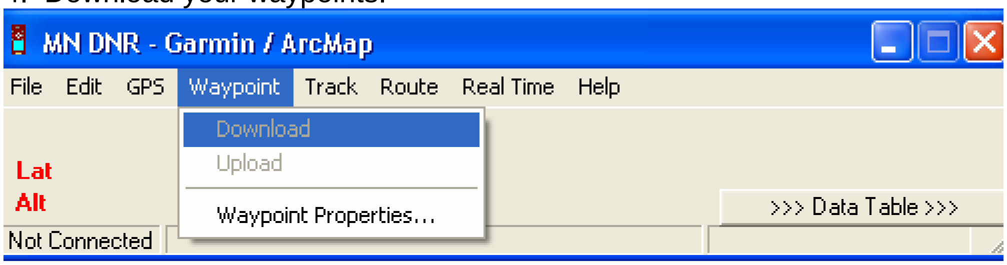
From GPS to GIS

1. Mark waypoints using your GPS.
Tip: It is best to delete all prior waypoints and start fresh.

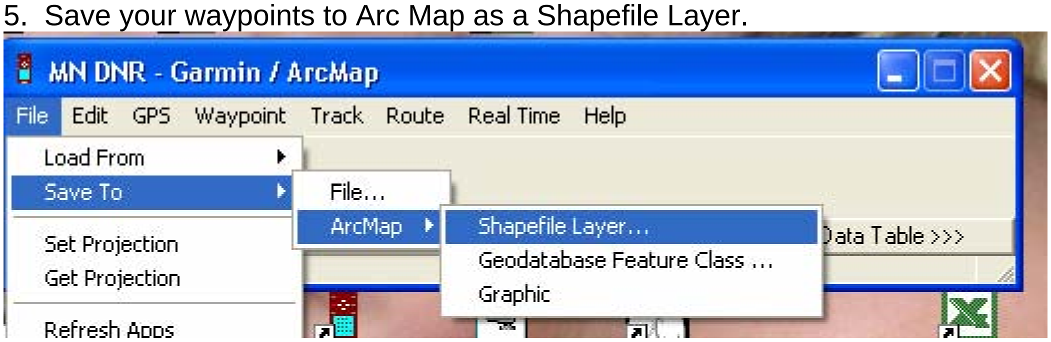
2. Connect the GPS unit to your computer.

3. Open the program DNR Garmin.
Tip: Make sure you set the proper projection. Check the ESRI box and select NAD_1983_StatePlane_Vermont_FIPS_4400.

4. Download your waypoints.



5. Save your waypoints to Arc Map as a Shapefile Layer.

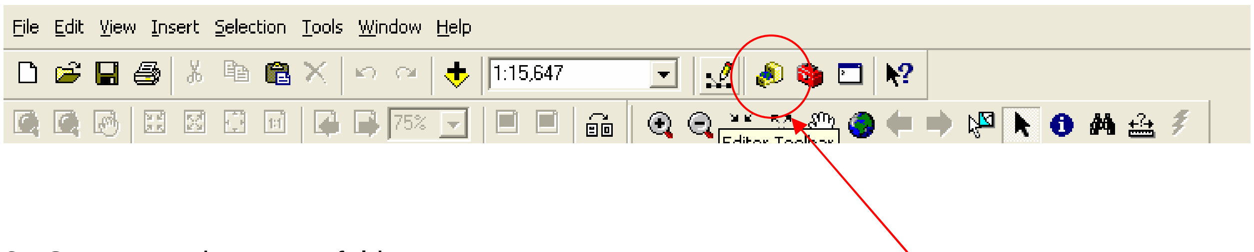


6. Open Arc Map and use the add data button to add point layers.

Creating Shapefiles

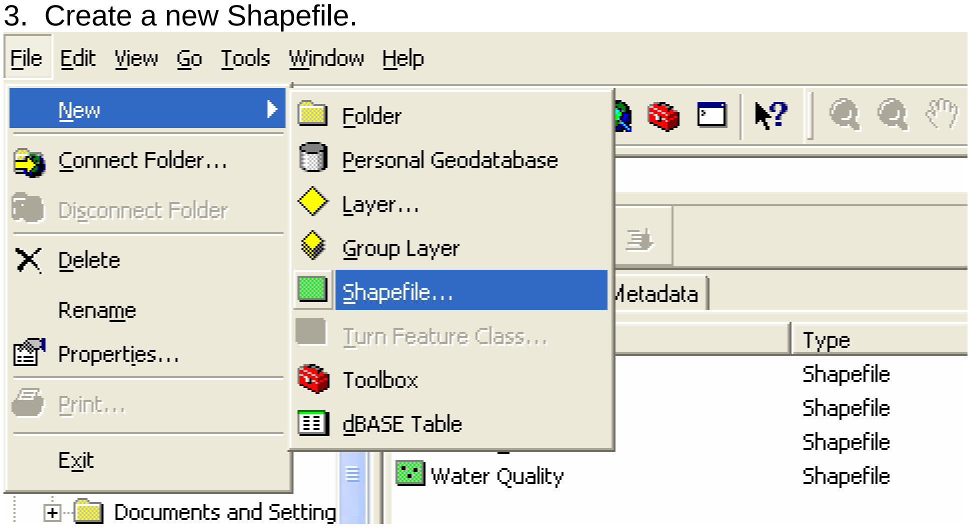
You can turn your waypoints into Shapefiles that are points, lines, or polygons (areas). You can also use an ortho photo (aerial photograph) to trace features and create Shapefiles.

1. Open the program Arc Catalogue.

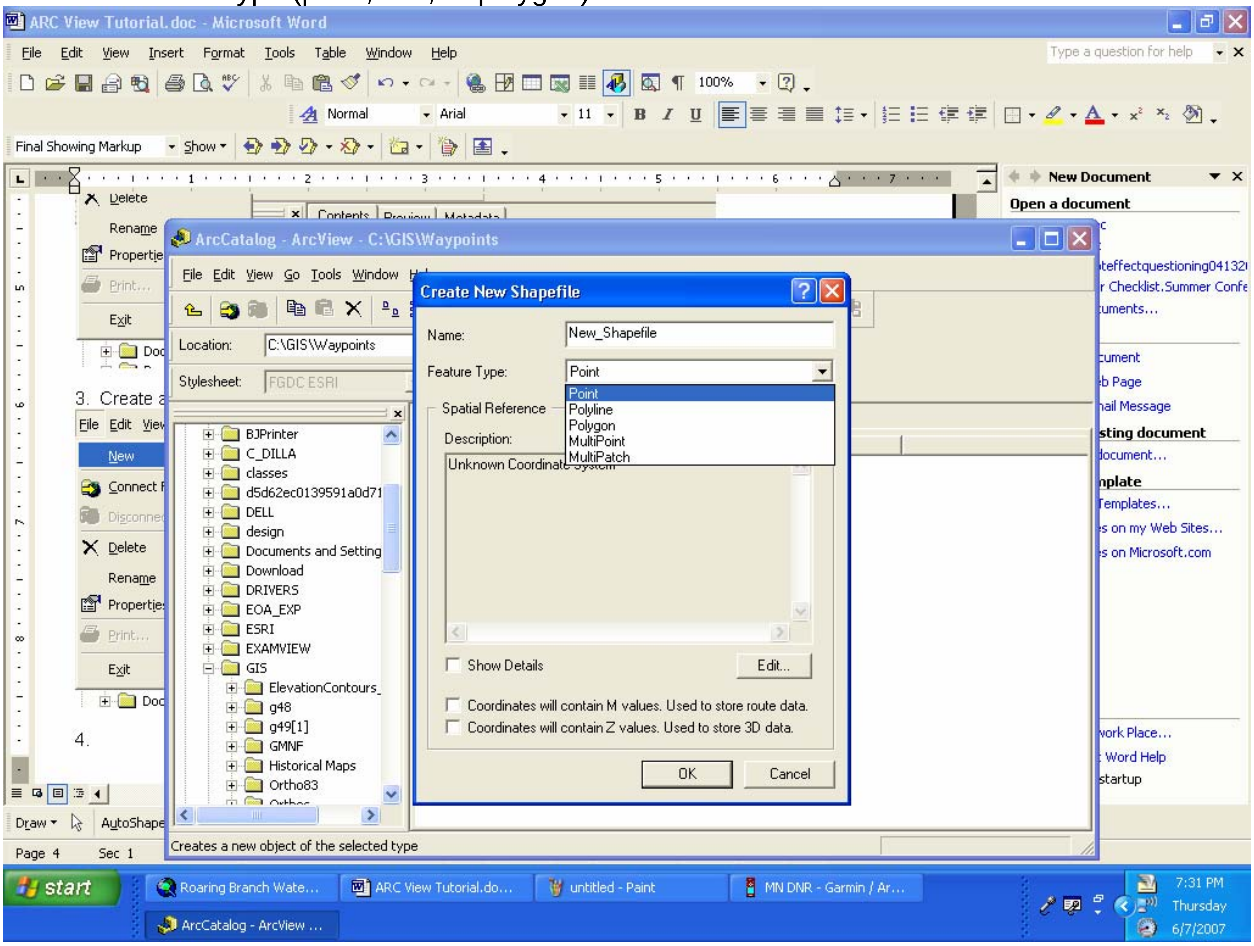


2. Connect to the proper folder.

3. Create a new Shapefile.

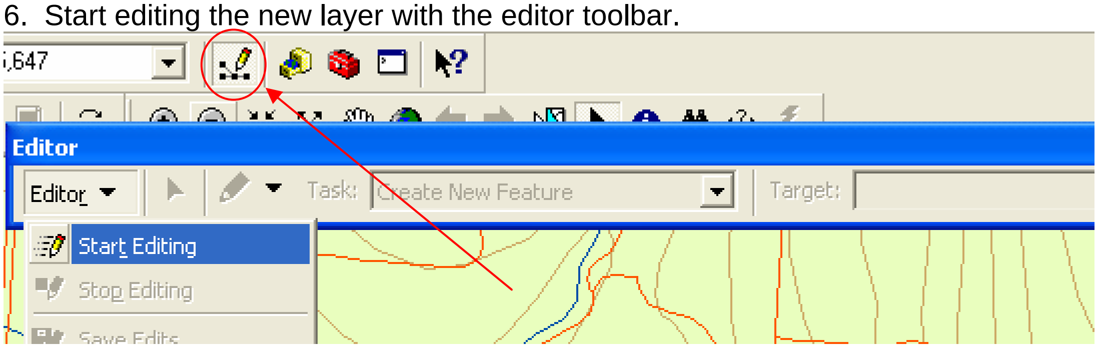


4. Select the file type (point, line, or polygon).

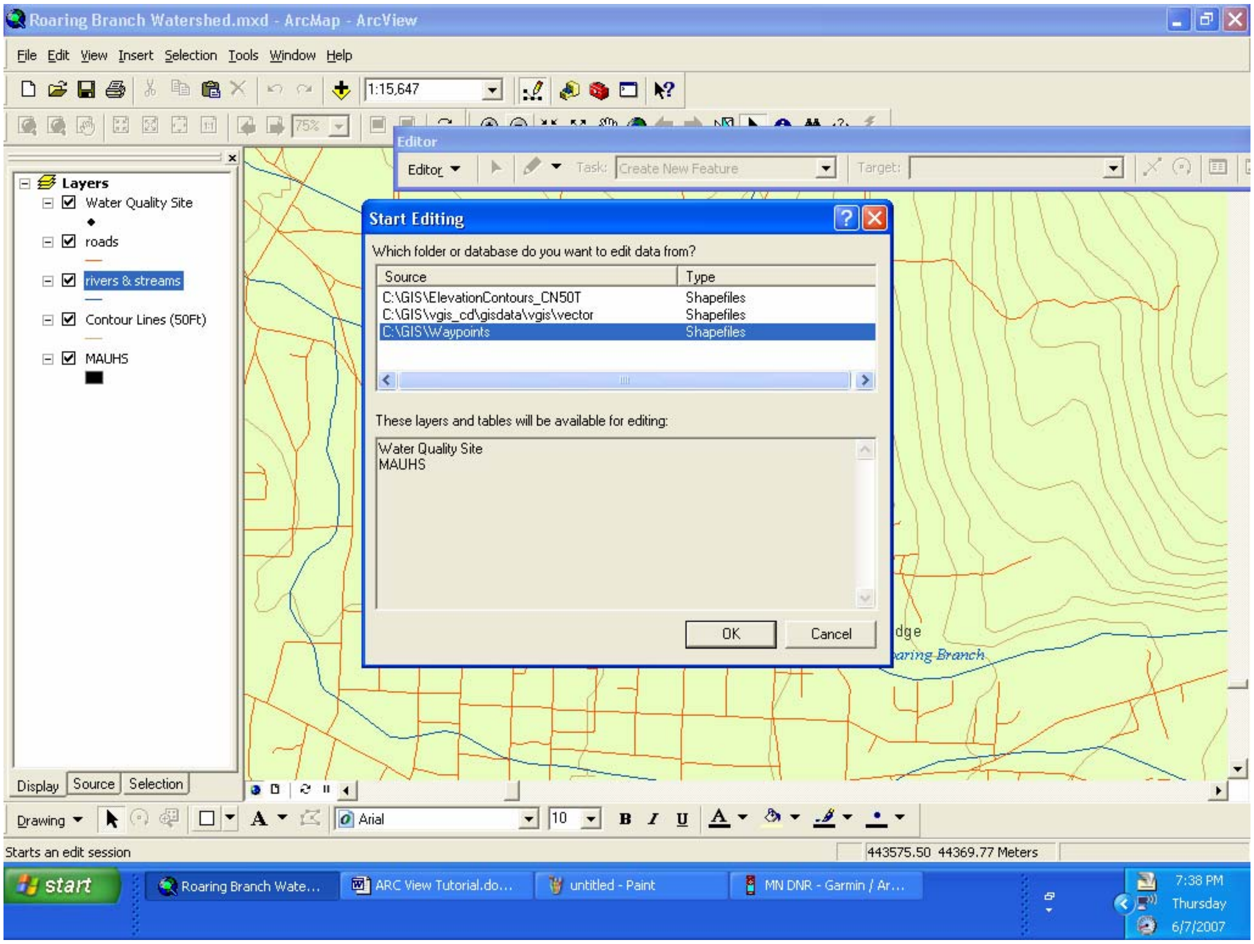


5. Return to Arc Map and add the new layer to your data frame.

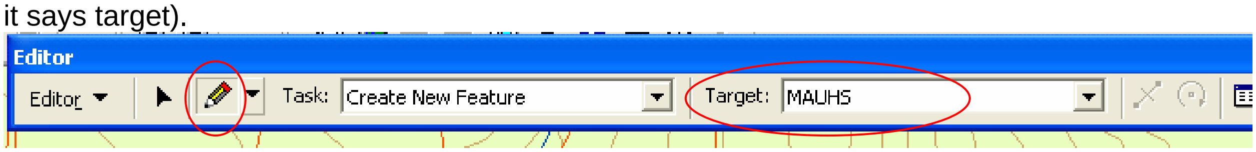
6. Start editing the new layer with the editor toolbar.



7. Select a folder or database to edit data from.



8. Use the sketch tool to create or edit data. Make sure that the proper layer is selected (where it says target).



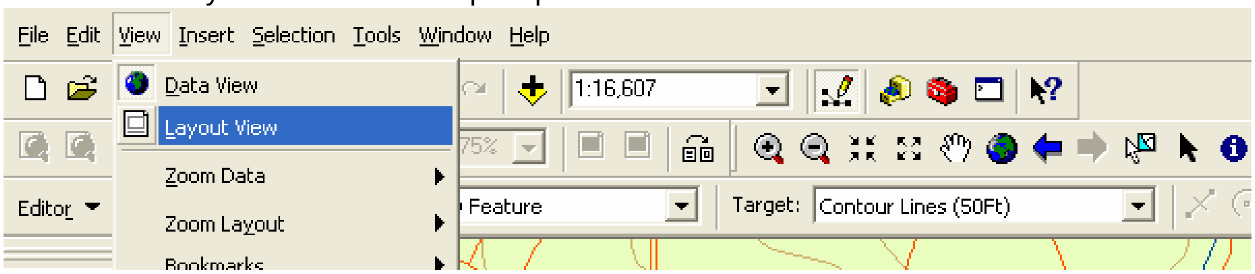
9. Save your edits and stop editing.

Adding the Essentials to Your Map

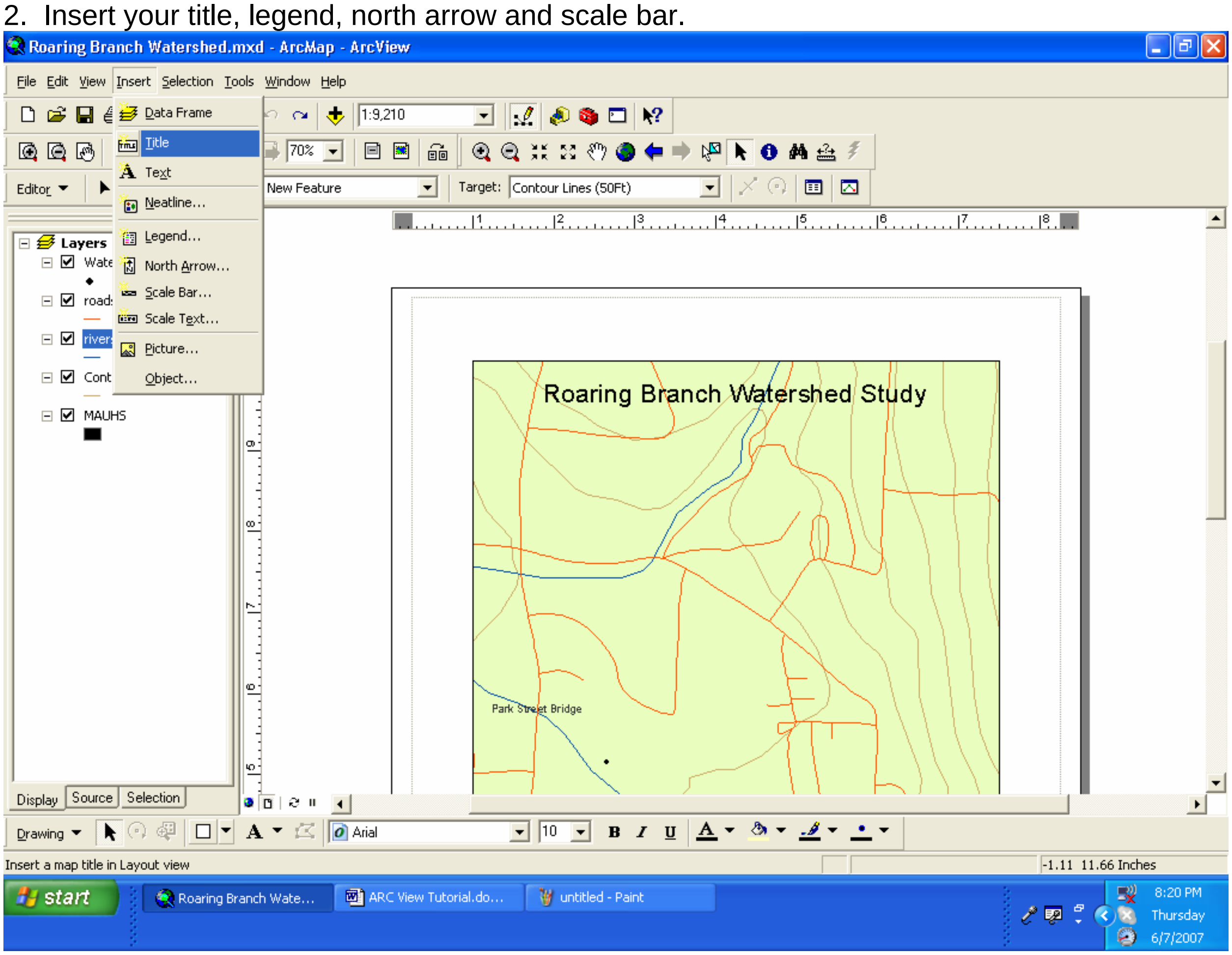
Every map needs four basic things:

- A title
- A legend
- A north arrow
- A scale bar

1. Select the layout view. This is a print preview view.



2. Insert your title, legend, north arrow and scale bar.



3. Follow the legend wizard to create a legend. Properties may be edited.

ARC VIEW Activity

1. Open Arc Map and add the following data layers through the Extras Folder on the C Drive:

- In the vgis_cd folder (under gisdata, vgis, and vector):
  - endanger.shp (endangered species)
  - ptschool.shp (schools)
- In the ElevationContours_CN50T folder:
  - Elevation_CN50T_line.shp (contour lines)
- In the vgis_cd folder (under gisdata, vgis, and vector):
  - rds.shp (roads)
  - dlgsw.shp (rivers & waterways)
  - deerwn.shp
- In the vgis_cd folder (under gisdata, vgis, and vector):
  - towns.shp
- In the orthos folder:
  - 092040.TIF (aerial photograph of Bennington)
  - 096040.TIF (aerial photograph of Bennington)

2. Zoom in on Bennington, Vt.

3. Use the identify tool and click on the high school. Then use the identify tool and click on an empty space anywhere within the town of Bennington.

4. Locate the CDC and locate the point that represents where the CDC is. Why do you think they don't line up?

5. Use the panning feature to find the circle where the monument is located.

6. Use the measuring tool to measure the distance from the monument circle to the high school. What is the distance?

7. Locate the Roaring Branch of the Walloomsac River just north of the school. Turn the towns layer off and compare the course of the layer to the course of the actual river on the ortho photo (aerial photograph). Why do you suppose they don't match up perfectly?

8. Notice the dynamic nature of the Roaring Branch. The town has sought to keep the Roaring Branch in one channel by building a concrete wall and a gravel berm, while the river tries to wiggle back and forth. What do you think the impact of trying to keep the Roaring Branch in one channel has been (especially to places downstream)?

9. Try to locate the high school, floodwall and soldiers' home on the ortho photo.

10. Use the find feature to locate the town of Stowe, Vt. Right click on Stowe and use the zoom to feature option. It may help to zoom out and turn off some layers (except for towns).

11. Use the identify feature to check to see if you have found Stowe. What county number is Stowe located in?

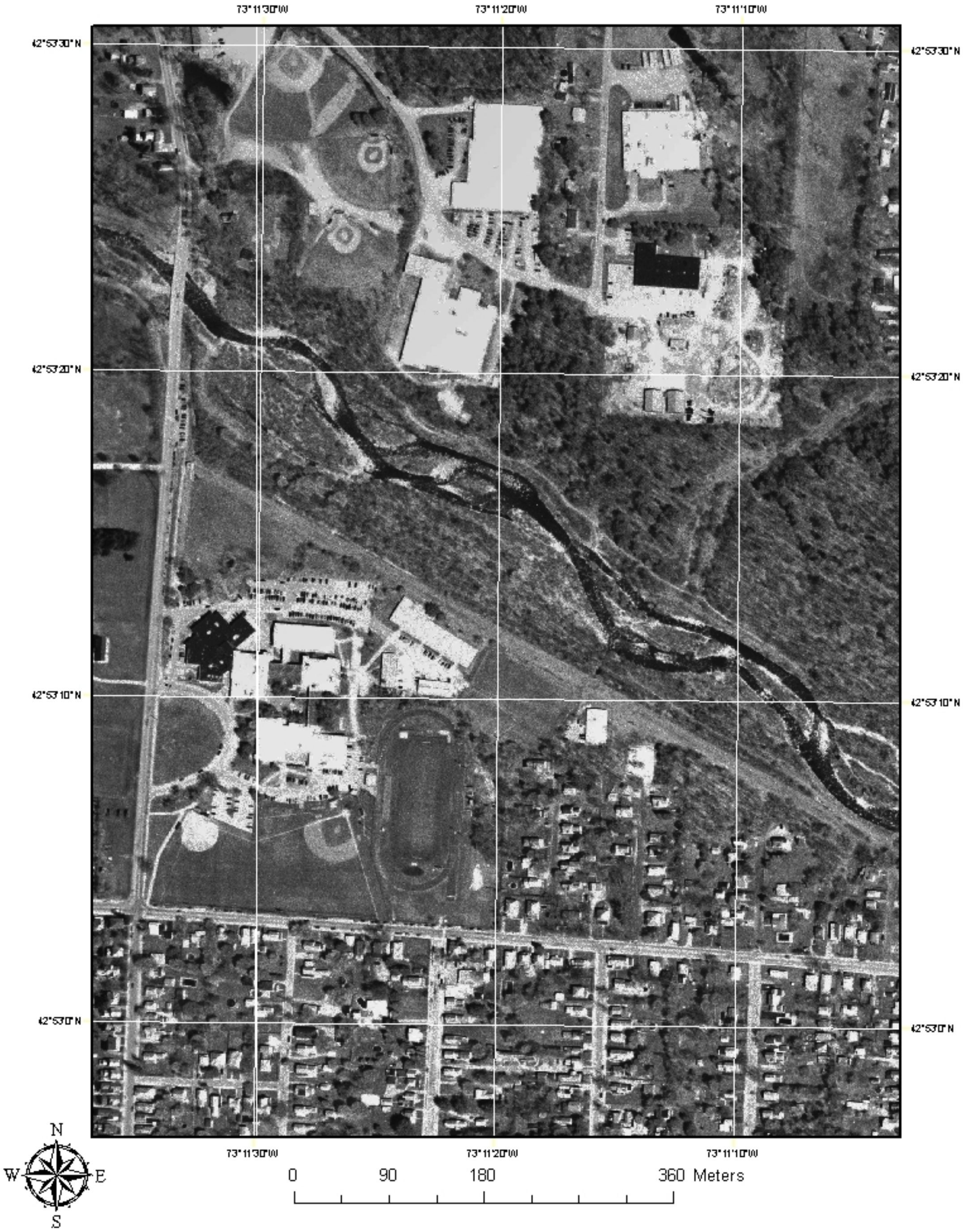
12. Right click on 092040.TIF and zoom to the layer.

13. Locate at least 3 endangered species in the vicinity of Bennington and give a description of them.

14. Locate the deer wintering yard to the west of Bennington on a small hill. How many acres does it cover?

15. Use the identify tool to find the elevation of the highest contour line on Mt. Anthony.

MAU Grid



Before class begins, use Arc View to create a grid of your school campus. The *VINS Community Mapping* website has a tutorial on making grids. You will need to have Arc View and your local orthophoto (aerial photograph). You can download Vermont GIS data like orthophotos and other data layers from VCGI (Vermont Center for Geographic Information). You may need to purchase some layers, like orthophotos. In the field, each group of students should have a clipboard, the school campus grid, a GPS unit and a pencil. Have students plot their waypoints on the grid manually. Some students may be confused about how to do this, but if they look at the coordinates carefully (to the degrees, minutes and seconds) and are able to plot points on a graph, they should be able to complete the task. Students will be able to assess how accurate their GPS units are.

Afterwards students can collect waypoints and download them into Arc View. During this process each group of students should have a GPS data sheet on a clipboard, a pencil and a GPS unit. A digital camera is optional. You can hyperlink digital photographs to your waypoints in Arc View.

A GPS data sheet should include the names of the student(s), the date and weather conditions or other relevant information. Each waypoint should include the waypoint number or name, information about it (ie. white ash tree) and the digital photo number that corresponds to the waypoint.

If you have Garmin GPS units you can use a free program (DNR Garmin) to download the waypoints. DNR Garmin can be downloaded for free off the internet. See my Arc View Tutorial for step-by-step directions on how to connect their GPS units with a cable into the serial port of a computer and download waypoints with DNR Garmin into Arc View. Students can create their own GIS maps by downloading the points onto a base map like a topographical map or orthophoto. Make sure the projection is the same on your GPS unit and in the map properties of your GIS map. If the projections are not identical, the waypoints will not align properly. Students can make a trail map, school campus map, invasive species map, etc. There are many possibilities. It is good to start with something basic. Once students have the skills they need with GIS and GPS, they can embark upon a meaningful service learning project to help the community or local ecosystem. Spatial analysis also fosters critical thinking. When students view and analyze a meaningful map, they can engage in problem solving and offer solutions that can help their school and/or community.

If time permits, a nice follow up activity is geocaching. You can create a geocache like a prize and journal inside a Tupperware container. You can give students the coordinates of the geocache, the school campus grid, a GPS unit and a clue. (A clue could be something like the geocache is located 50 paces south southwest of the large sugar maple tree). The first team to locate the geocache wins and gets the prize! The map and clue are also necessary because there is always some degree of inaccuracy with the GPS units. Students cannot totally rely on the go to feature to locate the waypoint. When they get close, they must also examine the map and clue to locate the geocache.

Resources:
http://www.esri.com/ ESRI GIS & Mapping Software Company – for information on how to get a site license for Arc View or free downloads for Arc Explorer. Arc View is recommended. Arc Explorer allows you to view data. Arc View allows you to view and manipulate data. I was able to purchase a site license for Arc View for every computer in my school in 2007 for $500.
http://www.vcgi.org/ Vermont Center for Geographic Information – to download GIS data layers, workshops, training, etc.
http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html DNR Garmin -- a program that will download waypoints from a Garmin GPS unit into Arc View or Arc Explorer.
http://www.vinsweb.org/education/cmp_resources.html I took a couple of workshops through the VINS Community Mapping program. Unfortunately, the program no longer exists. However, they still have tutorials and resources available on-line.

http://www.mindcontrolforums.com/gps1.htm How a GPS works.

If you have questions or difficulties e-mail drosenthal@svsu.org

Vermont Science Standards and GEs

7.1 Scientific Method
Students use scientific methods to describe, investigate, explain phenomena, and raise questions in order to:
• Generate alternative explanations -- hypotheses -- based on observations and prior knowledge;
• Design inquiry that allows these explanations to be tested;
• Deduce the expected results;
• Gather and analyze data to compare the actual results to the expected outcomes; and
• Make and communicate conclusions, generating new questions raised by observations and readings.

7.2 Investigation
Students design and conduct a variety of their own investigations and projects.These should include:
• Questions that can be studied using the resources available;
• Procedures that are safe, humane and ethical;
• Data that are collected and recorded in ways that others can verify;
• Data and results that are represented in ways that address the question at hand;
• Recommendations, decisions and conclusions that are based on evidence and that acknowledge references and contributions of others;
• Results that are communicated appropriately to audiences; and
• Reflections and defense of conclusions and recommendations from other sources and peer review.

This is evident when students:

S9-12:49
Students demonstrate their understanding of processes and change within natural resources by:
• Comparing the availability of natural resources and the impact of different management plans (e.g., management of forests depends upon use, lumber production, sugarbush, deer habitat, mining, recreation) within the management area (forest, farmland, rivers, streams); AND
• Choosing a Vermont ecosystem and tracing its succession before and after a damaging event, showing how the ecosystem has been restored through the maintenance of atmosphere quality, generation of soils, control of the water cycle, disposal of wastes and recycling of nutrients (e.g., flooding, former mining sites, glacial impact, deforestation, recovery of rivers from sewage/ chemical dumping, burning of fossil fuels); AND
• Explaining a natural chemical cycle that has been disrupted by human activity and predict what the long term effect will be on organisms (e.g., acid precipitation, global warming, ozone depletion, pollution of water by phosphates, mercury, PCBs, etc.); AND
• Tracing the processes that are necessary to produce a common, everyday object from the original raw materials to its final destination after human use, considering alternate routes including extraction of raw material, production and transportation, energy use and waste disposal throughout, packaging, and recycling and/or disposal (e.g., aluminum can, steel).

S9-12:26 Students demonstrate their understanding of electromagnetic forces by:

- Comparing and contrasting the wave nature of electromagnetic energy to other forms of waves (water, sound, etc.); AND
- Relating the particle nature of electromagnetic waves to their frequencies and to discrete changes in energy levels within atoms (e.g. red shift, blue shift, line spectra);
- Giving examples and explaining the wave nature of electromagnetic energy (refraction, diffraction, etc.) and describing and explaining the particle nature of electromagnetic energy (photoelectric effect, Compton effect)