Surveying Education in the Nineties
Something Old and Something New

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Abstract
At Pennsylvania College of Technology, an affiliate of The Pennsylvania State University, we believe in current technical education with an emphasis on practical applications. Our portfolio of programs includes Civil Engineering Technology (CT) and Surveying Technology degrees and a new four year Civil Engineering Technology degree (BCT). The Civil Engineering Technology (CT) and Surveying Technology (SU) Associate degrees are ABET accredited.

We recently received a National Science Foundation (NSF) Curriculum (ILI) grant. The major thrust of implementation reflects the revolution caused by technology in civil engineering and survey. We give each student not only the theory but also actual experience with the projects and equipment that are the "bread and butter" of civil engineering practice. Laboratories in cartography, photogrammetry, surveying and civil engineering are designed to integrate experiences in this new technology.

In the area of Geographic Information Systems (GIS), the merger of information from different sources, often in different formats, is the norm in civil engineering technology practice, using GIS-based systems. We must recognize and keep up with this trend. We purchased the Modular Geographic Information System (GIS) Environment (MGE) system from the Intergraph Corporation, which we feel best suits our educational needs.

This presents course designers with the requirement to balance education in the basics with training in the most modern applications. As a project in the second semester, we construct a Digital Terrain Model (DTM) and a map, produced at engineering scale (about 1 inch equals 35 feet with half foot contours) for an area of four acres controlled by traverse stations, also observed and reduced by students. The technique used is a modification of the old standby, stadia mapping. This paper discusses the application of GIS technology to that exercise.

Introduction
At Pennsylvania College of Technology, an affiliate of The Pennsylvania State University, we believe in current, applications-intensive technical education. Our portfolio of technical programs includes a two-year Civil Engineering Technology (CT) Program, with an emphasis in surveying, a two-year Surveying Technology degree and a new four year Civil Engineering Technology degree. We feel that in our programs we

teach the art and science of the application of abstract principles to the real world. While the techniques change, the basic ideas remain and explain why we do what we do. A good understanding of the basics alone is not enough. Today's Engineering professionals must understand modern applications as well. So nothing we teach is purely theoretical, just as nothing is taught as pure application without the basic knowledge to understand it. Our Civil Engineering Technology (CET) and Surveying Technology (SU) Associate degree programs follow the Accreditation Board for Engineering and Technology (ABET) standards. Both the CET and SU programs are ABET accredited.

We recently received a National Science Foundation (NSF) Curriculum (ILI) grant. The major thrust of the grant implementation reflects the revolution caused by electronics, satellite based measurement, and computer technology in civil engineering and survey. Concurrent with improved measurements is an increase in productivity. To start the implementation we purchased the Modular Geographic Information System (GIS) Environment (MGE) system from the Intergraph Corporation, which we feel best suits our educational needs. This system allows us to teach fundamentals while using the MGE to illustrate those fundamentals. As an educational institution, we were not interested in a one step “field-to finish” blackbox approach so common in production programs.

The problem we now face is how to give each student not only the theory but also actual experience with the projects and equipment that are now the "bread and butter" of Civil Engineering practice. The solutions should be performed on modern equipment with techniques used in today's practice. Students in our programs are provided opportunities for hands-on experiences and real problem-solving using industry standard equipment. Field-based laboratories and laboratories in cartography, photogrammetry, surveying, and civil engineering design were upgraded to include experiences in this new technology. Students are currently required to respond to competency-based curricula where they demonstrate ability in the use of essential pieces of equipment and the related supportive technologies.

In addition, we need to overcome the "fragmentation" experienced by students as a result of their exposure to coursework specific to surveying, highway design and land use. Improvements and integration include improved synthesis/integration of multiple source data through application of Geographic Information System (GIS) technology and improved survey measurement precision. Above all, we need to integrate these technologies and their use so students understand information and data base use for engineering and surveying problem solution.

With Geographic Information Systems (GIS), the merger of information from different sources (e. g. surveying, Global Positioning System and Photogrammetric activities), often in different formats, is the norm in civil engineering technology practice. Such information is used in the design of subdivisions, location of parks, design of transportation networks, and the husbandry of the environment. Most government and private engineering entities have switched to GIS-based systems and our educational institutions must recognize and keep up with this trend.

The implication is that greater quantities of information must be integrated to provide civil engineers, planners, and others with greatly enhanced predictive and planning capacities. Our students must understand that the information upon which decisions are based will have multiple and correlated inputs. This will improve the efficiency of designs, identify long term problems, and reduce costs. The capacity to integrate large quantities of information can greatly reduce the cost of major building and construction projects. The high cost of capital and the duration of a major project prior to completion both raise total cost. By reducing the time needed for planning, development and construction, up front costs are lowered. Information systems can greatly enhance the speed and accuracy of development and ensure that design expectations are more fully met. Students must understand the concept of flexibility in design and construction because of the availability of rapid response to "what if" alternatives GIS provides.

Student Project Chosen

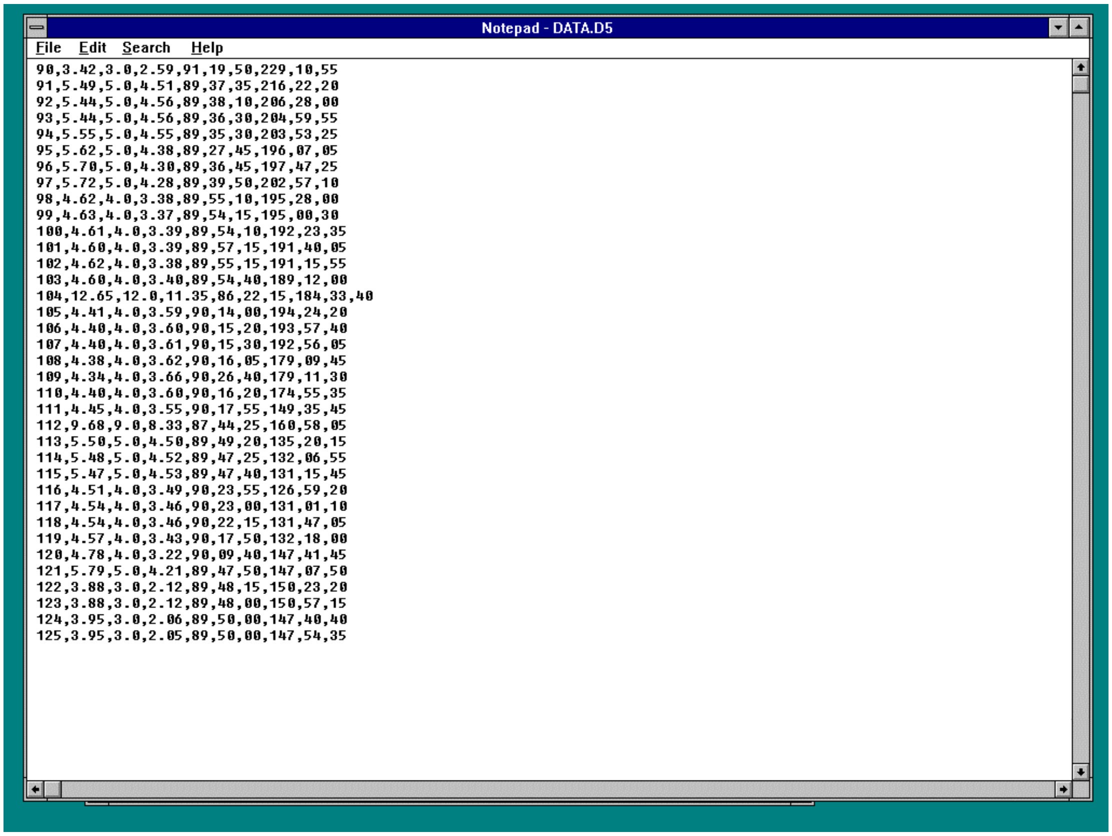
Decisions about the apportioning of education in the basics as opposed to training in the most modern applications always present course designers with a problem. Both the CET and SU programs require a four-semester series in surveying, with an emphasis on land and civil engineering applications. This was the first area in which we decided to apply the GIS. As a project in the second semester, our students make observations to construct a Digital Terrain Model (DTM) from which a map is produced at engineering scale (about 1 inch equals 35 feet with half foot contours). The area of the map (see Figure 1) is the open area in the upper middle of the aerial view, taken looking roughly south. It is about four acres and is surrounded by traverse stations, also observed and reduced by students. The technique used is a modification of the old standby, stadia mapping.

The principles of the technique are presented for completeness. The students use an electronic theodolite, Philadelphia rod and cloth tape. Student groups set up on one of the already coordinated (Pennsylvania State Plane (1983) North Zone (3701)) traverse stations and set the azimuth of an adjacent station on the horizontal plate of one of our electronic theodolites in lower motion. When the instrument is placed in upper motion in the direct position, the horizontal plate reads azimuth. This is called placing the instrument “in meridian”. Since the observer is a student, Top, Middle and Bottom wires, rather than interval, are observed, along with zenith distance (vertical angle) and azimuth. The height of the instrument above the station is measured with cloth tape for each observing session. Appendix A shows the mathematical algorithm for conversion of these observations into (X,Y,Z) coordinates.

Figure 1. The Penn College Campus. Area mapped is in the upper middle of the image and is about 4 acres in size. Note that the picture predates the construction of the College's Victorian House shown in Figure 3.

Each group annotates their field book's "remarks" column so that points observed which are not on the ground, such as the tops of walls, can easily be identified and later segregated. From this, the students produce planimetric and topographic ASCII files of observations (see Figure 2).

Instructional time is devoted to the standard file exchange protocols ASCII and .DXF, so students understand the process involved in converting observations to (X,Y,Z) coordinates and going from one application to another using .DXF files. Although they are capable of computing the (X,Y,Z) coordinates by hand, to save time, they use a program written by the faculty to make this transformation. The program also tests the half-intervals (Top - Middle and Middle - Bottom) to detect blunders. Agreement of 0.01 ft is required for the point to be accepted.

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92,5.44,5.0,4.56,89,38,10,206,28,00
93,5.44,5.0,4.56,89,36,30,204,59,55
94,5.55,5.0,4.55,89,35,30,203,53,25
95,5.62,5.0,4.38,89,27,45,196,07,05
96,5.70,5.0,4.30,89,36,45,197,47,25
97,5.72,5.0,4.28,89,39,50,202,57,10
98,4.62,4.0,3.38,89,55,10,195,28,00
99,4.63,4.0,3.37,89,54,15,195,00,30
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101,4.60,4.0,3.39,89,57,15,191,40,05
102,4.62,4.0,3.38,89,55,15,191,15,55
103,4.60,4.0,3.40,89,54,40,189,12,00
104,12.65,12.0,11.35,86,22,15,184,33,40
105,4.41,4.0,3.59,90,14,00,194,24,20
106,4.40,4.0,3.60,90,15,20,193,57,40
107,4.40,4.0,3.61,90,15,30,192,56,05
108,4.38,4.0,3.62,90,16,05,179,09,45
109,4.34,4.0,3.66,90,26,40,179,11,30
110,4.40,4.0,3.60,90,16,20,174,55,35
111,4.45,4.0,3.55,90,17,55,149,35,45
112,9.68,9.0,8.33,87,44,25,160,58,05
113,5.50,5.0,4.50,89,49,20,135,20,15
114,5.48,5.0,4.52,89,47,25,132,06,55
115,5.47,5.0,4.53,89,47,40,131,15,45
116,4.51,4.0,3.49,90,23,55,126,59,20
117,4.54,4.0,3.46,90,23,00,131,01,10
118,4.54,4.0,3.46,90,22,15,131,47,05
119,4.57,4.0,3.43,90,17,50,132,18,00
120,4.78,4.0,3.22,90,09,40,147,41,45
121,5.79,5.0,4.21,89,47,50,147,07,50
122,3.88,3.0,2.12,89,48,15,150,23,20
123,3.88,3.0,2.12,89,48,00,150,57,15
124,3.95,3.0,2.06,89,50,00,147,40,40
125,3.95,3.0,2.05,89,50,00,147,54,35
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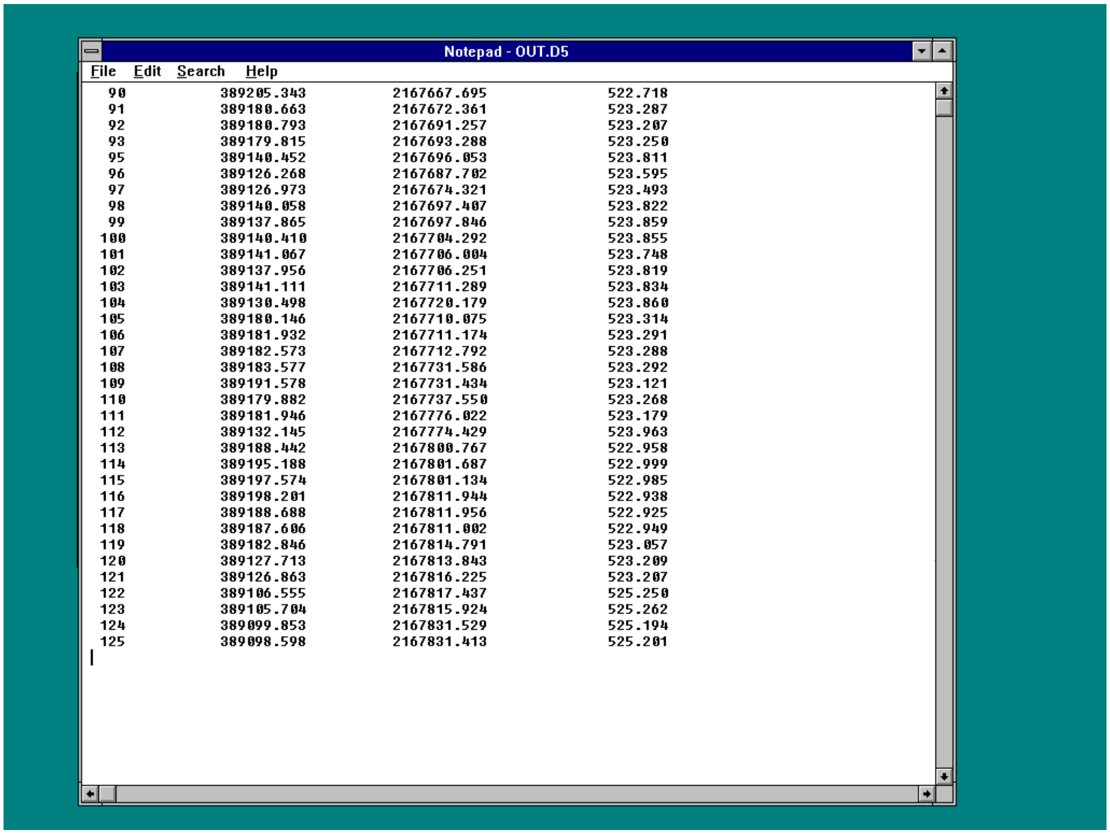
Figure 2. An example of a student ASCII data file prepared from the fieldbook, done in the Notepad editor. Order of data for each point is Point #, Top, Middle and Bottom wire readings made on the level rod, Zenith Distance in degrees-minutes-seconds format and Azimuth in that same format. Note that observation 94 does not meet the (top-middle) to (middle-bottom) criterion.

Figures 3a and 3b show examples of the program produced files of (X,Y,Z) coordinates and the accompanying “hardcopy” students use to check accuracy of input data. It is the (X,Y,Z) coordinate files that the students edit and copy-concatenate into planimetric and topographic coordinate files.



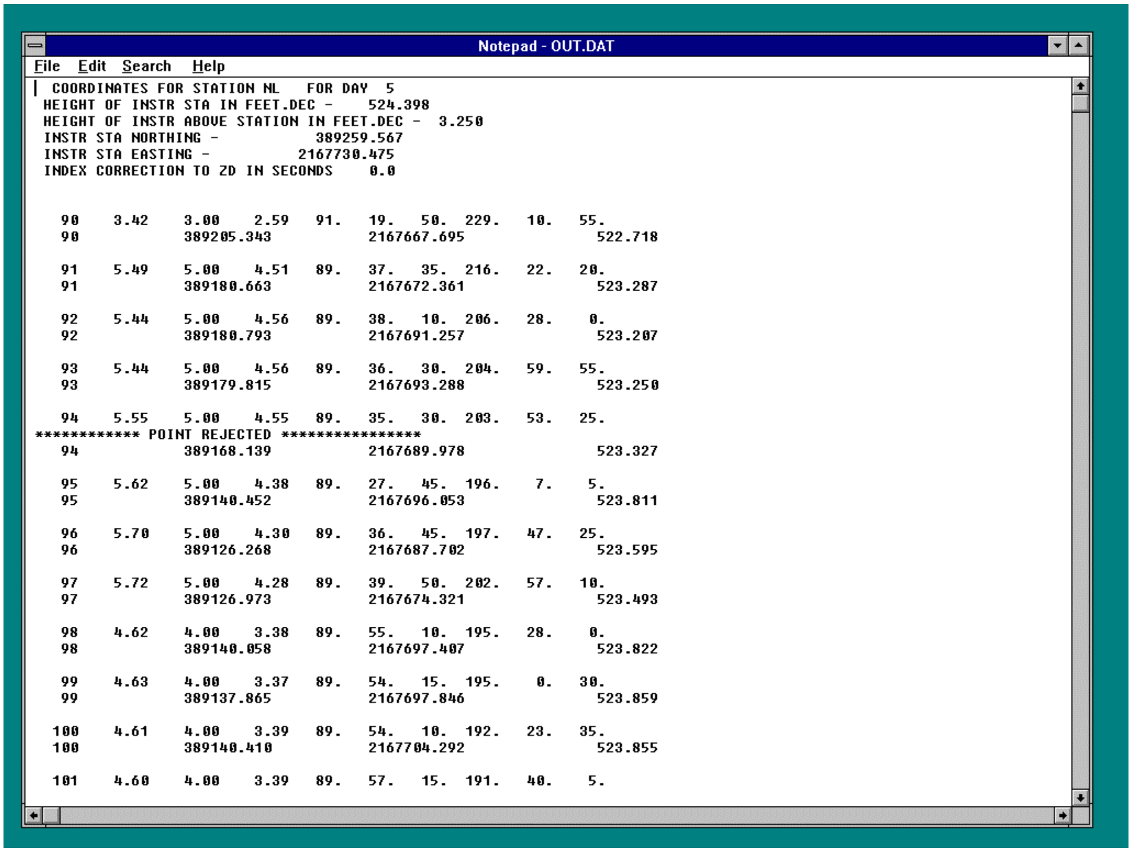
Notepad - OUT.D5

File Edit Search Help

90	389205.343	2167667.695	522.718
91	389180.663	2167672.361	523.287
92	389180.793	2167691.257	523.207
93	389179.815	2167693.288	523.250
95	389140.452	2167696.053	523.811
96	389126.268	2167687.702	523.595
97	389126.973	2167674.321	523.493
98	389140.058	2167697.407	523.822
99	389137.865	2167697.846	523.859
100	389140.410	2167704.292	523.855
101	389141.067	2167706.004	523.748
102	389137.956	2167706.251	523.819
103	389141.111	2167711.289	523.834
104	389130.498	2167720.179	523.860
105	389180.146	2167710.075	523.314
106	389181.932	2167711.174	523.291
107	389182.573	2167712.792	523.288
108	389183.577	2167731.586	523.292
109	389191.578	2167731.434	523.121
110	389179.882	2167737.550	523.268
111	389181.946	2167776.022	523.179
112	389132.145	2167774.429	523.963
113	389188.442	2167800.767	522.958
114	389195.188	2167801.687	522.999
115	389197.574	2167801.134	522.985
116	389198.201	2167811.944	522.938
117	389188.688	2167811.956	522.925
118	389187.606	2167811.002	522.949
119	389182.846	2167814.791	523.057
120	389127.713	2167813.843	523.209
121	389126.863	2167816.225	523.207
122	389106.555	2167817.437	525.250
123	389105.704	2167815.924	525.262
124	389099.853	2167831.529	525.194
125	389098.598	2167831.413	525.201

Figure 3a. File created by the coordinate program, listing point number, Northing (Y) coordinate, Easting (X) coordinate and the Elevation (Z) coordinate. Note that point number 94 is missing in sequence. It was rejected.

They then use an MS-DOS application called LI Contour (A B Consulting Co., Inc) to preview their work for completeness and for blunders previously undetected. The (X,Y,Z) coordinates can also be edited in the program, if necessary. The student groups then produce preliminary plots of planimetric detail, again to ensure completeness. Preliminary plots of the hypsographic information are also produced to ensure adequate density of data and as a blunder check. Once they check these data, the program produces a .DXF file of the planimetry showing point location and point name and another showing the location of hypsography points and their elevation.



Notepad - OUT.DAT

File Edit Search Help

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 COORDINATES FOR STATION NL   FOR DAY  5
HEIGHT OF INSTR STA IN FEET.DEC -    524.398
HEIGHT OF INSTR ABOVE STATION IN FEET.DEC -  3.250
INSTR STA NORTHING -           389259.567
INSTR STA EASTING -          2167730.475
INDEX CORRECTION TO ZD IN SECONDS    0.0


  90    3.42    3.00    2.59   91.   19.   50.  229.   10.   55.
  90            389205.343         2167667.695               522.718

  91    5.49    5.00    4.51   89.   37.   35.  216.   22.   20.
  91            389180.663         2167672.361               523.287

  92    5.44    5.00    4.56   89.   38.   10.  206.   28.    0.
  92            389180.793         2167691.257               523.207

  93    5.44    5.00    4.56   89.   36.   30.  204.   59.   55.
  93            389179.815         2167693.288               523.250

  94    5.55    5.00    4.55   89.   35.   30.  203.   53.   25.
************ POINT REJECTED ****************
  94            389168.139         2167689.978               523.327

  95    5.62    5.00    4.38   89.   27.   45.  196.    7.    5.
  95            389140.452         2167696.053               523.811

  96    5.70    5.00    4.30   89.   36.   45.  197.   47.   25.
  96            389126.268         2167687.702               523.595

  97    5.72    5.00    4.28   89.   39.   50.  202.   57.   10.
  97            389126.973         2167674.321               523.493

  98    4.62    4.00    3.38   89.   55.   10.  195.   28.    0.
  98            389140.058         2167697.407               523.822

  99    4.63    4.00    3.37   89.   54.   15.  195.    0.   30.
  99            389137.865         2167697.846               523.859

 100    4.61    4.00    3.39   89.   54.   10.  192.   23.   35.
 100            389140.410         2167704.292               523.855

 101    4.60    4.00    3.39   89.   57.   15.  191.   40.    5.
```

Figure 3b. Students receive a paper copy of each instrument position from the coordinate program. Note that observation 94 is marked as rejected. Students can then decide if they have made an entry error in their ASCII files or an error in observing in the field.

The MGE System is an enhancement to Microstation (Bentley Systems Inc), although this is akin to saying an automobile is an enhancement of the wheels and tires. The planimetric file is imported into an already set up project in Intergraph MGE. The layers of the .DXF file containing the point names appear as "tags," in Intergraph MGE and Microstation parlance. Students then manipulate line weights and place lines, curves and text to produce the planimetric detail. They show buildings as line polygons. The students symbolize the locations of trees, lightposts, walkways, fire hydrants, drains and other utilities. The .DXF file image containing this information is then deleted, leaving the linework and symbols. The students then import the .DXF file containing the elevation data and spot high and low points are noted and symbolized. This .DXF file image is also deleted. Using an application called Modeler, elevation data are read directly into the project and contour lines are cast at half foot intervals. The students then construct a legend and plot the project at the desired scale. Figure 4 illustrates that graphic.

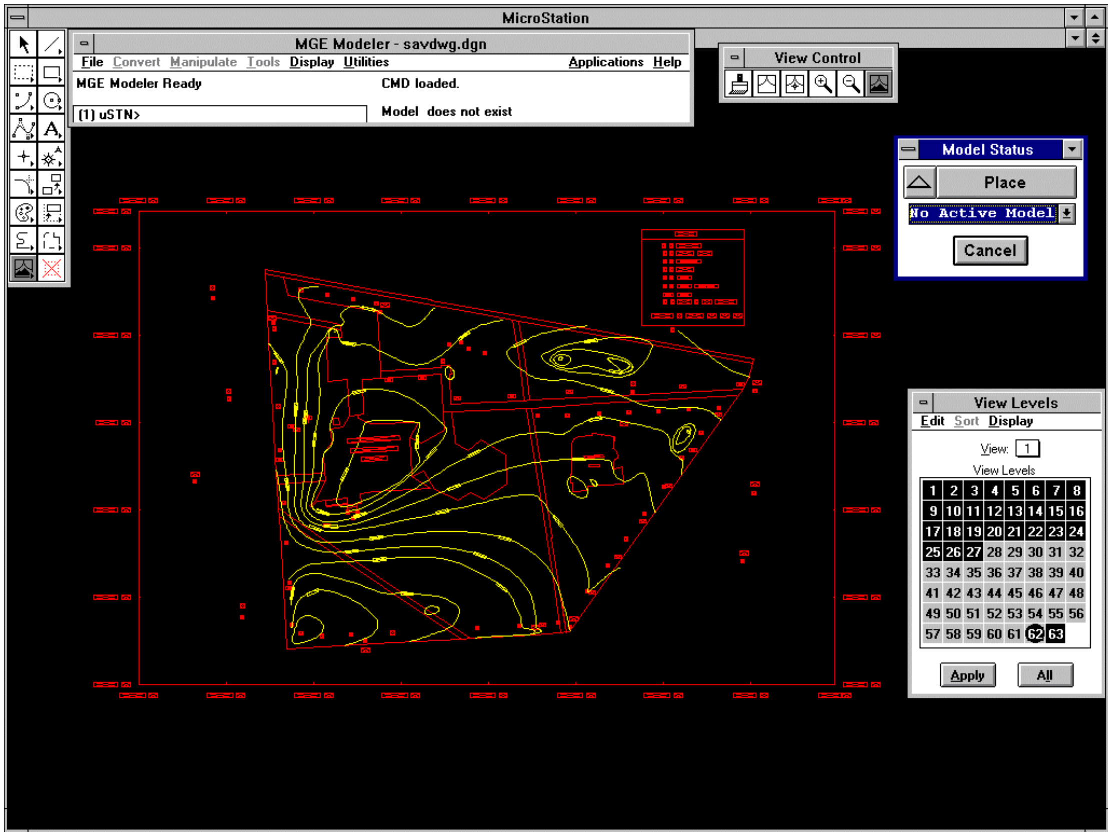

Figure 4. The completed student graphic, intended to be plotted as a “D” size map. Note the non-standard symbols used on this large scale graphic, listed in the legend. The designation “SF” in the border coordinates indicates Survey Feet. Note that the scale may be distorted by importation of the image into the word processing program.

We have also integrated the GIS into instruction in our photogrammetry course, required for SU students, using the same techniques with the output from our analytical plotter. Students also do an analysis, using GIS and its query language, for a civil engineering project in our Topographic and Cartographic Drafting Course.

Conclusion

Not only do our students gain an appreciation for modern techniques applied to classic mapping and Civil Engineering problems, but they also gain an understanding for the need and use of a series of applications. These applications, made by different entities, using different terminology, are all needed to produce the final product: the ASCII DTM and paper map, in the case of the surveying project. Our emphasis on fundamentals equips our students to perform these processes and other surveying or civil engineering tasks with the applications we use or with any others they will come across in what they call “the real world.”

Appendix A - Conversion of Observations into Point Coordinates

For each point to be mapped, the group observes Horizontal plate reading (Azimuth), Vertical angle and Philadelphia rod readings, Top, Middle and Bottom reticule wires.

Known from previous work are the station coordinates for the station over which the instrument is set. The half-intervals are computed and compared ([Top-Middle] and [Middle-Bottom]). If acceptable, the following are computed:

$$H \text{ (the horizontal distance)} = K * (\text{Top-Bottom}) * \cos^2 (\text{Vertical angle})$$

$$V \text{ (the vertical distance)} = 1/2 * K * (\text{Top-Bottom}) * \sin (2 * \text{Vertical angle})$$

where K is the Stadia Interval Constant, usually 100 in most modern instruments. Note the Stadia Constant, i. e. the distance from image convergence to plumb point, is zero in most modern instruments. Then:

$$X \text{ (easting)} = X_{\text{instrument}} + H * \sin (\text{Azimuth})$$

$$Y \text{ (northing)} = Y_{\text{instrument}} + H * \cos(\text{Azimuth})$$

$$Z \text{ (elevation)} = Z_{\text{instrument}} + \text{Instrument Height} + V - \text{Middle wire reading}$$

These coordinates are associated with the point description from the Remarks column of the fieldbook for later plotting in the CAD.

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Dr Sprinsky is an Associate Professor at Penn College. His M.S. and Ph.D. degrees are from The Ohio State University in Geodetic Science. He has a B.S. in Physics from the Polytechnic Institute of Brooklyn (Polytechnic Institute of New York). He has over twenty years of experience in civil engineering and mapping with the Army Corps of Engineers. His major research interests are in surveying and geodesy.