

Final Project Report:

GIS Applications for Site Planning at UNBC

GEOG413: Advanced Geographic Information Systems

Selena Schroeder

UNBC Student # 230013471

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Summary

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This report discusses several applications of GIS (Geographic Information Systems) and related technologies to site planning at UNBC (the University of Northern British Columbia). Raw data was collected to create thematic maps of the study site, and to model the site's elevation. DEMs (Digital Elevation Models) were built from a variety of primary and secondary data sources, and the resulting volumes were compared using the *Arc/Info cutfill* command. Finally, a design option involving adjustment the site's relief was modeled. The results show that volumetric comparison of DEMs based on data sets from different sources can be highly problematic due to differences in precision, accuracy, and data collection methods. On the other hand, volumetric analysis was useful in modeling proposed changes to the relief, provided that the baseline data was consistent.

The report begins with a brief introduction to the project area and the task summary of the various data types and processing steps used, then goes on to describe some of the technical challenges that were encountered. A discussion of the analysis and results follows, and several of the final outputs are provided in printed format.

Introduction and Study Area

The purpose of this project was, firstly, to provide baseline information and model potential design options for a proposed development at the UNBC campus in Prince George, and secondly, to evaluate the effectiveness of one method of calculating changes in relief over time. The area of interest is a parcel of land located to the south of the university campus, on the west side of the entrance road that leads from Tyner Boulevard to the University Ring Road. The site is approximately 10.5 hectares in area and includes part of Shane Creek , which carries runoff from Shane Lake down Cranbrook Hill towards Foothills Boulevard , then into the municipal storm sewer line. It contains wooded areas, but is dominated by a large pile of soil which was dumped there after being excavated from main university campus during its construction, in the early- to mid-1990s.

The data were examined at three different scales. The 'large study area' is defined by a 4 km by 4 km square surrounding the site. The 'small study area' refers to a square plot just larger than the site itself. The area where the relief has changed as a result of waste soil disposal is termed the 'elevation study area'.

Several design options are being developed for the site as part of a site planning course at UNBC. In order to facilitate the design process, a number of tasks were undertaken using GIS and related technologies:

- Two thematic maps of the site were produced, one showing 'Groundcover' and one showing 'Observed Features'.
- Several DEMs were constructed, showing the relief as represented by various data sources, and numerous volumetric analyses were performed, to calculate the volume of waste soil deposited on the site.
- A new DEM was created to model a proposed site design that would result in a net zero change in soil volume.

While the first task was relatively straightforward, the second and third required a more in-depth analysis of

various data sources and procedures.

Data Types and Processing Steps

A number of different data sources were utilized for this project: an *AutoCAD* file of the UNBC Masterplan, primary and secondary GPS Data; TRIM1 and TRIM2 data sets; data from the City of Prince George ; and a new contour line coverage based on a proposed design. This section describes how each of the data sets was processed for use in the project and outlines the steps taken to perform volumetric analyses.

Masterplan and Secondary GPS Data

In order to define the site boundary and understand the transportation context of the site, the shape and width of surrounding roads needed to be defined with relatively high precision. Because the roads features provided in available data sets such as TRIM and City Data were rough and inappropriate for site design use, the UNBC Masterplan file was used instead. Having been obtained from the architectural firm which manages it, the Masterplan was converted from *AutoCAD* .*dxf* format to an *Arc/Info* coverage, and georeferenced to UTM coordinates (see ‘complications’ section below for details on georeferencing). [Figure 1](#) shows a portion of the georeferenced Masterplan. The roads were then extracted in *ArcEdit* and used to define the site boundary.

Primary GPS Data

Primary GPS data were collected for the small study area only. A symbol dictionary was created in *Pathfinder Office* and loaded into a *Trimble* receiver, to distinguish between features such as points representing power poles, lines representing streams, and polygons representing areas of surface water build-up. On the site, these features were recorded, along with general position points along transects which covered the elevation study area in increments of approximately five metres. [Figure 2](#) provides an illustration of the features and positions in their raw, unedited format. The GPS data sets were differentially corrected in *Pathfinder Office* using base station data ftp'd from the Internet (ftp://ftp.cansel.ca/public/base_station/bc/prince_george/ssf), and exported into both *Arcview shapefile* and *Arc/info generate* formats, as both features and position points. For an example of the effects of differential correction, see [figure 3](#) .

The feature data sets were manipulated in both *Arcview* and *Arc/Info* to create two smooth, readable maps: one for Groundcover, and one for Observed Features. Commands such as *spline* and *buffer* were used, but a significant amount of interpretation had to be done by reviewing field notes. Although the user bias introduced during this part of the process may be considered unacceptable for most GIS purposes, the final maps produced provide a more easily readable and usable format for the purposes of site planning. The Groundcover and Observed Features maps are provided as figures [4](#) and [5](#) .

The position data set, once assembled to include an elevation attribute (see ‘complications’ section below for more details on assembly), was manipulated mainly within *Arc/Info*. For the sake of simplicity and because no

specific breaklines had been collected, the point coverage was converted into TIN (Triangular Irregular Network) format using *arctin*. The TIN was then converted to a lattice using *tinlattice*. [Figure 6](#) provides an illustration of the DEM created from primary GPS data.

TRIM1 and TRIM2

Because one of the project aims was to do an analysis of volumetric change over time, Both TRIM1 and TRIM2 data were used to create DEMs. The TRIM data sets were provided at a scale of 1:20,000 and the contour interval for elevation data was 20 metres.

TRIM1 data were obtained in geographic coordinates as *Arcview shapefiles*, converted to *Arc/Info coverages*, and projected into UTM coordinates. The TRIM1 coverages were then clipped to an area just larger than the large study area. Data from four TRIM2 data tiles were imported into *Arc/Info* from *.e00* format, appended, then clipped to the same extents as the TRIM1 data and joined with additional attributes using *fcode* tables from the Internet (<http://srmwww.gov.bc.ca/gis/trimfeatures.htm>).

To create breaklines for each of the two TRIM data sets, water, cultural, and transportation coverages were appended, rejoined with their attributes, clipped to an area just larger than the large study area, and ungenerated into *generate* files. To create DEMs, the *createtin* command was used in *Arc/Info*, with the respective contour layers as coverages and the new *generate* files as soft breaklines. Lakes and other flat features could have been extracted and ungenerated separately to use as hard breaklines, but were not, in order to save time, and because cartographic output was not a purpose of the TRIM data. The TINs were then converted to lattices using *tinlattice*, and the lattices were clipped to the extents of the large study area. [Figures 7](#) and [8](#) show the contours, breaklines and DEMs derived from the two TRIM data sets.

City Data

Data from the City of Prince George had already been appended and assembled in *PCI* for an earlier project, and a subset corresponding to an area just larger than the large study area was clipped and exported from *PCI* into *Arc/Info coverages*. A subset of breaklines covering the same area was also exported from *PCI* into an *Arc/Info generate* file. These exports were performed by the lab instructor. The horizontal scale of the City Data was approximately 1:5,000 and the elevation contour interval was 1 metre.

To create a DEM from the City Data, the *createtin* command was used in *Arc/Info*, with the contour layer as the coverage and the generate file as soft breaklines. The TIN was then converted into a lattice using *tinlattice*, and the lattice was clipped to the extents of the large study area. [Figure 9](#) shows the contours, breaklines and a DEM derived from the City Data.

Volumetric Analysis of the Various Data Sets

With three different DEMs for the large study area (TRIM1, TRIM2, and City Data), and an additional one for the elevation study area (GPS Data), the task remained of calculating the amount of waste soil on the site. This was attempted using the *cutfill* command in *Arc/Info*.

To begin with, all the DEMs were clipped to the extents of the elevation study area. Next, volume differences between the various DEMs were calculated, assuming a chronological order of TRIM1, TRIM2, City Data, GPS Data. [Figure 10](#) provides an illustration of these results; the relief in these lattices represents the difference in volume between one DEM and the next (not the total value of the elevations).

To see if results of the volumetric analysis within the elevation study area represented an actual change in volume, or were merely representative of a discrepancy between the data sources themselves, volume changes were also calculated for the large study area. The results of this analysis are shown in [figure 11](#) and discussed in more detail below.

New DEM for the Proposed Design

Most design proposals for the site involved removal of the waste soil, which would result in a considerable cost (see analysis of results below for discussion of the magnitude of this cost). The group working on the site planning project, however, wanted to develop an option that incorporated the soil into the site design, instead of having it removed. The main elements of the proposed design were a tobogganing hill and a small pond. A new DEM was created which, once analyzed with the *cutfill* operation, resulted in a net volume change of approximately zero, as compared to the City Data DEM (see analysis section below for rationale of using City Data as a baseline).

The new DEM was assembled first as contour lines. The contour line coverage from the City Data was clipped to the extents of the small study area, displayed in *Arcview*, and converted to a *shapefile*. In *Arcview*, the existing contours were adjusted or deleted, and new contours were added. The *shapefile* was then converted back into an *ArcInfo* coverage, and the elevation values were updated in *ArcEdit*. The boundary of the proposed pond was copied into a new coverage using the *put* command, then ungenerated into a generate file for use as a breakline. To create a DEM of the new contours, the *createtin* command was used, with the new contour layer as the coverage and the pond generate file as a hard breakline. The TIN was then converted into a lattice using *tinlattice*. The process was repeated several times until the *cutfill* analysis showed a net change in volume of approximately zero. [Figure 12](#) shows the new contour coverage created, as well as the new DEM. Further site elements, such as housing, a wastewater treatment system and a micro-hydro generation scheme were designed by the site planning group using manual drafting techniques, and are not included in this report.

Technical Problems/Complications

Although the minor technical complications that arose throughout the process will not be detailed herein, two major problems consumed enough time and energy to warrant attention in this report. This section provides a

detailed description of the complex processes that were required to export the GPS data and georeference the Masterplan.

Exporting GPS Data

Pathfinder Office offers a number of export formats for GPS data, including *Arc/Info generate* files and *ArcView shapefiles*. Both the *generate* files and the *shapefiles*, however, exhibited technical problems when utilizing data dictionaries and 3-dimensional positions.

Exporting the *Trimble .ssf* format into *Arc/Info coverages* provided three files for each feature, one *.aml* file, one *.ps* file and one *.pts* file. When executed, the *.aml* file was designed to generate a coverage using the *.ps* file for point positions, and then join the *.pts* file to create attributes. However, the *aml* made use of the 'INFO' subprogram within *Arc/Info* and because of problems with the university's copy of that program, the *.aml* resulted in a coverage with features but without attributes such as elevation, which the GPS receiver had indeed captured.

Exporting the data to *Arcview* presented a different set of problems. For features, the exported *shapefile* format worked only the first time that a theme was viewed, and thereafter reported the error, "Number of shapes does not match number of table records." For positions, the *Arcview* format displayed properly, but the *Arc/Info* command *shapearc* would not convert the *shapefile* to a coverage, due to an "unsupported shape type" error.

The solution was to open the *.pts* file in *MS Excel*, give it appropriate heading names, and save it as a comma-delimited text file. Then, it was opened as a table in *Arcview*, and exported to *.info* format. The attribute-less *Arc/Info coverage* was opened as a theme and converted to a *shapefile*. Then, the *join* function in *Arcview* was used to join the two tables. Finally the new *shapefile* was converted back into *Arc/Info* using *shapearc*, this time without any error messages, and the attributes were reattached using *joinitem*.

Georeferencing the Masterplan

Another problem arose when trying to georeference the Masterplan file of the university. The file was obtained from architects in the *AutoCAD .dxf* format, but because the file format was newer than the university's copy of *Microstation*, it could not be opened directly. *FME* was used to convert the Masterplan file into *Microstation*, *Arc/Info* and *ArcView* formats. All formats appeared to be in metres but were not explicitly georeferenced, and both the northing and easting values for the coordinates were negative and far from the actual location of the site.

After several unsuccessful attempts by both the lab instructor and myself to georeference the file by changing the global origin in *Microstation*, georeferencing was attempted using *Arc/Info* and *ArcView*. The *Arc/Info coverages* and *Arcview shapefiles* translated by *FME*, however, came across in a cumbersome 40 layers. Instead of using the *FME* conversions, the *.dxf* file was converted into the two formats using *dxfac* and 'convert to shapefile' respectively, creating a single *coverage/theme* with an attribute that distinguished between different layers.

A coverage called 'Gps99' from a previous UNBC project was the only georeferenced coverage I could find that contained recognizable Masterplan features at a fine resolution. However, it was somewhat rough and did not contain any crisp intersections or corners that would be appropriate to use as point references. In *ArcEdit*, I displayed Gps99 as a background coverage and the new Masterplan coverage as the edit coverage, in the hopes of moving the Masterplan features to align with the recognizable Gps99 features. I selected all line features of the coverage and tried moving them to line up with Gps99, but many of the elements were corrupted in the move process, so I did not save the moved features.

In *Arcview*, I displayed both the new Masterplan theme and the Gps99 theme. I then zoomed to the extents of both themes, so that each appeared as a small dot on the screen. I drew a rectangle around the dot representing the Masterplan theme, then selected everything inside the rectangle, including the rectangle itself (without the rectangle, only a 'stretch' arrow would appear when pointing at the dot; with the rectangle, empty space was available to point at and a move arrow appeared). I moved the Masterplan 'dot' onto the Gps99 'dot', then zoomed in and repeated the procedure until the recognizable features were accurately aligned. Again, several elements were corrupted, but enough remained to identify precise intersections and corners, which could be used to calculate the offset between of the original coordinates and their corresponding UTM coordinates.

Six points were chosen to compare the georeferenced *shapefile* and the uncorrected *coverage* of the Masterplan, and (x,y) offsets were calculated for each, all of which came within 0.05 metres of one another. The six sets of offset (x,y) values were averaged and recorded.

Back in *Arc/Info*, I listed the *.tic* and *.bnd* files of the Masterplan coverage. I then created a new coverage with tic and boundary values equal to those of the Masterplan coverage minus the calculated offset. Using the *transform* command with the simplest option, *similarity* (which moves all the features without any stretching or warping), the Masterplan coverage was referenced to UTM coordinates and could now be viewed in overlays with other data.

Results and Analysis

Thematic Maps

The Groundcover and Observed Features maps provided an invaluable resource to the site design team. Although the output was mainly cartographic in nature, the data assembly procedures were somewhat complex because of software glitches. The use of data dictionaries seemed to complicate the process rather than making it easier. Given the present software available at the university, recording attributes in a notebook and attaching them to features at a later point might prove to be a more efficient data-handling strategy for future GPS projects of a similar nature and scale.

DEM Construction and Volumetric Analysis

In the elevation study area, the results would seem to suggest that the waste soil deposited on the site amounted to approximately 290,000 cubic metres between the time that the TRIM2 data were collected and the time that the City Data were collected, and approximately 550,000 cubic metres between the time that the City Data were collected and the time that the new GPS data were collected. Assuming that the TRIM2 data were collected in the early- to mid-1990s, right before or during the excavation of the main university campus, and that the City Data were collected in the late-1990s, and knowing that the dumping of waste soil continues to the present day, this analysis may seem reasonable.

If the calculated volume were correct, the approximate cost of soil removal to restore the site to its original relief (calculated at \$2 per cubic metre, from a rough estimate provided by contractors) would be \$1.68 million, excluding any costs for soil disposal or ecological restoration. A closer look at the quality of the data, and the assumptions behind the analysis, however, reveals that these calculations are far from being an accurate representation of the waste soil on the site.

Because several different site planning group members were involved in collecting the GPS elevation data on the site, some of whom were completely unfamiliar with the technology and methods, the data collected were not consistent. Instead of being laid out in regular, five-metre transects, the elevation points were almost random. Although most of the intended area was covered, there were significant gaps, which resulted in a highly variable data layer. In addition, although the *Trimble* GPS receivers can achieve a horizontal precision as fine as 1-2 metres (on a day with low PDOP), the vertical precision is much coarser, perhaps only 9-10 metres. Significant spikes and dips in the GPS DEM show that the actual vertical precision achieved was within the 30-40 metre range. Although this problem was realized early in the project, it was decided that the GPS elevation data should still be modelled, to provide an illustration of the data quality (or rather, lack thereof).

Because the GPS DEM was of low precision and questionable quality, the site planning group decided that it should not be used in the design process. The City Data DEM, although not completely up to date, does show an identifiable demarcation of the waste soil pile. Out of the various DEMs produced, the City Data DEM appears by comparison with the observed terrain to be the most accurate. Although additional waste soil has been added to the site since the time that the City Data was collected, the volumetric change between TRIM2 and City Data was selected as the preferred model.

The difference in resolution between the TRIM2 data layer and the City Data is significant. While TRIM2 data consisted of contour lines with 20 metre intervals at a 1:20,000 horizontal scale, the City Data had contour intervals of only one metre and a horizontal precision of 1:5,000. Therefore, it would be faulty to assume that, because the large pile of waste soil was recognizable on the City Data DEM, but not on the TRIM2 DEM, the analysis represented a change over time. Instead, the *cut/fill* operation merely illustrated a difference in elevation values brought out by an increase in precision. In addition, the assumptions outlined above regarding the times when these data sources were created may not be accurate. Other factors could also play a distorting role, such as whether the height of forest cover was included in, or excluded from, the elevation data. Nevertheless,

calculating the volume change between the TRIM2 and City Data DEMs might at least provide a conservative approximation of the waste soil quantities on the site.

Within the elevation study area, which covers approximately 50,000 square metres, an increase of approximately 300,000 cubic metres is modelled between TRIM2 and City Data. When the total is averaged out over the entire elevation study area, the mean increase is approximately 6 cubic metres per square metre, or an average 6 metre increase in elevation. However, an examination of volume changes within the full extents of the large study area show that an increase in volume seems to be a general trend between TRIM1 and TRIM2 and between TRIM2 and City Data.

Within the large study area, an increase of approximately 100 million cubic metres is modelled between TRIM2 and City Data. When the total is averaged out over an area of 16,000,000 square metres (4 km by 4 km), the mean increase is approximately 6 cubic metres per square metre, or an average 6 metre increase in elevation. Because the offset calculated within the elevation study area is virtually identical to that calculated in the larger data set, and because there is no evidence to indicate that large quantities of soil were deposited throughout the extents of the large study area, the calculated change in volume within the elevation study area cannot be taken as an accurate representation of the amount of waste soil deposited on the site. Furthermore, the 6 metre change in elevation is made insignificant by the 20 metre vertical resolution of the TRIM2 data.

In order to verify that the results were not due to an error in data processing, several of the lattices were rebuilt and the *cutfill* operation re-performed, with results that were approximately equivalent with the original calculation. The small variance could be related to different extents used to generate the initial TINs, building or cleaning coverages at different points in the process, or other minor factors, but are not significant enough to warrant attention.

The results of the volumetric analysis show that the comparison of DEMs built from data sources with variable precision and accuracy does not provide a meaningful indication of actual changes in relief. The cost savings represented by avoiding waste soil removal and disposal could therefore not be calculated by comparing different data sets. The costs would depend on the amount of soil that would be removed for alternative designs.

DEM Generated for the Proposed Design

Since the City Data DEM was considered to be the most accurate and precise of the various DEMs produced, the site planning group decided that it should be used as the baseline upon which to design changes in relief. The most simple design scenario would be to assume that site would be leveled out to match the elevations of surrounding roads, creating a basically flat relief with a slight slope. A contour coverage was created to represent this scenario and converted into a DEM. A *cutfill* analysis on the elevation study area showed that approximately 62,000 cubic metres of soil would need to be removed to flatten out the site. This would cost approximately \$124,000, not including disposal cost.

An alternative design scenario would be to reshape the soil and keep it on site. The DEM created to represent the proposed hill and lake design was analyzed against the City Data DEM and showed a net change in volume of approximately zero. Based on the rough calculations of cost savings, the design group was able to justify a modest expenditure for site remodeling that would result in an improvement to the recreational amenities provided at the university.

Output

This section contains hard copies of all of the figures referred to in the main body of the report. For the location of electronic copies of these figures, see the Appendix below.

[Figure 1: Manual Georeferencing of the Masterplan](#)

[Figure 2: Raw, Uncorrected Data collected by GPS](#)

[Figure 3: Example of Differential Correction of GPS Data](#)

[Figure 4: Groundcover](#)

[Figure 5: Observed Features](#)

[Figure 6: DEM generated from Primary GPS Data](#)

[Figure 7: DEM generated from TRIM1 Data](#)

[Figure 8: DEM generated from TRIM2 Data](#)

[Figure 9: DEM generated from City Data](#)

[Figure 10: Differences in Volume within the Elevation Study Area](#)

[Figure 11: Differences in Volume within the Large Study Area](#)

[Figure 12: Proposed Changes in Terrain with Net Zero Change in Volume](#)

References

The only external sources utilized in the preparation of this project were:

- Arc/Info Help module
- ArcView Help module
- Assistance from the Lab Instructor
- Base station data from ftp://ftp.cansel.ca/public/base_station/bc/prince_george/ssf
- UNBC Masterplan file from architectural firm, Dylan and Chernoff, Inc.
- TRIM2 attribute data from <http://srmwww.gov.bc.ca/gis/trimfeatures.htm>

Appendix

All of the data for this project can be found on the 'samson' server at: /home/selena/geog413/project

The file named 'finalreport.doc' is an electronic version of this report.

The subfolder named 'postscript' contains all the figures referred to in the report, in *postscript* format. Detailed information on these files is outlined in the chart below.

The file named 'finalproject.apr' is the *Arcview* project file that contains all of the layouts used as final outputs.

The following table summarizes the contents of the various subfolders.

Subfolder Name	Description of Contents
av-ft	site features adapted from the primary GPS data, mainly in <i>ArcView shapefile</i> format
boundaries	boundary definitions for the various study areas
dem	contour coverages, TINs and lattices representing elevation data and volumetric analyses in the study area
dem2	a partial set of rebuilt DEM layers, created to repeat the modelling procedure and ensure that errors were not accidentally introduced through inconsistent data processing methods
ex-ai-ft-cr ex-ai-ft-uc ex-ai-ps-cr ex-ai-pf-uc ex-av-ft-cr	data exported directly from <i>Trimble .ssf</i> files; the following abbreviations apply: <ul style="list-style-type: none">- ai = <i>Arc/Info generate</i> format- av = <i>Arcview shapefile</i> format- ft = feature data- ps = position data

ex-av-ft-uc ex-av-ps-cr ex-av-ps-uc	<ul style="list-style-type: none"> - cr = data that has been differentially corrected - uc = uncorrected data
fromfme	several different file formats of the UNBC Masterplan, as translated by <i>FME</i>
frompci	data from the city of Prince George , exported from <i>PCI</i> into <i>Arc/Info coverages</i> and <i>generate</i> files
gps99	a gps coverage of the university lands, collected in 1999 as part of a previous project
gpsfiles	primary gps data collected for this project, in <i>Trimble .ssf</i> format
legends	a number of <i>Arcview</i> legend files used in the map outputs
masterplan	the original Masterplan file obtained from the architects ('19048-08-01.dxf'); the georeferenced version of the Masterplan in the format <i>Arc/Info coverage</i> format ('masterplan'); and other coverages employed in the georeferencing process
postscript	<p>all of the final output maps and figures, in <i>postscript</i> format; the following file names apply:</p> <ul style="list-style-type: none"> - figure 1 = masterplan.ps - figure 2 = rawgps.ps - figure 3 = correction.ps - figure 4 = groundcover.ps - figure 5 = observed.ps - figure 6 = mydem.ps - figure 7 = t1dem.ps - figure 8 = t2dem.ps - figure 9 = citydem.ps - figure 10 = newdem.ps - figure 11 = cfbigbox.ps - figure 12 = cfdist.ps
templates	layout templates that were produced to standardize layouts produced in <i>ArcView</i>
trim1	TRIM1 data, as received
trim1used	TRIM1 data, after conversion and manipulation, as used in the project
trim2	TRIM2 data, as received
trim2used	TRIM2 data, after conversion and manipulation, as used in the project