PRELIMINARY LAKE UNION MAPPING RESOURCES

1) Sanborn Insurance Maps

Wealth of information. More info here: http://en.wikipedia.org/wiki/Sanborn_Maps
The UW libraries only have them on Microfilm: http://uwashington.worldcat.org/title/sanborn-fire-insurance-maps-washington/oclc/2830013641533&referer=brief_results

But the Seattle Public Library has a subscription to the digital database where you can download digital versions of these if you are a library card holder:

http://seattle.bibliocommons.com/item/show/2469476030_digital_sanborn_maps_1867-1970

There is supposedly someone that has compiled many Sanborn maps over time for Lake Union. I am trying to track this person down for you. I have included some Sanborns of the Pioneer Sqaure/ downtown area in the Google Earth KMZ attached. So you can get an idea of them. We have not acquired/georeferenced these for the Lake Union area.

2) General Land Office Survey Notes and Maps

I have included the GLO plat maps in the attached KMZ. More background information can be found here: http://riverhistory.ess.washington.edu/glo.php
You can download individual township/ranges plat maps from the Puget Sound River History Website above as well. All notes from which these maps are derived are located here: http://www.blm.gov/or/landrecords/survey/ySrvy1.php

There is a wealth of information related to trees, soils, terrain in these notes though they are only along section lines. You can read more about how we used these sources in a somewhat dated chapter we wrote found here: http://riverhistory.ess.washington.edu/pubs/cms_03.pdf
Specifically look under the section "Mapping a Forgotten Landscape" section (pg 7.)

There is also a masters thesis that compiled these notes for Seattle that is a good resources that relies heavily on these notes: http://uwashington.worldcat.org/title/flora-of-seattle-in-1850-major-species-and-landscapes-prior-to-urban-development/oclc/2850061322782&referer=brief_results

3) Coast & Geodetic Survey Topographic Sheets (T-sheets)

These maps are by far the most spatially 'accurate' historical maps I have worked with. They are very good for shorelines and nearshore features. I have included some for Seattle (and Lake Union) in the attached KMZ.

More info here: http://riverhistory.ess.washington.edu/tsheets.php (you can also download the original scans from our website too.

PRELIMINARY LAKE UNION MAPPING RESOURCES

4) USGS Maps

There are several available for Seattle for the past 150 years. You can get them at the map library in Suzzallo. The older ones tend to be more spatially imprecise due to the scale of mapping. I have included a 1897 land classification map that is based on USGS survey in the KMZ. I have also included portions of other USGS maps, but unfortunately they do not cover Lake Union (but you will get the idea).

5) Aerial Photography

There are a lot of historical aerial photos available in the map Library. I have included some 1940 photos of the Duwamish for your reference (I don't have any georeferenced for Lake Union).

6) Bird's Eye Views

Most of the bird's eyes I've seen were drawn without much depiction of Lake Union. Here are three that you can view & download from the Library of Congress that have Lake Union. The 1891 one is particularly detailed for the Lake Union area.

http://memory.loc.gov/ammem/pmhtml/panhome.html

(do a keyword search for "Seattle").
1884 Bird's eye view of the city of Seattle, W.T., Puget Sound, county seat of King County 1884. H. Wellge, del. Beck & Pauli, lithographers. Published by J.J. Stoneer, Madison, Wisconsin. Library of Congress Geography and Map Division Washington, D.C.
http://memory.loc.gov/ammem/pmhtml/panhome.html

1891 Birds-eye-view of Seattle and environs King County, Wash., 1891. Drawn by Augustus Koch, published by Hughes Litho. Co., Chicago. Library of Congress Geography and Map Division Washington, D.C. http://memory.loc.gov/ammem/pmhtml/panhome.html

1925 Seattle birdseye view of portion of city and vicinity. Drawn by Edwin C. Poland.published by Kroll Map Company, Seattle. Library of Congress Geography and Map Division Washington, D.C.

Other Miscellaneous Sources

Suzallo Special Collections& Map Collections: Go on down to the map collection. A quick search turned up these, just to name a few: http://uwashington.worldcat.org/title/lake-union-industrial-district/oclc/2830021589253&referer=brief_results

http://uwashington.worldcat.org/title/lake-union/oclc/2830057197440&referer=brief_results

http://uwashington.worldcat.org/title/latest-official-map-greater-seattle-1911/oclc/2830027025008&referer=brief_results

Early Washington Maps databases
http://content.wsulibs.wsu.edu/cdm-maps/

Attached PDFs: Denny Regrade, 1893–2008: A Case Study in Historical GIS by Aaron Raymond
Introduction to Historical GIS & the Study of Urban History by Donald A. DeBats and Ian N. Gregory

Figure 5 Sluicing of Denny Hill during Regrade One. A flume carried water and debris into Elliott Bay, c. 1908.
Source: University of Washington, Special Collections.

Figure 6 "Spite mounds" briefly dotted the landscape as some owners continued to fight to save their properties, c. 1910. Contractors were instructed to sluice around stubborn residents on Denny Hill, leaving them with little means of access and resulting in a surreal urban landscape.
Source: University of Washington, Special Collections.

taken to prepare and execute a successful historical GIS framework using the Denny Regrade as an example.

Study Area: Defining Spatial and Temporal Boundaries

An essential first step in performing a successful GIS project, whether or not it is historically based, is to define the spatial boundaries of the study area. Because the regrades represent the largest organized efforts to remove Denny Hill, this project initially planned to define the study area by combining the full extents of Regrade One and Regrade Two. However, a closer examination of the evidence revealed that a large portion of the Regrade Two area was included not with the goal to flatten Denny Hill but to make way for a major new north-south arterial (Dexter Avenue), which would better connect the then burgeoning northern suburbs and downtown. Furthermore, even though some portions of Denny Hill extended beyond it, Denny Way became the northern boundary for the study area, given its long-standing role as both a physical and a psychological barrier that separates multiple neighborhoods from one another along its path. The final study area encapsulated the entirety of Regrade One and that portion of Regrade Two that lay south of Denny Way.

Because historical GIS incorporates the essential added dimension of time, consideration was also given to the appropriate temporal boundaries for the study area. Had the temporal boundaries been strictly defined by the respective start date of Regrade One and end date of Regrade Two, May 1906 and December 1930, the full impact of the regrades on the urban form as it existed both before and after any regrade efforts had occurred would unfortunately be hidden. As a result, the study period was extended as far back as the historical evidence would faithfully allow and forward to the present day (1893–2008). As this was a case study in historical GIS, the most would be made of time.

Creation of Historical Digital Datasets

Once the contextual history had been reconstructed and the temporal and spatial boundaries determined, the process of translating (i.e., *digitizing*) historical evidence into suitable digital formats for use in a historical GIS could begin. Namely, digital datasets containing historical spatial objects (i.e., *fea-*

tures), such as building footprints from 1905 or a contour line that predated the regrades, and their corresponding characteristics (i.e., *attributes*) were created. Given the integral role that features and their spatial relationships play in the successful execution of a historical GIS, additional source materials were gathered to ensure the integrity of their spatial history. For this project, the additional source materials included Sanborn Insurance maps, locally produced historical maps (e.g., Kroll Map Company and Baist Real Estate Atlas), city engineering records, photographs, municipal archives, and county assessor records. After examining and interpreting the historical spatial evidence, core digital datasets were created for blocks, topography, and buildings.

Historical blocks. Research showed that the initial street network for downtown Seattle and the study area had been platted with uniform street widths of 66 feet. The uniformity in street widths resulted in uniform block sizes, either 360 by 240 feet or 240 by 240 feet, throughout downtown. As streets were widened over time to accommodate increased traffic flows, these uniform block sizes, and by association the sizes of parcels in these blocks, were consequently altered. Once created, the historical block dataset proved to be a crucial tool, as it was used as a spatial baseline on which other historical datasets would be referenced.

For example, nonspatially referenced images, such as scanned maps of historical-building footprints or contour lines, could be spatially linked (i.e., *georeferenced*) against the historic block dataset. The georeferencing of digitized features is an integral step in the development of a historical GIS. One cannot simply trace a building footprint on a blank digital GIS canvas; both the canvas and the building footprint must also be defined in geographic coordinate space to enable the drawn feature to have spatial and analytical relevance. Georeferencing accomplishes this key goal, and its importance in the process of developing a historical GIS cannot be understated (Madry 2006).

Historical topography. Given that the topography of nearly the entire expanse of downtown Seattle has been altered by at least one of the many regrades that have occurred since the city was founded in 1851, re-creating the original topographic landscape and its subsequent changes for the study area were key elements to the project's success. Historic sewer survey maps dating from 1891, seven years before any part of Denny Hill was removed, were used as the primary source material to digitally re-create the historical topography (Williams 1891). These large-scale maps (about 39 by 72 inches) depicting 10-foot contour lines were scanned, clipped, and georeferenced. The historical contours were then digitized via manual tracing. Geoprocessing steps were then followed to alternatively represent the historical terrain as a continuous surface that could later be used in the process of creating three-dimensional visualizations.

Historical buildings. This singular dataset captured the spatial record of built structures within the study area's temporal and spatial boundaries. Scanned images of historical maps showing building footprints clipped at the block scale were imported and manually georeferenced. Building footprints were then manually traced and digitized for each built structure, both existing and destroyed, within the study area boundaries. During the digitization process, for each digital building footprint created, key attribute information was also captured, including height, year built, year destroyed (when applicable), use when first built, use in 1937, and use in 2008. The process of digitizing building footprints and entering key attribute information was reiterated for each identifiable built structure for the time period, ultimately producing a dataset containing 1,487 structures across a 105-year period.

It should be noted that, when applicable, building uses for 1937 were recorded using detailed building and photographic records from a countywide initiative, funded by the Works Progress Administration, undertaken to photograph and document all built structures during that time (Becker 2002). As the assessor records were already being reviewed for each building as part of the overall research effort, unique building use in 1937 was recorded given the high level of confidence in the 1937 records. Building use information for 2008 was also recorded given the widespread availability and accessibility of such information. Original use of a building when it was first built was discerned primarily from either assessor records, Sanborn Insurance maps, photographic records, building morphology, or any combination of these sources.

Historical Buildings Dataset: Temporal Priority, Digital Warehouses, and Layer Files

A distinct methodological departure from traditional GIS dataset development took place during the creation of the historical buildings dataset. Normally, features within a dataset represent physically and geographically discrete objects in space at a fixed moment in time. For example, reflecting the reality on the ground that any two buildings cannot occupy the same space at the same time, a dataset of building footprints for 2008 would likewise represent each feature, that is, each building, as its own distinct object separated from other objects in digital geographic space.

However, within a historical GIS framework, the priority is placed on time and not space. As a result, rather than creating a separate historical building dataset for each year of study (1892, 1894, 1895, etc.), a strategy was adopted whereby the historical building dataset became a single digital warehouse containing all the building footprints created for the project. The practical result of this approach meant that buildings were literally digitally drawn over one another, as the important information to capture was not only that this particular building existed at this particular location but that it also existed between years A and B.

To illustrate, imagine that at the northwest corner of an intersection, a one-story house was built in 1900—the first built structure to occupy that space. The house lasted until 1908, when it was torn down as part of the Regrade One effort. The lot remained vacant until 1916, when a two-story retail space was built at the same location. This building survived until 1985, when it was in turn replaced by a 30-story condominium, which remains standing today. In sum, the historical spatial record shows three separate structures occupying the same space across time.

Using the digital warehouse approach, all three built structures were represented as individual features within the historical buildings dataset, each drawn with its unique building footprint and each having its unique "year built" and "year destroyed" attribute information stored as well. In terms of discrete space, these objects appear to overlap in digital space (figure 7); however, in terms of discrete time, the focus of a historical GIS, these objects are unique and distinct from one another.

The strategy of creating a single repository for all building features across time versus creating separate datasets for each year has two main advantages. First, having all of the historical building features in a single dataset builds in an ability to select only those buildings for a given year. At its core, GIS is a visualization system for databases that contain spatial features and corresponding attribute information. For example, if an analyst wanted to study only those buildings that existed in 1908, a direct select by attribute query

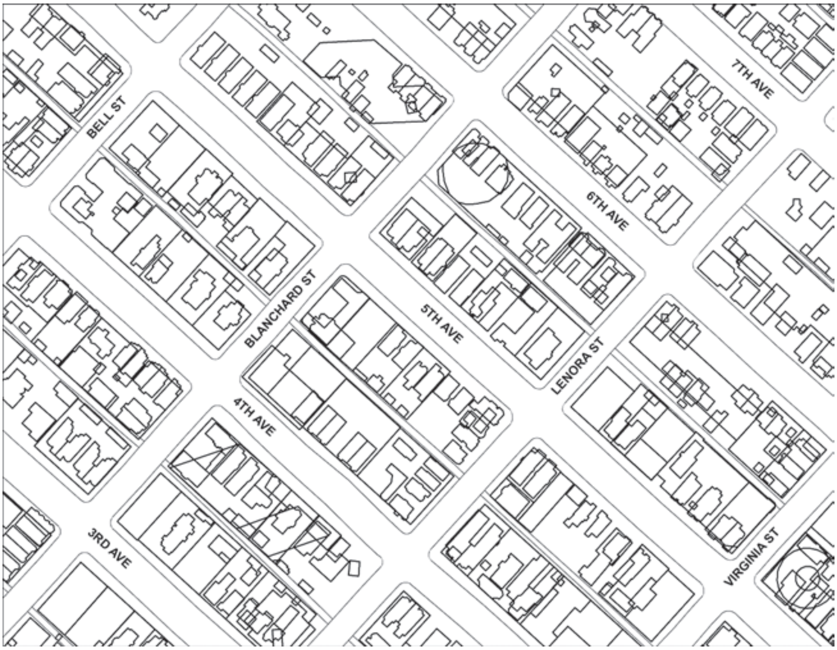

Figure 7 Digital image of warehouse showing historical building footprints overlaying one another

could be executed against the historical buildings dataset to select the desired records. Once selected, these records can then be easily exported to create a new separate dataset unique to 1908. In this light, the single repository dataset can be viewed as a warehouse with the ability to produce an array of child datasets containing only those buildings desired by the researcher for a given moment or even period in time.

Second, the digital warehouse approach enables changes made to features stored in the warehouse to be automatically replicated across any datasets that were originally produced using features stored in the warehouse. This ability to replicate changes across datasets is made possible through the use of a type of dataset called a layer file. In GIS a *layer* file operates as a cartographic tool—it stores visualization settings, such as color, symbology, and label choices, for a feature dataset—and itself does not contain any geographic data. Instead, a layer file acts as a pointer to a parent feature dataset (i.e., *shapefile*) that does contain the underlying geographic and spatial data. Essentially, the layer file is a cartographic lens through which the underlying data stored in the associated shapefile are interpreted and visualized. Because the layer file acts as a pointer to the shapefile and is dependent on the shapefile for spatial structure and information, changes made to data in the shapefile are automatically reflected in the layer file. The relationship exists because a layer file is created from a unique shapefile and in turn points uniquely to that shapefile.

To continue the corner example from above, suppose that it was discovered, after the assessor records were examined in more detail, that the dimensions for the 1916 retail space were actually 55 by 100 feet instead of 60 by 120 feet. Using the editing capability of GIS, the building footprint for this feature would be manually reshaped within the digital warehouse. In other words, the singular historical buildings shapefile that acts as the digital warehouse would be updated. As a result, all layer files that contain this 1916 building and point to the historical buildings shapefile would automatically reflect the updated building footprint as 55 by 100 feet.

The time savings this approach offers the researcher are dramatic in comparison to the alternative approach of creating and editing separate shapefiles for each year of study. For example, using the digital warehouse approach, a change to a building footprint for an 1893 building that still existed in 2008 would require the editing of a single shapefile. Alternatively, if using an approach of creating a separate shapefile for each year of study, editing the building's footprint would take place 108 times versus 1. The time savings become more evident when considering both the number of edits and the number of features requiring edits in building a successful dataset from scratch. Beyond time savings, the risks of introducing error into the historical GIS framework are also substantially mitigated by having only one versus scores of shapefiles to maintain (Gregory et al. 2007b: 46; Madry 2006). The main disadvantage of the digital warehouse approach is that the visual spatial area of the shapefile itself becomes increasingly more cluttered with each new feature added, thereby potentially making the selecting or editing of a particular feature more difficult. However, this cluttered space can be managed in GIS by limiting the number of building footprints that are displayed using definition queries. Given the advantages of the digital warehouse approach, dramatic time savings in data management and reduced risk in the introduction of error, a somewhat more visually cluttered dataset is well worth the price.

Data Validation

A high level of data integrity and spatial fidelity during the digitizing process are key elements in creating a successful historical GIS. As with any GIS, the quality of outputs created is directly proportional to the quality of the input datasets—quality in, quality out. Although this maxim holds true in traditional GIS as well as in information technology frameworks in general, it is particularly important in historical GIS, as the datasets used by the analyst to perform GIS operations are often ones created by the analyst himself.

The quality of the historical digital datasets produced by the digitization process is directly proportional to the quality and breadth of the historical source materials referenced to create those datasets (Wilson 2001). As a result, to better ensure higher levels of data integrity, three key data validation techniques are recommended for historical GIS. First, data validation should take place on a continual basis both during and after the digitization process. Second, datasets should be continually inspected against source materials to identify, correct, or delete errant records or to add records missing altogether during construction. Third, interim test information products, such as baseline maps and test selection queries, should also be used to further refine and improve the overall integrity of the historical digital datasets being produced.

The process of translating analog historical source material into digital datasets is the most critical determining factor in the success of a historical GIS. The demands of time and attention required to ensure high-quality outputs should not be underestimated by the researcher considering embarking on such an endeavor (Beveridge 2002; De Moor and Wiedemann 2001; Gregory et al. 2002, 2007b; Knowles 2008; Siebert 1997). Estimates for this stage of the historical GIS process range between 60 and 80 percent of the total effort to create and execute a historical GIS project (Gregory et al. 2007b: 41). Ultimately, the creation of quality historical digital datasets provides the foundation not only for the digital visualization of historical built environments and natural landscapes but also for meaningful analytic operations that have the potential to add to our understanding of the history of both space and place (Cunfer 2008).

Historical GIS: Creating New Historical Data and Information

Once the historical record had been successfully translated into digital format, the historical datasets could then be used in GIS both to create visualizations and to perform analyses (Rumsey and Williams 2002). The respective outputs created by GIS yielded not only new data but also important new information about the history of the Denny Regrade. The section below outlines the main information products created by the Denny Regrade historical GIS project, geovisualizations and analytic tables, with examples of how each contributed new information and insights into Seattle's urban past.

Geovisualizations

One of the core elements of any GIS is geovisualization, the ability to graphically display spatial and attribute information. The cartographic capability of GIS enables users to interact with the data in a visual format, creating opportunities to identify new patterns, relationships, and ideally to discern new information (Bodenhamer 2008; Diamond and Bodenhamer 2001; Gregory et al. 2007a, 2007b; Knowles 2002, 2008). GIS makes two- and three-dimensional geovisualizations of geographic, and in this case historical, data possible. Exploiting the integrative visual power of GIS, geovisualizations are well positioned to interweave once disparate pieces of information, even ones from different moments in time, into powerful visual statements that communicate information about the past. Listed below are key geovisualizations produced by the Denny Regrade historical GIS.

Regrade One and Regrade Two. This map represents the extents of both major regrades in relation to one another, outlines the footprint of Denny Hill, and displays the street grid and study area (figure 8). The key component of this map is the historical footprint of Denny Hill set against the backdrop of a contemporary aerial photograph of Seattle. The central questions of where Denny Hill once stood and where the Regrade took place, two questions not immediately or easily addressed in the existing historical record, now can be answered by GIS and also can be given immediate spatial relevance for a contemporary audience.

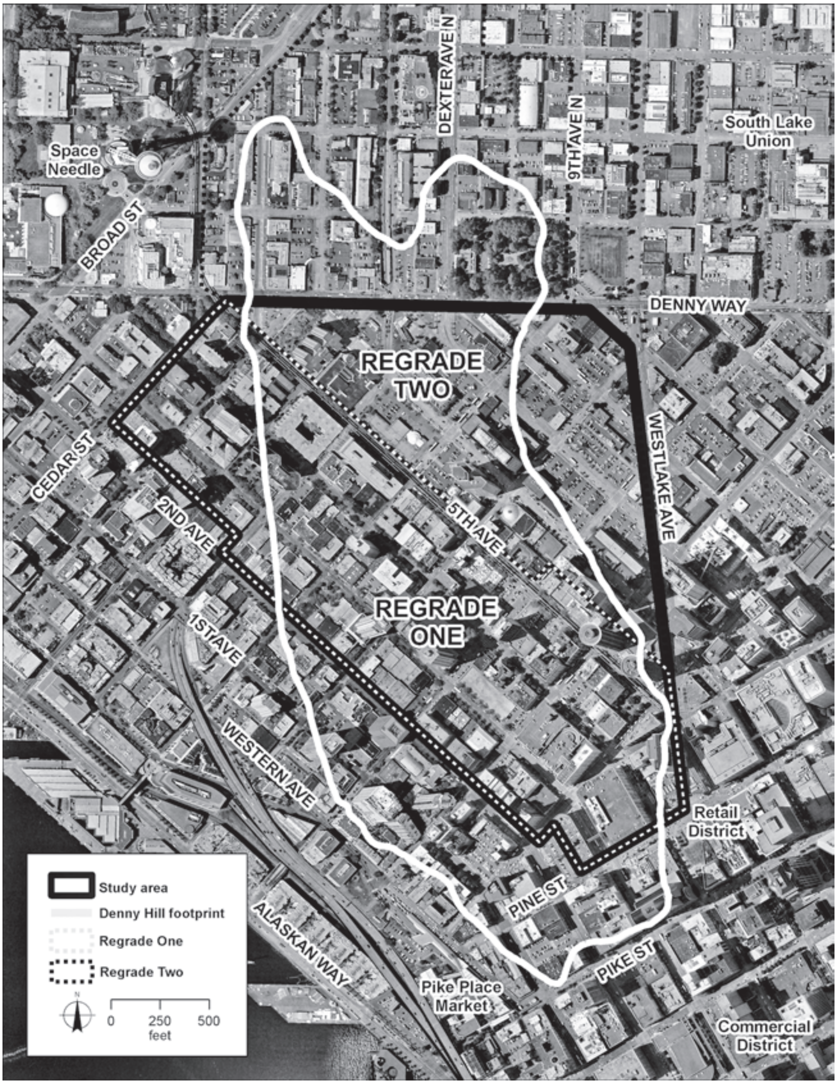

Figure 8 Historical footprint of Denny Hill superimposed on contemporary aerial photograph of downtown Seattle

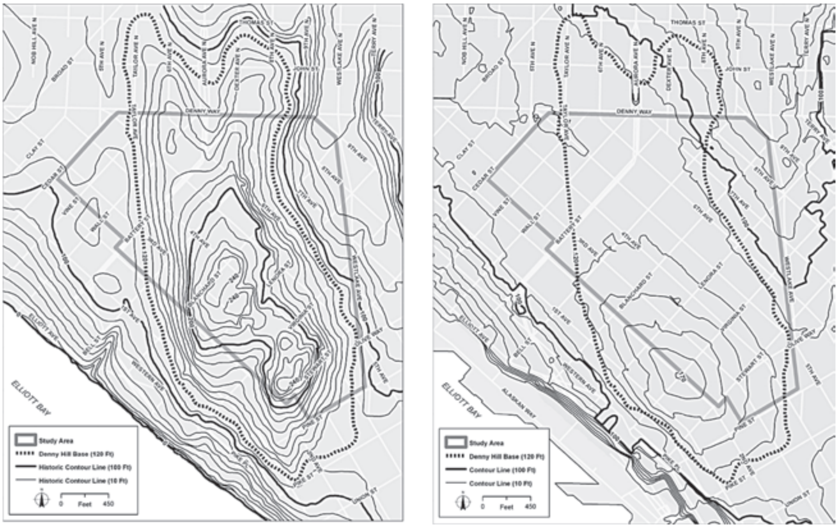

Figure 9 Comparison of topographic changes across time. At left, original topography showing original characteristics of Denny Hill and its immediate area; at right, topography of the same extent today. The contemporary street grid has been overlaid on both maps for reference.

Historical topography. These two maps respectively show the historical and contemporary contour lines for Denny Hill and its immediate surroundings (figure 9). These geovisualizations offer greater nuance regarding the character and extent of Denny Hill. For example, the historical contour map reveals the steep slopes adjacent to the retail district and the twin peak morphology of the hill itself. The latter feature is vaguely referenced in the historical literature, yet through GIS it is brought into sharper relief. Additionally, the topographic maps are superimposed on the present-day street grid to better orient the reader and communicate how both Denny Hill and the adjacent shoreline have been reshaped over time.

Three-dimensional visualizations. A time series of three-dimensional visualizations uses key dates as points of demarcation between 1893 and 2008 (figure 10). Geovisualizations depicting dates earlier in the study period highlight an intact Denny Hill and its associated initial urban form. The three-dimensional time series proves especially effective at communicating the full force of change brought on the study area's built and natural environ-

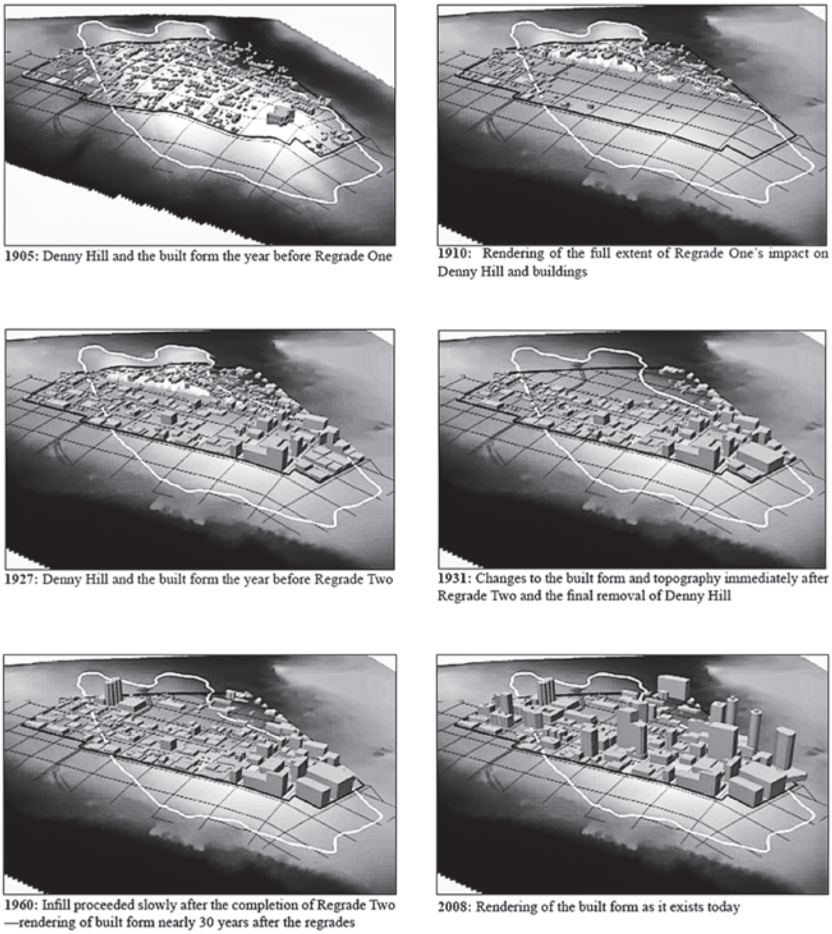

Figure 10 Selected three-dimensional geovisualizations illustrating dramatic changes to both natural and urban landscapes across time. The historical footprint of Denny Hill is included for reference.

ments over time, particularly for Regrade One and Regrade Two. Additionally, qualitative aspects of the built form are better understood through this three-dimensional visualization. For example, the reader can watch buildings appear and disappear, identify trends in building heights, and observe gradual increases in building density across time.

Geovisualizations through historical GIS enable visually uniform and consistent comparisons of space across time from multiple perspectives, a capability that would have been extremely cumbersome if not impossible prior to the advent of GIS. Although somewhat taken for granted, the ability to create original historically based geovisualizations represents a fundamental and powerful ability of GIS to bring historical urban landscapes to life (Rumsey and Williams 2002).

Analytic Tables

Another core capability of GIS is its ability to manipulate and analyze data as a means to create new data. Coupled with a newly digitized historical record, the analytic capacity of GIS uniquely positions historical GIS not only to create new data but also to yield new information about the past (Gregory et al. 2001). For example, by translating once analog information, such as building heights and building footprints, into digital formats one can calculate building square footage and urban densities.

Furthermore, by using the inherent structure of the underlying GIS data model to store and manage information (i.e., spatial features represented as unique records with corresponding unique attributes stored in a tabular format), the historical GIS analyst can choose discrete years, defined time periods, or both as baselines to perform spatial and, more important, temporal analysis. For example, if a researcher wanted to choose only those buildings that existed in 1972, a query could be performed to select those buildings and export them as a distinct dataset for further study. The selection could be performed not only for discrete years but for a period of years as well (e.g., 1972 or 1970s). In sum, historical GIS enables the researcher to more easily perform comparative analysis across time, a key function noticeably lacking in traditional GIS models, where time is treated as a fixed variable (Chrisman 1997: 28; Dragicevic et al. 2001; Goodchild 2008). For the Denny Regrade historical GIS, two main categories of analytic tables were produced: building use and urbanization matrices.

Building use. These tables capture and summarize various types of information regarding the historical built space and changes to that space in the Denny Regrade (tables 2–3). The main elements analyzed include type of building use and number of buildings, total square feet, and relative proportions of built space devoted to a respective use. For example, in 1893 there were over 360 single-family residential structures in the Denny Regrade, and by 1960 only one remained standing. Additionally, prior to the rise of the

Table 2 Number of buildings in existence, by building use per year indicated

Building use	1893	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2008
Single-family	320	361	198	178	49	30	18	1	—	—	—	—	—
Multifamily	69	76	113	131	57	53	51	30	28	31	56	42	51
Hotel	10	13	19	14	16	15	15	18	23	24	26	25	25
Residential (subtotal)	399	450	330	323	122	98	84	49	51	55	82	67	76
Office	—	—	1	10	18	18	28	38	41	47	52	52	52
Retail	2	3	17	43	68	74	77	75	71	70	67	57	44
Auto	—	—	2	19	49	80	100	93	83	64	98	51	42
Industrial	5	7	7	9	9	10	13	12	12	11	11	9	7
Public assembly	13	13	8	4	3	3	3	3	6	7	7	7	4
Public services	5	5	3	3	1	1	4	1	1	1	1	1	1
Stable	26	27	20	11	1	—	—	—	—	—	—	—	—
Shed	218	234	139	128	18	13	4	1	1	—	—	—	—
Other	—	—	—	—	3	3	3	3	3	3	4	5	5
Total	668	739	527	550	292	300	316	275	269	258	322	249	231

Table 3 Percentage of built space in square feet, by building use per year indicated

Building use	1893	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2008
Single-family	44.8	44.9	18.0	10.0	2.0	1.2	0.7	0.0	—	—	—	—	—
Multifamily	14.8	15.5	23.0	23.0	18.3	17.9	24.8	19.5	16.1	21.0	29.9	25.7	38.0
Hotel	18.0	17.4	28.7	17.3	17.9	17.3	14.1	15.2	20.3	17.6	14.9	17.5	14.6
Residential (subtotal)	77.6	77.9	69.7	50.3	38.2	36.5	39.7	34.7	36.4	38.6	44.9	43.3	52.6
Office	—	—	1.0	13.4	12.3	12.3	17.3	16.1	19.8	26.5	25.7	30.3	26.8
Retail	0.6	0.6	5.1	10.9	22.8	23.5	18.9	24.3	21.2	16.2	10.9	12.4	9.8
Auto	—	—	0.7	9.9	13.4	14.0	12.1	15.2	16.1	13.4	15.3	10.5	8.2
Industrial	0.8	2.1	3.2	3.5	2.8	3.5	3.3	2.7	2.3	1.7	1.0	0.9	0.6
Public assembly	4.2	3.8	11.4	6.7	7.9	7.9	6.4	5.4	3.0	2.6	1.6	1.9	1.4
Public services	8.0	7.2	5.5	3.3	0.9	0.9	1.2	0.6	0.5	0.4	0.3	0.3	0.3
Stable	3.8	3.6	1.9	0.9	0.2	—	—	—	—	—	—	—	—
Shed	5.0	4.7	1.6	1.1	0.1	0.1	0.0	0.0	0.0	—	—	—	—
Other	—	—	—	—	1.3	1.3	1.0	0.9	0.7	0.6	0.4	0.5	0.4
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 4 Rate of urbanization per decade

Decade	Number of buildings created	Number of buildings destroyed	Square feet created	Square feet destroyed	Urbanization factor[a]
Pre-1900	694	11	1,114,013	6,709	166.05
1900	336	178	1,176,541	435,069	2.70
1910	119	411	1,096,296	581,908	1.88
1920	119	113	2,032,106	412,018	4.93
1930	40	293	111,508	546,703	0.20
1940	42	41	390,115	82,267	4.74
1950	43	70	1,648,455	321,616	5.13
1960	31	37	1,519,131	245,406	6.19
1970	24	35	1,854,702	114,572	16.19
1980	14	18	2,187,996	252,495	8.67
1990	9	20	894,701	121,699	7.35
2000	16	29	2,714,354	233,464	11.63
Total	1,487	1,256	16,739,918	3,353,926	4.55
Regrade One	28	440	681,049	849,005	0.80
Regrade Two	6	273	11,157	429,494	0.03
Regrade (subtotal)	34	713	692,206	1,278,499	0.54

[a]Defined as the ratio of built space created to built space destroyed per decade and per regrade.

automobile, stables once dotted the landscape in the Denny Regrade, with as many as 27 structures devoted to stable use in 1900. By the beginning of the 1930s this building type had all but become extinct. By categorizing and analyzing building typology using historical GIS, research revealed new types of historical data and patterns of use previously hidden or absent from the historical record.

Urbanization matrices. Numerous analytic tables were produced that captured changes in the rate of urbanization over time. Each table created for the study highlighted different aspects of the built form, including building height, square footage, number of stories, and building age. The sample table presented here utilizes historical building square footage data to create an "urbanization factor" illustrating the pace of urban change in the Denny Regrade (table 4).

The urbanization factor is defined as the ratio of the amount of building square footage created to the amount of building square footage destroyed for a given year or period of time. For example, during the 1970s over 1.8 million square feet of new building space was created, while only a little more than 100,000 square feet of space was destroyed. The urbanization factor for this period was calculated as the second highest in history with a numerical value of 16.19. Compared to the overall mean urbanization factor of 4.55 for the entire period of study, the 1970s represented a nearly fourfold increase in the rate of urbanization and the greatest single period of urbanization for the area throughout the entire twentieth century. Additionally, with respect to the regrades, the ferocity of their destructive impact becomes more clearly evident. Over the entire study period, a 108-year span, the total amount of built space destroyed in the study area was 3.7 million square feet, 1.3 million square feet of which resulted directly from Regrade One and Regrade Two. In other words, a full 37 percent of the total amount of built space destroyed in the study area is directly attributable to the regrading of Denny Hill. This figure is even more astonishing when one considers that the majority of this man-made destructive force was completed in only seven years.

The geovisualization and analytic capacities of GIS arguably represent the potentially transformational role that GIS can play in historical research: historical GIS has the ability to create new historical data where they did not exist before in the historical record. Although seemingly oxymoronic in tone, historical GIS enables the researcher to ultimately create new information and insights into past places that help us better understand how those places came to be.

Historical GIS: Enhancing the Historical Narrative

Having created new historical data through historical GIS analysis, the baseline historical narrative of the Denny Regrade can be revisited and enhanced by incorporating this new information. It is important to note that historical GIS by itself cannot provide much added value to the history of a given place. In other words, to leverage the potential of historical GIS fully, it is essential that the results of a historical GIS analysis be interpreted in the context of an established understanding of the history of a given place (figure 11).

For example, simply bringing to life the historical topography of a hill that once existed in downtown Seattle by itself bears little impact on our understanding of Seattle's urban history. However, armed with the under-

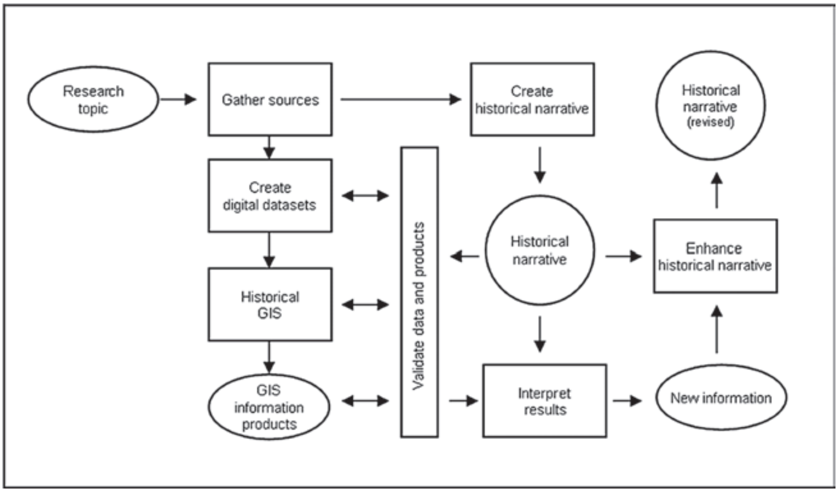

Figure 11 Conceptual model highlighting the relationship between historical GIS and its utility in enhancing the historical narrative

standing of the history of Denny Hill and its removal, the ability to visualize and locate Denny Hill's footprint, steep slopes, and twin peaks takes on added meaning to help us understand why the hill was removed. By locating the steep slopes adjacent to the burgeoning downtown retail district, one can better understand the motivation to remove the hill in the name of improved commerce and mobility through the downtown core.

The following summarizes a few of the more salient historical insights directly gained from conducting a historical GIS for Denny Hill and the Denny Regrade.

Location of Denny Hill

Having translated the 1891 topographical map of downtown Seattle into a digital GIS layer, the full extent and location of the original Denny Hill could be definitively determined. Once correctly georeferenced, the historical topographic detail overlaid atop the contemporary street grid and aerial photography provided a digital link between the now missing hill and current space. This is particularly important in light of the fact that only a single historical document, in the vault of the city archives, had actually mapped the historical topography of Denny Hill prior to any regrades. The ability of historical GIS to translate this document into a digital format that can then be integrated into contemporary space proved to be a powerful tool to better understand the import and impact of Denny Hill.

Characteristics of Denny Hill

By digitally overlaying historic Denny Hill atop downtown Seattle, the full extent of the hill and its characteristics could be discerned. For example, its base spanned more than 60 blocks, it had twin peaks close to the downtown retail district, and its steep bluff along Pike Street rose over 100 feet across a single block. All of this key information, although vaguely referenced in the historical record, was produced and clarified through historical GIS.

Extent of Regrades

Although conventional historical wisdom has combined the regrading of Denny Hill into a single event, historical GIS confirmed that the removal of the hill was primarily the result of two large separate efforts (Regrade One and Regrade Two). In actuality, the removal of Denny Hill took no fewer than seven separate regrade projects across a period of 32 years. It is this fact, directly generated using historical GIS, that most directly challenged the established and accepted historical narrative of the Denny Regrade. Historical GIS provided the ability to locate the separate regrade efforts both spatially and over time in a single model. In addition, the destructive scope of the regrades was illustrated through GIS. The two main regrade efforts alone were responsible for destroying 1.3 million square feet of built space—a fact heretofore absent from the documented historical record but illuminated by historical GIS.

Building Use and Form

The data produced using historical GIS (see the earlier discussion of the analytic tables) are indeed new bits of historically based data. The results reveal a more refined and nuanced picture of how the urban form in the Denny Regrade changed over time. For example, by 1960 the sole single-family residence remained standing in the study area from a high of over 360 such structures in 1900. Additionally, larger office buildings have emerged since the 1980s as a major building typology in the regrade area. Similar trends and changes can be discerned for other uses and building types; however, these trends were essentially invisible and inaccessible prior to setting up a historical GIS.

Conclusion

As the compelling history of Denny Hill and its associated regrades show, historical GIS offers the researcher a means to enhance the historical picture across space and time. The usual constructions of historical narratives have tended to focus on the chronological sequencing of key events using traditional, nondigital sources. While references to the spatial qualities of history are often made in these types of inquiries, the opportunity to realize the full potential of incorporating the spatial component of history via GIS technologies has rarely been pursued. More than ever before, historical GIS allows the researcher to exploit and incorporate the possibilities of spatial analysis into established historical narratives. Historical GIS has not only the potential but also the power to enrich new constructions of historical narratives and expand those that currently exist. The opportunity historical GIS presents for academic and historical research should not be overlooked.

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Donald A. DeBats and Ian N. Gregory

Introduction to Historical GIS and the Study of Urban History

Over the past decade or so geographic information systems (GIS) methodology has become an accepted tool in historical research (Gregory and Ell 2007; Knowles 2008). Although often regarded as a mapping tool, GIS is perhaps better thought of as a type of database. What makes a GIS database unique is that a location is stored for each item of data, with this location taking any of a variety of forms: a point, a line, a polygon representing an area or zone, or, in the case of a raster system, a pixel. GIS can then present instantly on the screen a map showing the distribution of any variable or combination of variables in any of the chosen locational formats. This electronic display of information becomes an analytic tool, allowing the refinement of research questions, with answers displayed instantly: GIS creates a display of information once visible only in paper form, drawn slowly and expensively first by cartographers and then by vector plotters. GIS and its associated tools transform mapping into a dynamic exploratory process.

The fact that the data in a GIS database are spatially referenced allows a researcher to produce maps quickly, easily, and potentially in large volumes; but a number of other advantages also make GIS a platform that is well suited to the analysis of the geographies of the past. The first is that, as all data in a GIS-informed project have an explicit spatial location, it is easy to ask questions about where features are located in relation to each other. As Anne Knowles (2000: 453) notes, the enhanced visualization component of GIS has very positive results for historians, making available "dimensions of historical reality and change that no other mode of analysis can reveal."

Social Science History 35:4 (Winter 2011)
DOI 10.1215/01455532-1381814

Second, as the locational data are based on real-world coordinate systems, such as latitude and longitude, Universal Transverse Mercator, or British National Grid, any dataset can potentially be integrated with any other dataset. Thus, for example, data on specific buildings based on points can be integrated with demographic data from census tracts represented as polygons, transport information can be represented as lines, and data on heights can be represented as pixels on a raster surface. This enables complex representations of a study area to be built up from multiple, apparently incompatible sources.

Third, and perhaps most important, GIS allows the researcher to explore the topic under study in a way that explicitly considers the impact of space and location. This might involve using formal spatial statistical methodologies (Fotheringham et al. 2000; Maguire et al. 2005) or might simply involve asking questions about why different places appear to behave in different ways. The increasingly sophisticated suite of statistical tools that accompany GIS software provide insight into the strength, rather than just the existence, of a spatial pattern, indicating how tightly grouped or widely dispersed it is. As correlation coefficients are to a scatter plot, so measures of the characteristics of spatial distributions are to the visualization of those patterns, providing indexed scores of the strength of complex relationships. Spatial statistics likely will assume increasing importance in guiding the development of GIS as this revolution turns from visualization to more ambitious analytic pursuits. At the very least, GIS enables and encourages the researcher to think carefully about the geography of the topic under study and the explanatory power of that geography.

While GIS approaches have these advantages, they also have a number of drawbacks. First, the time it takes to create a GIS database can be large, greatly increasing the variety of costs associated with a GIS-informed project. Second, the use of GIS software requires that the researcher learn certain technical skills, demanding additional time and effort. Third, and perhaps most fundamental, there is a lack of strong geographic skills among historians who are more used to asking questions about change over time. This relative neglect of the geographic tradition means that even with a good database and the technical skills to use it, a researcher still needs the conceptual tools to frame research questions and conduct the research in ways that make full use of the available spatial and thematic information. The good news in respect to this last issue is that GIS has reawakened interest in the importance of geography and space to the historian (Bodenhamer et al. 2010; Gregory 2003). Myron Gutmann (2002: ix) puts the case well: "GIS enriches both qualitative and quantitative approaches to history . . . enabl[ing] students, teachers, and researchers to think differently about the past."

Historical GIS in Urban History

The most important factor in determining the extent to which historical GIS will become an established part of the discipline of history is the success or otherwise that its practitioners have in delivering research that demonstrates that GIS can and is making a direct contribution to knowledge in the discipline. Key to this is not the fact that GIS is used but instead that the research advances our understanding of the topic under study. The field where arguably the most progress has been made toward this goal is urban history. A number of reasons may be identified for this. First, urban history has a long tradition of acknowledging geographic features, as exemplified by the work on Milwaukee produced by Kathleen Conzen (1976) and Michael Conzen and Kathleen Conzen (1979); Michael Katz's (1975) study of Hamilton, Canada; John Kellogg's (1982) study of segregation in Lexington, Kentucky; Sherry Olson's (1989) study of Montreal; and the Philadelphia Social History Project (see Hershberg 1976, 1981). Urban studies also tend to offer the historian a rich variety of spatially referenced sources, such as maps, addresses, street names, electoral lists, gazetteers, and tract-level data. More pragmatically, urban areas tend to be relatively small, reducing the size of the spatial databases required. Nevertheless, boundary problems and controlling the size of the population as well as the number of variables being examined are important considerations as the researcher moves from the database construction phase of an urban project into its more substantive phases.

In an early paper concerned with the development of a database on Tokyo's urban growth, Loren Siebert (2000) provides a frank account of how he created such a database, what he sees as its potential, and the problems he encountered in developing it. More recent papers have moved the field forward by looking at how spatially informed databases can be used to make a contribution to knowledge in urban history. Andrew Beveridge (2002) takes tract-level data on population, ethnicity, and other socioeconomic variables for New York City from censuses from 1900 to 2000. He uses these to show how the city grew over the twentieth century and how different ethnic areas developed in the larger city. His approach is primarily descriptive, deploying detailed spatial and temporal data to present a narrative of the development of ethnic segregation. Colin Gordon (2008) follows a similar approach in his study of the decline of St. Louis since 1945. He draws on a wider range of sources and makes extensive use of maps to produce a book that explores how and explains why St. Louis experienced urban blight and decay after World War II.

Amy Hillier (2002, 2003) follows a more targeted analytic approach, focusing on the relationship between mortgage redlining (the process of not giving mortgages to certain areas because of the perceived problems of their residents) and ethnicity and poverty in Philadelphia in the 1930s. She combines data on home loans for a sample of specific addresses, maps of the different "residential security zones" used to define redlined and other areas, data from a 1934 residential survey, and the 1940 census. Using spatial statistical techniques, she shows that areas with high African American and recent immigrant populations were more likely to be redlined than others, but she is also able to challenge the assumption that once areas had been redlined, their subsequent decline was inevitable because of the problems of getting a mortgage. Etan Diamond and David Bodenhamer (2001) follow a somewhat similar approach in a study of white flight in 1950s Indianapolis. They take data from two censuses, 1950 and 1960, and the locations of churches in the city at the start and end of the 1950s and compare the changing ethnic makeup of the city with the changing locations of churches. Their aim was to explore the assumption that mainline Protestant churches followed the white population in abandoning inner-city areas. They found very little evidence that churches moved out of areas that had large and growing African American populations but found that when they did relocate, this would typically be to suburban areas with overwhelmingly white populations.

More recent work in this field has begun to use large databases constructed from individual-level information. This has been particularly driven by the awareness that segregation and spatial concentrations of social groups can only really be understood and seen when working with data at this level. To this end significant work has been undertaken in Hartford, Connecticut (Schlichting et al. 2006; Tuckel et al. 2007), looking at African American populations in the city during the Great Migration. Donald A. DeBats (2008) also uses individual-level data in a similar way but compares two contrasting cities: Alexandria, Virginia, and Newport, Kentucky.

These examples all use primarily quantitative, social science–style approaches to analyze cities that are almost all American. A contrast is provided by the work of Keith Lilley and colleagues, who use GIS to explore medieval cities in England and Wales. Their approach is based on using GIS to integrate and explore archaeological records, surveys conducted using the Global Positioning System (GPS), and environmental data. They use these to shed new insights into the structure of towns in this period (Lilley et al. 2005a, 2005c) and also to disseminate information about them to a wide audience in an interesting and attractive way through the *Mapping the Medieval Townscape* (Lilley et al. 2005b) and *Mapping Medieval Chester* (Mapping Medieval Chester Project 2009) websites. This work illustrates that while quantitative approaches have shown the most progress to date, perhaps reflecting the development of historical GIS and GIS technology more generally, the use of GIS does not force the researcher to take a particular approach to quantitative data. Many different types of data can be included in a GIS, and the approach to analyzing them is very much determined by the interests of the researcher and the available sources.

This Collection

The essays in this collection mainly reflect social science approaches to analyzing urban history. Jason A. Gilliland, Sherry H. Olson, and Danielle Gauvreau use GIS individual-level data from Montreal for the years 1881–1901 to explore patterns of spatial separation on four dimensions: language, religion, socioeconomic status, and age. GIS is important in this investigation because it allows the identification of spatial aggregations at various scales that are consistent across time, facilitating comparison and testing for the salient level of spatial separation on those four dimensions. The work identifies "frontier areas" of diversity and high levels of growth but also reveals an industrial city committed to a pattern of housing stock that made its own contribution to the maintenance of patterns of spatial differentiation. Montreal emerges as a city with high and consistent levels of residential segregation based on ethnicity and socioeconomic status, both most noticeable at the micro level.

The project by Donald A. DeBats on Alexandria, Virginia, and Newport, Kentucky, uses individual-level data to map the populations of these two small mid-nineteenth-century cities, one commercial and one industrial, one based on slave labor and one based on immigrant labor. With the populations assigned to specific addresses, GIS allows the display of social, economic, and political data across the cities, revealing the contrasting spatial patterns associated with their very different political economies. The work contrasts the extent of vacant land in the cities and their use of river frontage and explores the differences in the extent of home ownership. It uses kernel-density measures of the distribution of social groups to explore neighborhood formation and, with individual-level political information, the political influences of such groupings.

Mathew J. Novak and Jason A. Gilliland use GIS with a database of retailers in the commercial city of London, Ontario, between 1844 and 1916 to track the changing distribution of businesses, particularly those in the broad categories of food retailers and fashion retailers. But of course retail establishments and their distribution tell us far more about a city than where people shopped; as Novak and Gilliland point out, the retail sector of a city defines "vital places in the public realm where people congregate and interact." The work suggests that while food retailers, such as butchers, opened shops to serve the localized needs of an expanding city, businesses dealing with fashion, especially dry goods shops, remained committed to a presence in the city's retailing core. This concentration created a crucial mass of options that attracted customers and facilitated comparison shopping. Those fashion shops that located in the periphery tended to be smaller and offered less choice than the major dry goods stores in London's central retailing district.

Finally, Aaron Raymond demonstrates the ability of GIS to visualize change. He uses GIS to discover the extent of topographic alteration of Seattle between 1906 and 1930 and to show the impact of these changes on the spatial profile of the city. The specific point of his study is the massive effort to remove from the city's business district Denny Hill, 245 feet high and 60 blocks in area. The city developers attacked the hill and the buildings on it in two massive "regrades" to permit the expansion of the central business district of this major port city. Raymond's work preserves the building dimensions and shapes that were lost over a 105-year period of Seattle's history, allowing a unique view of urban development over time.

Conclusion

Each of these articles shows how GIS can make a contribution to our understanding of urban history. Most of them do this with large datasets about individual people, households, or properties. They then focus on a range of questions that stress the geographic aspects of urban history, including segregation, core and periphery, and topography. The GIS provides the framework that helps the researcher ask questions concerning what, where, and when. The final and most important stage in the research process is to ask why. GIS does not of itself answer this. Instead, it provides the descriptive information that the researcher has to explain. In this way the GIS enhances analytic skills through its ability to summarize large amounts of complex information in space and time. Explaining why these patterns are as they are remains the task for the skilled historian, not the computer. It is well known that learning GIS skills and building GIS databases represents a major investment of time and effort. Each article describes this effort in some detail. The question remains, is it worth it? Judging by the innovativeness and success of the articles in this collection, the answer is clear—yes, it is. In all of this, there are clear signs that GIS is encouraging a revival of urban history.

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