GIS Spatial Analysis for the Design of Urban Open Space

by

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This thesis is dedicated in memory of Jean Stephans Kavanagh, FASLA.

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ABSTRACT

Urban design in the landscape tradition has a unique set of users and uses due to the nature of urban sites in densely developed areas, yet many urban designers employ the same basic approach in terms of their design process and site analysis methods as they would in suburban or rural areas. In addition, urban design theory is not adequately reflected in the analytical methods traditionally used by landscape architects, nor do traditional methods adequately synthesize the multitude of complex information urban designers must consider throughout all phases of the urban design process. However, GIS offers unique tools for data management, visualization and most importantly spatial analysis, allowing the urban designer new methods for the design of urban open space.

The author examines the traditional site design process and site analysis methods, the most common GIS spatial analysis techniques, and the theoretical framework of urban design in the landscape architectural tradition in an effort to determine the applicability of GIS functionality as a resource to the traditional design process, determine the applicability of GIS spatial analysis tools to aid and enhance the traditional site analysis methods, and determine the applicability of GIS spatial analysis tools as a means to analyze the key dimensions of urban design as set forth by urban design theory. GIS spatial analysis tools are demonstrated following the traditional design process in an application study at Republic Square, an urban park in Austin, Texas.

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CHAPTER I

INTRODUCTION

Urban Design in the Landscape Architectural Tradition

The study of urban design, despite the broad interests and concerns to be discussed hereinafter, is at the heart of this research. However, urban design as a term is vague, confusing, and does little to describe the intended area of study – no more so than the terms 'urban' or 'design' individually articulate a clear definition. Therefore, a brief examination into the nature of urban design, its practitioners, their products, and a definition is justified and prerequisite to any further discourse.

Urban design lies at the crossroads of four environmental design professions: city planning, civil engineering, architecture, and landscape architecture. All four professions unarguably are responsible for the design of the urban environment, but none can rightfully claim urban design solely as its own. In truth, each profession has its own unique process and products that are supplementary and collaborative in producing the built urban form (Lang 2005).

City planning primarily shapes urban design through concern for social and economic development issues such as the distribution of land use activities and the transportation network connecting them. Civil engineering is responsible for infrastructure in urban design such as utility networks and stormwater management systems. Architecture designs individual buildings or complexes of buildings which often dictate the form and pattern of the urban environment. Landscape architecture focuses on the open spaces between buildings – mainly streets, squares, parks, or any other public urban space (Lang 2005).

This research study is primarily concerned with urban design in the landscape architectural tradition, to a lesser extent city planning and architecture, and gives little attention to the issues of civil engineering. All of the four professions are related, but certainly some are more related than others. Therefore, as the author refers to 'traditional' or 'typical' elements throughout the study, it is in reference to the process, methods, and products of urban design as practiced by landscape architects – or designers in the related fields of city planning and architecture who practice urban design in the landscape architectural tradition.

Finally, a definition: "Urban design is an integrative design field addressing the traditional and overlapping concerns of city planning, civil engineering, architecture, and landscape architecture . . . with the single concern for the design of the public, urban realm at the city and precinct level" (Lang 2005). It is important to note two principles from this definition: the emphasis on the public, and the reference to the scale of urban design at the city and precinct level. Urban design is not a land use map, it is not a drainage system, it is not a singular building or a singular plaza – urban design is the overlapping and interweaving elements that create the urban fabric for the use of everyday people.

Justification and Significance of Study

Urban design as a discipline is built upon over a hundred years of theoretical and practical development. Geographic Information Systems (GIS) as a technology is based on roughly fifty years of conceptual development. However, studies linking urban design to GIS have only occurred for about a decade. The recent interest in GIS is not unique to urban design – GIS across many disciplines has gained appeal and credibility as a legitimate aid in data management, visualization, and analysis. This can be attributed to three reasons: the increasing ease of use, the lowering cost of the technology, and the availability of data. In addition, courses in GIS are now mandatory in most undergraduate and graduate landscape architecture and city planning curriculum.

Unfortunately, due to the relative immaturity of this topic, much of the research on urban design and GIS has been primarily focused on the justification or suitability of GIS for use in urban design, or simply as a tool for visualization and modeling. Furthermore, while this research has done much to develop and expand the theoretical framework for GIS as a tool in urban design, few studies have concentrated upon the practical application of GIS following the traditional process of urban designers and their specific methods and techniques for designing the urban environment. This study aims to bridge a gap between urban design in practice and GIS as a tool for decision-making and analysis.

Problem

Urban design is about more than designing in the city. Urban design projects have a unique set of users and uses, and the unique context of dense development – yet many designers employ the same basic approach and design process to urban sites as they would suburban and rural sites. The design process used today, as practiced by professionals and taught in university courses, fails to address the unique nature of urban design in practice and in theory. An urban site design process sensitive to the complexity of the urban environment, based on classic urban design theory, is imperative.

Of the phases of the traditional site design process, the approach to the site inventory and analysis phases requires the most serious revision when adapting from suburban and rural sites to the urban realm. The multitude, density, and complexity of urban elements requires a unique set of site attributes to be inventoried and unique methods and techniques of analysis to be used – yet many designers use the same checklist of environmental and physical site attributes and site analysis techniques as they would any other project outside the urban environment. An inventory list including the unique social and functional aspects of the urban environment needs to be developed, along with analysis methods capable of synthesizing this complex inventory.

GIS is a unique tool for data management, visualization, and analysis of complex and multitudinous information. Professionals from many environmental design fields – namely city planners, civil engineers, and landscape architects – have been interested in utilizing the technology for their specific processes and purposes since its inception in the 1950's. Researchers began exploring the links between GIS and urban design in the early 1990's but efforts have focused more on the issues of urban design in the tradition of city planning and architecture than on issues of urban design in the landscape architectural tradition. Furthermore, few researchers have tested these links through practical application based on the traditional site design process.

Intent and Scope

The intent of this research study is threefold: to examine the fitness of GIS as a resource in the traditional site design process, to explore the use of GIS-based spatial analysis tools to aid and enhance the analysis of urban sites, and to apply GIS in practical applications of urban design based on the classic theory of urban design in the landscape architectural tradition. The intent is unquestionably broad, as research must be when building upon a subject of relative infancy. The long-term objective of this research is to aid future studies in the development of a GIS-based urban site design process utilizing the full data management, visualization, and specifically spatial analytic functionality of GIS.

It is not the intent or within the scope of this study to criticize the traditional site design process or site analysis methods – they will be taken for what they are and assessed only on their applicability to urban design. Additionally, GIS spatial analysis tools will be employed as provided “out-of-the-box” with no intent of developing new methods of analysis. Classic urban design theory will be judiciously selected on its relation to the intent and goals of this study, with no intent of incorporating the vast theoretical framework of urban design in all its traditions.

Research Approach

A review of judiciously selected research and literature relating GIS to urban design, for any purpose or application, will begin the study. This review will be followed by an in-depth examination into three areas of emphasis critical to the research at-hand: the traditional site design process including the methods and techniques of site analysis, the GIS spatial analysis tools, and finally urban design in theory and practice. This critical background information will provide the framework to implement GIS toward urban design application studies. These application studies will provide insight for the critical analysis necessary to fulfill the intent of this research study.

CHAPTER II

LITERATURE REVIEW

Justification of GIS for Urban Design

In the roughly ten years of research concerning the application of GIS for urban design, justification of the topic has proliferated through common themes. Often relating back to the efficiency of GIS, justifying GIS for urban design has become more convincing as researchers continue to find new methods for GIS to aid, enhance, or replace traditional techniques of urban designers for analysis and visualization of the urban fabric. The development of GIS software, coupled with the greater availability of digital data and the development of information technology in general, has led to the increased use of GIS by urban designers and the subsequent justification of researchers to develop the conceptual framework for GIS-based urban design methods and procedures.

With his 1996 publication of “Adapting Geographic Information Systems to Sketch Planning Needs”, a Master’s Thesis in City Planning at Massachusetts Institute of Technology, Raj R. Singh for likely the first time introduced the concept of linking GIS functionality to classic urban design theory. Using basic GIS datasets and the urban design theories of luminaries such as Kevin Lynch, Christopher Alexander, and Jane Jacobs, Singh was able to successfully adapt GIS analytical functions to the traditional analytical techniques of contemporary urban designers. Singh argued that recognizing patterns and trends in the landscape of the urban realm is key to urban design, and that GIS is well-suited to find such patterns and trends that could otherwise be missed by a person due to their subtlety and breadth of information.

In all fields of research studying the applicability or suitability of GIS, one central idea in the justification of the technology is in regard to its efficiency. Following the adage, “Time is money,” the efficiency of GIS as a time-saver tool has a direct correlation to GIS as a cost-efficient tool. GIS is a cost-effective tool when used for land analysis where designers can more efficiently identify opportunities and constraints of proposed sites (LaGro 2001). Moughtin et al. (2003) agrees, citing the example of hypothetical scenarios of land development being constructed in a shorter time with the use of GIS as opposed to traditional manual methods.

The advancements in GIS and information technology paired with the increased availability of GIS data have significantly expanded the analytical functionality of GIS for site analysis in the design process (LaGro 2001). For opportunities and constraints analysis (LaGro 2001), hypothetical scenario construction (Moughtin et al. 2003), or for the visualization and evaluation of alternative designs (Xia and Qing 2004), GIS functionality related to site analysis has been credited time and time again as the justification for research applying GIS to urban design or land design in general.

The graphic nature of GIS has led to research exploring the strengths of mapping and modeling tabular data in order to visualize existing conditions, change over time, and future scenarios. For local government, GIS is beneficial where both visual and tabular data are used for urban site planning (Rubenstein 1996). Furthermore, three-dimensional computer modeling as a visualization tool is becoming more common in urban design (Moughtin et al. 2003). Greene (2006) states that GIS is a powerful visualization tool because it not only shows the significance of impacts to the urban environment, but their spatial distribution as well. Xia and Qing (2004) complement this view by stating that designers also benefit from the ability to visualize potential change to the urban fabric in context to other urban phenomena represented by layered GIS datasets.

The increased use of GIS by urban designers and the increased presence of GIS education in academic curricula undoubtedly have justified the continued research on the topic. Though typically applied to planning applications in the urban realm, GIS is utilized more and more in urban design analysis and in the design process (Carmona et al. 2003). According to Pamuk (2006), GIS education is now a standard component of curricula in both undergraduate and graduate degrees related to urban studies such as city and regional planning. In addition, LaGro (2001) believes that the role of GIS and related spatial information technologies will substantially expand specifically in the fields of land planning and design.

Finally, and of most significance to this study, researchers have also aimed to justify the use of GIS to aid, enhance, or replace traditional urban design methods and techniques. With the publication of their book GIS in Site Design in 1998, Hanna and Culpepper introduced a method of site analysis for landscape architects and other site designers called the GIS Graphic Method. This method merged GIS analysis and mapping techniques with the traditional site analysis process that most landscape architects are comfortable with. Hanna and Culpepper (1998) believe that landscape architects are uncomfortable with using GIS because a method had never been created to parallel the traditional site analysis process, and declare the time has come for landscape architects to embrace advancements is design technology. Similarly, Al-Kodmany (2000) agrees that adapting and combining computerized and non-computerized techniques is most useful when using GIS in the urban landscape for design.

GIS–based Site Analysis in the context of Urban Design

Though the process of site analysis is an established and well-documented topic of literature, methods and procedures of site analysis specific to urban sites are of less volume – and methods incorporating GIS are scarce. According to Hanna (1999), site analysis should only consider those conditions that are relevant to the decisions being made. One can infer from this statement that the site analysis process undertaken by designers should obviously be site-specific, but also scale-specific and sensitive to the context of the project. In other words, the site analysis process used in residential landscaping should not be adapted to urban design without considerable review of the unique circumstances associated with the difference in scale, context, and complexity of each project type.

The most prolific example of an urban specific analysis procedure is likely Kevin Lynch's 'Imageability' studies outlined in his seminal book The Image of the City, published in 1959. By having local inhabitants of urban neighborhoods sketch what he referred to as the elements of the city – paths, edges, districts, nodes, and landmarks – in plan view, Lynch was able to analyze the legibility and public image of an urban environment's form. Singh (1996) later researched adapting this method using GIS for the purpose of finding patterns in the urban landscape to serve the needs of urban designers.

GIS is well-suited for site analysis in the context of urban design for three notable reasons; first, GIS allows crucial comparison of many layers of physical and socio-economic information; second, local governments often collect and maintain extensive amounts of GIS-related data; and thirdly, much of the available data is of particular importance to urban design site analysis such as population statistics, environmental resources, and existing land uses (Carmona et al. 2003).

Traditional vs. Modern Design Process

The crux of existing research is certainly the comparison of traditional 'pencil and paper' versus modern 'technology-aided' design methods. This debate resonates through all disciplines of design and each method yields its advocates and opponents. There is a general hesitancy among some designers to embrace modern methods that do not reflect the flexible and intuitive nature of the traditional design process, while others claim an analytic design process using GIS meets the adapting needs of today's designer.

The traditional design approach is characterized by the reiterative process of pencil sketches on layers of trace paper, producing form from concept. According to Al-Kodmany (2000), GIS and other available software does not yet afford designers the flexibility needed in the form-giving stages of the design process. The consensus among many designers, in concurrence with the views of Al-Kodmany, is that computers are not design tools. Researchers also agree that generating design with the stand-alone aid of a computer is difficult due to the originality, complexity, and general exploratory nature of the design process (Xia and Qing 2004). Before GIS will be accepted as a useful instrument in the formative stage of design, it must become sensitive to a more intuitive process (Koninger and Bartel 1998).

Though GIS is not praised for its ability as a form-giving design tool, researchers have advocated GIS as a resource throughout other phases of design. The design process as a whole is guided by information and decision-making, both of which are aptly-suited for the benefits of a GIS-supported design process. As more and more urban-relevant information becomes available in GIS format, GIS becomes key to adding value to information for the purpose of design in all processes (Batty et al. 2000). In contrast to the previous opinions of GIS being rigid and inflexible, Koninger and Bartel (1998) point to the adaptability of GIS to adjust and support through the different stages of design.

Developing a technology-based design process in order to support the traditional design process, as opposed to emulating it, is a topic of dialogue throughout existing research. Hanna and Culpepper (1998) express that GIS will not become a realistic alternative until a GIS process emulates the traditional design process of site designers. Correspondingly, Batty et al. (1998) assert that the developments in technology-based design to date have focused on supporting the design process rather than enabling it. In the opinion of Batty et al., computer software may never enable the creative process of urban design, and therefore future research should emphasize the use of GIS as one of the most important tools for supporting design.

Despite research encouraging greater use of GIS in the process of design, designers continue to rely solely on traditional design tools. Singh (1996) explains that this is more the fault of GIS's youth than a reluctance to explore analytic design methods. Some research, however, warns that as increased demands and complexities confront urban designers a shift toward GIS-based methods will be not only relevant, but essential. The facility to visualize complex interactions of urban phenomena in the same analysis environment is vital to urban planning and design. Simply as a practical matter, it is no longer possible for traditional maps to accommodate the needs of urban decision-makers (Maantay and Ziegler 2006). Comparing whether traditional or technology-based design methods are more meaningful to the urban designer will likely remain disputable throughout GIS's youth.

GIS as a Decision-Making Support Tool

Urban planning as a discipline has a more sophisticated framework of decision-making support than that of urban design due to its emphasis on information, visualization, and forecasting. Whereas urban planners have a heritage of decision support systems, urban designers do not, posing difficult conceptual issues in relating urban design to technology-supported decision-making (Batty et al. 1998). Regardless, researchers linking urban design to GIS have largely concentrated on the use of the technology for spatial analysis and decision support (Xia and Qing 2004). As research moves forward, emphasis on bridging urban planning's information management practices with urban design standards and theory will be key to the conceptual framework for a GIS-based decision-making support tool for urban design.

The urban environment represents a complex ecology of physical and socio-economic forces resulting in unique design circumstances. As urban areas become more dense and diverse, the amount of information necessary to comprehend the urban make-up reaches exhausting depths. Urban designers unquestionably need tools and others aides to manage and synthesize the volumes of information considered throughout their design process (Putra, Wenjing and Yang 2003). Considering that most of this information is spatial in nature, a geographic database like that used in GIS is inherently necessary. In fact, Al-Kodmany (2000) states that GIS is now a common tool for the inventory, analysis, and communication of spatial data, and is broadly considered as the most powerful and flexible system for decision-making.

Of course, a GIS database of urban information is not considered to be of any effectiveness as a stand-alone decision-making tool. Existing research has expressed that no matter how comprehensive and precise an urban spatial database is, it is near worthless without the affiliation of two crucial components. First, urban design guidelines are imperative in order to provide definitive descriptions of desired relationships and rules between urban elements (Putra, Wenjing, and Yang 2003), and secondly, the capability of the user to effectively blend GIS functionality with extensive urban design knowledge (Pamuk 2006). The success of GIS as an urban decision-making tool therefore cannot be achieved independently by the experienced urban designer or the experienced GIS technician, but from the alliance of both disciplines.

Insofar, urban design has fundamentally drawn upon the formalized process of “Survey-Analysis-Plan”, first proposed by Patrick Geddes in his 1915 publication, Cities in Evolution (Batty et al 1998). Putra, Wenjing and Yang (2003) propose that the utilization of an urban GIS database throughout the process of urban design will prove to be an essential decision-support tool to urban designers and refine Geddes’s traditional design methodology to “Urban GIS Database-GIS Spatial Analysis-Urban Design Decision-Making.”

GIS Functionality for Urban Design

The functionality of GIS is often compared to that of CAD (Computer-aided Drafting) which has been a standard, and in most cases only, computer software tool of designers for the last three decades. While CAD software will likely always be the preeminent choice of drafters, designers and researchers are finding benefits of GIS beyond the functionality of typical CAD programs. Three general advantages GIS has over CAD include thematic layering capabilities, more analytical functions, and more advanced modeling of the environment (Al-Kodmany 2000). Consequently, the traditional method of representing cities with CAD is slowly being amended by GIS spatial data models (Batty et al. 2000). Furthermore, Batty et al. (2000) expounds by claiming the traditional methods of representing cities by CAD models are now yielding to modern techniques based on GIS spatial data analysis.

In the book Planning and Urban Design Standards, published by the American Planning Association (APA) in 2006, some of the most common GIS functions used by urban designers are explained including queries (location, attribute, and Boolean), buffering (also referred to as proximity analysis), and overlay analysis (including suitability studies). Considering the multitude of highly complex analytical tools built-in to common GIS software, this is a relatively short list of some the most elementary and intrinsic functions of GIS technology. Nevertheless, despite the availability of such tools, only a handful of analytical functions are useful for land planning and design (LaGro 2001). In concurrence with both APA (2006) and LaGro (2001), Batty et al. (1998) state the three GIS functions urban designers can use extensively throughout the process of analysis and design are queries, thematic mapping, and overlay analysis.

In addition to the common GIS functions referenced above, more sophisticated capabilities of GIS useful in the urban environment include modeling and forecasting future conditions, change detection, and statistical analysis (Greene and Pick 2006). Site selection and suitability studies are also the domain of GIS functionality. Determining the location of new urban elements such as parks or plazas can be achieved through proximity analysis and Thiessen polygons created from existing locations, allowing urban decision-makers to easily recognize underserved areas (Pamuk 2006). Moreover, when selected urban sites need to be related to the community to which it serves, population studies using overlay mapping techniques bridge socio-economic data to the urban environment (Moughtin et al. 2003).

One of the more recent developments in GIS technology is the ability to extend two-dimensional analytical functionality into the third dimension. As 3D CADD and GIS modeling capabilities improve, 2D maps and 3D models are beginning to merge (Batty et al. 2000). By simply extruding the third dimension from the 2D plan form, be it a building or any other urban feature, urban designers now have the functionality of two-dimensional GIS utilizing three-dimensional visualization (Batty et al. 2000). Three-dimensional GIS certainly offers promising prospects to the field of urban design, though most existing research has focused on its use for modeling and visualization as opposed to analysis and design decision-making.

GIS Data for Urban Design

Among the abundance of available GIS data, certain datasets have been established as fundamental ‘base map’ elements of the urban design database. According to Singh (1996), the core GIS datasets needed to depict a general image of the city are land use, streets, parcels, building footprints, aerials, and census information. In addition to these six layers, soil types, flood zones, and vegetation data are important to broader land planning issues (Rubenstein 1996). The location of utilities is also a useful GIS data layer (Rubenstein 1996), though Russ (2002) warns that utility maps, whether in a GIS format or not, are generally considered to be loosely accurate and utility locations should always be field-verified when considered in site design. Sidewalk information is of specific interest to urban designers mainly due to the impact of the work of Jane Jacobs and her celebrated book, The Death and Life of Great American Cities, published in 1961. Singh (1996) acknowledges the importance of sidewalks toward urban design, but reports that sidewalk data is seldom found in the construction of urban design databases.

Fortunately, GIS data has become exceedingly accessible both in terms of its availability and ease of acquisition. The significant increase in the availability of GIS data is likely tied to internet boom of the late 1990's and faster downloading speeds afforded by broadband technology. The increased ease of data acquisition has largely been driven by developments in Global Positioning System (GPS) and remote sensing technology (Maantay and Ziegler 2006). Whether by downloading data from the internet, scanning and digitizing paper maps, remote-sensing of aerial imagery, or utilizing the latest technology provided by GPS, GIS data creation and acquisition is no longer the laborious and expensive albatross around the neck of GIS users. For smaller scale urban projects where data on parcels and buildings are necessary but often unavailable, the simple and time-honored approach of data creation from field-surveyed information is a viable solution. This type of data is extremely relevant to urban design, yet historically under-utilized by urban designers (Dodge and Jiang 1998).

The scale at which GIS data is created, or can be found at, is critical to the reliability and credibility of the analysis for which it is being used. Analysis of the urban environment requires data at the scale of city block, street segment, or land parcel, which is typically the smallest geographic unit of data available in the urban domain. GIS was long considered to be of limited use to urban designers until data became available at a site design scale. The availability of GIS data at a street-level scale has profound implications for urban designers (Batty et al. 1998). Even for broader planning studies, data at the parcel-level scale has important applicability. Parcel-level data allows regional analyses to be executed with exceptional detail, and conversely, parcel-level analyses can be correlated to an entire region (American Planning Association 2006).

Determining the suitability of GIS data for a specific project is a crucial pre-inventory and pre-analysis task. In addition to scale, data accuracy should be examined and considered throughout all processes of land planning and design (LaGro 2001). Likewise, Maantay and Ziegler (2006) delineate three categories of data selection criteria: scale (or level of detail), quality (referring to accuracy and currency), and, similarly to Hanna (1999), relevance to the site and program of the project. As an example, USGS digital topographic maps are considered to be of an appropriate suitability for terrain analysis in large-scale planning studies, but for site design in an urban setting topographic mapping should be accurate and reliable at contour intervals or two feet or less (Maantay and Ziegler 2006), such as that of a commercial survey.

GIS for Visualization, Communication and Modeling

In 1998, Batty et al. expressed that the most significant link between CAD and GIS in the context of urban design was for visualization. Ten years later, the existing body of research linking GIS to urban design has more than substantiated that claim, focusing heavily on GIS as a tool for visualization and communication of urban conditions. Of all the tasks associated with the urban design process, visualization has likely been most significantly impacted by the development of GIS and related digital technologies (Batty et al. 2000). Visualization is about the graphic communication of information – an exercise inherent to GIS technology. GIS aides the urban designer in visualizing the distributions, clusters, and patterns in spatially-oriented data (Al-Kodmany 2000) that may otherwise go unnoticed in a tabular format. Regardless of its complexity or volume, GIS can often depict urban information in simple, diagrammatic maps. This ability to communicate information visually to design professionals and layman alike is what makes GIS a vital tool in the urban decision-making process (Maantay and Ziegler 2006).

In addition to the two-dimensional maps and diagrammatic visualizations often produced by GIS, three-dimensional models produced by GIS and associated CAD software are regarded as essential tools for urban design. 3D visualization can inform, and in many cases is required for, site location studies, design reviews, and as a tool for public participation (Shiode 2001). Coinciding with this position, Maantay and Ziegler (2006) state that 3D visualization is imperative for assessing the aesthetics, scale and character of the urban environment, as well as street activity and the existing conditions of buildings. Arguably, one of the most crucial tasks of the urban designer is understanding the spaces and voids created by the buildings and other masses that construct the urban environment. By simply extruding two-dimensional features such as parcels or building footprints, a crude but sufficient three-dimensional model can relate critical relationships between massing and voids of an urban area (Maantay and Ziegler 2006).

Whereas CAD-produced 3D models are often less functional in nature, a GIS-based 3D model supplanted with attributes is integral to urban analysis (Shiode 2001). Though CAD models lack analytic functionality and GIS models lack a photo-realistic level of detail, the two technologies together are an important resource for urban designers. CAD and GIS techniques have blurred creating an effective tool for 3D visualizations (Ervin 2004). Some of the functionality associated with 3D urban GIS models include quantitative analysis of spatial conditions, volume-oriented analysis of building density, spatial analysis of open space and greenery, and light and shadow studies (Koninger and Bartel 1997). Moreover, when non-spatial attributes are extruded along the z-axis, 3D urban GIS models provide a unique visualization opportunity unparalleled by 2D maps or tables with associated charts. When non-spatial attributes of urban features are used as the z-value in 3D GIS models, such as number of occupants per office building, otherwise non-geographic conditions can be related to each other geographically (Maantay and Ziegler 2006).

An often associated feature of both CAD and GIS 3D models is the computer-animated ‘walk-through’ or ‘fly-by’. 3D visualizations coupled with computer animation afford the urban designer the capacity to fully evaluate and understand the spatial circumstances of complex urban areas (Koninger and Bartel 1997). In situations where site visits are not practical, urban designers need alternative methods to assess the aesthetics and functionality of urban features – computer-animated visualizations accommodate this need (Maantay and Ziegler 2006). Computer-animated ‘walkthroughs' also excel as a communication tool when proposed changes to an urban area need to be effectively exhibited in public participation exercises (Al-Kodmany 2000). Undoubtedly, the analysis and visualization products facilitated by 3D GIS models represent the pinnacle of research relating GIS technology to urban design.

Future Directions for GIS in Urban Design

The relative infancy of research tying GIS to urban design leaves numerous paths for future studies. However, existing research often identifies one crucial flaw of GIS – a flaw likely common to all disciplines of GIS users. The rigidity of GIS, both in terms of its user interface and its spatial-temporal framework, is consistently mentioned as not reciprocating the intuitive and flexible nature of urban design methods and real-world circumstances. In order for GIS to appeal to urban designers, new analysis interfaces must be created to mimic their non-linear and less-rigid mode of thought (Singh 1996). Likewise, the temporal analyses afforded by GIS can at best be described as crude in comparison to the sophistication of GIS in the first three dimensions. The complexity of urban reality can not be adequately represented by the current generation of GIS and its rigid spatial-temporal framework (Sui 1998). As environmental sensitivity and sustainable design continue to widen in practice, GIS must support data models once thought foreign to geo-spatial technology. Pollution and climate studies require quantitative temporal analysis that must be incorporated with an adequate, four-dimensional data structure (Koninger and Bartel 1997). Future advancement is necessary both in terms of software development and the refinement of analytical methods before GIS will provide this kind of framework. According to Sui (1998), the new research agenda for GIS in urban design should aim to integrate the sophistication of analytical techniques with the intricacy of real world phenomena. Henceforth, research efforts relating GIS technology to urban design must push the rigid and highly-rational interface of GIS toward a flexible and non-linear system analogous to urban design in practice and the complexity of real-world circumstances.

CHAPTER III

BACKGROUND

Traditional Site Design Process

The traditional site design process in use today (Figure 3-1) has its roots in the general planning method of Sir Patrick Geddes (Figure 3-2). The Geddesian method of "Survey – Analysis – Plan" has served as the antecedent and model for nearly all site design processes since its inception in the early 20th century. Geddes encouraged all town planning efforts to be preceded by a comprehensive survey of both local and regional conditions, followed by an analysis of impacts toward the entire ecological region as a result of proposed planning decisions. The traditional site design process is merely a permutation of the Geddesian planning method with the inclusion of additional steps.

Figure 3-1 Traditional Site Design Process

Figure 3-2 Geddesian Planning Method

Geddes's method is a precursor to the rational, decision-making model that the traditional site design process is based upon today (Batty et al. 1998). Although often mistakenly thought to be an exclusively artistic process, it is informed and guided by research, decision-making and continuous efforts of trial – test – change (Carmona et al. 2003). In this regard, the process can be considered as a parallel to the scientific method.

However, unlike the scientific method, the traditional site design process is highly flexible and intuitive. Despite being a sequential process of steps, it cannot be accurately characterized as linear. Though seemingly paradoxical, the process is perhaps best described as a non-linear sequence of actions. It is conceptualized and often diagrammed as linear, but the process is cyclical and reiterative in practice (Figure 3-3) (Batty et al. 1998, LaGro 2001, Carmona et al. 2003, Moughtin et al. 2003).

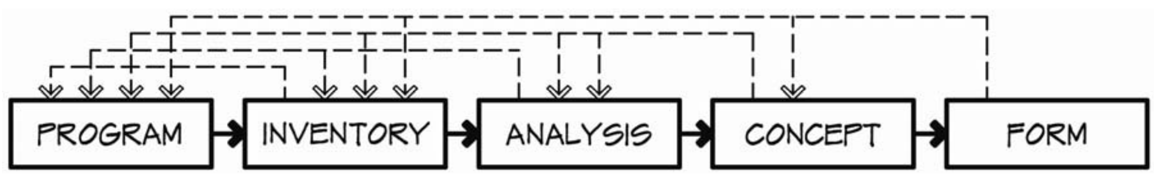

Figure 3-3 Traditional Site Design Process with Cyclical and Reiterative Sequence

The aforementioned site design process assumes a typical scenario of a land developer commissioning a design for a specific site. However, in some cases the client or land developer will approach the designer with a pre-developed program, in need of a suitable site. A site selection phase must then precede any further phases of the site design process. For the purposes of this research study, the former scenario will be considered.

The Program Phase

The program phase addresses two key questions: who will be using the site, and what will they be using it for? A description of intended site functions and facilities along with known or expectant users is essential. Goals and objectives, like most programming tasks, are defined in a collaborative effort between designer and client.

The Inventory Phase

The inventory phase aims to collect all data relevant to the site and its intended use according to the program (Table 3-1). Data is obtained through secondhand sources or directly from site observations. Existing conditions of the site and its context are typically documented in a series of thematic maps.

The Analysis Phase

The site analysis phase synthesizes the data collected in the inventory in an effort to deduce the most essential and critical characteristics of the site. The interrelationships of all site and contextual attributes are carefully studied enabling the identification of design opportunities and constraints. Typically, a single composite site analysis map is produced portraying the suitability of locations for the programmed uses of the site.

The Concept Phase

The concept phase spatially integrates the site conditions with the proposed uses of the site. Bubble diagrams and conceptual sketches organize both the functional and spatial relationships of programmed site criteria. Several conceptual alternatives are often generated before a plan is chosen for further development in the final phase of site design.

The Form Phase

The form phase calls upon the designer's education, experience, and native talent to give artistic form to the diagrammatic conceptual plan. Design form is articulated in greater detail through schematic studies ultimately resulting in a preliminary design. Plan, section, and elevation drawings express the design intent to the client for final review and approval.

Upon completion of the form phase, several tasks are required to translate the site design into built form. Production of construction documents and specifications and construction administration are among many key steps in post-design project implementation. However, true to the cyclical and reiterative nature of the site design process, it is not uncommon for design inadequacies to surface during post-design project implementation requiring revision to all phases of the process back to and including the program.

Table 3-1 Typical data attributes collected and mapped during inventory phase of traditional site design process.

Category	***Sub-Category***	***Attribute***
Physical	Geology	Landform
		Depth to bedrock
		Seismic hazards
	Soils	Classification
		Bearing capacity
		Fertility
	Topography	Elevation
		Slope
		Aspect
	Hydrography	Surface water
		Drainage patterns
		Flooding
	Climate	Temperature
		Precipitation
		Sun/Shade
		Wind
Biological	Vegetation	Plant Communities
		Specimen Trees
	Wildlife	Habitats
		Endangered Species
Cultural	Legal	Political Boundaries
		Land Ownership
		Land Value
		Property Lines
		Right-of-Way
		Easements
	Land Use	Classification
		Zoning regulations
	Utilities	Water
		Sewer
		Gas
		Electric
		Telecommunications
	Circulation	Streets (Layout/Hierarchy)
		Traffic (Volume/Speed)
		Parking
	Sensory	Views
		Noise
		Odors
	Historic	Resources
		Genus Loci

Source: Adapted from LaGro 2001.

Site Analysis Methods and Techniques

The goal of the site analysis phase is threefold: identify the opportunities and constraints of the site, determine the suitability of the site for the specific programmed land use, and understand the characteristics of the site that will influence decision-making throughout the design process. Three categories of methods or techniques are commonly employed in a traditional site analysis: analytical diagramming, suitability analysis, and non-spatial analysis. The specific methods or techniques utilized are at the discretion of the designer and dependent on the nature and scale of the project (Moughtin et al. 2003).

Analytical Diagrams

Analytical diagrams are simple, abstract representations of site characteristics using symbols, hatches and anecdotal notes, often in the form of a map. In the urban context, they are intended to clarify the relationship of site issues and explain the space and form of the site better than a written description (Carmona et al. 2003). The 'mental mapping' exercises applied in Kevin Lynch's Imageabilty studies are a preeminent example of analytical diagramming in urban design.

Suitability Analysis

A suitability analysis is derived from the site inventory maps with the typical result being a single composite map (LaGro 2001). The process links the program with the site inventory in an effort to determine the appropriateness of the site for the intended use (APA 2006). A suitability analysis involves three steps. First, formulate a suitability ranking criteria for each site factor. Secondly, reclassify and map each site factor according to its suitability rank. Thirdly, combine the reclassified maps into a composite suitability map ranking each area of the site according to the established suitability criteria. This method is based upon the overlay analysis techniques and land use planning process developed by Ian McHarg, often referred to as 'McHargian Overlay Analysis'.

Non-Spatial Analysis

Of the three categories of site analysis methods and techniques, non-spatial analysis is the least common and generally not preferred by designers. Non-spatial analysis is less-graphic in nature and therefore utilized more by urban planners and statisticians. Techniques include lists, matrices, and quantitative representations. Lists are typically qualitative descriptions of site attributes, though can be used for quantitative data as well. Matrices provide the designer a cross-examination of the intended uses with site characteristics. Quantitative representations are often charts and graphs displaying mathematical and measurable attributes of the site.

GIS Spatial Analysis

Spatial Analysis is what takes GIS beyond a map-making and data management utility. The spatial analysis tools built-in to GIS allow the user to see patterns and spatial relationships between geographic features. Basic functionalities and simple analytical methods can produce complex and sophisticated spatial analyses. Based on single or multiple layers of data, spatial analysis creates new information from existing data. The most common GIS spatial analysis tasks include: queries, proximity analysis, overlay operations, reclassification, map algebra, density analysis, statistical analysis, change analysis, topographic analysis, and 3D visualization. Some of these tasks operate as stand-alone tools, while others work in combination as a process in order to produce the intended spatial analysis results. Regardless, all of these tasks overlap and intertwine during typical spatial analyses.

Queries

Querying the GIS database is arguably one of the simplest GIS functions used in spatial analysis. A query searches the GIS database for features that meet certain user-defined criteria. Queries can identify features based on their location, by the attributes associated with features, or a combination of both known as a Boolean query.

Proximity Analysis

Proximity analysis answers questions about what is adjacent or nearby to features. Proximity analysis tools create buffers or setbacks of a user-defined distance in order to examine what features and attribute data are within a certain distance of the feature. Buffers and setbacks can be created as one-ring or multiple-ring distances.

Overlay Operations

Overlay operations, not to be confused with overlay analysis models, are functions that create a new layer by relating the spatial correlation of certain attributes between two or more layers using an algebraic rule. Two of the most common methods are union and intersection analysis. A union analysis identifies locations where any of the specified attributes occur in either layer, regardless of whether or not they are spatially coincident, producing a dataset where at least one of the attribute criteria is met at any location. An intersection analysis identifies locations where the specified attributes overlap in each layer, producing a dataset with a spatial extent that meets all attribute criteria at any given location.

Density Analysis

Density analysis allows the user to see the patterns and concentration of geographic features. Density tools measure the number of features within a user-defined geographic unit, allowing better visualization of feature distribution. The result displays one of three geographic patterns: clustered, uniform, or random distribution.

Reclassification

Reclassification combines data by aggregating, merging, or dissolving feature attributes or spatial extents into broader categories, producing a new field of reclassified values. Reclassification is typically used to reassign attribute values to a system of hierarchy, ranking, or coded values. This process simplifies data management and often adds clarity to maps.

Raster Math

Raster Math is used with raster data where each grid cell has as assigned numerical value. Raster Math can combine raster data layers by summing or multiplying each grid cell value by the spatially coincident grid cell on another layer. Grid cell values can be weighted prior to summing or multiplication, which is particularly useful for overlay suitability analysis models.

Topographic Analysis

All topographic analysis in GIS is derived from a digital elevation model (DEM). Topographic analysis tools are typically used to generate contours (at a user-defined interval), slope gradient maps (by percent or degree), and slope aspect maps. Topographic analysis also has visual and hydrological applications when used to define viewsheds and watersheds.

3D Visualization

3D analysis in GIS typically does not go beyond visualization and modeling applications. 3D terrain models are often produced, though any continuous data surface can be modeled in 3D to examine the changes in feature magnitude at different locations. Discrete features such as areas and points can be protruded into the third dimension using any non-spatial numerical attribute as a z-value, providing a unique visualization opportunity.

Statistical Summary

Unlike most spatial analysis tasks, statistical summary is most often used to compare non-spatial attributes to non-spatial attributes. Statistical summary, the most basic and common statistical analysis tool, summarizes the non-spatial attributes of features to a table, giving the user statistics such as the sum, frequency, mean, maximum, and minimum of values for the selected attributes of each feature. This table can then be exported to spreadsheet software for further analysis, or for the creation of quantitative representations such as charts and graphs.

Change Analysis

Change analysis is less common than most GIS spatial analysis tasks due specifically to the difficulty in attaining GIS datasets representing features at different time periods, or at different time periods at a suitable interval for the specific analysis at hand. When data is available, GIS change analysis compares features over time, detecting and measuring change to spatial (location and extent) and attribute (character or magnitude) conditions. Change analysis enables the user to anticipate future conditions, evaluate projected results of an action, and see the impact of events after they have taken place (Mitchell 1999).

Urban Design: Theoretical Framework

Camillo Sitte

Camillo Sitte was a 19th century Austrian architect and is considered the founder of both modern city planning and urban design. His revolutionary book, City Planning According to Artistic Principles (1889), – a title which essentially defines the term ‘urban design’ – reintroduced aesthetic and compositional principles that had been absent from urban design since the medieval and baroque eras. Sitte’s main argument was that city planning (herein referred to as ‘urban design’) was not merely a technical endeavor, but also an exercise in artistic expression. In order to achieve this, urban designers must not only focus on the built environment, but also be sensitive to natural functions of the city such as the public’s artistic and social needs.

Sitte visited and studied established and notable European cities searching for universal principles of artistic city form, assessing their visual and functional character through sketch and observation. The resulting principles are a celebration of public space, streets, and squares (plazas). Sitte claimed that the character of a city lies in its public space, and urban design should emphasize this civic culture through artistic, human-scale environments.

Five of Sitte’s principles are of key concern to urban design: (1) the design elements of the city - the street, square, and building, (2) the spatial relationship of buildings to open space, or mass and void, (3) the creation of human-scale environments through a sense of enclosure, (4) the size and shape of buildings, squares, and their proportional relationship to one another, and (5) the use of greenery as a natural element in harmony with the built urban environment.

Sir Patrick Geddes

Sir Patrick Geddes was a Scottish biologist, sociologist, urban planner, and theorist in the late 19th century and early 20th century. His book, Cities in Evolution (1915) established urban design theories and methods still relevant and in active use today. Environmentalist, Regionalist, and Ecological thought in the field of urban planning has its roots in the work of Geddes, as does the traditional site design process of urban designers.

Geddes encouraged a holistic and systematic approach toward urban planning, where the city's entire regional character would influence planning decisions at the local scale. Geddes's major claim was that the social life of cities should be rooted in the natural patterns of the landscape (APA 2006), and therefore the construction of the social and political dimensions of the city must consider the unique character of its ecological region (LeGates and Stout 2000).

Prior to any planning decision Geddes advocated a comprehensive survey of the local and regional character including physical, social, cultural, and historical conditions. In addition, the survey should follow with a civic exhibition allowing the public and planners to critique and analyze major planning decisions in a democratic manner. This method of "Survey – Analysis – Plan", along with the emphasis of public participation in the planning process, are two of Geddes's most significant contributions to urban design.

Kevin Lynch

Kevin Lynch was a 20th century urban planner and is widely acclaimed as the most important figure in 20th century urban design. His most significant work, The Image of the City (1960), introduced the concept of environment psychology to urban planning (APA 2006). By studying the public perception of their urban environment through a unique analysis method known as 'mental mapping', Lynch was able to empirically research the legibility of cities, develop a typology of structural elements upon which cities are perceived and constructed, and formulate the theory upon which he is best known, that of city 'Imageability'.

Lynch argued that the no one is capable of accurately perceiving or understanding the city in all its complexity, therefore people distort and visualize the urban environment in simple underlying forms – which he referred to as elements. These elements give legibility to the city and are necessary to create a strong visual image of the city. Understanding the public perception of urban environments and designing in an effort to make the city more legible – or 'imageable' – causes the public to react to their environment more effectively, increasing their ability to navigate through it and ultimately producing a more psychologically satisfying urban experience.

Lynch's method of analysis for determining the legibility of urban environments involved cognitive 'mental mapping' exercises where individuals were asked to sketch an area of their city using simple diagrammatic symbols. These sketches were then synthesized and aggregated according to their most common features in an effort to determine the collective 'public image' of a specific area. This image was compared to a field survey of the same area as observed by a trained professional. The more accurately the 'public image' resembled the field surveyed map, the more legible the city. Lynch's five elements of the city – paths, nodes, landmarks, districts, and edges – were largely derived from, refined, and developed in the analysis of these maps (Lynch 1960). According to Moughtin (2003), Lynch's theories of urban form are likely the most important contribution to urban design in the 20th century.

Jane Jacobs

Jane Jacobs was a 20th century architectural critic and journalist. Her book, The Death and Life of Great American Cities (1961), was a harsh attack on historic and early

20th century theories and methods toward urban design and renewal. Through observational research on the way people used streets and sidewalks, Jacobs was able to change the attitudes of architects and planners toward a street-level and people-oriented approach to urban design.

Jacobs's major emphasis was on urban vitality. By considering the social and functional aspects of urban neighborhoods Jacobs developed three criteria for vitality at any scale of urban design: (1) size – both physical extent and number in population, (2) density – the concentration of people and buildings, and (3) diversity – in terms of people, land uses, and street activities. Jacobs argued that large numbers of people concentrated in neighborhoods with a mixture of overlapping and interweaving uses and activities promoted and sustained urban vitality – the impetus of successful urban design.

Jacobss defined three scales of the city – which she referred to each as a neighborhood – which served as the basis for her method of observational analysis: the city as a whole, the city district, and the city street. Each has a unique socio-functional character, yet all three are supplementary and necessary for the success of each neighborhood scale individually and as a whole. However, it is clear Jacobs held highest regard for the city street and sidewalk, to which she referred to as "the city's most vital organs" upon which the public participated in an intricate "street ballet" of urban vitality.

Ian McHarg

Ian McHarg was a 20th century Scottish-American landscape architect and planner. His book, Design with Nature (1969) brought environmental and ecological concerns to the attention of planners, and introduced his unique suitability analysis method based on what he called ‘environmental determinism’ in land use planning. McHarg’s approach to planning is viewed as a predecessor to the idea of environmental sustainability (APA 2006), and his analysis techniques played a crucial role in the development of GIS software.

McHarg’s primary concern was in ecologically-sensitive metropolitan expansion and development. In McHarg’s view, cities are part of a wider, functioning ecosystem requiring urban planners and developers to consider the natural bio-physical factors of land development – with the goal of lessening the impact of the built environment on the natural processes of its larger ecological system. For this reason, he recommended dense, clustered development that minimized disruption to the land and its natural resources.

McHarg’s suitability analysis method – commonly referred to as ‘McHargian Overlay Analysis’ – was a rational decision-making process aimed at identifying the most appropriate areas for land development based on the bio-physical attributes of a site. Each site attribute was mapped on a themed layer and assigned a numerical value based on a scale of suitability for the intended land use, where a higher number indicated higher suitability. These values were transferred to a clear acetate sheet with shades of adhesive film, where a darker shade indicated higher suitability. Each themed layer of acetate was overlaid on top of one another in order to analyze the composite suitability of the site, where the darkest areas had the highest numerical value and therefore the highest suitability. The fundamental techniques of overlay analysis pioneered by McHarg were highly influential in the conceptual development of GIS technology, where his process is still widely applied and accepted (Hanna and Culpepper 1998).

Urban Design: Analysis

Site analysis in the urban environment is distinct from suburban and rural environments both in character and approach. An urban site in a built-up area requires unique attributes to be inventoried due to the complex context of dense development (Table 3-2). Comparatively, urban site inventory and analysis must consider a much broader range of social and cultural issues than sites in suburban and rural areas (LaGro 2001).

Site analysis methods and techniques used in built-up urban areas fall into the same categories as the methods and techniques of traditional site analyses: analytical diagramming, suitability analysis, and non-spatial analysis. However, suitability analyses are least common due to the scale and context of urban sites which often do not lend themselves to the conceptual framework of suitability analysis. Several methods of analysis have been developed specifically for urban areas, such as Giambattista Nolli's figure-ground mapping, Kevin Lynch's 'Imageability' studies, and William H. Whyte's time-lapse photography of pedestrian activity.

As with projects in suburban and rural areas, urban projects occur at a variety of scales; however, the multitude, density, and unique attributes of urban features requires special attention to the scale of the data informing the urban site analysis. While a regional analysis can be informed by data at the parcel scale, data at the scale of an entire region can not be assumed to hold true for analysis of a single parcel. Therefore, the size of a project or the physical extent of its impact should dictate the scale of the data inventory and analysis (APA 2006). In addition to data at an inapplicable scale, availability of data depicting attributes of concern to urban designers is often scarce.

Similar to the traditional site analysis, the goal of an urban site analysis is to synthesize and summarize the inventory into information that will inform and guide decision-making throughout the design process. Opportunities and constraints are often identified in a written summary along with gaps in the inventory or analysis that require further study (APA 2006). The mapped product of the analysis is typically a series of annotated analytical diagrams or a comprehensive composite analysis map.

Table 3-2 Data attributes collected and mapped during urban analysis in the landscape architectural tradition.

Category	***Sub-Category***	***Attribute***
Social	Demographics	Population
		Housing
		Age
		Education
		Income
		Race
Legal	Parcels	Land Use
		Land Value
		Land Ownership
	Districts	Zoning
Morphology	Buildings	Form
		Condition
		Value
		Ownership
		Architectural Character
	Open/Green Space	Parks
		Plazas/Squares
	Perceptual Elements	Paths
		Nodes
		Landmarks
		Districts/Neighborhoods
		Edges
Circulation	Streets	Pattern
		Hierarchy
	Sidewalks	Width
		Functional Character
	Traffic *(Pedestrian/Vehicular)*	Speed
		Volume
	Mass Transit	Routes
		Facilities
	Parking	Street Parking
		Parking Lots
Environmental	Topography	Elevation
		Slope
	Hydrography	Rivers/Streams
		Floodplains
	Vegetation	Native Trees
		Street Trees
	Microclimate	Sun/Shade
		Wind

Summary

The traditional site design process, rooted in the Geddesian planning method, is a rational, decision-making model guided and informed by research and artistic expression. It is a flexible and intuitive process, cyclical and reiterative in practice, and paradoxically conceptualized as a non-linear sequence of actions. The five phases of the process – programming, inventory, analysis, conceptual development, and form-giving design – develop the client's goals and objectives for an undeveloped site into design form.

The site analysis phase aims to identify the opportunities and constraints of the site, determine the suitability of the site for the intended use, and deduce the site characteristics that will influence design decision-making. The three categories of site analysis methods and techniques are analytical diagramming, suitability analysis, and non-spatial analysis. All three categories synthesize quantitative and qualitative site attributes by linking the site inventory to the program of intended uses through analysis.

GIS spatial analysis takes GIS beyond map-making and data management by showing the patterns and relationships of geographic features. Basic GIS functionalities and simple analytical methods produce complex and sophisticated analyses, creating new information from existing data. The most common GIS spatial analysis tools are queries, proximity analysis, overlay operations, density analysis, reclassification, map algebra, topographic analysis, 3D visualization, statistical analysis, and change analysis.

The theoretical framework for urban design in the landscape architectural tradition is represented by five theorists for the purpose of this study: Camillo Sitte, Sir Patrick Geddes, Kevin Lynch, Jane Jacobs, and Ian McHarg. Each theorist represents the diverse but supplementary components of urban design: Sitte, the morphological component; Geddes, the ecological component; Lynch, the perceptual component; Jacobs, the socio-functional component; and McHarg, the environmental component. Urban design in practice today is largely based on the pioneering work of these theorists.

Site analysis for built-up urban sites is distinct from sites in suburban and rural areas due to the complex context of dense development. This requires a unique set of attributes to be inventoried that considers a broader range of social and cultural issues. The methods and techniques of analysis for urban sites generally fall under the same categories as in suburban and rural sites, with the exception of suitability analysis which often are not applicable to the typical urban site scale and context.

Urban design occurs at a variety of scales and special attention must be given to the scale of the data informing the analysis. The size of the site or the physical extent of the site’s impact should dictate the scale of the inventory and analysis. Availability of data that is both relevant to the site’s intended uses and at an appropriate scale for analysis is a common issue.

CHAPTER IV

APPLICATION

Approach

The following chapter demonstrates the application of GIS spatial analysis tools for the design of urban open space. The site selected for the demonstration is Republic Square in Austin, Texas, a park in the central downtown district. It is important to note the use of term “application” as opposed to “case study” as it is not the intent of this work to produce a comprehensive analysis of this particular site in the manner of a case study, but rather the opposite – to provide a thorough examination of the most common GIS spatial analysis tools and only use Republic Square as a means for this application.

The decision to use an existing site in a centrally-located urban environment was deliberate and essential for the argument and scope of this work. It is not the intent to demonstrate the use of GIS spatial analysis as a site selection tool – this type of application arguably falls under the realm of urban planning. Additionally, the application of GIS for site selection is well-researched and accepted throughout many disciplines. It is the argument of this work that GIS spatial analysis is well-suited to aid the urban designer throughout the inventory and analysis phases of design, and consequently, the program phase will be lightly discussed only as a means to inform the application, and the concept and form phases will be omitted from this work.

Fifteen GIS datasets were obtained for this application from three sources: the City of Austin, Texas Natural Resources Information System (TNRIS), and the U.S. Census Bureau. Table 4-1 shows the datasets obtained and their specific source. All data was acquired on the days of January 20th and 21st, 2008. The GIS software used in this application was ArcGIS Desktop ArcInfo 9.1 produced by ESRI, including extensions Spatial Analyst and 3D Analyst.

Table 4-1 Republic Square GIS Datasets and Sources

Source	***Dataset***
City of Austin	Aerial Imagery
	Bike Routes
	Building Footprints
	Contours (2ft)
	Creeks
	Lakes
	Land Use
	Lots and Right-of-Way
	Parks
	Street Centerlines
	Transit Corridors
	Transportation
	Trees
TNRIS	FEMA Flood Hazards
U.S. Census Bureau	Census Demographics

The application is divided into two sections: first, the inventory, and second, the spatial analysis. The inventory will be carried out as a series of thematic maps, sequentially produced by their related categories from Table 3-2. A brief, pragmatic description of each category of maps will explain what the maps represent, their significance, and any relevant results.

The spatial analysis section will examine one spatial analysis technique at a time by applying it to a relevant datasets. A description of the general concepts and specific methods will be followed by a brief discussion of its applicability to Republic Square and results of significant importance. All maps produced during the inventory and spatial analysis phases are intentionally diagrammatic in an effort to mimic the analytical diagrams typical of traditional site analyses.

Republic Square

Republic Square is as old as the City of Austin itself, designed as one of four symmetrically placed city squares in the 1839 “Plan for the City of Austin” by Edwin Waller. Waller’s plan, known as the “Waller Grid”, was a one-square mile regular grid of streets, consisting of 306 platted lots that were auctioned off in 1839 under the large oak trees in the southwest corner of Republic Square. The park remained unchanged until 1950 when it was paved over as a parking lot. In 1976, due in most part to efforts by the Sierra Club, the park was rededicated as Republic Square and remains today as it was developed at that time.

Revitalization discussions began in 1986 but did not result in any substantiated efforts until 1999 when the Austin City Council, Downtown Austin Alliance, and the Austin Parks and Recreation Department formed the Republic Square Task Force to make recommendations for the revitalization of the park.

This application considered as its program the five major goals and objectives set forth by the task force recommendations, which include: to renovate and revitalize the urban open space, create a public, pedestrian-oriented gathering place, attract a variety of users and uses as a social and cultural destination, promote downtown economic growth and vibrancy, and do so while retaining and respecting the historic character and value of the park.

Scale and Extent of Analysis

The area referred to as the 'Core Downtown' district in the Downtown Austin Design Guidelines (City of Austin Design Commission 2000) will be used as the geographic extent for this application, or what can be referred to as the analysis area. In accordance with the theoretical framework and overall argument of this study, the application must consider Republic Square as a single element of a greater urban fabric. Subsequently, the analysis of Republic Square must consider the surrounding contextual area and interrelationship of the park to its greater urban district.

Three of the five theorists previously discussed influenced the scale and extent of this application. Geddes encouraged a holistic and systematic approach to urban planning where the entire regional character influenced decisions at the local scale. Jacobs defined three scales of the city – each called 'neighborhoods': the city as a whole, the city district, and the city street. Lynch's 'elements' are highly apparent in the boundary of the Core Downtown area – which of course represents one of Lynch's elements, the 'district' – and likely were influential in its development by the City of Austin Design Commission. With this theoretical framework in mind, the application was approached from a regional scale with the Core Downtown area understood to be the urban 'neighborhood' or 'district' of Republic Square. Following the application, a critical analysis of the functional limitations of GIS-based spatial analysis will discuss how and when this technology influences the scale and extent of analysis.

Figure 4-1 represents the Core Downtown area as defined by the City of Austin Design Commission in their Downtown Austin Design Guidelines (2000). Figures 4-2 and 4-3 are aerial images for the Core Downtown area and Republic Square, respectively.

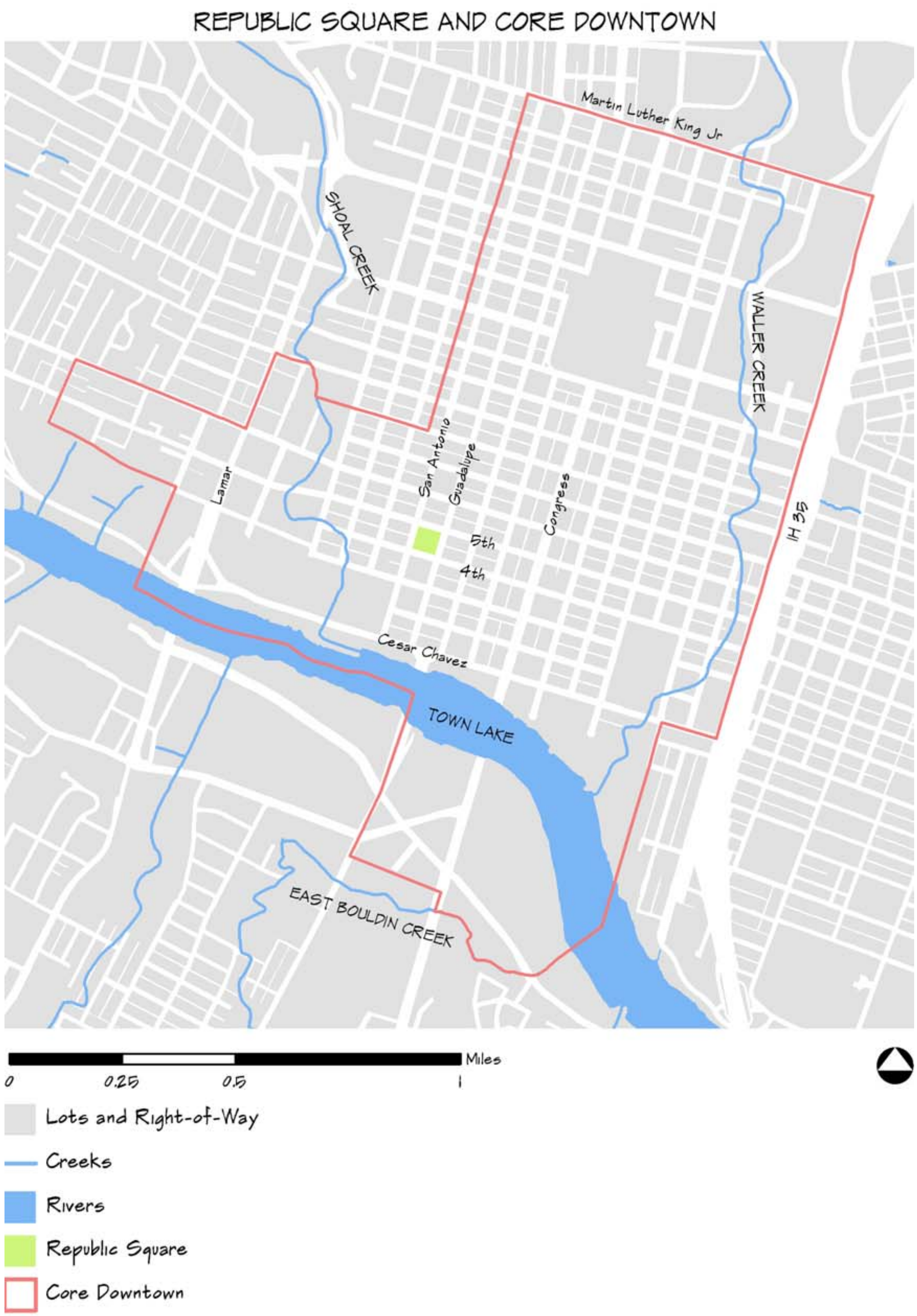
REPUBLIC SQUARE AND CORE DOWNTOWN
Martin Luther King Jr
SHOAL CREEK
WALLER CREEK
San Antonio
Guadalupe
Lamar
Congress
5th
4th
IH 35
Cesar Chavez
TOWN LAKE
EAST BOULDIN CREEK
Miles
0
0.25
0.5
1
Lots and Right-of-Way
Creeks
Rivers
Republic Square
Core Downtown

Figure 4-1


AERIAL - CORE DOWNTOWN
Miles
0
0.25
0.5
1
Core Downtown
Republic Square

Figure 4-2

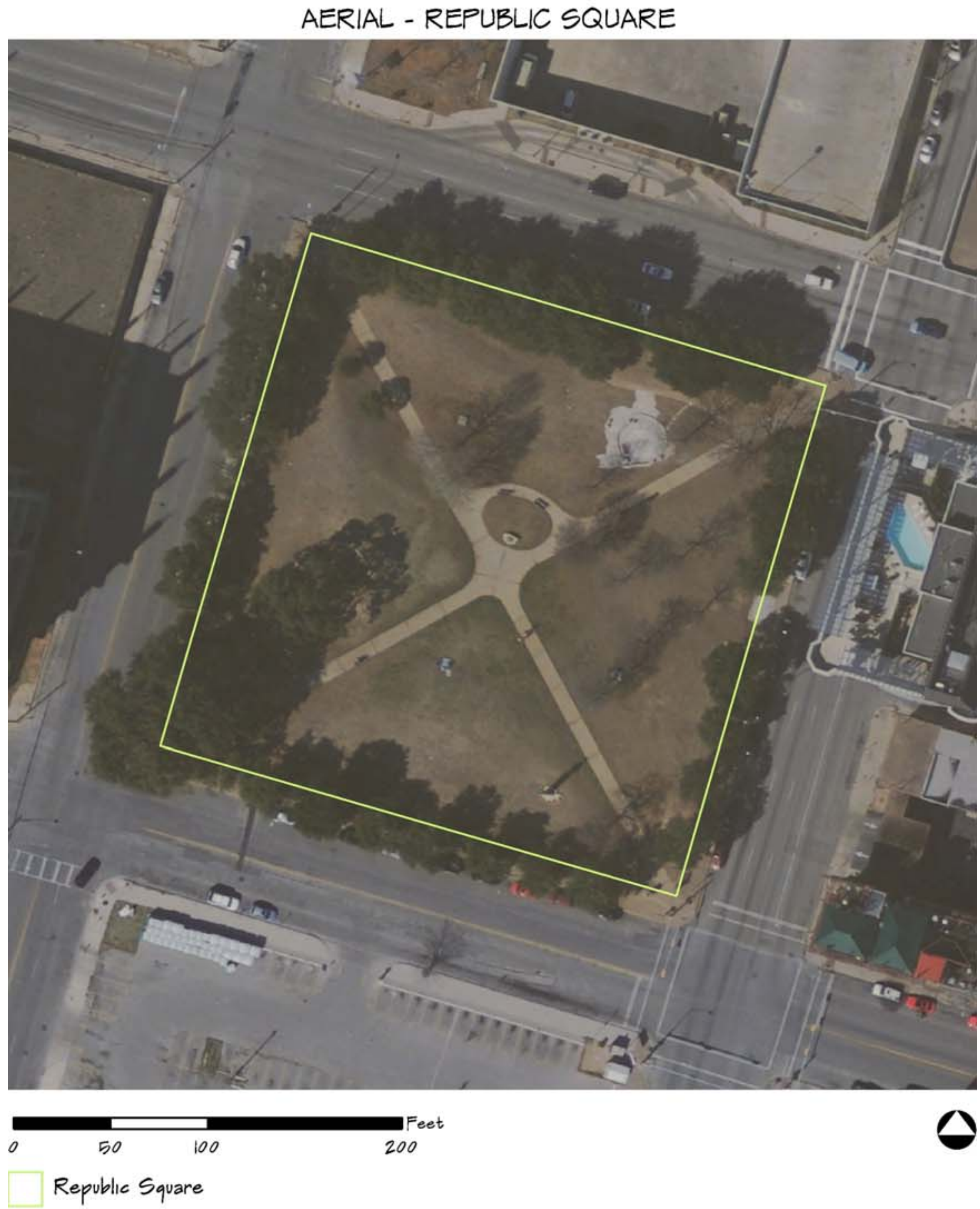

Figure 4-3

Inventory

Social

Figures 4-4, 4-5, and 4-6 represent demographic attributes of the Core Downtown area. This data was obtained from the U.S. Census Bureau and depicts 2000 Census Summary File 1 results at the census block level. Population, housing units, and the median age of residents are important indicators for determining the potential number of users and the types of uses for Republic Square.

The total population of the Core Downtown area is 3,557 residents, living in 1,918 housing units. The median age of residents ranges from 13 to 72 years old by census block with the average median age of census blocks being 38 years old.

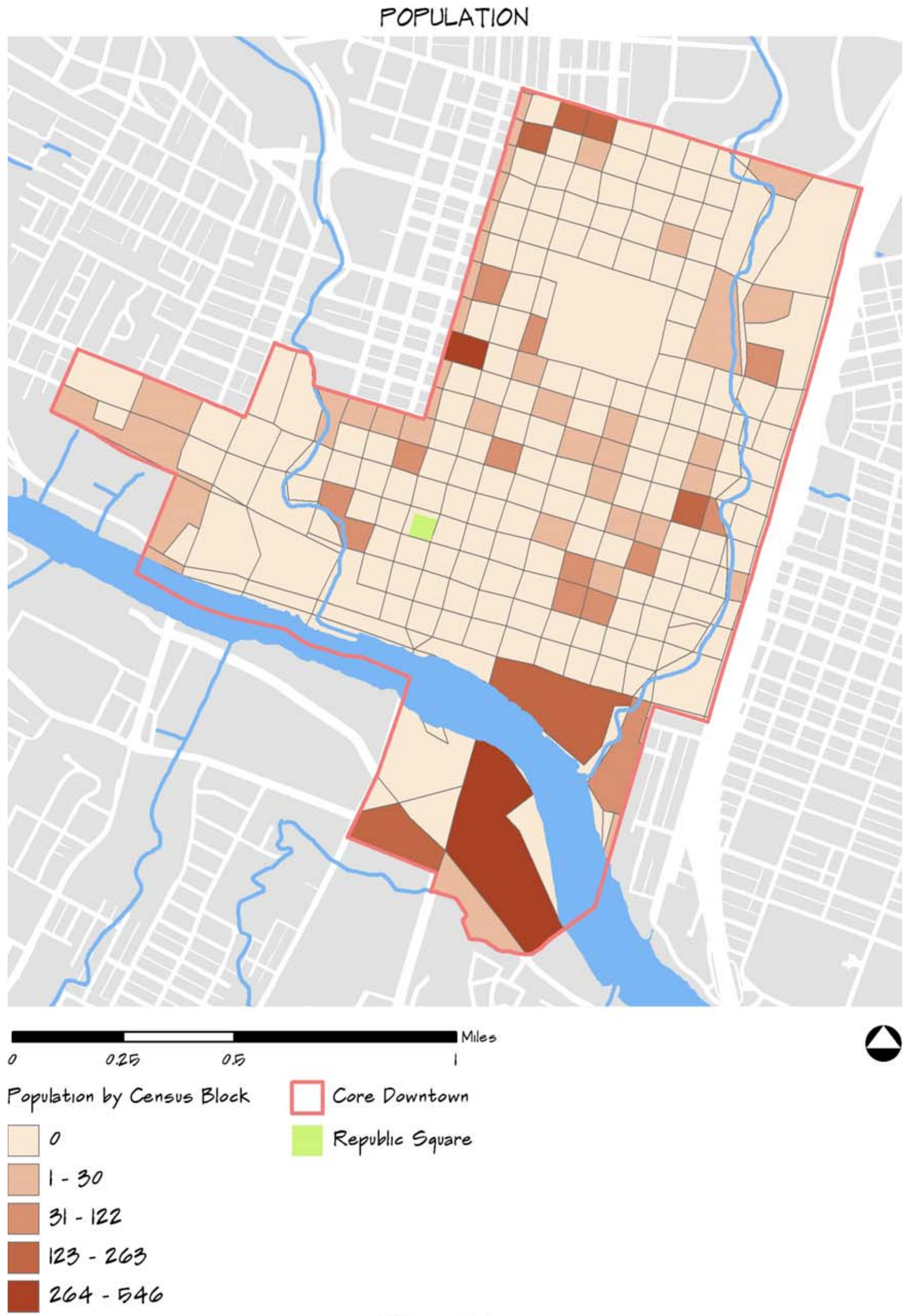
POPULATION
0
0.25
0.5
1
Miles
Population by Census Block
0
1 - 30
31 - 122
123 - 263
264 - 546
Core Downtown
Republic Square

Figure 4-4

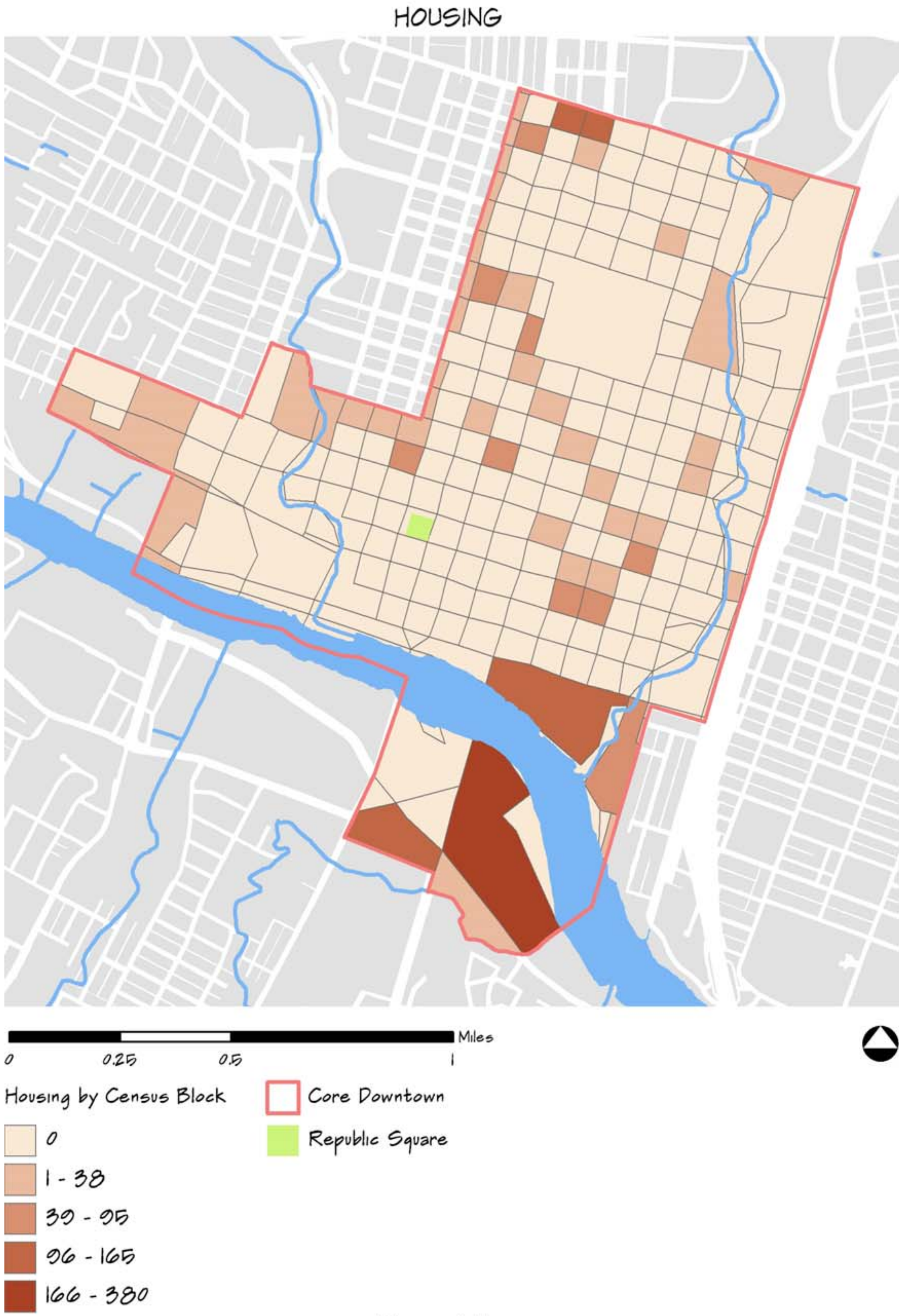
HOUSING
0
0.25
0.5
1
Miles
Housing by Census Block
0
1 - 38
39 - 95
96 - 165
166 - 380
Core Downtown
Republic Square

Figure 4-5

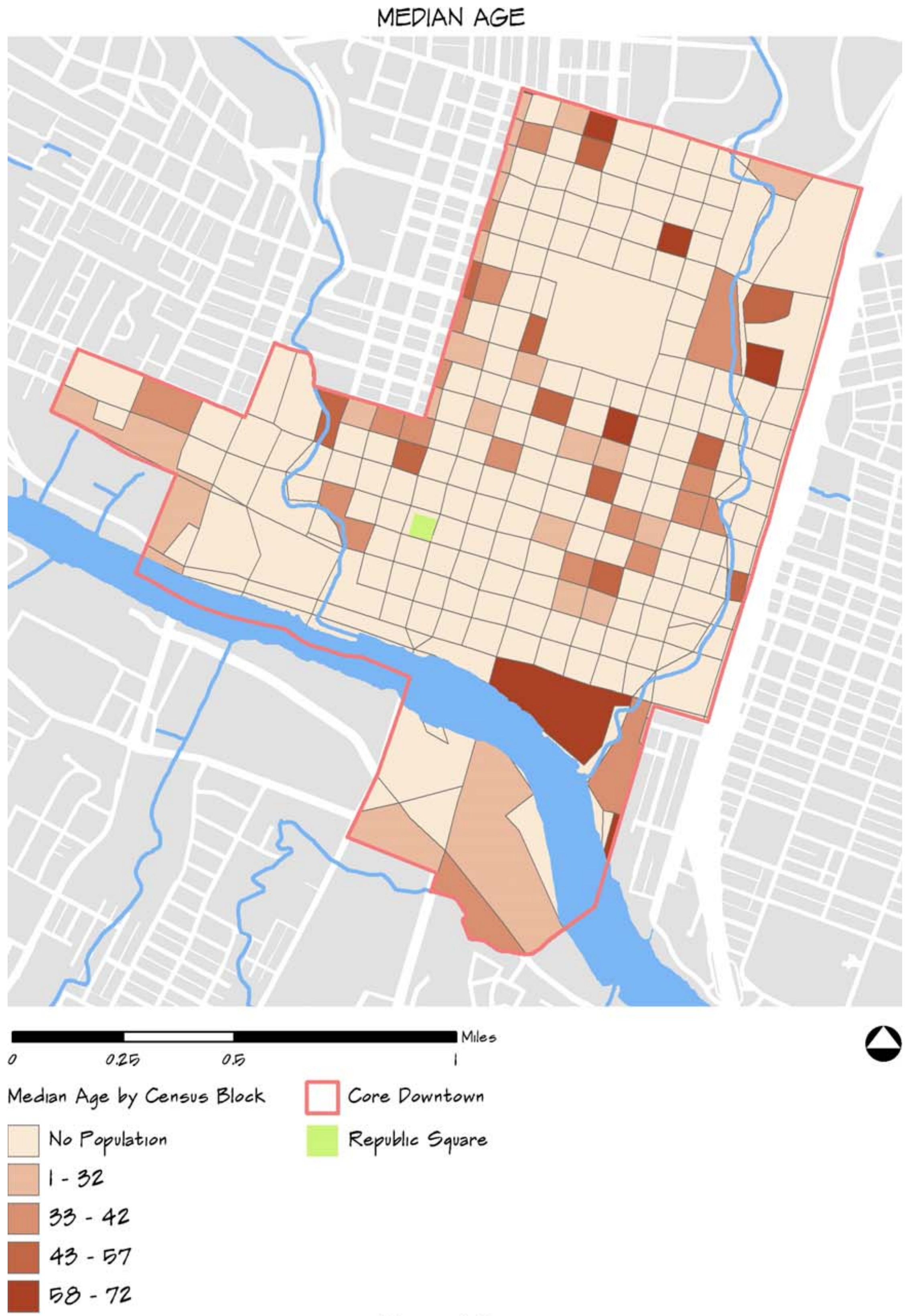
MEDIAN AGE
Miles
0
0.25
0.5
1
Median Age by Census Block
No Population
1 - 32
33 - 42
43 - 57
58 - 72
Core Downtown
Republic Square

Figure 4-6

Legal

Figures 4-7 and 4-8 represent land use attributes of the Core Downtown area. This data was obtained from the City of Austin and depicts land use at the parcel level in the year 2003. Land use is an important indicator for determining the diversity of uses and activities in the Core Downtown area as well as the immediately adjacent land uses to Republic Square. An inventory of all City of Austin Parks in the Core Downtown area characterizes the context of Republic Square in terms of geographic relationship to other parks and overall “greenness” of the Core Downtown area.

Streets and Office land use categories account for just over half of the land use at 29% and 22%, respectively. Parks account for 5% of the land use in the Core Downtown area, with the most significant parks being the linear park systems along Town Lake, Shoal Creek, and Waller Creek, and the three squares – one of which being Republic Square – from the 1839 “Plan for the City of Austin” by Edwin Waller.

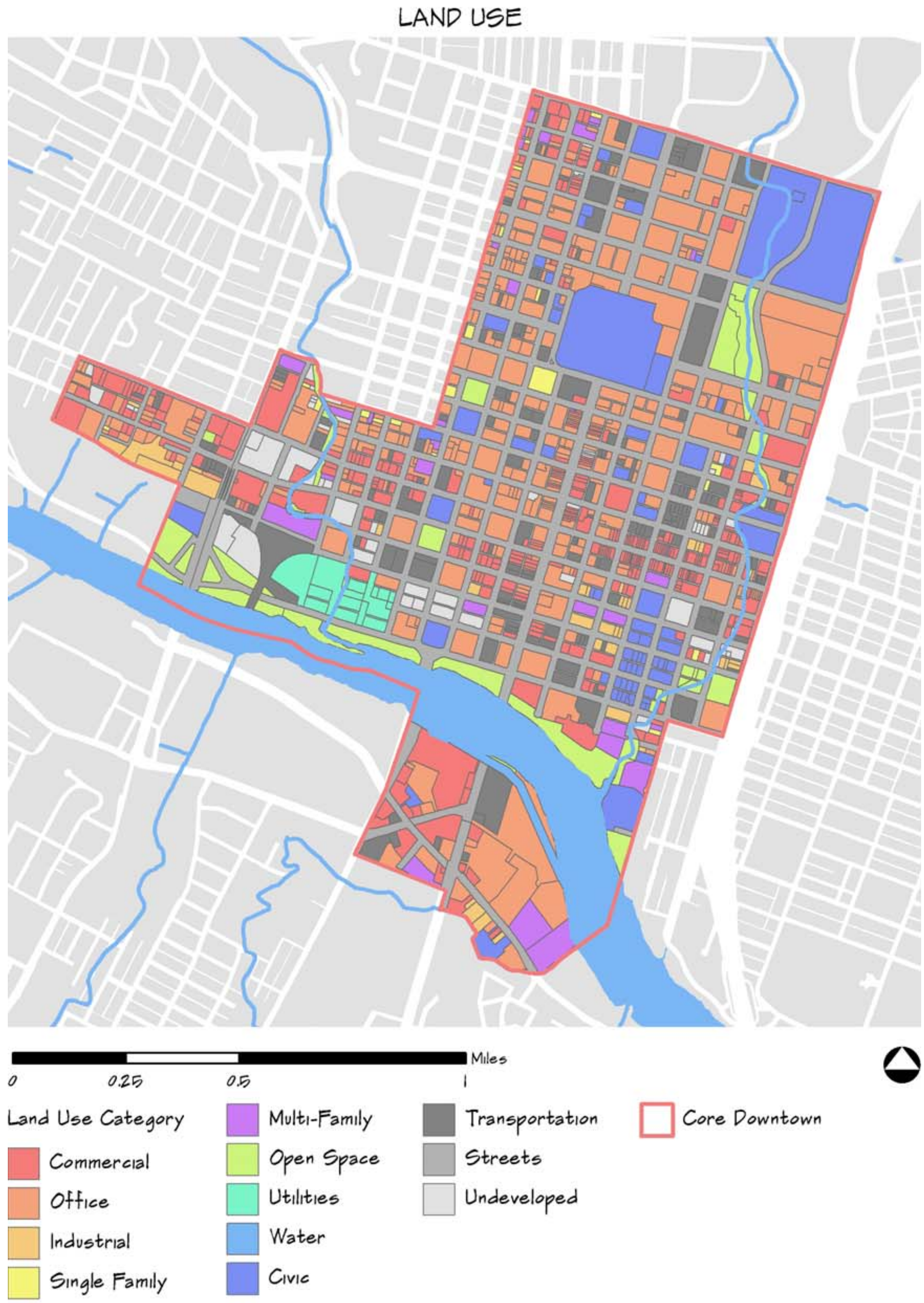
LAND USE
Miles
0
0.25
0.5
1
Land Use Category
Commercial
Office
Industrial
Single Family
Multi-Family
Open Space
Utilities
Water
Civic
Transportation
Streets
Undeveloped
Core Downtown

Figure 4-7

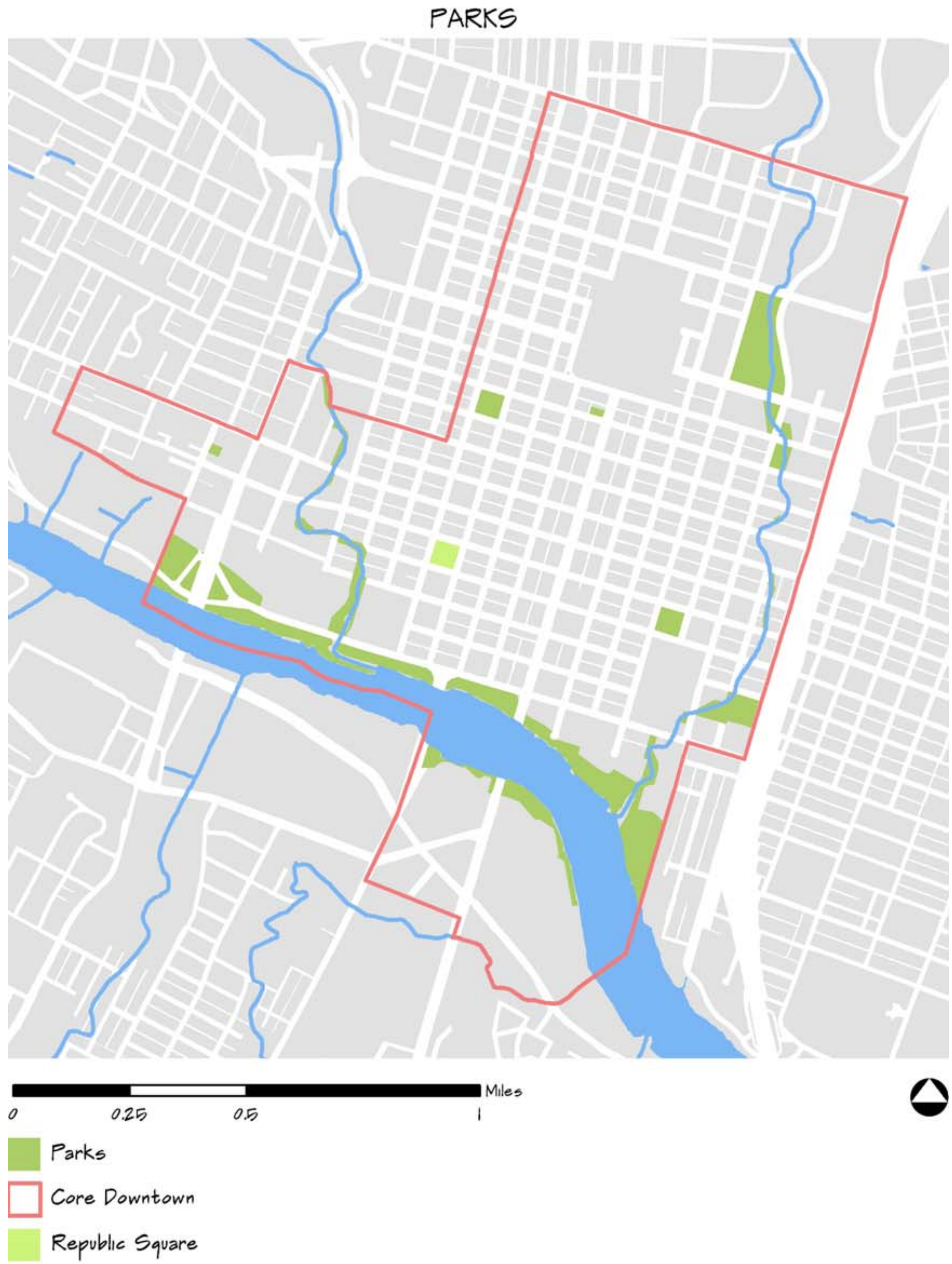

Figure 4-8

Morphological

Figures 4-9 and 4-10 represent the urban form of the Core Downtown area. This data was obtained from the City of Austin and depicts parcels and building footprints in the year 2003. Understanding urban form as delineated by buildings and the open space between buildings is important so that modifications or additions to the urban form are sensitive to historic and current patterns of development.

The block pattern of the Core Downtown area, as indicated by aggregated parcels, is mainly a regular grid of blocks and streets – the exceptions being the area to the west of Shoal Creek, east of Waller Creek, and south of Town Lake - as designed in the 1839 “Plan for the City of Austin” by Edwin Waller. The building footprints indicate the building density – and subsequent lack of open space – to be centralized in the Core Downtown area and adjacently northeast of Republic Square.

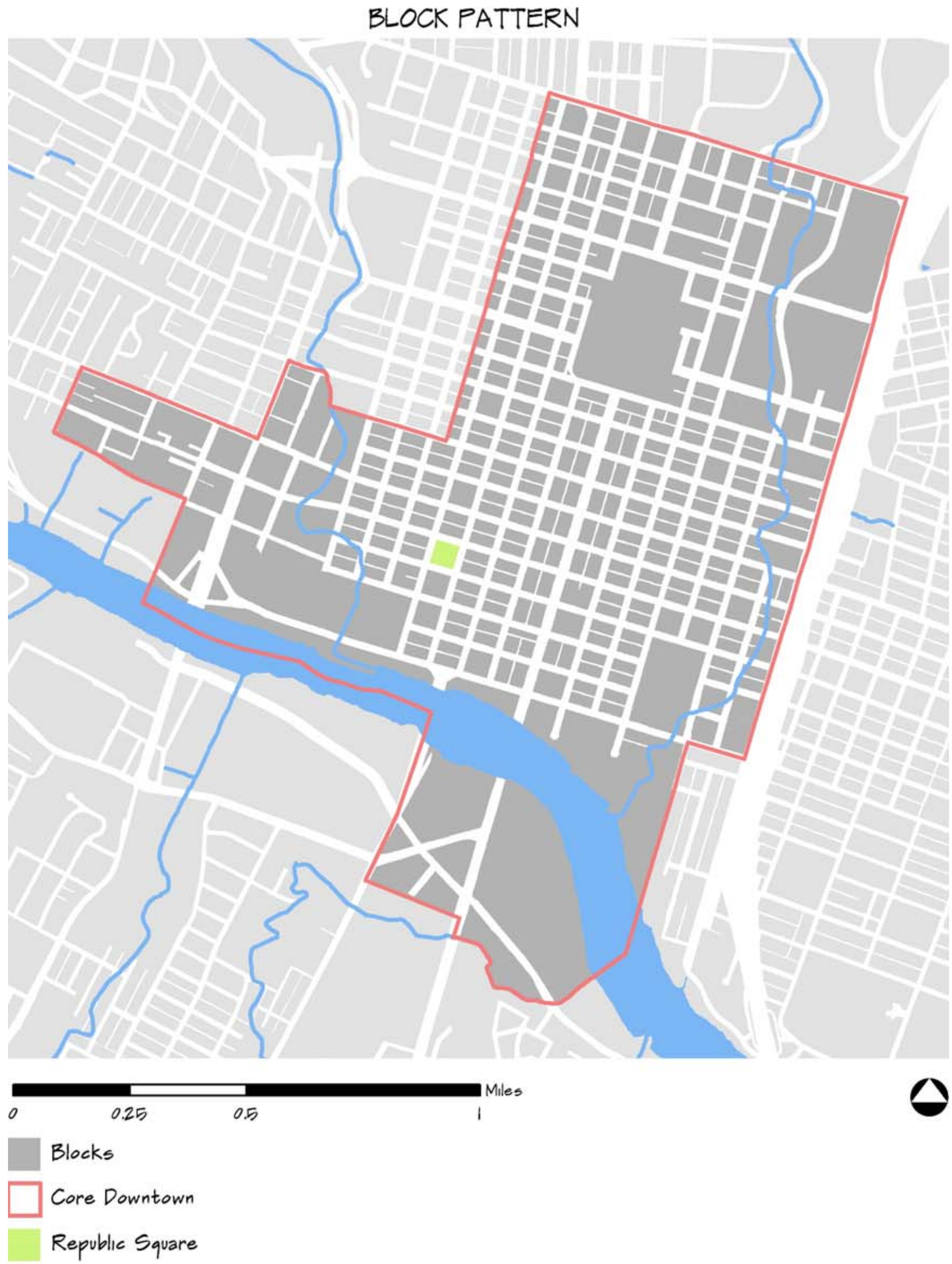
BLOCK PATTERN
Miles
0
0.25
0.5
1
Blocks
Core Downtown
Republic Square

Figure 4-9


BUILDINGS
Miles
0
0.25
0.5
1
Buildings
Core Downtown
Republic Square

Figure 4-10

Circulation

Figures 4-11, 4-12, 4-13, 4-14, 4-15, and 4-16 represent the network of transportation infrastructure for pedestrian and vehicular circulation. This data was obtained from the City of Austin and depicts circulation paths along street centerlines and parking areas with dates of publication ranging from 2003 to 2007. Understanding transportation networks is important for determining the level of mobility for pedestrian and vehicular circulation as well as the level of access – both crucial factors which influence the amount of use and ultimate vitality of Republic Square.

Republic Square sits at the intersection of two major arterial streets enabling high vehicular mobility in addition to high traffic volume which in turn creates high visibility. However, these two major arterial streets are one-way in direction which can lead to access issues. Fortunately, the two minor arterial streets opposite the major arterial streets are two-way which aids vehicular access.

Republic Square is also at the intersection of two transit corridors in addition to being flanked on three sides by bike routes, creating high mobility and access for transit-type transportation. The most significant circulation issue at Republic Square is posed by the 30 to 40 miles per hour speed limits on the surrounding streets which is arguably less than desirable for "pedestrian-friendly" streets. Parking, however, is not an issue as the entire city block to the south is a parking lot.

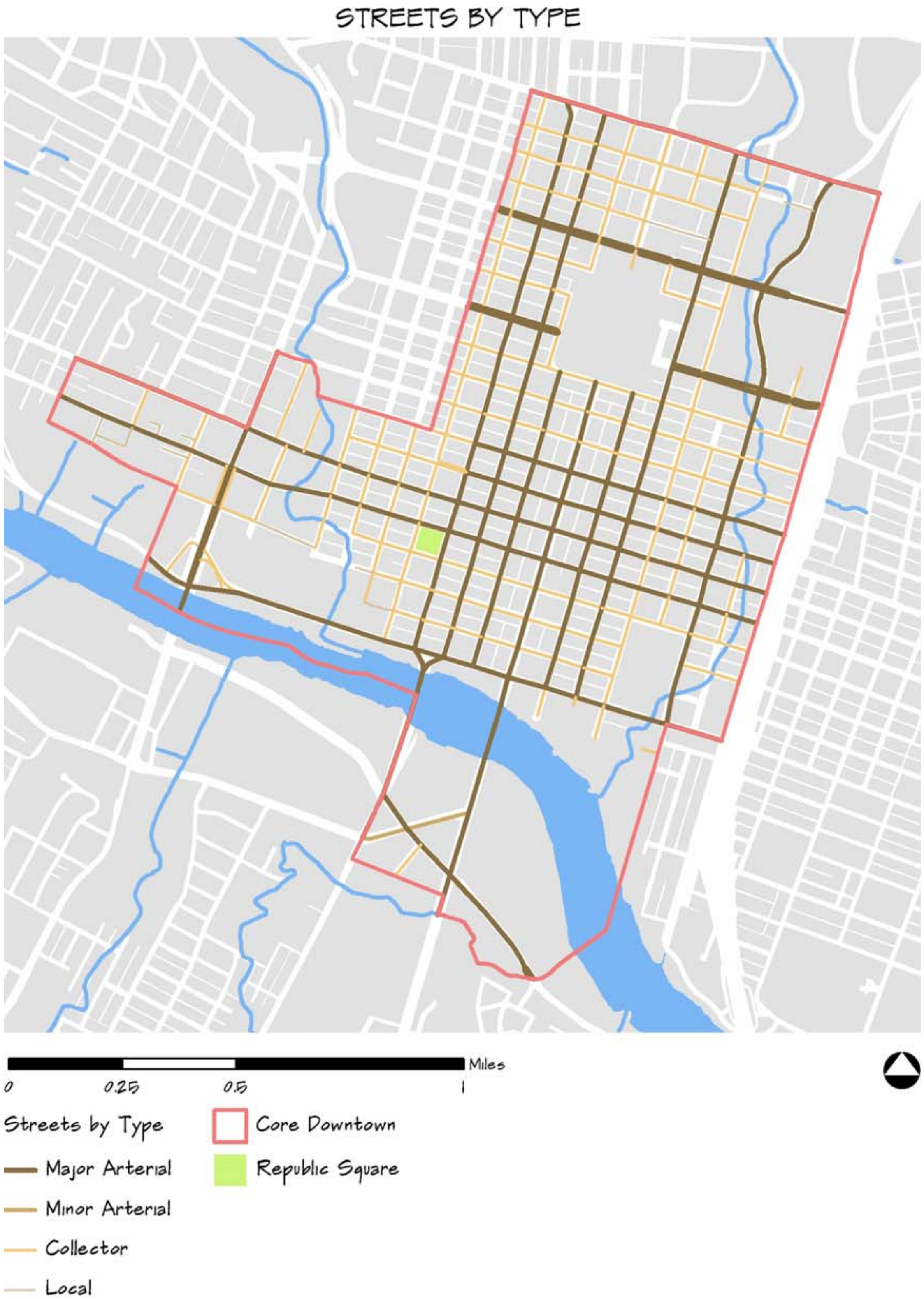
STREETS BY TYPE
Miles
0
0.25
0.5
1
Streets by Type
Major Arterial
Minor Arterial
Collector
Local
Core Downtown
Republic Square

Figure 4-11

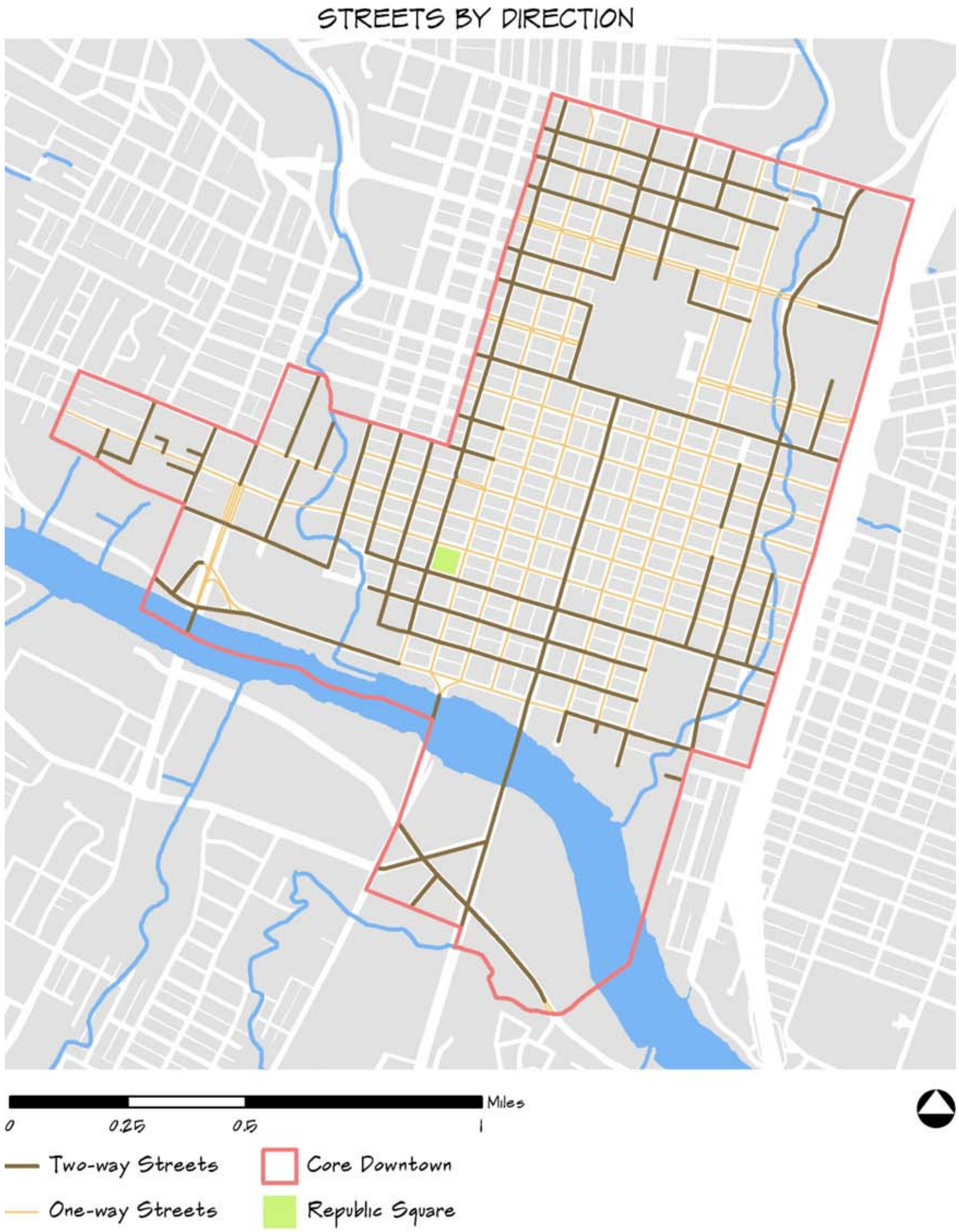
STREETS BY DIRECTION
Miles
0
0.25
0.5
1
Two-way Streets
One-way Streets
Core Downtown
Republic Square

Figure 4-12

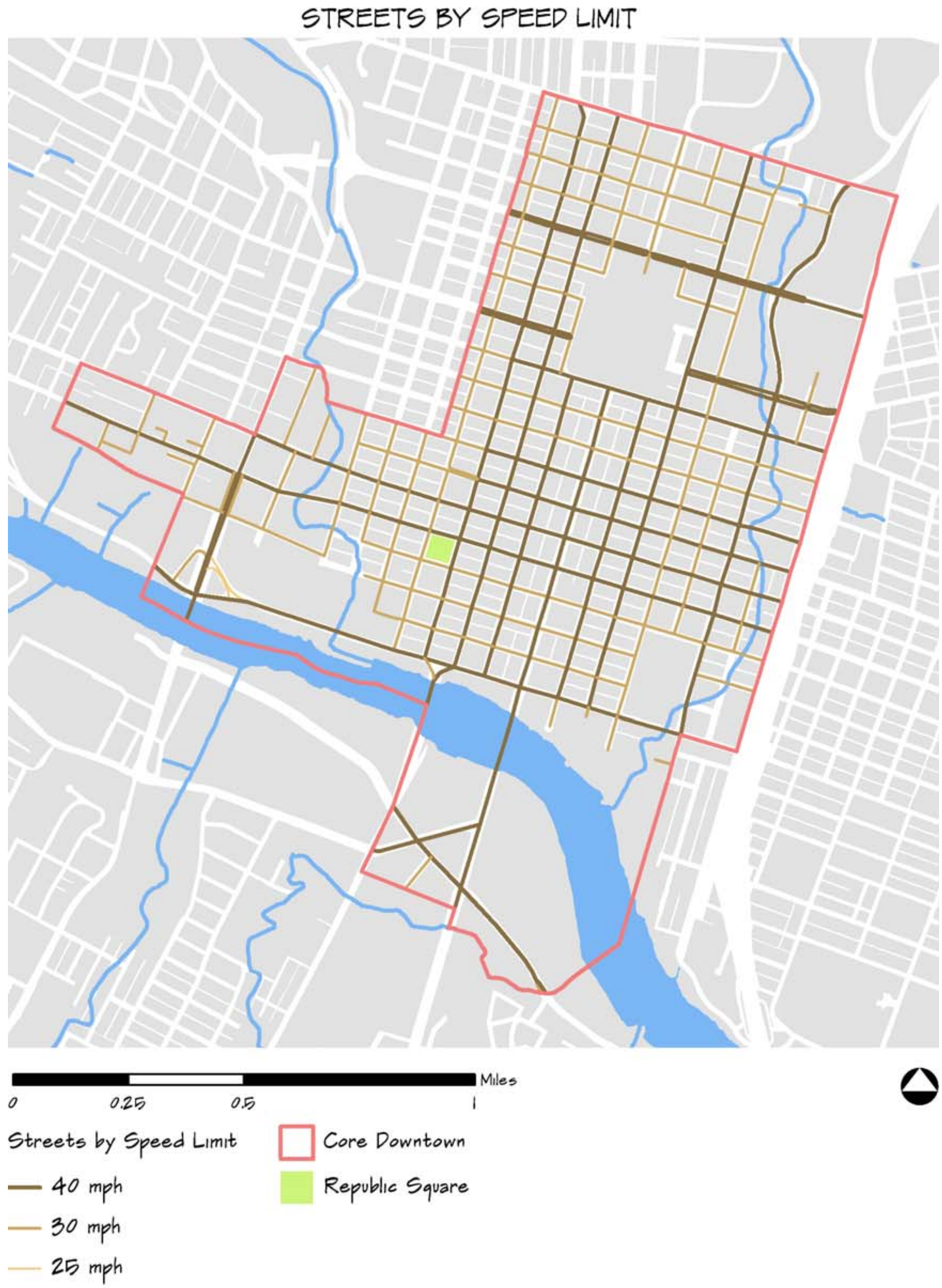
STREETS BY SPEED LIMIT
Miles
0
0.25
0.5
1
Streets by Speed Limit
40 mph
30 mph
25 mph
Core Downtown
Republic Square

Figure 4-13


TRANSIT CORRIDORS
Miles
0
0.25
0.5
1
Transit Corridors
Core Downtown
Republic Square

Figure 4-14

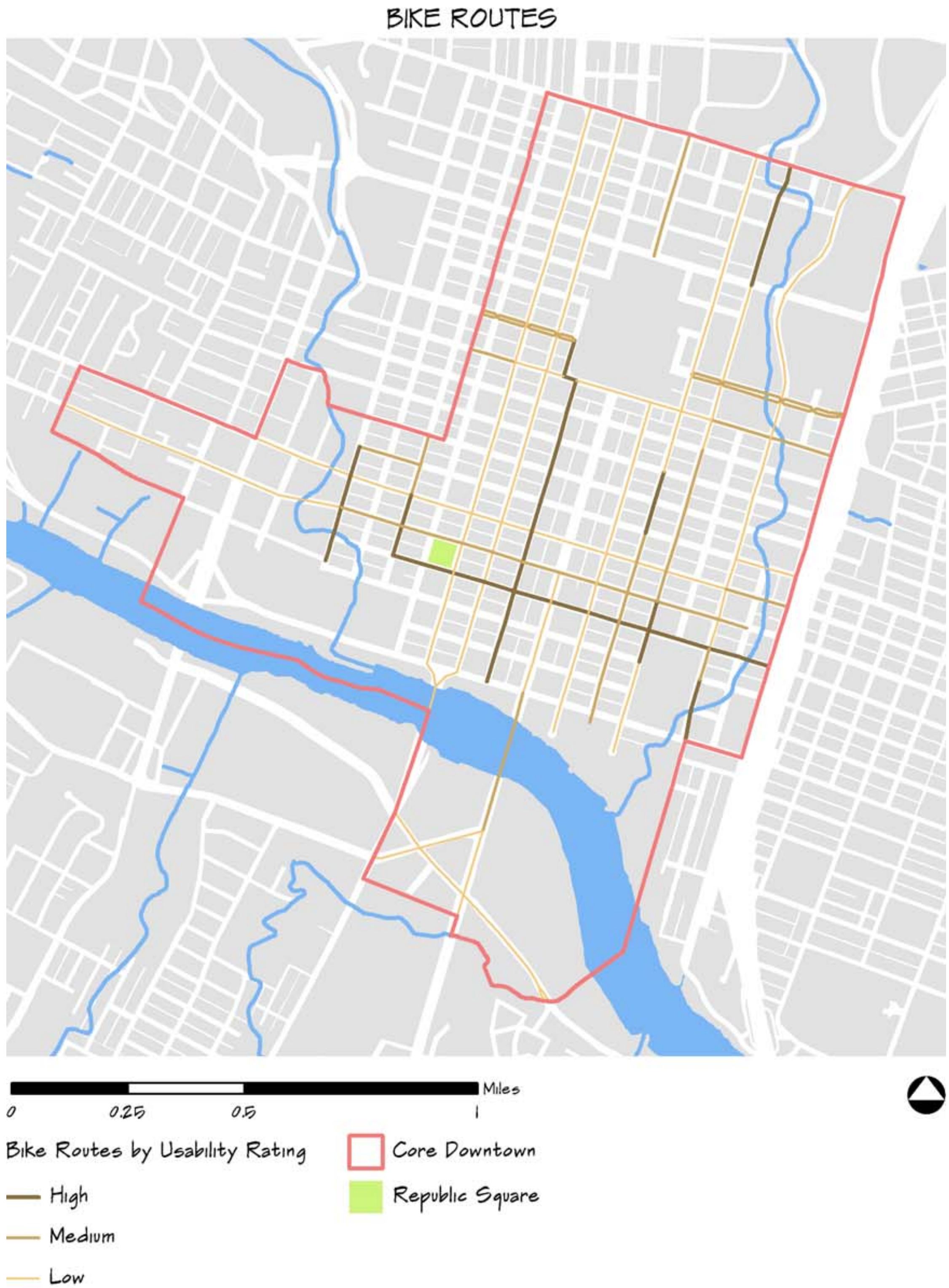
BIKE ROUTES
Miles
0
0.25
0.5
1
Bike Routes by Usability Rating
High
Medium
Low
Core Downtown
Republic Square

Figure 4-15

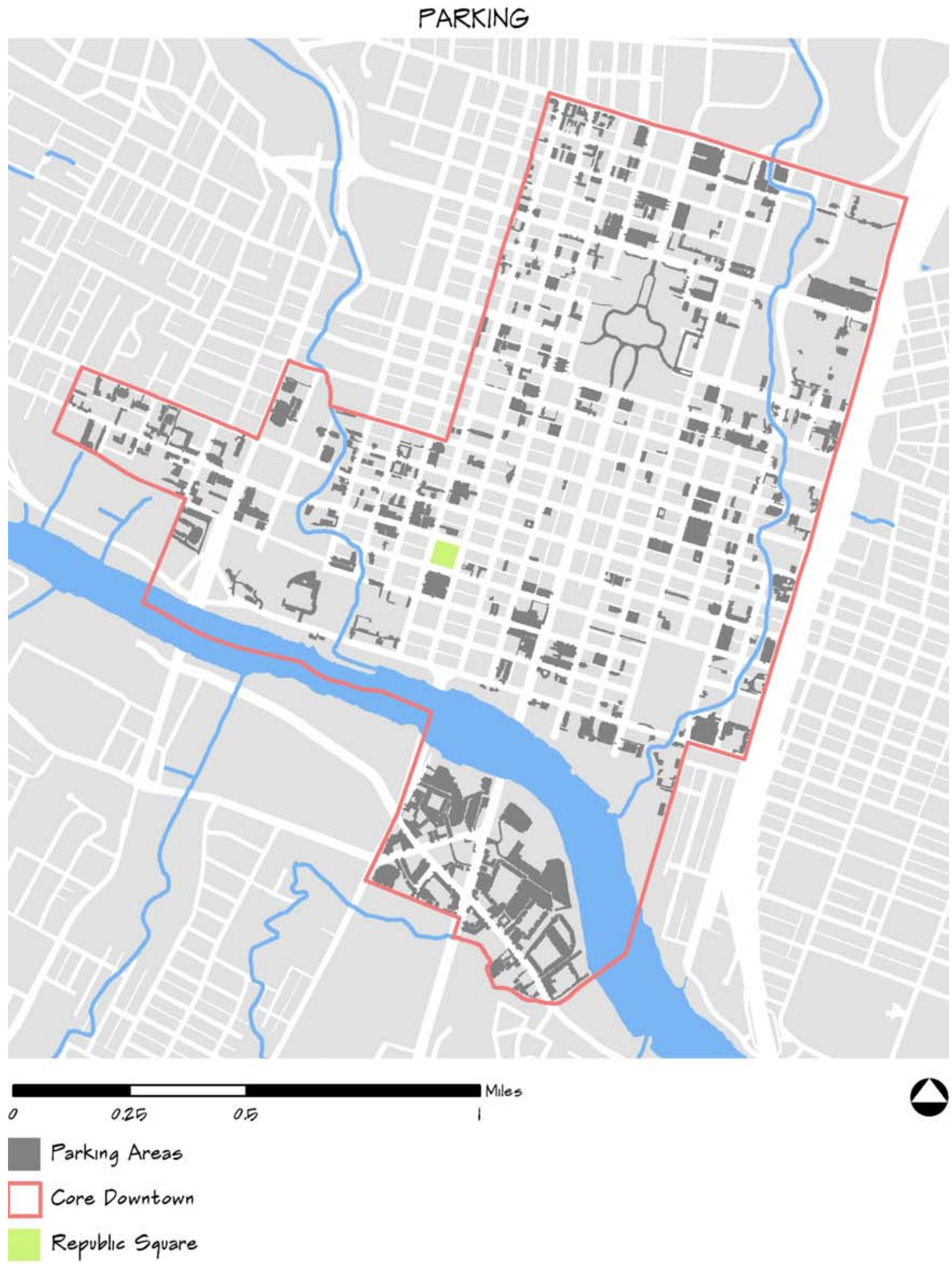
PARKING
Miles
0
0.25
0.5
1
Parking Areas
Core Downtown
Republic Square

Figure 4-16

Environmental

Figures 4-17, 4-18, 4-19, 4-20, and 4-21 represent the topographic, hydrographic, and vegetative features in the Core Downtown area. This data was obtained from the City of Austin and depicts elevation contour lines and hydrography lines and polygons from 1997, and a downtown tree dataset from 2002. FEMA flooding data was obtained from the Texas Water Development Board. These environmental factors are important when considering stormwater drainage and flooding hazards, as well as the overall "greenness" of the Core Downtown area and general environmental sustainability concerns.

The elevation of the Core Downtown area ranges from 424 feet at the low point to 572 feet at the high point. Republic Square sits between 474 feet and 484 feet. Republic Square and its immediate surrounding areas generally slope to the south toward Town Lake. Within Republic Square the site generally slopes to the southwest with the exception of three bermed areas.

The hydrographic features in the Core Downtown area are Shoal Creek, Waller Creek, and Town Lake, a dammed portion of the Colorado River. Flood hazard areas do exist in the areas surrounding the hydrographic features but do not lie any closer than two city blocks from Republic Square. The downtown tree dataset, which does not cover the entire Core Downtown area but does include the area of Republic Square, indicates large masses of mature trees surrounding and within the square.

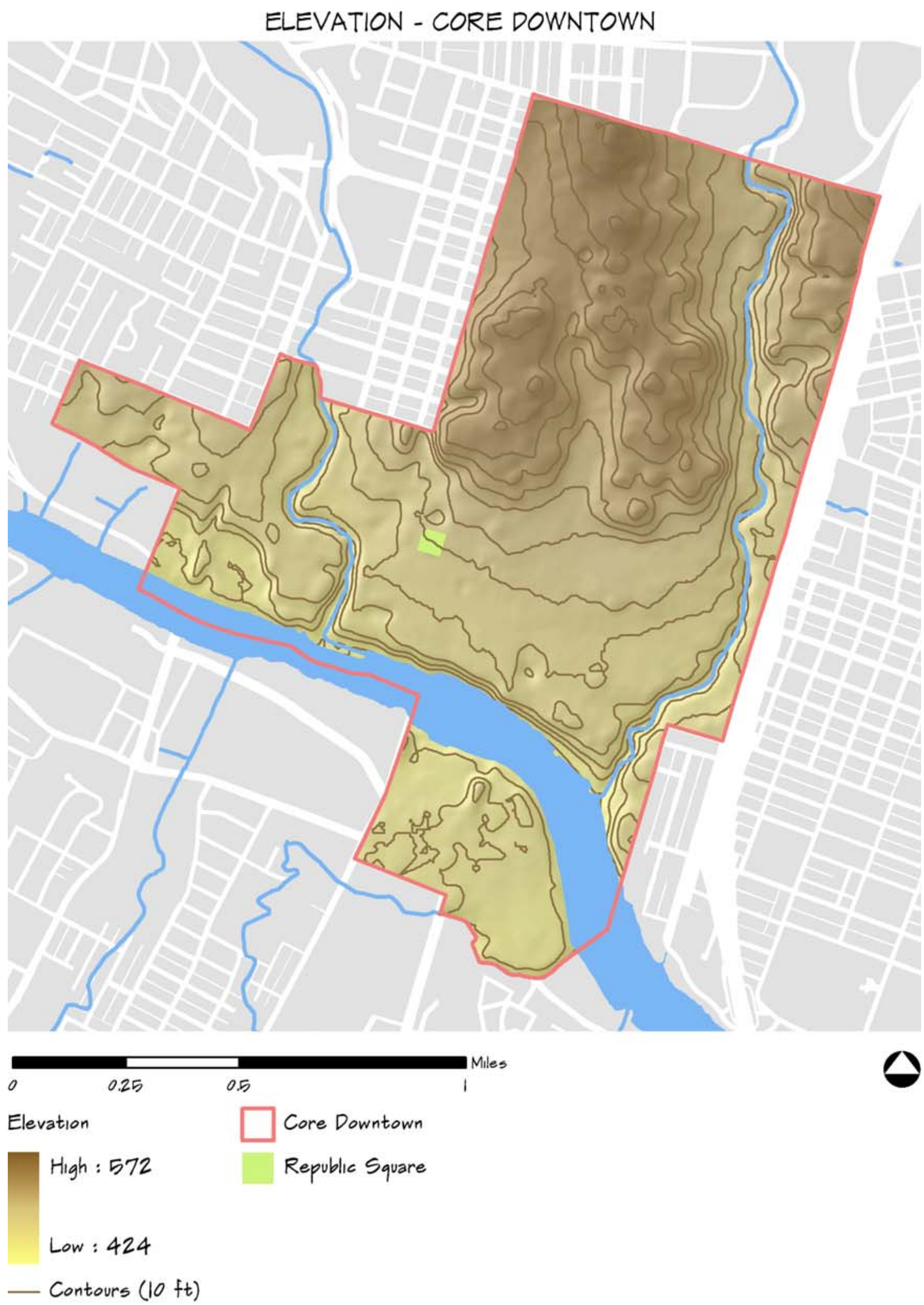
ELEVATION - CORE DOWNTOWN
Miles
0
0.25
0.5
1
Elevation
High : 572
Low : 424
Contours (10 ft)
Core Downtown
Republic Square

Figure 4-17

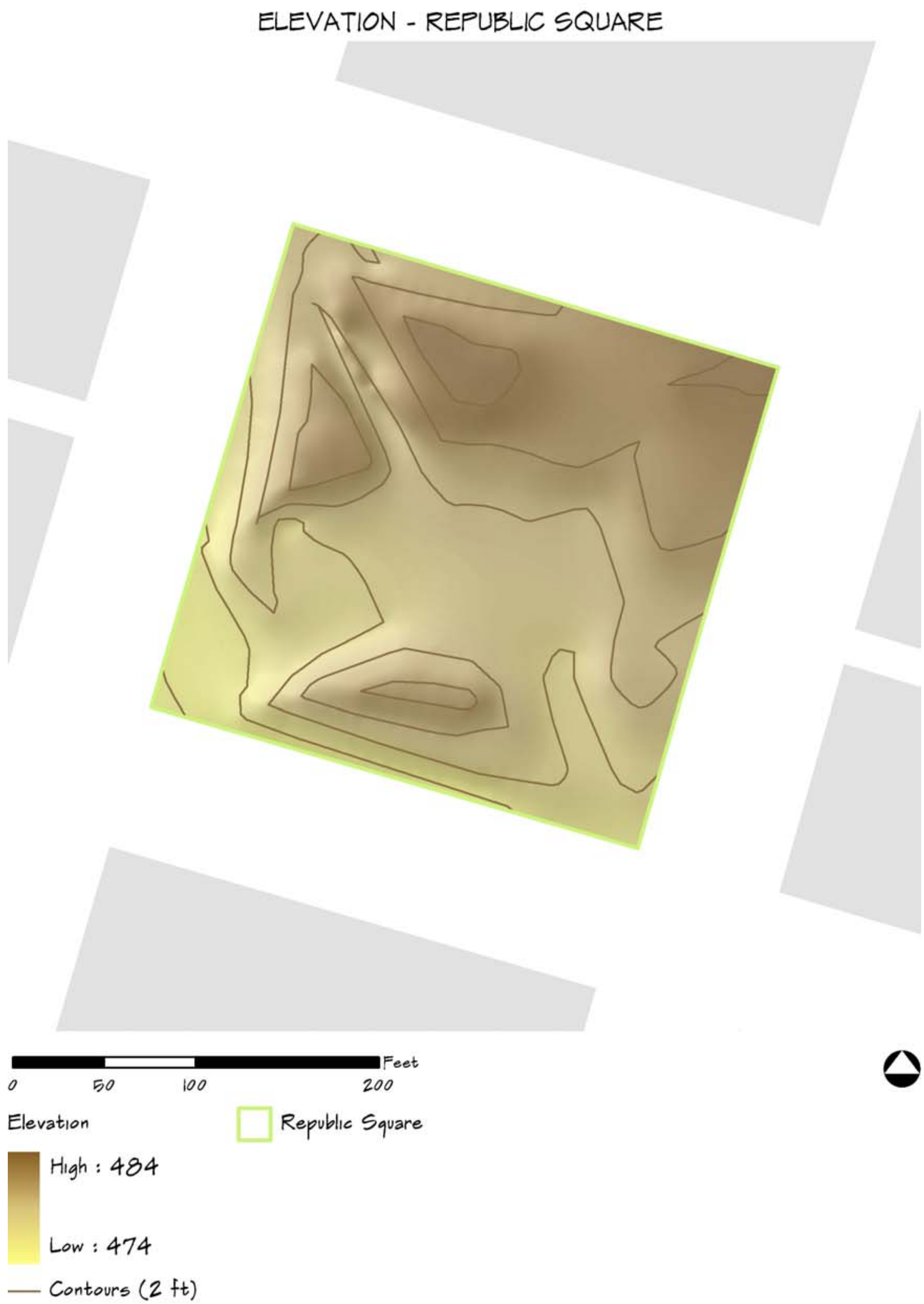
ELEVATION - REPUBLIC SQUARE
Feet
0
50
100
200
Elevation
Republic Square
High : 484
Low : 474
Contours (2 ft)

Figure 4-18

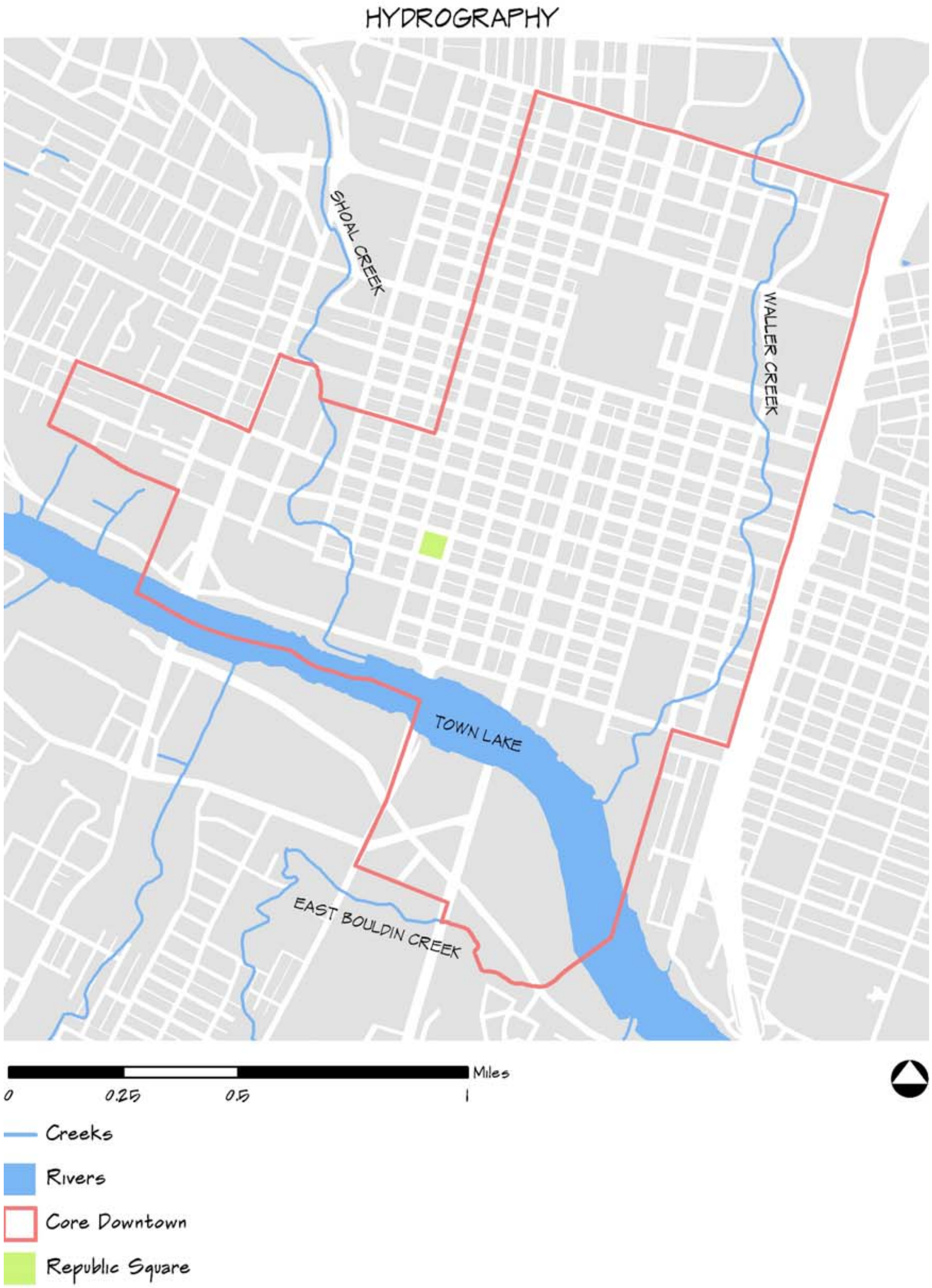
HYDROGRAPHY
SHOAL CREEK
WALLER CREEK
TOWN LAKE
EAST BOULDIN CREEK
Miles
0
0.25
0.5
1
Creeks
Rivers
Core Downtown
Republic Square

Figure 4-19

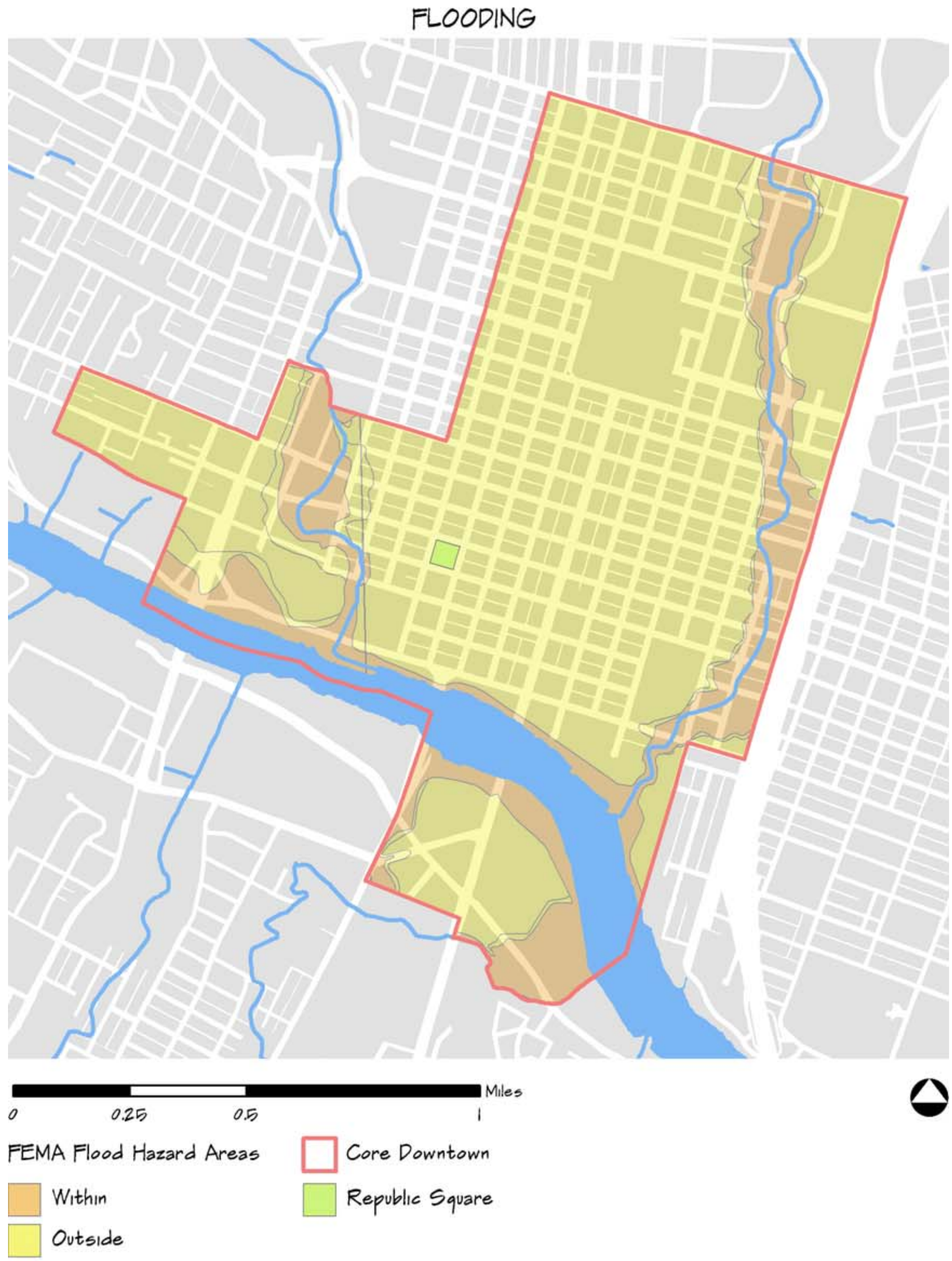
FLOODING
Miles
0
0.25
0.5
1
FEMA Flood Hazard Areas
Within
Outside
Core Downtown
Republic Square

Figure 4-20

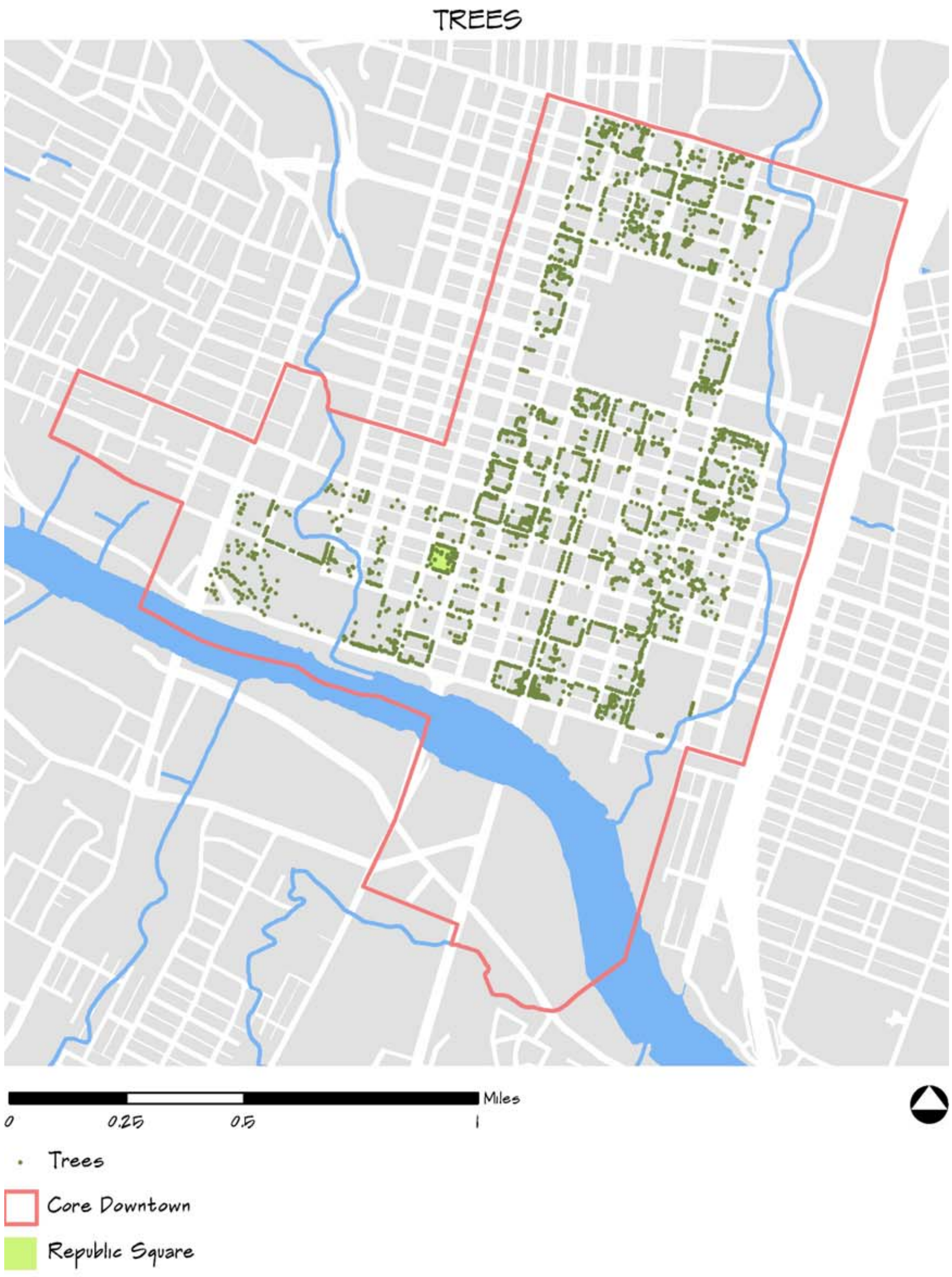

Figure 4-21

Spatial Analysis

Proximity

Despite queries being the simplest and most common analysis tool, proximity analysis is typically a prerequisite for many queries and therefore most ideal to begin any application of spatial analysis. Proximity analysis creates a buffer around a feature of a specified distance in order to determine what is within or outside that distance from that feature. In the case of Republic Square, determining what is adjacent or nearby is critical for understanding the anticipated users and uses of the site as a result of its context.

Determining a buffer distance for analysis is critical as it needs to reflect a realistic area "served" by Republic Square, or what can be called its catchment area. For the purpose of this application, this distance will be set by what is considered to be a desirable walking distance. According to Untermann (1984), pedestrians are likely to walk to a destination that is less than five minutes in walking distance from their initial location – longer if the experiential quality of the path is high or shorter if constraints such as steep grades are present.

Figure 4-22 represents walking distances at intervals of one minute from Republic Square. Using an average walking speed of three feet per second as encouraged by APA (2006), the average pedestrian walks 180 feet per minute. Therefore, each ring of the proximity analysis represents 180 feet, for a total of a 900 foot buffer distance. Figure 4-23 represents the determined catchment area for Republic Square – a five minute walking distance of 900 feet.

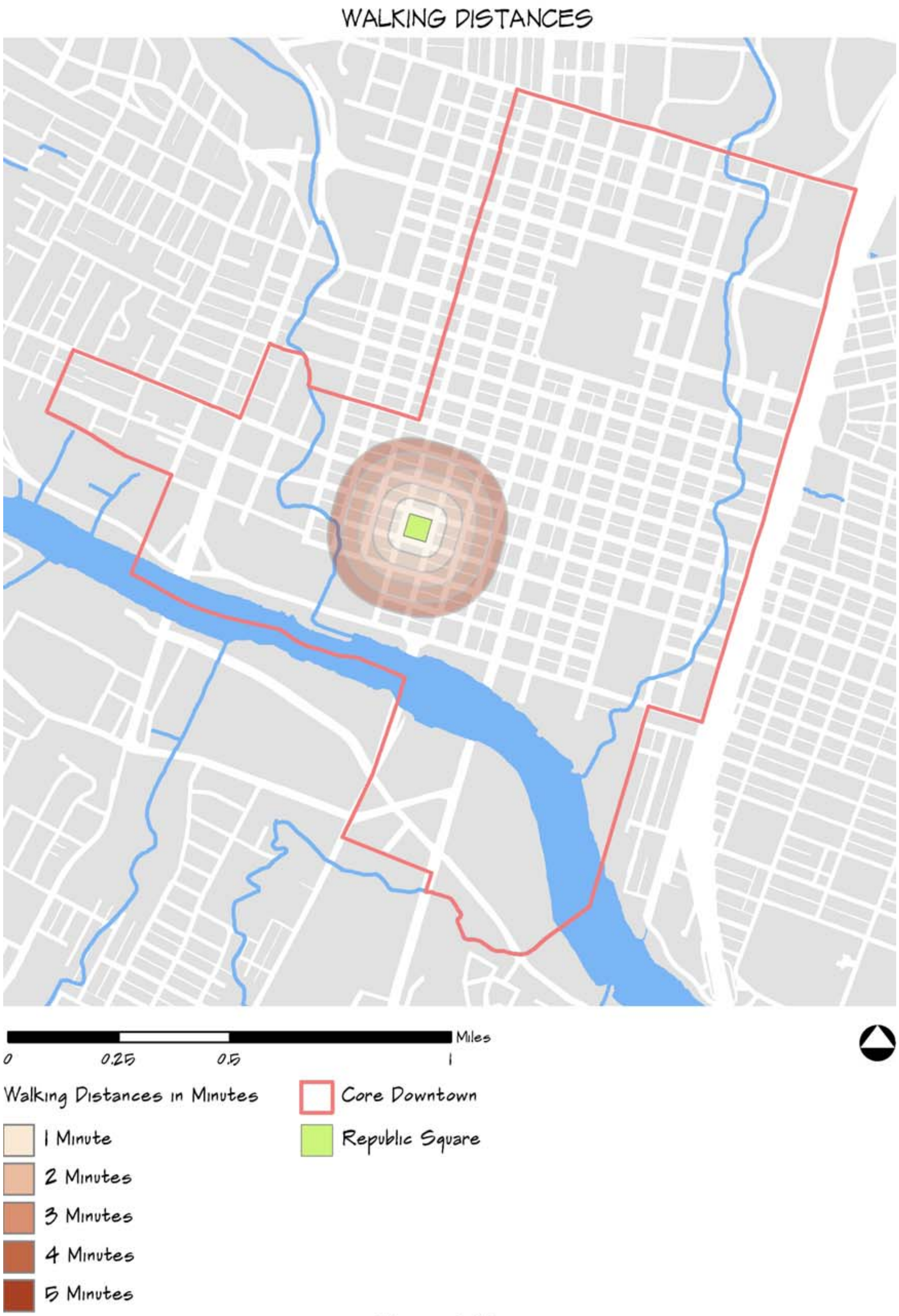
WALKING DISTANCES
Miles
0
0.25
0.5
1
Walking Distances in Minutes
1 Minute
2 Minutes
3 Minutes
4 Minutes
5 Minutes
Core Downtown
Republic Square

Figure 4-22

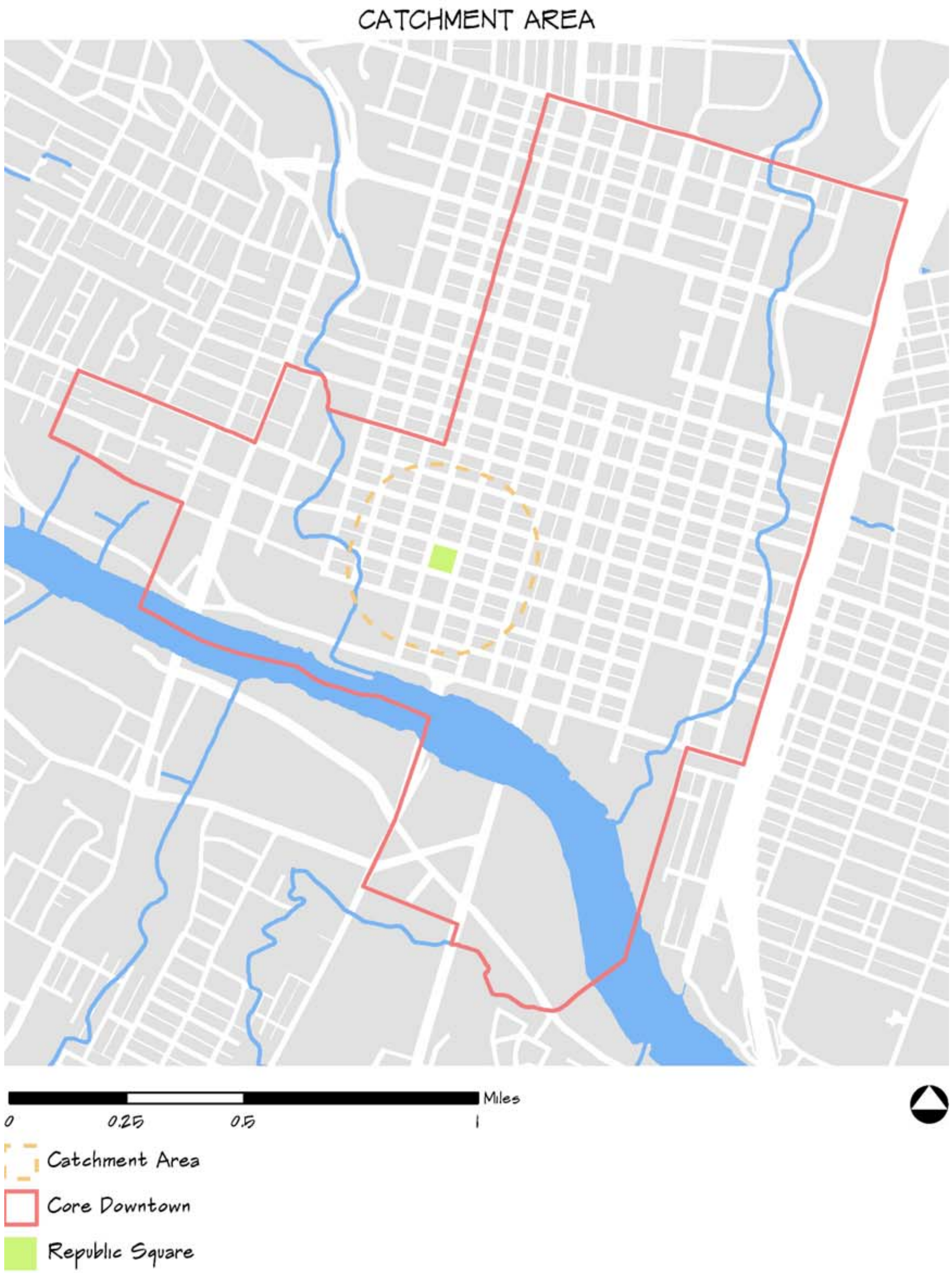
CATCHMENT AREA
Miles
0
0.25
0.5
1
Catchment Area
Core Downtown
Republic Square

Figure 4-23

Queries

Proximity analyses by their nature lead to questions of what is nearby or distant from spatial features. In addition to these types of location-based queries, attribute-based queries are necessary to identify features by their descriptive qualities. It is not uncommon in many analyses to query features that meet both location and attribute criteria in a two-step Boolean query method.

After determining the catchment area for Republic Square using proximity analysis buffer tools, it is important to consider the urban phenomena within that buffer to better understand the relationship of the square to its contextual surroundings. Republic Square, as a unique open space amidst dense commercial land uses, informally defines an urban district by it catchment area. The application of query analyses determines not only what is inside this neighborhood also the particulars of it character.

Figure 4-24 represents buildings within walking distance of Republic Square by means of a location-based query. Due to the lack of residential land uses, the majority of users of Republic Square will be workers from the commercial office buildings within the catchment area. Identifying these buildings, and subsequently their occupants, is the first critical step toward determining the anticipated users and uses of the square.

Figure 4-25 represents trees in poor health within Republic Square. The dataset of downtown trees provided an attribute field ranking all trees as one of three conditions of health: poor, fair, or good. In one the few applications of spatial analysis at the single-parcel scale, a simple attribute query identifies trees of a specific condition that will require special attention during the conceptual development of the site design.

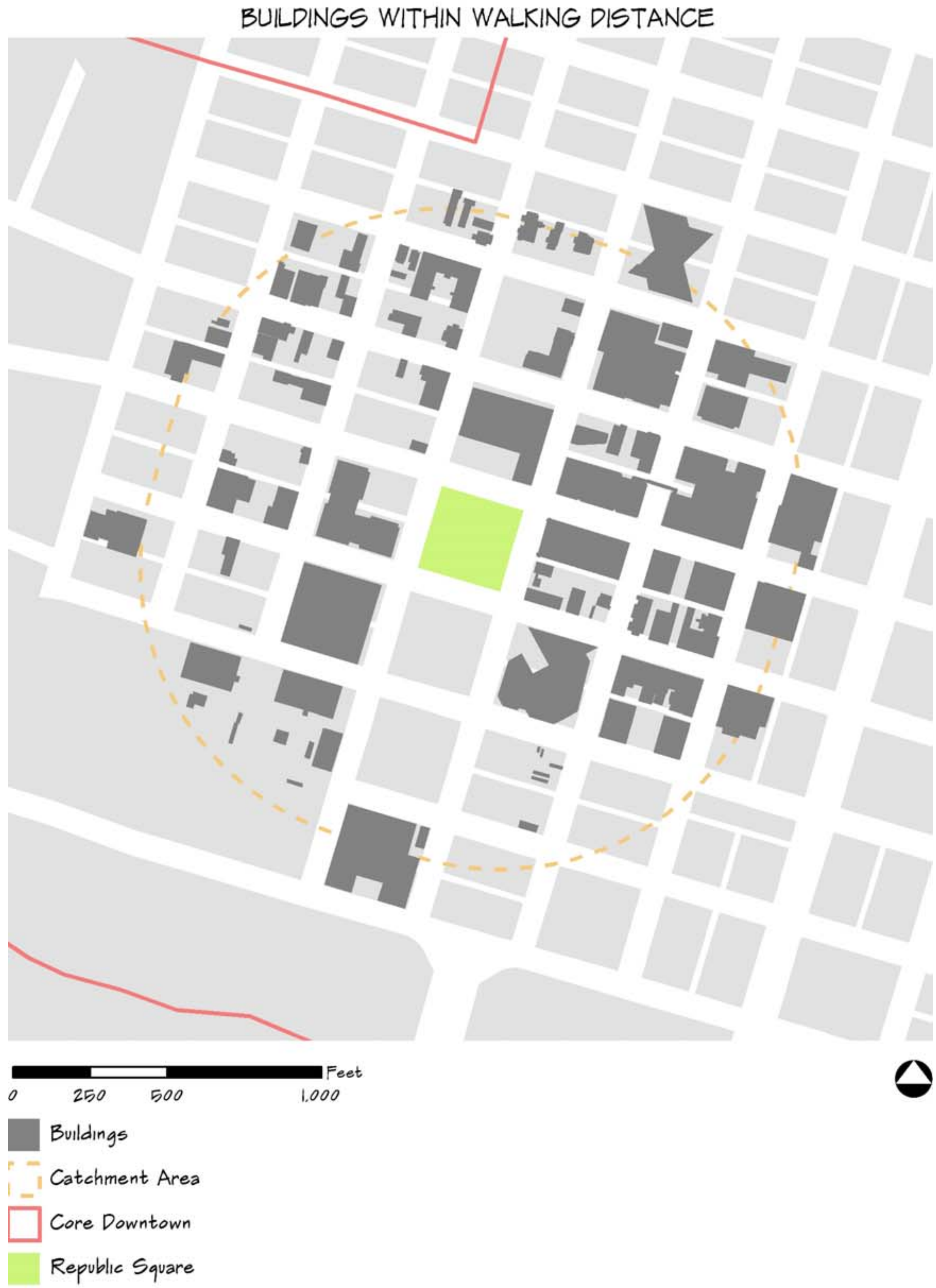
BUILDINGS WITHIN WALKING DISTANCE
Feet
0
250
500
1,000
Buildings
Catchment Area
Core Downtown
Republic Square

Figure 4-24

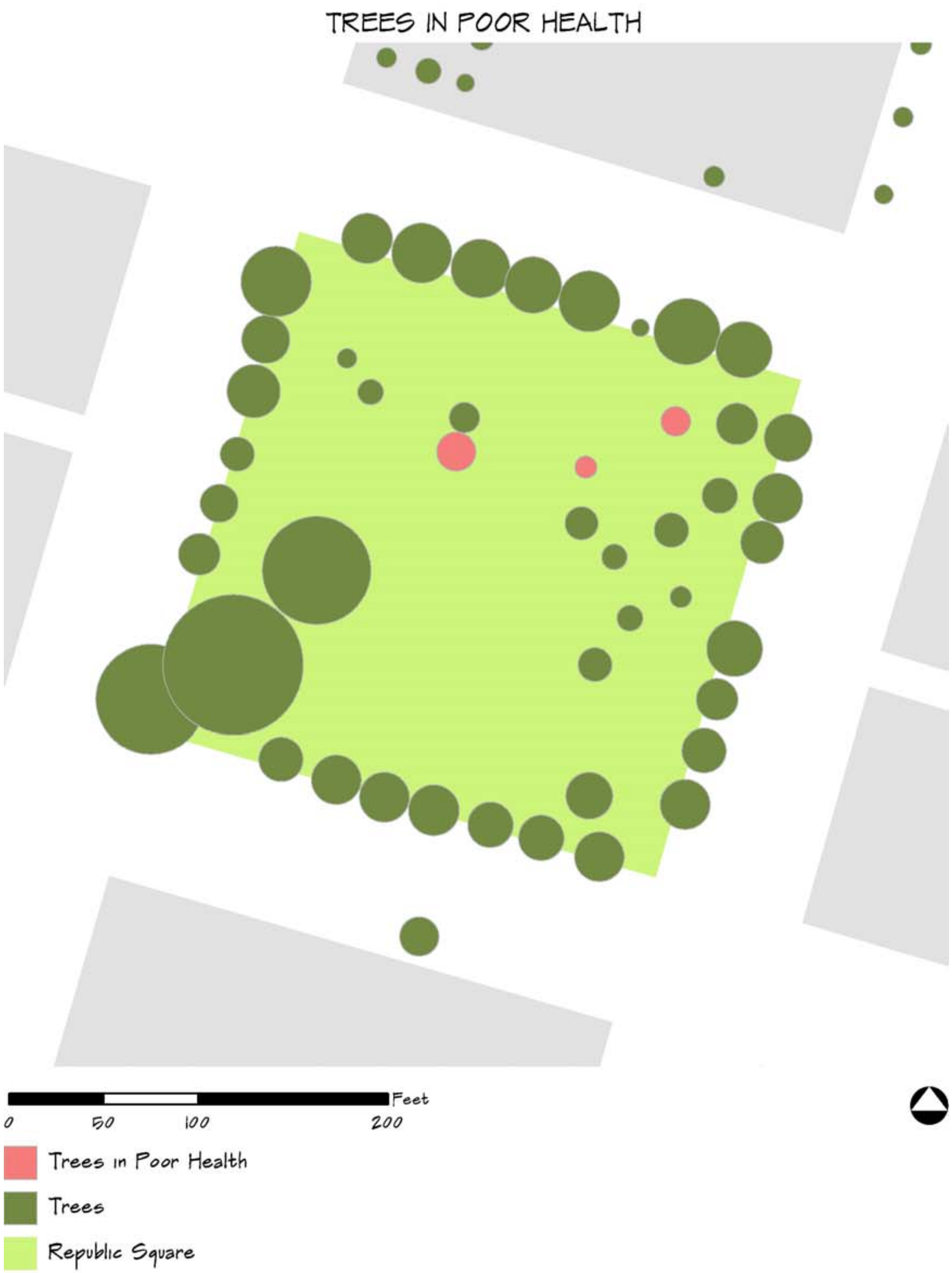
TREES IN POOR HEALTH
Feet
0
50
100
200
Trees in Poor Health
Trees
Republic Square

Figure 4-25

Density

Density is essential for urban diversity and vitality. A density analysis measures the quantity of features within a specified areal unit. In urban design applications, density of people and buildings are of key concern as they relate to not only the numbers of users but also the overall efficiency and sustainability of urban areas.

Population density is often expressed as people per square mile due to the scale or large areal extent used during typical density calculations. However, for Republic Square, where census block population figures in most cases represent a single city block, population density is best expressed as people per acre. GIS-based density analyses can represent the density of features in three ways: by defined area, by interpolated raster surface, or by dot density (Mitchell 1999) – this application explores the two former.

Figure 4-26 represents population density by a defined area – in this application a census block. Density in the Core Downtown area varies from 0 people per acre in census blocks where there is no population, to 81 people per acre in the most dense census block. The average density of all census blocks in the Core Downtown area is 3 people per acre.

Figure 4-27 represents population density by an interpolated raster surface using census block centroids. The resulting density figures are drastically different to the figures when calculated by defined area due to one fundamental difference in the two methods – though both are expressed as people per acre, the defined area calculation uses an varying areal extent of a census block, while the surface calculation uses a uniform areal extent as specified by the analyst known as the neighborhood search radius. Density is calculated using this radius – in this application a quarter-mile – at each cell of the resulting raster producing an interpolated surface between census block centroids.

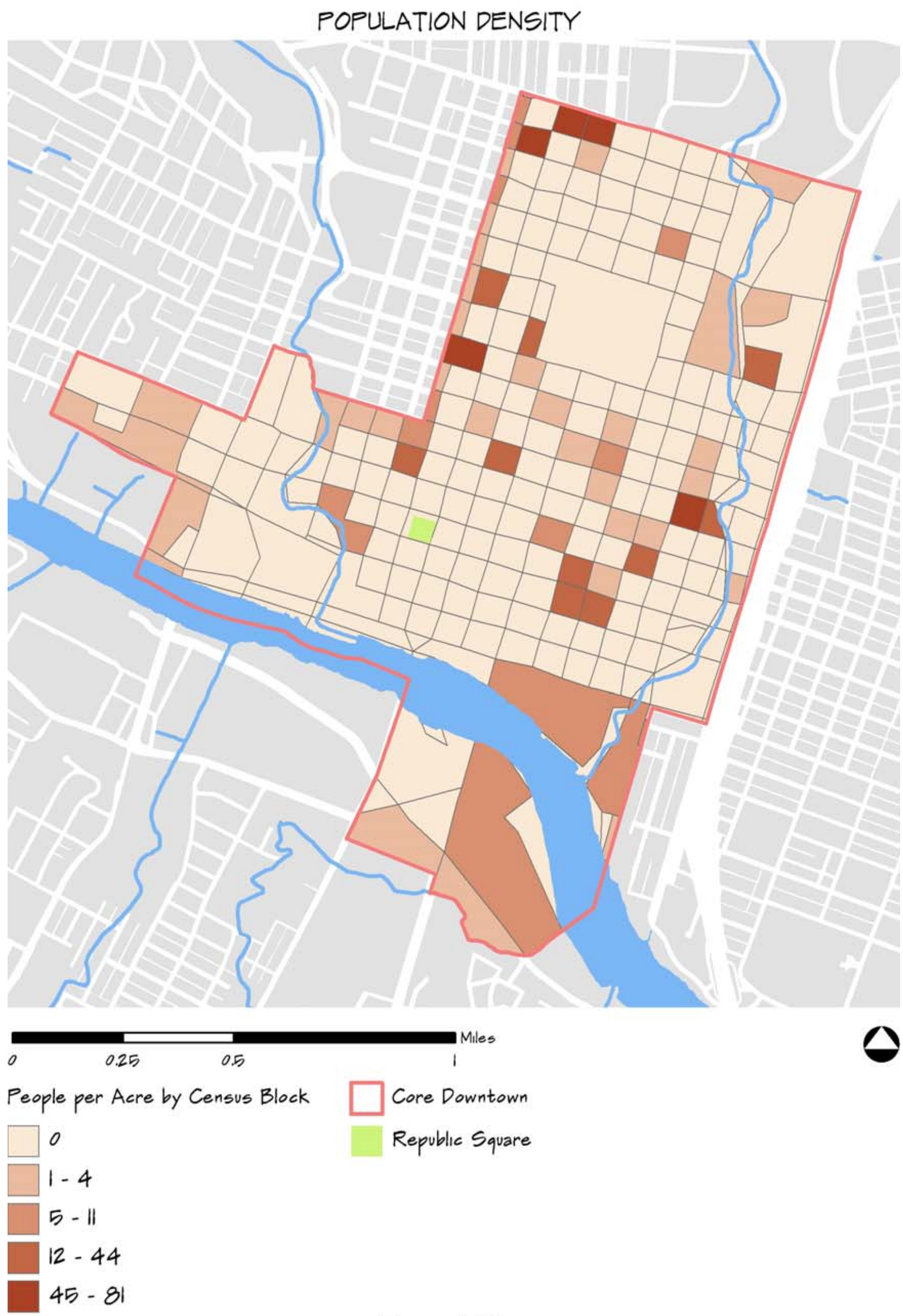
POPULATION DENSITY
Miles
0
0.25
0.5
1
People per Acre by Census Block
0
1 - 4
5 - 11
12 - 44
45 - 81
Core Downtown
Republic Square

Figure 4-26

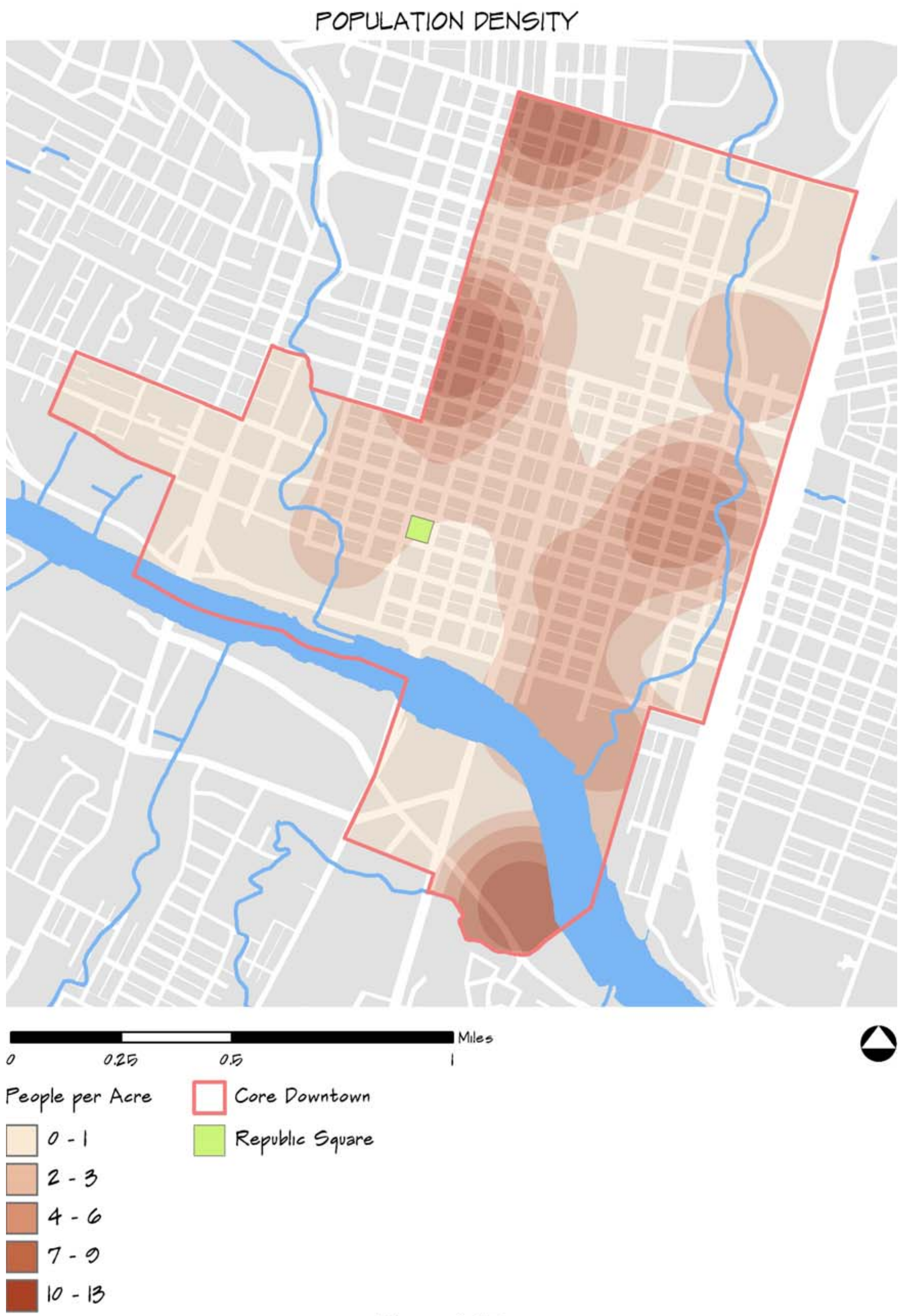
POPULATION DENSITY
Miles
0
0.25
0.5
1
People per Acre
0 - 1
2 - 3
4 - 6
7 - 9
10 - 13
Core Downtown
Republic Square

Figure 4-27

3D Visualization

3D visualization is more often used as a means to visualize the existing or proposed design form or urban environments than as a component of analysis. However, most spatial analyses can be projected into the third or “z” dimension as a unique method of relating the magnitude of features in the z dimension to the spatial relationship of the same features in the x and y dimensions. Additionally, features attributes can be extruded using a z-factor that will exaggerate the differences between features.

The result of 3D visualization does not produce any new information from data, but rather presents a new perspective of viewing analysis results. Of course, 3D visualization can be applied during the inventory phase of urban design as well. In this application at Republic Square, one 3D visualization map was produced from inventory data, while a second was produced from analysis results.

Figure 4-28 represents the number of housing units in the Core Downtown area – the same data as represented by Figure 4-5 during the inventory phase. In what appears to be a 3D model of buildings is actually the magnitude of housing units per census block exaggerated by a z-factor of 10. Census blocks are still categorized into five classes in the legend using a graduated color ramp but the unique heights of each feature adds a second perspective on comparing the number of housing units per census block.

Figure 4-29 represents housing density as an interpolated raster surface – similar to the density surface produced for Figure 4-27 but for housing rather than people. In what appears to be a topographic model of terrain elevation is actually the housing density as expressed in housing units per acre and exaggerated by a z-factor of 100.

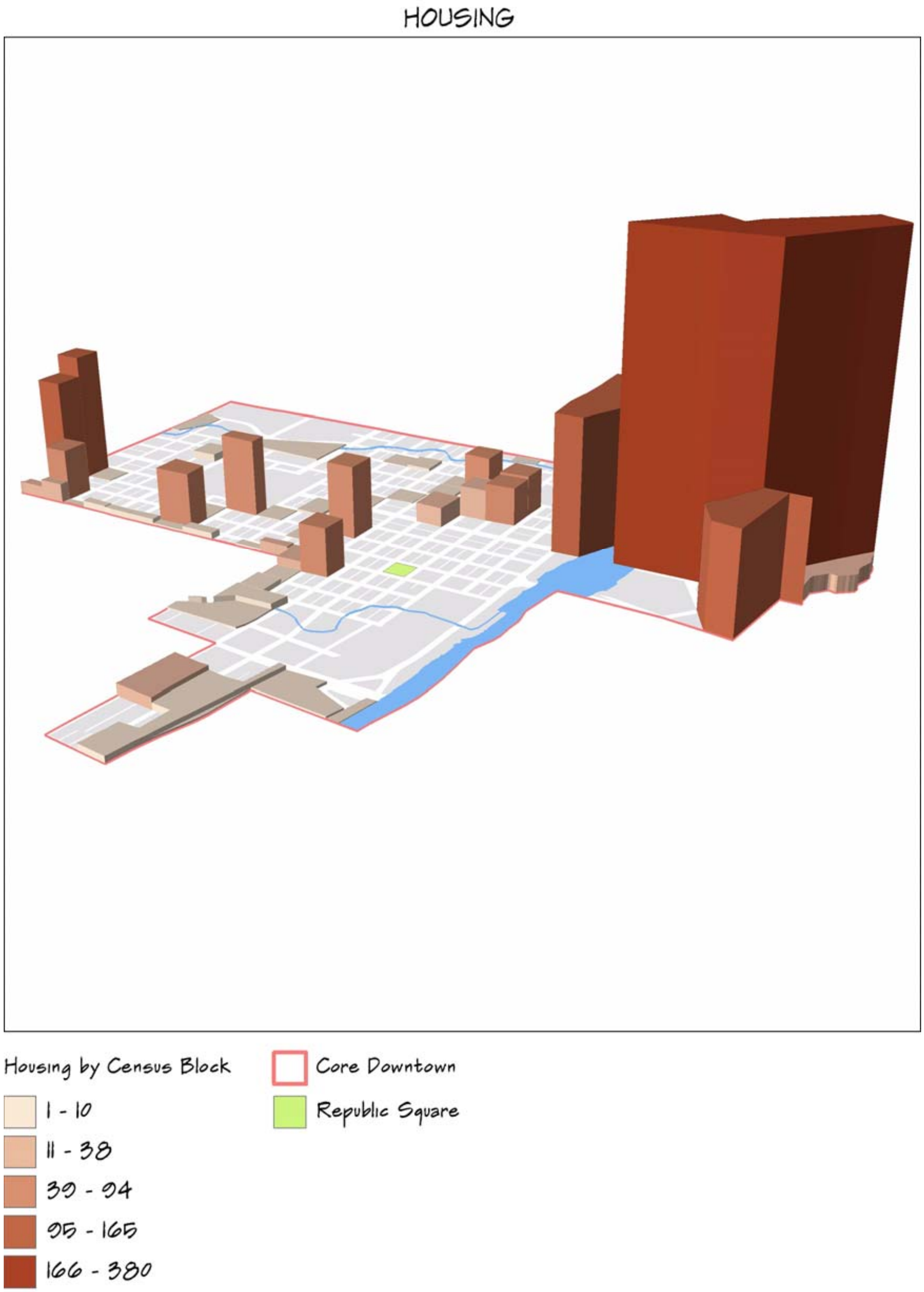
HOUSING
Housing by Census Block
1 - 10
11 - 38
39 - 94
95 - 165
166 - 380
Core Downtown
Republic Square

Figure 4-28

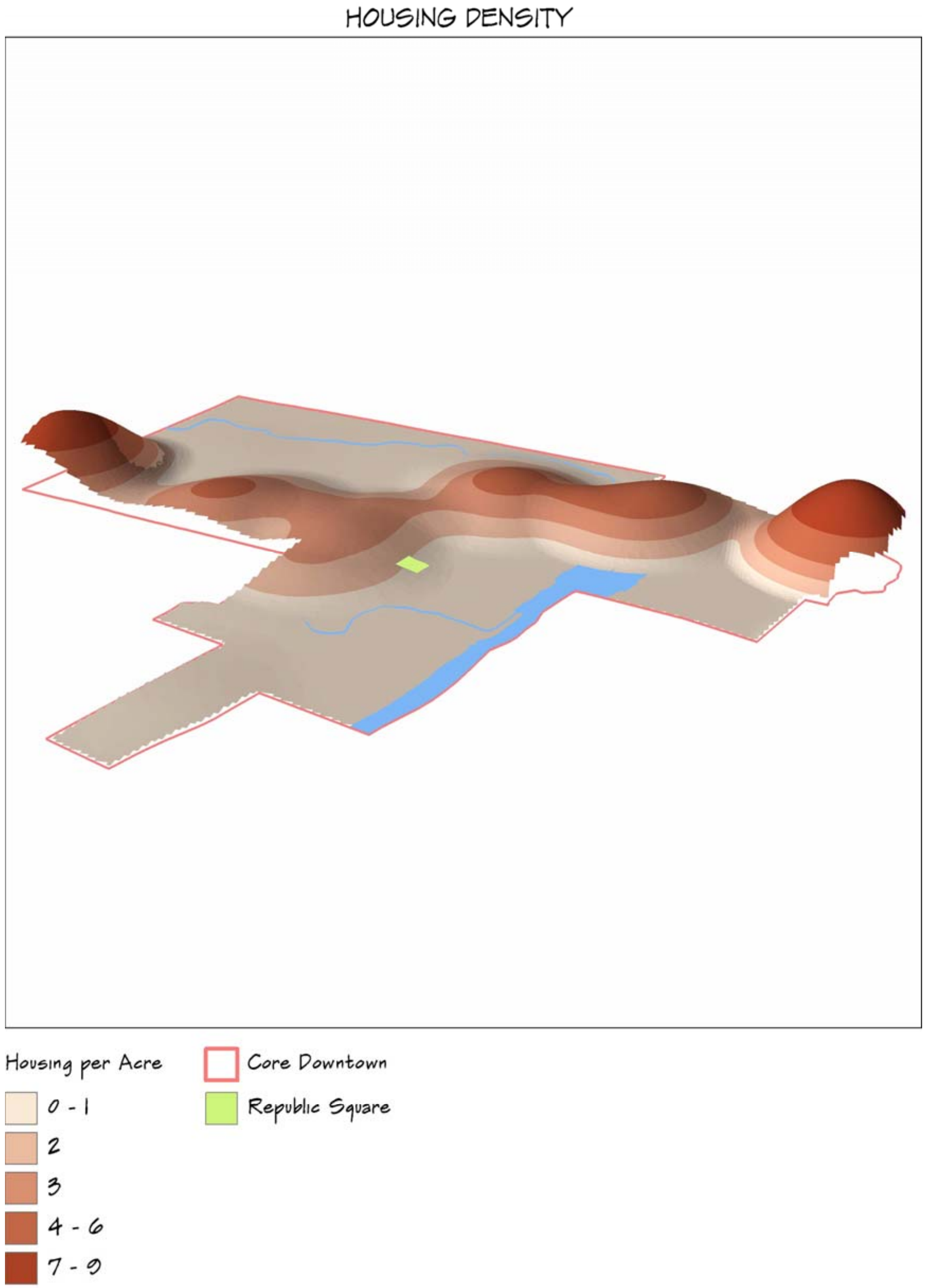
HOUSING DENSITY
Housing per Acre
0 - 1
2
3
4 - 6
7 - 9
Core Downtown
Republic Square

Figure 4-29

Topographic

One of the most important concerns for site designers of any discipline is in regard to the slope of the terrain. Though topographic analysis encompasses slope analysis, aspect analysis, and viewshed analysis among others, determining slope is always a critical component of any site analysis. Slope plays an important role in both drainage and accessibility issues throughout any site.

For Republic Square, two digital elevation models (DEM) were generated from the contours dataset obtained from the City of Austin – one for the Core Downtown area and one for Republic Square. Each raster was produced with cell sizes appropriate to the scale of the two extents resulting in a more generalized DEM for the Core Downtown area and a more detailed DEM for Republic Square. These datasets are seen in Figures 4-17 and 4-18. Using these DEMs, GIS topographic analysis tools can generate a new raster expressing the slope gradient as a percentage or degree of rise.

Figures 4-30 and 4-31 represent slope in percent rise for the Core Downtown area and Republic Square, respectively. The DEMs are classified into five categories to distinguish breaks in the slope important to site design in terms of walking paths and ADA accessibility: 0-2% to represent flat slopes, 2-5% to represent slopes that do are accessible and do not require a hand rail, 5-8% to represent slopes that are accessible and do require a handrail, 8-20% to represent slopes that are not accessible, and finally slopes greater than 20% which are not only non-accessible but also generally considered to be undesirable for able-bodied people to walk. The results of the analysis show that in the context of Core Downtown area, Republic Square sits at generally a 2-5% slope, as well as within the site with the exception of three bermed areas.

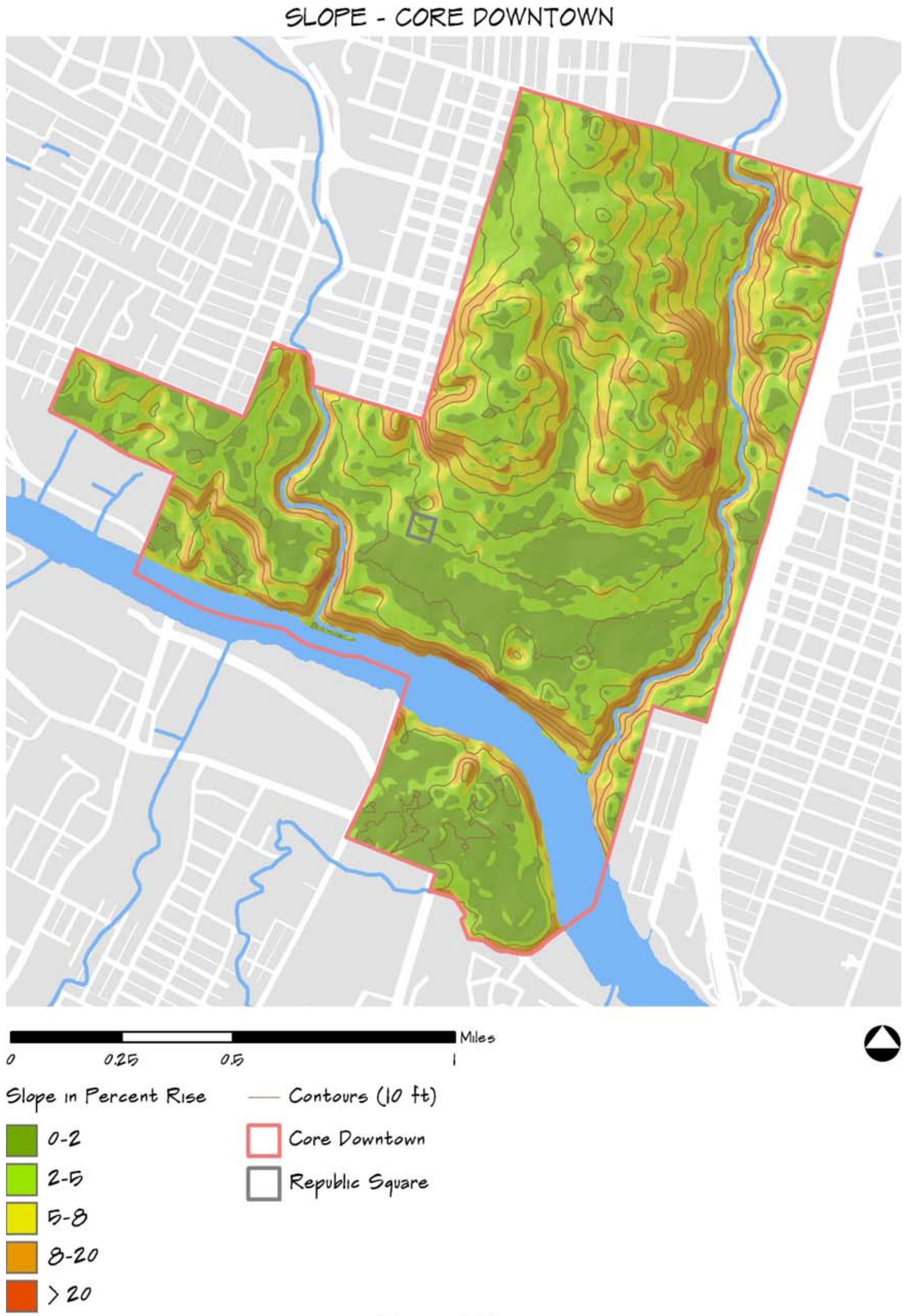
SLOPE - CORE DOWNTOWN
Miles
0
0.25
0.5
1
Slope in Percent Rise
0-2
2-5
5-8
8-20
> 20
Contours (10 ft)
Core Downtown
Republic Square

Figure 4-30

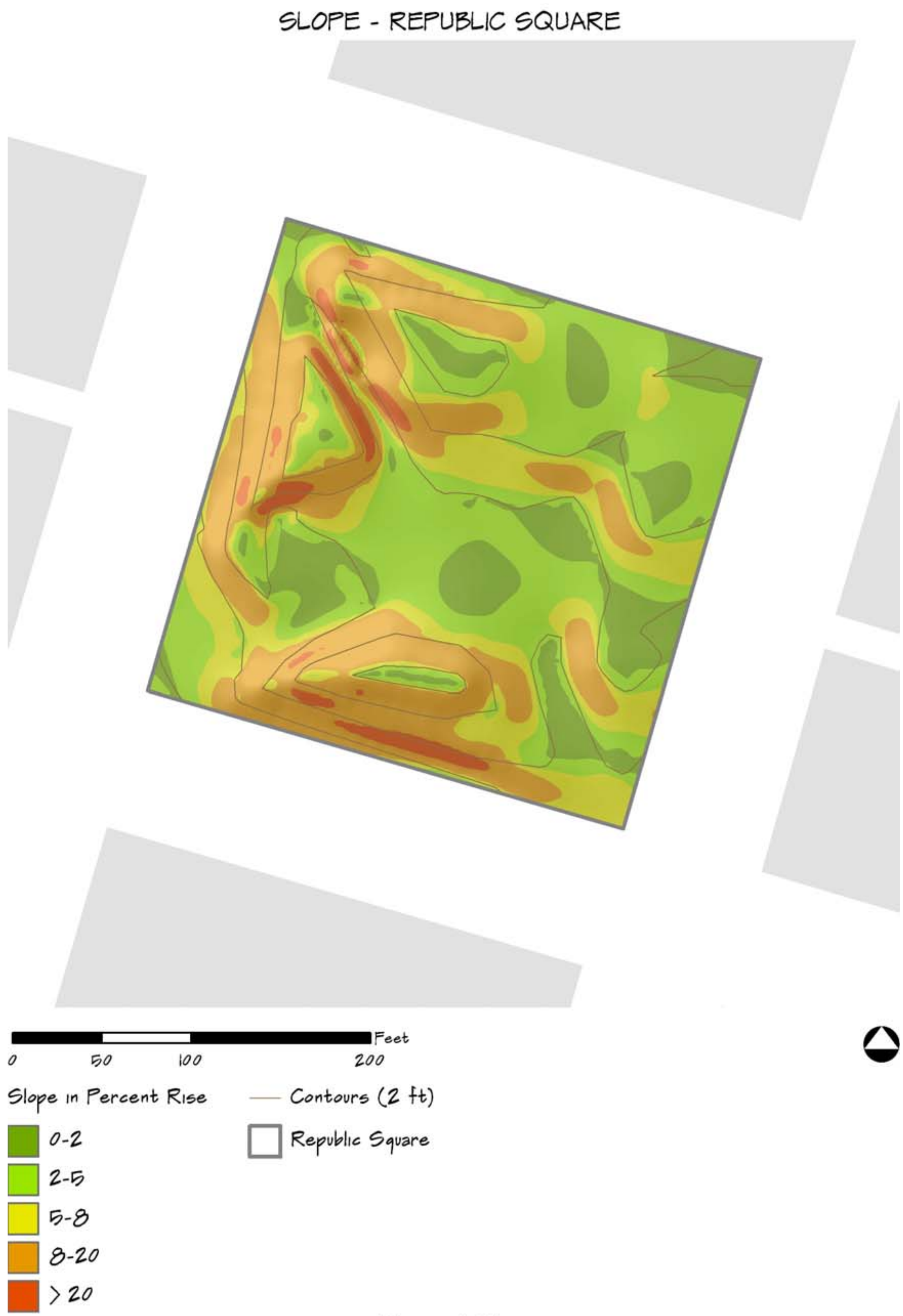
SLOPE - REPUBLIC SQUARE
Feet
0
50
100
200
Slope in Percent Rise
0-2
2-5
5-8
8-20
> 20
Contours (2 ft)
Republic Square

Figure 4-31

Change

Change Analysis is often difficult to produce due to the lack of historical data at dates applicable to the project at hand. When historical data is available, change analysis can be used to determine the impact or results of an action or event or to anticipate future conditions or needs (Mitchell 99). In the case of urban design, identifying the trends in changes to the urban landscape can influence how a designer can approach a design in an effort to either support or inhibit the future development of these trends.

At Republic Square two datasets were obtained with historical data available as well: from the City of Austin, Land Use in 1995 and 2003; and from the U.S. Census Bureau, Census Population from 1990 and 2000. The former are qualitative datasets that describe the character of features by their land use, while the latter are quantitative datasets that describe the magnitude of features by population figures. As a result, each change analyses for the two types of data are uniquely mapped.

Figure 4-32 represents land use in the Republic Square catchment area in 1995 and 2003. Two maps in this figure display the same quantitative information about the character of the catchment area land use but separated by eight years. Changes appear to be subtle and require close attention to detail by the viewer, an issue to be rectified in the next section discussing statistical summary.

Figure 4-33 represent the change in population in the Core Downtown area between 1990 and 2000. One map displays quantitative and measurable changes in population figures between two dates as expressed by percent increase or decrease for each census block. Census blocks with population of zero in 2000 are omitted as mathematically they cannot be expressed using the percent change formula.

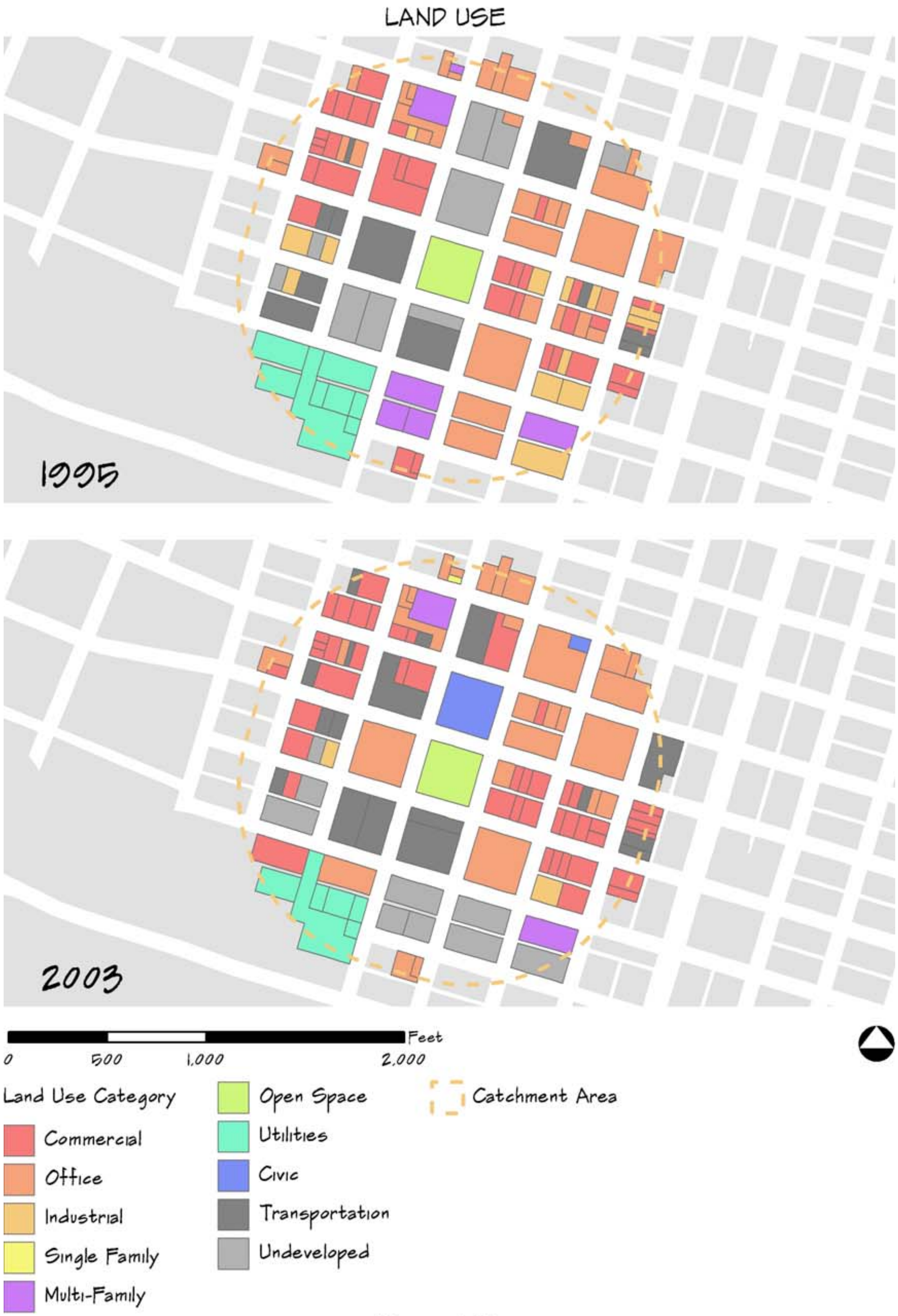
LAND USE
1995
2003
Feet
0
500
1,000
2,000
Land Use Category
Commercial
Office
Industrial
Single Family
Multi-Family
Open Space
Utilities
Civic
Transportation
Undeveloped
Catchment Area

Figure 4-32

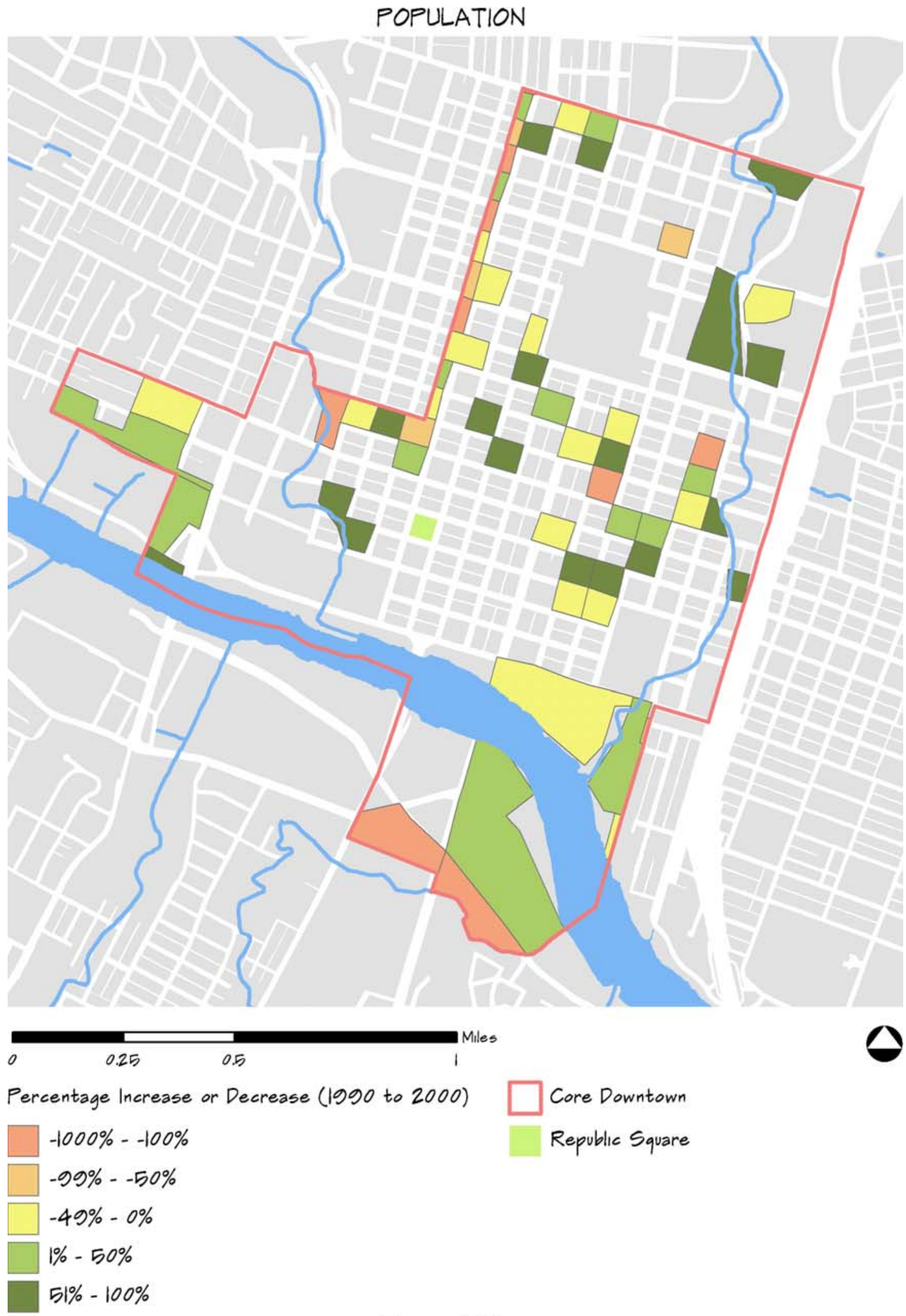
POPULATION
Miles
0
0.25
0.5
1
Percentage Increase or Decrease (1990 to 2000)
-1000% - -100%
-99% - -50%
-49% - 0%
1% - 50%
51% - 100%
Core Downtown
Republic Square

Figure 4-33

Statistical Summary

Statistical summary analysis simplifies database information into a smaller table by summarizing features that belong to a group or category, so rather than viewing the specific information about each individual feature the analyst can see the big picture. For example, identifying patterns and relationships in land use by viewing a database of thousands of individual parcels is near impossible, but running statistical summary on land use parcels using their category classification simplifies the task to a table with a manageable set of records. Statistical summary can summarize both quantitative data and qualitative data – land use categories can be expressed in a field representing the count or frequency of each category by number of parcels, or the area of each category can be summarized by the total, average, minimum and maximum square footage for all parcels.

Tables 4-2 and 4-3 are both the result of statistical summary analysis on land use within the Republic Square catchment area and the Core Downtown area, respectively. Table 4-2 uses the land use category field to summarize the total square footage of each land use in both 1995 and 2003. Similarly, Table 4-3 uses the land uses category field to summarize the total square footage of each land use category for the Core Downtown area in 2003.

Table 4-2 Catchment Area Land Use in 1995 and 2003

Land Use Category	***1995 Square Footage***	***2003 Square Footage***
Commercial	361,508	473,532
Office	557,081	615,302
Industrial	153,746	26,479
Single Family	0	2,302
Multi-Family	143,145	68,194
Open Space	75,993	75,993
Utilities	223,536	150,439
Civic	0	82,921
Transportation	302,191	356,218
Undeveloped	276,061	241,880

Table 4-3 Core Downtown Land Use in 2003

Land Use Category	***2003 Square Footage***
Commercial	4,521,868
Office	9,914,438
Industrial	727,140
Single Family	217,174
Multi-Family	1,165,908
Open Space	2,484,095
Utilities	737,270
Water	3,122,451
Civic	4,729,898
Transportation	3,303,862
Streets	13,785,279
Undeveloped	1,263,084

Comparatively, Table 4-2 to many viewers may clarify the changes in land use between 1995 and 2003 in the Republic Square catchment area to a much greater extent and with greater ease than by viewing the change analysis map discussed previously (Figure 4-32). Likewise, viewing the land use square footage figures for the Core Downtown area (Table 4-3) as a list can be a greater aid when the question relates to "how much", as opposed to "where is it" represented by Figure 4-7.

Statistical summary tables can further enhance inventory or spatial analysis maps when they are used to produce charts and graphs. As a second resource for communicating the results of inventory and analysis, charts can often clarify data to a greater degree than maps when the geographic or spatial relationship of features is of less importance. Figure 4-34 and 4-35 represents charts produced from Tables 4-2 and 4-3, respectively. It is arguable whether statistical summary tables and charts carry weight as spatial analysis on their own: however, when used in conjunction with inventory and spatial analysis maps, these non-spatial representations greatly enhance the intended message of site analysis results.

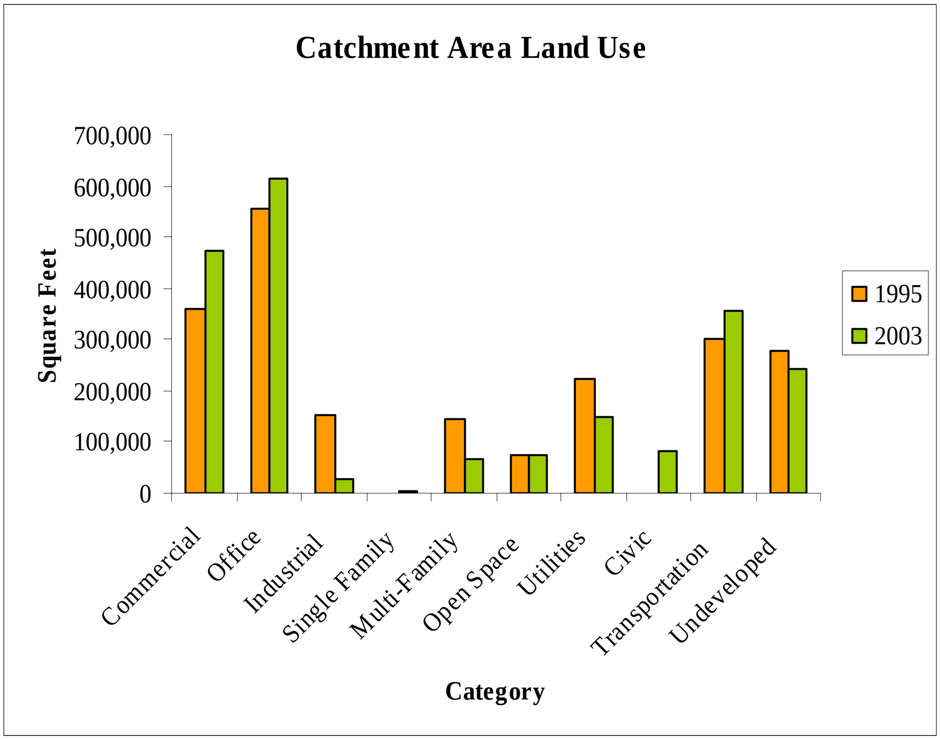

Figure 4-34

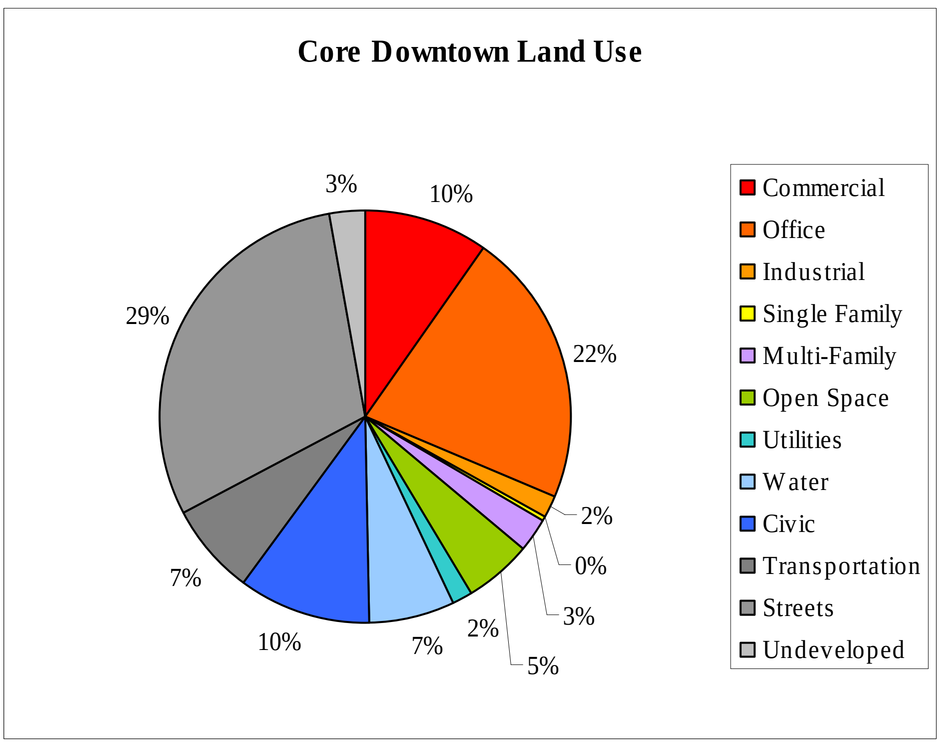

Figure 4-35

Overlay Operations, Reclassification, and Raster Math

Overlay operations, reclassification, and raster math analysis are all powerful spatial analysis tools for use in projects where site selection and suitability modeling are applicable. However, for the revitalization of Republic Square, a pre-existing site in a dense, built-up urban environment, these tools are generally not applicable.

Overlay operations, such as union and intersection, essentially deduce from two or more datasets the locations of features that meet either location or attribute criteria – a technique well-suited for site selection. Reclassification, when used in its typical fashion for creating a hierarchy or ranking of values, is an important step in determining the suitability of a site for intended uses – again, as a means for site selection. Raster math is not applicable to Republic Square for two reasons: first, the lack of raster type data available, and second, the use of raster math analysis is better-suited for environmental applications in suburban or rural areas.

It is not the intent of the author to imply that these three tools are not applicable to design of urban open space, but simply to state that an attempt to apply these techniques to Republic Square would be ill-suited.

CHAPTER V

CONCLUSION

Summary of Findings

Design Process

The first research objective of this study was to examine the traditional site design process of urban designers and determine the applicability of GIS functionality as a resource to this process. Figures 3-1, 3-2, and 3-3 represented diagrams of the traditional site design process, the Geddesian planning method, and the traditional site design process with a cyclical and reiterative sequence, respectively. In order to facilitate the discussion of the application of GIS in the design process, a new diagram (Figure 5-1) has been conceptualized by the author:

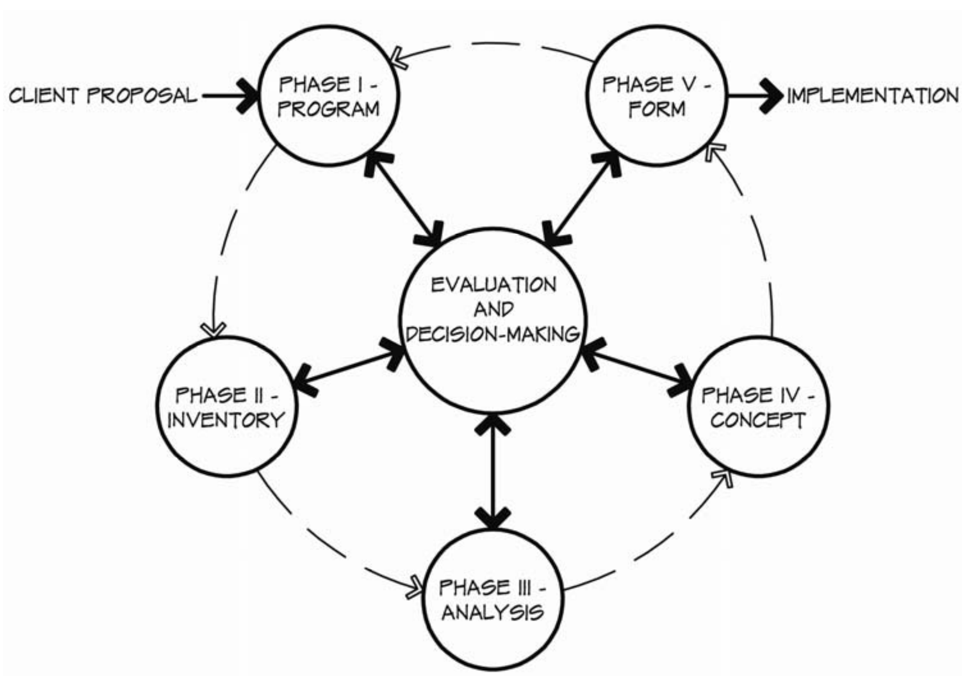

Figure 5-1 Design Process with Intermediary Evaluation and Decision-making Phase

Figure 5-1 represents the traditional site design process with a cyclical and reiterative sequence, similar to Figure 3-3, but with important conceptual differences. This diagram shows the same five phases of the process – program, inventory, analysis, concept, and form – with the inclusion of a new intermediary step, an evaluation and decision-making phase. This diagram is also graphically represented cyclically and therefore it is important to recognize the entry and exit points of the cycle: the client proposal and design implementation, respectively.

This study has demonstrated the application of GIS functionality for use in the inventory phase by thematic mapping, and the analysis phase by spatial analysis tools. However, GIS can also directly or indirectly influence and aid the development of all phases of the process as a resource in the intermediary evaluation and decision-making phase. The ability to manage and synthesize voluminous and complex information for analysis and visualization makes GIS a powerful and flexible decision-making support tool (Al-Kodmany 2000, Putra, Wenjing and Yang 2003).

Site Analysis

The second research objective of this study was to examine traditional and GIS-based analysis methods and techniques in an effort to determine the applicability of GIS spatial analysis tools to aid and enhance the site analysis phase of the design process for urban sites. The goal of the site analysis phase is to synthesize the inventory and identify the opportunities and constraints posed by the site conditions. The result of this analysis is typically a single composite map addressing the factors influencing the suitability of the site for specific uses.

The three methods of site analysis typically employed by site designers include analytical diagramming (sketches and maps), suitability analysis (McHargian overlay technique), and non-spatial analysis (lists, matrices, charts and graphs). All three of these methods can be in some manner mimicked or duplicated by GIS. However, many factors dictate whether a traditional or GIS-based approach is better-suited for a specific site analysis such as project time and budget, or GIS data availability and scale.

The first method, the analytical diagram, is a simple, abstract representation such as a sketch or map of site conditions using symbols, hatches and anecdotal notes. In a similar manner, GIS thematic maps deduce real-world phenomena into points, lines, polygons, and raster surfaces, but also with the functionality to add graphic symbols and text. However, GIS thematic mapping undoubtedly enhances the analytic capabilities of analytical diagramming through GIS spatial analysis tools.

The second method, suitability analysis based on the McHargian overlay technique, is rarely applied in the same manner today as McHarg did in his time through the use of shaded acetate sheets. However, this technique is widely applied and accepted today by planners and landscape architect through the use of GIS technology (Hanna and Culpepper 1998). Though suitability analysis is often not applicable in urban design due to the conceptual framework of the technique and the nature or urban sites, when applicable it is unarguable that GIS-based suitability analysis is superior to the outdated technique utilizing shaded acetate sheets.

The third and last method, non-spatial analysis, utilizes lists, matrices, charts and graphs to represent qualitative or quantitative data in a non-geographic manner. Though GIS is not intended as a means to produce lists and matrices, it certainly can aid in the data management and synthesis of the information informing these products. GIS does have the ability to produce charts and graphs, though whether GIS or traditional spreadsheet and database software applications are superior for this process is certainly arguable. However, the ability to deduce large datasets, some of which that might only be found in a GIS format, into simple tables using the statistical summary tool enhances the urban designer's ability to comprehend the voluminous and complex information considered in urban design.

In addition to these three general methods of site analysis, ten specific GIS spatial analysis tools were examined: queries, proximity analysis, density analysis, 3D visualization, topographic analysis, change analysis, statistical summary, overlay techniques, reclassification, and raster math. All of these tools, either in concept, principle, or methodology were applied in the urban realm by urban geographers before the development of GIS technology. However, the same processes applied without the aid of GIS unquestionably lack the ease, speed, and accuracy of GIS-based spatial analysis methods and techniques.

Urban Design

The third and final research objective of this study was to examine selected classic urban design theory in the landscape architectural tradition and determine the applicability of GIS spatial analysis tools as a means to analyze the key dimensions of urban design. The work of Camillo Sitte, Sir Patrick Geddes, Kevin Lynch, Jane Jacobs, and Ian McHarg each focuses on unique but interrelated dimensions of the urban landscape, all of which are crucial toward the success of urban sites. At all scales –

parcel, block, district, or city-wide – urban designers must consider the morphological, ecological, functional, social, and environmental concerns during the design development of urban open space.

Camillo Sitte was primarily concerned with the both the built and natural character of the city, in terms of its visual and functional character and its form. As a means for analysis Sitte traveled to notable urban areas in Europe and simply observed and sketched, often using the technique pioneered by Giambattista Nolli known as figure-ground mapping. Developing a figure-ground map in GIS is a simple map-making task that does not require any spatial analysis functions. By using a building footprint layer overlaid on a parcel layer a clear depiction of the urban form and pattern can be achieved. In fact, with just three layers – street centerlines, parcels, and building footprints – most questions relating to urban form, pattern, and circulatory functions are answered.

Sir Patrick Geddes was primarily concerned with the ecological relationship of the social life of cities and the natural patterns of the landscape. He encouraged a holistic and systematic approach to urban planning where regional character would influence decisions at the local scale. On many levels, both conceptually and pragmatically, GIS is fundamentally well-suited to address the concerns of Geddes regarding social and environmental relationships at local and regional scales. Whether using density or change analysis to determine trends in socio-economic demographics, or topographic and proximity analysis to determine the spatial relationship of the natural environment to the cultural features of urban areas, GIS spatial analysis is a means to relate the regional context of urban design to sites as small as a parcel. Furthermore, the systematic approach of Geddes – survey, analysis, plan – conceptually mimics the geoprocessing model of most GIS analyses.

Kevin Lynch was primarily concerned with the physical and structural elements of the city that influenced the public perception and overall legibility of the urban environment. Through an aggregation of “mental maps” developed from surveying inhabitants of urban areas, Lynch created a diagrammatic representation of the ‘public image’ of the city. In addition to the this survey, Lynch also had an independent field analysis of the same area conducted by a train professional upon which he compared the public image to in an effort the determine the accuracy and ultimate legibility of the city. However, in Lynch’s own words, “the independent field analysis predicted rather accurately the group image derived from the interviews (Lynch 1960).” Considering that GIS is a diagrammatic representation using points, lines, polygons and other symbols to portray the real-world environment, and that many GIS datasets are available depicting the urban environment, it is reasonable to for a trained, professional urban designer to utilize GIS as a means to develop a basic understanding of the paths, nodes, landmarks, districts, and edges that are likely to shape the public’s “image of the city.”

Jane Jacobs was primarily concerned with the socio-functional character of urban neighborhoods and the stimulating factors that encouraged urban vitality. Jacobs encouraged a street-level, people-oriented approach that questioned who is using urban open space, and what are they doing? The three criteria Jacobs defined as necessary qualifiers for urban vitality were size, density and diversity. In the opinion of the author, GIS spatial analysis is best-suited to analyze the concerns of Jacobs more so than any other urban theorist discussed in this study.

When analyzing the size of the urban neighborhood, in terms of geographic extent and magnitude of inhabitants, an urban designer can utilize demographic and morphological datasets to perform queries, proximity analysis, density analysis, 3D visualization, change analysis and statistical summary – all of which aid in determining geographic trends and spatial relationships that define neighborhoods and their size. When analyzing the density of urban neighborhoods, in terms of people and buildings, an urban designer can utilize demographic and building datasets to perform queries, proximity analysis, 3D visualization, statistical summary, and of course density analysis – all of which aid in determining the density of urban areas. When analyzing diversity, in terms of people, land uses, and activities, an urban designer can utilize demographic and land use datasets to perform queries, proximity analysis, density analysis, and statistical summary – all of which aid in determining both the diversity and spatial distribution of people and activities.

Ian McHarg was primarily concerned with the environmental and ecological factors of urban design that directly influenced sustainability and conservation. McHarg's unique suitability analysis technique used bio-physical factors of sites to determine the most fit uses and areas for development – a model which would serve to be crucial in the development of GIS technology. However, many sites in downtown, built-up, dense urban environments are not sensitive or susceptible the kind of bio-physical factors McHarg analyzed in city-edge or urban fringe applications in more suburban or rural locations. But when applicable, GIS datasets such as elevation, hydrography, flooding, and land cover, whether at the city-core or city edge, can be used to perform queries, proximity analysis, topographic analysis, and even reclassification, overlay operations and raster math to determine the effect of the environment on the proposed design, but more importantly the proposed design on the environment.

Critical Analysis

Two limitations impact this and all applications of GIS spatial analysis for the design of urban open space – the first, data availability, is a practical limitation, and the second, analysis scale, a conceptual limitation. That is to say that the former is surmountable, while the latter is not.

Table 3-2 lists the typical attributes inventoried for analysis in urban design, while Table 4-1 represents the available GIS datasets for the Republic Square analysis area. Clearly, the available data does not reflect the depth and range of the inventory necessary to inform a comprehensive analysis. However, it is important to note that while this has much to do with the nature of GIS data, even traditional site analysis methods that do not utilize GIS technology would be hard-pressed to obtain the inventory information from Table 3-2 in its entirety.

The most notable urban design attributes that are rarely found as a GIS dataset include information related to buildings and streetscapes. An inventory of building form, condition, and architectural character is preferred for urban design in the landscape architectural tradition, but certainly mandatory in the architectural tradition. Of greater importance to urban design in the landscape architectural tradition is the lack of GIS data regarding critical components of streetscapes – namely sidewalk widths and functional character. While transportation datasets often include vehicular traffic attributes such as speed, volume, and functional use, this type of data is seemingly non-existent for pedestrian sidewalk traffic.

The second limitation to GIS spatial analysis for the design of urban open space relates to the scale at which GIS data is available, and more importantly, the minimum scale at which GIS spatial analysis produces meaningful information. GIS data is available in two distinct formats: vector format, consisting of points, lines, and polygons, and raster format, a grid of cells or pixels that form a continuous surface. While scale has less impact conceptually on the attributes of points and lines, the scale of polygon or raster-based attributes has a critical impact on the suitable scale of analysis.

Polygons, as well as raster cells, contain attribute information that is assumed to hold true for the geographic extent of that individual feature, whether a land use value for a parcel or an elevation value for a raster cell. Therefore, the scale of the data dictates the scale of the analysis. If the project site does not extend beyond a single parcel, GIS spatial analysis using data at the parcel scale can only determine the spatial relationships, patterns, and trends of the project site parcel to the surrounding parcels – nothing will gained in terms of the site conditions within the parcel.

Understanding the difference between “parcel to parcel” analysis and “intra-parcel” analysis is crucial for urban designers transitioning from traditional methods of site analysis to GIS-based spatial analysis methods. Traditional site analysis methods rely heavily on the relationship and interplay of intra-site attributes, with less emphasis on the contextual, “parcel to parcel” conditions. In this regard, GIS spatial analysis does not wholly replace traditional methods, but rather aids and enhances the traditional process at a scale beyond the project site.

Future Directions

The primary focus of this study was to bridge a gap both theoretically and practically between GIS technology and urban design. Specifically, this study aimed to determine the applicability of GIS spatial analysis tools to aid and enhance the traditional design process and site analysis methods of urban designers in the landscape architectural tradition. However, despite the many interests and concerns discussed insofar, urban design is at the heart of this study.

GIS, whether used for data management, visualization, or analysis, offers unique resources to the process of urban design. However, GIS technology is just one part of a broader family of resources under the umbrella of what is known as geospatial technology. Geospatial technology encompasses all resources for the management, visualization, and analysis of geographic information, including GIS, GPS, and remote sensing technologies. More recent additions to the geospatial technology family include software such as Google Earth and Google SketchUp, both of which provide unique opportunities for extending the functionality of traditional geospatial technologies.

In the opinion of the author, the practical limitations of GIS spatial analysis for the design of urban open space caused by a lack of data are surmountable, but only through future research into the applicability of geospatial technology as a resource to the urban design process. Each aspect of the technology - GIS, remote sensing, GPS, Google Earth, and Google SketchUp - is growing more and more interrelated and thereby providing more of the data management, visualization, analysis, and most importantly data acquisition functionality urban designers need in order to comprehend the complex and voluminous information considered in the process of urban design.

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