Informing Planning Decisions through GIS Documentation of San Antonio's Historic Colonial Landscape

Azza Kamal, Angela Lombardi, Shelley Roff, and Betzaida Pollet

Abstract

The city of San Antonio, Texas still retains a bold imprint of the Spanish colonial intervention, with the core of the city demarcated by a series of linear irrigation channels begun to be built around 1718, known as acequias. Using Geographic Information Systems (GIS), this paper develops the first digitization of historical surveying maps to document the historic landscape and identifies different colonizing features, which had greatest impact on the development of San Antonio's urban fabric. Results establish a tool to guide policies for urban regeneration and heritage tourism implementation around the traces of the historic landscape. The digital model produced supports heritage management professionals and offers a prototype approach for documentation methods and management of the National Historic Trails.

A. Kamal (Corresponding author) • A. Lombardi • S. Roff • B. Pollet
College of Architecture, Construction and Planning, The University of Texas at San Antonio, San Antonio, TX 78207, USA

Email: azza.kamal@utsa.edu;
Email: angela.lombardi@utsa.edu;
Email: shelley.roff@utsa.edu
Email: bpollet@bcad.org

1. Introduction

Maps are a visual key for communication with land use planners and historic preservation professionals. As a powerful analytical tool, historical maps can provide the foundation for a successful integration of historical evidence with existing physical structures such as urban patterns, buildings, fluvial and landform geography. For more than two decades, historians and archeologists have intertwined maps and digital tools using computer platforms to yield solutions and to inform policies for urban management and analysis of historic districts, a means to preserve the existing and uncovered traces of historical features. Graphic products, encompassing both maps and tabulation data sets, can provide the technical and visual tools and hence serve as a communication bridge to overcome the conceptual differences that often isolates the humanities and social science branches of the historic preservation field from in its more scientific counterparts. (Limp, 2000). Cartographic products are not only important component in urban management and historic preservation applications, they can also serve an important role in spatial exploratory data analysis (EDA), which is defined as the use of a variety of graphic methods to display visual, complex structures in data sets. A parallel method is provided by utilizing 2D and 3D GIS platforms to display complex data in its spatial domain. Through incorporating large data sets, GIS tools were utilized by Limp and Gisiger (1992) to prepare maps showing the spatial distributions of more than 941,000 archeological sites throughout the United States. Also, the work of the GIS lab at Arthur Temple College of Forestry and Agriculture's (ATCOFA) in East Texas provides another example for documenting National Historic Trails. William (2010) and his team used points surveys from the site to document a segment of the El Camino Real de los Tejas between Texas and Louisiana, supporting the NPS's development of a comprehensive management plan for the trail. Revealing previously undiscovered patterns of land forms, these mapping efforts immediately provide decision makers with important information.

In San Antonio, Texas, the historic core of the city still preserves visible remnants of the Spanish colonial intervention, whose agricultural, architectural and urban morphology manifest a prototype used for the foundation of frontier, colonial settlements established by the Spanish in the New World. This historic core is demarcated by a series of linear irrigation channels, known as acequias, whose construction began around 1718. The acequia system was essential aspect of colonial planning, since it provided the irrigation needed for the colonists' first agricultural endeavors. This paper presents the findings of the first phase of the Franciscan Missions (figure 1)of

the Camino Real project funded by the University of Texas at San Antonio and proposes the first digital documentation and management plan for the irrigation channels that contributed to the settlement patterns within the zone where the Camino Real de los Tejas passed through the city of San Antonio in the eighteenth century. The paper identifies specific colonizing landscape features with a focus on the acequia system as the first phase of the incremental formation of the Spaniards' settlements. It also explores the historical development of the acequias, and identifies the tool to guide planning policies and urban management of historic sites and to establish zones for heritage tourism near the historic traces of the acequia system.

With the help of computer technology, this paper, and the broader project encompassing the five Franciscan missions, advances the method of documentation and the analysis of historic sites, well beyond previous endeavors to study San Antonio's Spanish colonial landscape. Our research team utilized (GIS) to examine the correlations between acequia pathways and modern land uses where traces of the acequias are yet to be uncovered by archeological research, and offered policy recommendations to preserve this zone through a management plan coordinated between municipal agencies. Through a virtual and interpretative approach of the historical sources including surveying maps and archival documents, the documentation process uncovered the potential archeological sites of the acequia system in areas currently inhibited both by residential and commercial activities, pressing for an intervention through an urban management plan.

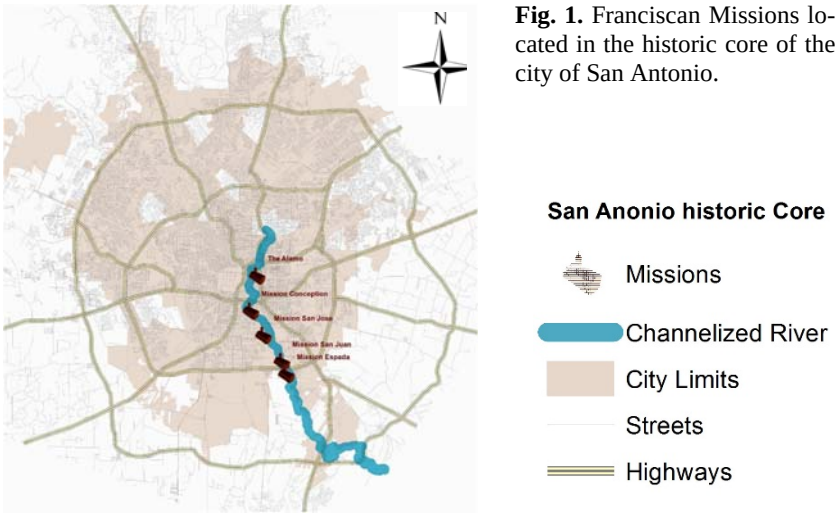


Fig. 1. Franciscan Missions located in the historic core of the city of San Antonio.

1.1 Documentation of Historic Sites

Digital documentation of historic sites can improve the linkages of research on site characteristics and patterning with the management of the historic resources. Williams and his associates assisted a large military base to evaluate almost 2,000 pre-historic and historic sites to identify the similarity in the sites in both the material and spatial domain (Williams et al. 1990). Williams dealt with a large data set including 50 to 100 different observations about site properties, and utilized GIS and linked robust exploratory data analysis software to assess the sites. Each of the 2,000 sites were integrated in the GIS model, and the GIS analysis contained more than three dozen environmental data layers. Rather than organize sites by the traditional categories of "village", "bluffshelter", etc. the researcher defined more than two dozen categories that integrated both site attributes and landscape properties. Analytical sorting of all site were used to organize the 2,000 sites into different classes to facilitate the management. After categorization of the sites, each group of similar sites were managed as a population instead of individuals. Using GIS, the distribution of sites in each group was compared to land use at the installation with the goal of determining what changes could be made that would maximize the preservation of representative sites from each group while minimizing the effects of installation activities. Conversely, in the event that a site risked a serious impacts, its uniqueness and the distribution of other similar sites could be assessed. (Limp, 2000). Results of this research entailed identifying a series of complex patterns among the sites between the sites and the landscape. (Williamson, et al., 2000).

In a comparative method used to document the journey of the Spanish explorer *Hernando De Soto* during his explorations in the Southern U.S. in 1541-42th, Limp (1990) examined the alternative route that *De Soto* might have taken through the Ouachita Mountains and compared the visual traces of these routes with the written reports left by the *entrada*. Caffney and Stancic (1991) used least cost routing, a method used to investigate site suitability as pathways to travel between Creek colonial outposts on the island of Hvar and nearby watchtowers. (Limp, 2000).

Utilizing the geospatial technologies of remote sensing and GPS in addition to archaeological research of existing trail resources, a comprehensive GIS analysis enhanced the approach's credibility in the collection, storing, and validating of historic and existing trail resources of El Camino Real De Los Tejas. Both the development of a geodatabase and route's verification strategized the preparation of the trail's comprehensive management plan, which in turn assists with the protection of trail resources (Williams, 2010).

In light of these examples, the digital model produced for San Antonio's historic core stands out as an invaluable resource for heritage management professionals both in public and private sectors.

1.2 San Antonio's Historic Landscape

Between the sixteenth and the eighteenth centuries, Spaniards embarked on a complex process of settling the northern frontier of New Spain (Habig, 1968). Three major caminos were established by Spanish explorers and missionaries in the 1700s, whose purpose was to connect the government in Mexico with its northern territories. The Spanish set forth to settle these regions in order to protect their silver mines further to the south and their trading centers to the north from British and French competitors. The 2500-mile long Camino real de los Tejas was a branch of the main road heading out of Mexico City that branched off towards Saltillo, then northeast towards Monterey, Laredo, San Antonio, Nacogdoches and across the Louisiana border at the Sabine River. Military, religious and mercantile factors participated in this process of settlement. The Franciscans friars arrived and built their missions with the intent to evangelize indigenous people and to strengthen the northern border of New Spain against the French and British presence (Turanzas, 1961).

The Franciscans, a powerful contender in the development of this frontier, developed a formula for their settlements where the construction of self-supporting mission complexes and land exploitation were key features. They maintained traditions of some earlier sixteenth century architectural features, such as the mission church, and introduced new elements such as fortified walls to defend the mission enclosure and established irrigation systems. The five San Antonio missions are important prototypes of this frontier pattern. The cultural landscape around the five missions and the San Antonio urban pattern also retain elements of the eighteenth century presidio, founded in 1718 and civil settlements, such the villa San Fernando, founded in 1731, as well as la Villita, located on the west side of the San Antonio river. The missions, presidio and villa created a complex and dynamic settlement network with the potential of becoming a big city settlement (Dominguez, 1989).

Spanish missionaries and colonists constructed a series of hand-dug ditches, which included dams and slew skates, the acequias, serving to bring river water to the missions' and to the civic settlements' land. They are considered some of the earliest recorded engineered water systems in the nation,

shaping the landscape for more than two centuries. A system of eight acequias related to the San Antonio River was constructed since 1718, and functioned as an effective water distribution system for nearly 200 years, allowing the irrigation to surrounding land for farming and pastures both for mission residents and for civilians. Following the Missions secularization, since 1794, the agricultural land of the Missions was subdivided into agricultural plots known as the suertes, which were outlined perpendicularly to the irrigation channels – the acequias – for providing the necessary water for irrigating the different properties. The acequias, also providing potable water together with some creeks and the river, allowed the growth of this dynamic settlement network into a contiguous urban settlement. The historic urban landscape of the city is currently shaped by Colonial acequia landscape, with nineteenth century historic neighborhoods overlapping the colonial land subdivisions, mostly with same orientation and patterns.

The historic urban landscape of the city is shaped by Colonial acequia landscape with nineteenth century historic neighborhoods overlapping the colonial land subdivisions, mostly with same orientation and patterns. An in-depth investigation of these missions, the relationship between the different missions and with other structures along the border, such as presidios, forts or pueblos, the construction of the acequias and their distribution along the San Antonio River, will illuminate how the Spaniards established their dominion over the northeastern frontier in the eighteenth century. The current project focuses on the historical development of the acequia system of San Antonio's five missions. Existing acequias in the areas of the missions San Juan Capistrano and San Francisco de la Espada are currently protected and managed by the National Park Service. However a complete assessment of condition and vulnerability of the undiscovered acequias and other features of the Colonial landscape still need to be carried out through archaeological documentation in order to effectively complement the preservation efforts of the city of San Antonio. A comprehensive urban management plan for the eighteenth century Colonial landscape should also be developed in order to define strategies for preservation and enhancement.

2. Methodology

In order to examine the relationship between the historic landscape attributed to the eighteenth-century acequias and the modern urban fabric and land use, a documentation of the historic landscape features including

acequias and historic forms of land subdivisions, was completed by our research team. The process also included digitizing the different segments of acequias including different names, and category (primary or secondary); and carefully verifying their locations in order to generate a digital model for the acequias as they were built. Following acequias digitizing, the zone expanding on both sides of the acequias that could be integrated in a management plan as an urban regeneration zone was examined. Three primary phases encompassed the documentation, including: I) identifying sources for historic surveying maps; II) digitizing different landscape features as surveyed in the historic maps with a focus on the acequia segments, and III) generating a digital map using GIS with an imbedded database of the landscape features with a focus on acequias. A digital model was created for the eighteenth-century acequia system by analyzing the desired zone to either side of the channels. An overlay of modern land use patterns was included, thus enabling an analysis of the intersection between the two historical layers, as explained next:

2.1. Data Sources

Historical surveying maps and archival documentation from the early eighteenth century to the early twentieth century were acquired from various sources found in the US, Mexican and Spanish archives. The Spanish Archives, a part of the Bexar County Archives, and the City of San Antonio Municipal Archives were fundamental for identifying the parceling and distribution of lands surrounding the acequia system to Native Americans at the point of the secularization of the five San Antonio missions in the late eighteenth and early nineteenth centuries. In addition to this, the Old Spanish Missions Collection at the Our Lady of the Lake University in San Antonio provided historical documentation in the form of photocopied collections from a substantial number of archives in Mexico. Historical surveying maps from different sources were scanned/or downloaded and saved as JPEG files to incorporate in the digitization of the historical landscape features (see Table 1).

Maps were analyzed for accuracy, comprehensiveness, reliability, and legibility. Based on preservationists' orthodox tools in data verification, an accuracy scale was calculated for each of the nine maps listed in Table 1 using the number of features identified in each map (i.e. acequias, street names, Mission locations and their associated complexes, building footprints, etc.).

Table 1. Historical surveying maps and landscape features used in digitization

Source	Year	Landscape Features retrieved from surveying maps						
		Acequia	Street names	Missions	Building footprints	Land subdivisions/ Labores	San Antonio River	Presidio
First Acequia plan	1733					X	X	X
Sanborn maps	1896	X	X	X	X		X	
San Antonio map	1889	X	X	X		X	X	
Plat book maps	1840s-1880s	X	X	X		X	X	
Brown Book maps	n.d.	X	X	X		X	X	
Rullman map	1912	X		X		X	X	
Guirad map	1874	X		X		X	X	
Texas Civil Work map	n.d.	X		X		X	X	
San Antonio Nomination to the World Heritage List	2014	X		X		X	X	

The reliability was then estimated and linked to the cumulative accuracy scale of each source. The three sources (San Antonio 1889 map, Plat book map, and Brown book map) were designated as high accuracy sources, and consequently were highly reliable. However, due to the limitation of the areas they cover, other sources were utilized to fill in the data gap in order to regenerate a comprehensive San Antonio historic landscape map.

2.2. Digitizing Colonial Landscape Features

Structuring the Digital Database: The collection of historic maps from the above mentioned sources were scanned and stored in a geodatabase assembled for the project folder. Translations were made from archival documentation and from travelers' accounts, most importantly the accounts of Sargeant Martin de Alarcón in 1718 and Fray Juan Agustín Morfi who passed through San Antonio in 1778 (Morfi, 1967 and Céliz, 1933). These translations were analyzed for content relevant to our project and interpreted using open coding that is most appropriate for a simple content analysis. Open coding is a method to generate phrases and simple concepts from the complex qualitative data sources, and using these concepts to create more abstract categories (Babbie, 2001, Strauss & Corbin, 1998, and Punch, 2009). Using the term "acequia" or water channels as a thematic unit of analysis (Krippendorff, 2004), all keywords and concepts were categorized

into groups, and classified by theme (i.e. year, landscape feature, owner, condition, sourcec). All themes and their subcategories were transformed into a list, and added to the tabulation of their corresponding landscape layer by creating a new field in the attribute tables for each theme. Categories under each theme were manually added to the field.

Georeferencing and Verification: Scanned maps from the different sources were georeferenced using ArcGIS 10.2.2 (ESRI, 2014), and with the aid of multiple control points carefully selected to minimize distortion due to the low quality of the historic surveying maps (see figures 2 a & b). Control points were assigned to the corners of the urban blocks that maintained the form, proportions, and the same street names. Distortion errors were further corrected throughout the digitizing process by comparing blocks proportions and street names in the historic maps and the 2014 parcels data obtained from Bexar County Appraisal District. Using digitizing tools of ArcGIS 10.2.2 (ESRI, 2014), land subdivisions and acequia segments were crossed-checked for the reliability of paper maps. All acequias were digitized as a line shapefile encompassing all segments, and a tabulation of these segments was generated on GIS. To incorporate the different attributes of all segments (i.e. source of surveying maps, year, name, and definition), each segment of the acequia was included in the tabulation as a separate record, hence appeared in a different row. International Historic Documentation Standards were adopted to assess the quality of the surveying maps through using an accuracy scale for each landscape feature (RecorDIM, 2007). A 20% accuracy level for each map showed a minimum of three legible landscape features (streets, street names, land subdivisions).

Fig. 2. (a) left & (b) right. A scanned map with the distortion, and after geroreferecing/adjustment using control points.

2.3. An Approach for Creating Urban Regeneration Zone

Using the 2014 parcel layer, a land use map was created for areas located within the acequias' quarter-mile buffer. The buffer intersection with the land use was identified for the purpose of an urban management proposal as the Urban Regeneration Zone (URZ). Stretching from the northern part of the city's inner-loop to more than seven miles south of the inner-loop, URZ traversed the boundaries of 15 different Neighborhood Associations (NAs), and encompassed 12 different segments of acequias representing the formation and functions of the water channels (see figure 3). The old pathway of the San Antonio River, which was mostly aligned with the 1794 suertes, was channelized to form a more rigid pathway in the modern landscape of the city, particularly in the areas located within the NAs (see figure 4).

Fig. 3. Neighborhood Associations and the proposed acequias URZ

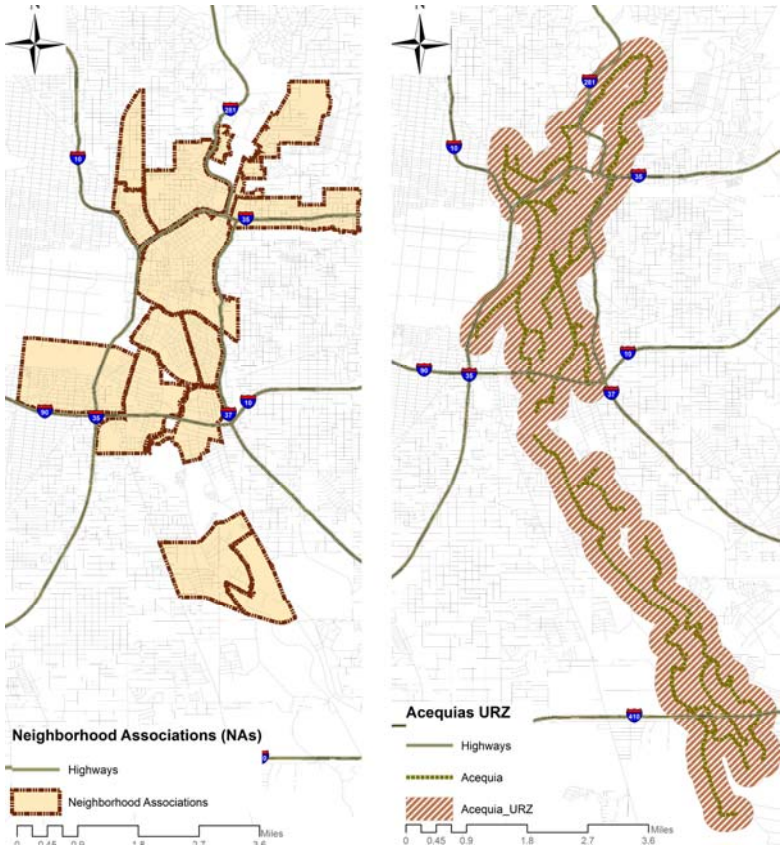
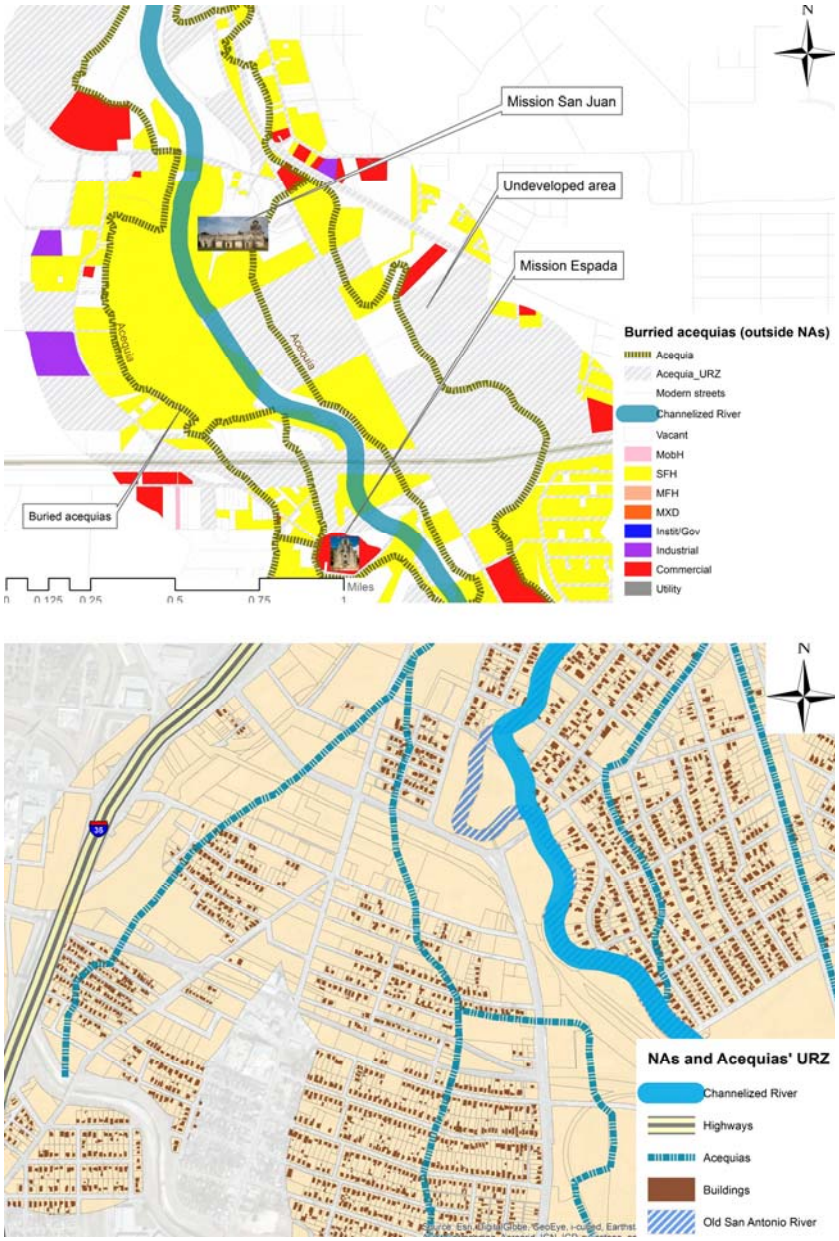


Fig. 4. Example of land use within Acequias URZ located outside the NAs (top), and inside NAs (bottom)



3. Urban Management

3.1. Morphology of Urban Regeneration Zone (URZ)

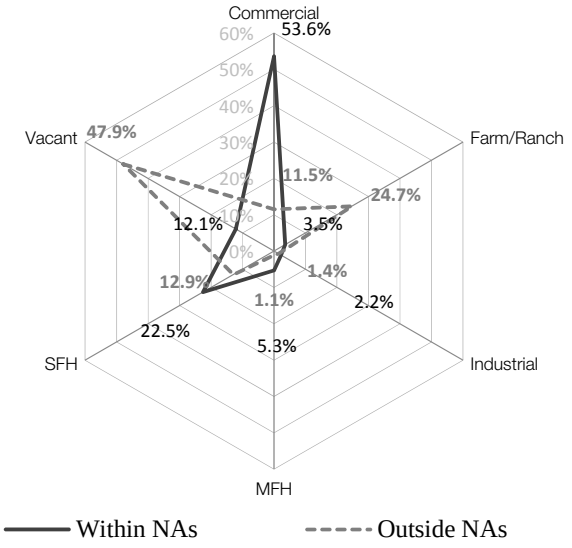
The historic urban landscape of San Antonio is the result of different patterns of exploitation phases overlaid throughout the history. Most of these patterns were utilized for agriculture – with the only exception of the central core of the city - during the Spanish Colonial period, and were subsequently urbanized during the course of the nineteenth century. The morphology of the nineteenth century urban expansion reflects the antecedent patterns of the suertes, acequias, and the old San Antonio River.

To examine the central core for regeneration, an analysis of the morphology of the areas located along the acequias was the priority for this paper, and a distinction between the areas located within NAs, and those outside NA boundaries was made. The digitized acequias encompassed two categories of irrigation channels: primary, which historic maps shown as channels linked directly to the old San Antonio River; and secondary, which transported the water from the primary acequias to the land, and represented by finer line types throughout the different historic maps. Both types overlaid a mix of San Antonio's historic patterns that was chronologically emerged since early eighteenth century. Historic patterns were primarily shaped by landscape patterns formed by the suertes, remaining city blocks in the core, in addition to regenerated subdivisions of modern blocks and streets. The zone spanning quarter-a-mile on each side of the acequia system, intersecting with different land uses, was separated by layer for further examination, and proposed as an Urban Regeneration Zone (URZ). Land uses overlaid the URZ were distinguished by location (inside vs. outside NAs). The significance of this distinction in analyzing land uses helps recognizing the impact of development type on the URZ. It also aims to stimulate a neighborhood-tailored policy for urban management of land and infrastructure through the administrative structure of each neighborhood. Using parcel-level data, percent of land uses of the acequias' URZ, was calculated (see figure 5), and land uses weighing less than 1% of the total parcel acreage were omitted from this analysis.

The results of land use analysis revealed a contrast between the percentage of commercial and residential activities of URZ inside NAs, and the concentration of vacant sites in the areas of URZ outside NAs. While more than 81% of the parcels within NA boundaries were used for commercial

and residential activities, only around 25% of parcels outside NAs were allocated to the same activities. Vacant parcels, whether designated as farm or ranch or just vacant, represented slightly over 15% of the total land use within NAs territory, and on the contrary accounted for 72% of the total land use outside NAs

Fig, 5. Percent of land use acres intersecting with acequias URZ, within and outside the Neighborhoods Associations (NAs).



3.2. Approaches to Land Management

The management of the historic urban landscape requires a strong corpus of interdisciplinary and innovative planning instruments, strictly connected with the local context. Conservation of urban and landscape heritage has emerged due to its importance as a component of public policy, and is dealt with as a response to the need to preserve shared values. In order to undertake a land management plan for the historic urban landscape of San Antonio, with a focus on the URZ identified in this paper, it is recommended to adopt the most recent standard-settings of the Historic Urban Landscape issued by UNESCO (2011). Appropriate technical instruments need to be developed to observe, document, and protect the integrity and authenticity both of architectural and urban features. Different tools need to be incorporated

to monitor and manage changes in order to promote quality of life without burdening the legacy of the history of the urban context through the evaluation of cultural, social, and economic processes of urban and landscape values.

Tools adopted from UNESCO (2011) that could be applied to the URZ include:

- Civic engagement, including incorporating stakeholders views of their urban context, and the value and approaches of addressing the vision for preserving their urban landscape, patterns, and zone around the acequias.
- Knowledge and planning tools that recognize cultural significance and diversity, and at the same time, provide a managment framework that assures the improvement of the quality of life and the regenration of urban spaces within the URZ.
- Regulatory system using measures for the conservation and management of the tangible and intangible attributes of the urban landscape in the URZ (i.e. , social, environmental and cultural values).
- Financial capabilities through capacity building and support innovative income generating development, rooted in tradition. Promooting mixed-sponosorship using government and global funds from international agencies, private investments at the local level, and micro credit programs.

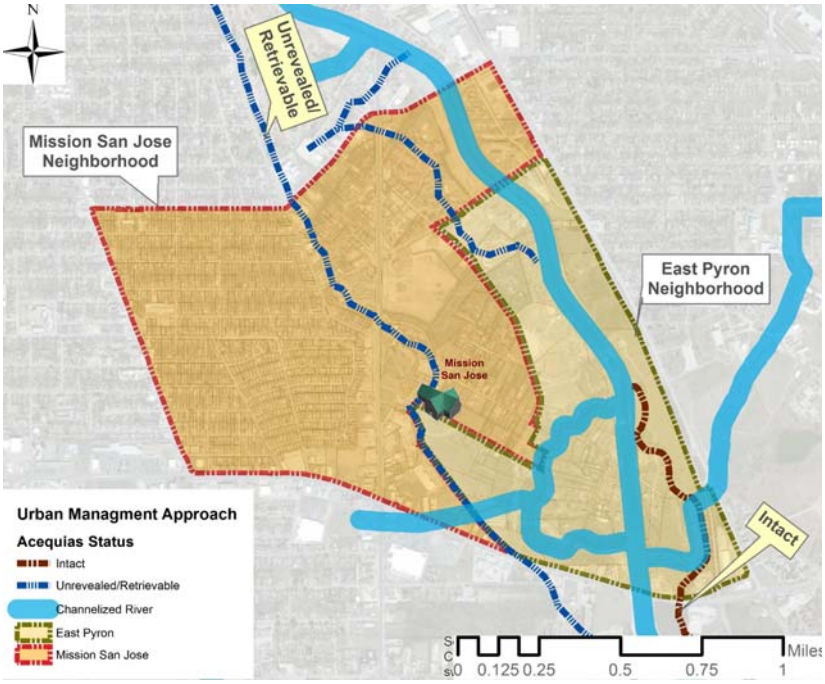
4. Conclusions

The digital documentation of the eighteenth-century irrigation channels –the acequias- and the analysis of land uses intersecting with the acequias' buffer zone resulted in:

- Nine different sources of historic surveying maps, ranging from the 1840s to 1912 were used to digitize the eighteenth century historic landscape of the city of San Antonio.
- Acequias built in the early eighteenth century encompassed 12 different segments representing the formation and functions of the water channels; serving agricultural activities as clean water irrigation channels and ditches for water overflows.
- The Urban Regeneration Zone (URZ) intersects with different land use patterns in 15 neighborhoods.

- The majority of parcels that have the potential for retrievable acequias are located within neighborhood associations with more than 81% use allocated for residential, both SFH and MFH, and commercial activities.
- Acequias spanning a total of 209,141 feet (63,746 meter) were digitized using nine different sources of surveying maps, which encompassed 33.2% intact structures and 66.8% undiscovered structures that could be retrieved through archeological research (see Figure 6).
- Areas within the URZ located outside NAs entailed 72% of land uses designated as vacant and farm/ranch.
- Unrevealed/retrievable acequias were digitized using an accuracy scale, ranging from 20%-80%. Further archeological research could use prioritized sites, mostly those with 80% accuracy, for excavation.

Fig, 6. Potential retrievable acequias within NA boundaries, conflict with existing structures, and accuracy level.



5. Recommendations

The significance of this paper lies in the successful integration of multi-layered digital information, and the application of visualization technology that uncovered the colonial pattern of settlements and the connections now made with the modern urban grid of the city. The geodatabase generated for the acequia system and the Old San Antonio River provides state of-the-art information for historians, preservationists, and planners regarding the history of Latino communities in Texas. It establishes an essential tool to guide planning policies for urban regeneration of historic neighborhoods and to implement heritage tourism around the remnants of the acequias. The discoveries within the Urban Regeneration Zone (URZ) identified the land use features, including type, and percentage, with high potential for uncovering acequias within them. Parcels intersecting with, or adjacent to, the rediscovered acequia system need to receive special designation for their historic values through preservation, monitoring, and recognition by future planning decisions. The geodatabase also stands out as an invaluable resource for the desired heritage management plan that needs to be administered by professionals both in public and private sectors. The plan, if incorporated by the National Park Service (NPS), will offer a prototype for subsequent implementation of documentation methods and management of the National Historic Trails.

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