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Examining Segregation Between Chinese and Euroamerican Residences Using Suitability Modeling Within the Built Environment at Terrace, Utah: A Case Study

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EXAMINING SEGREGATION BETWEEN CHINESE AND EUROAMERICAN RESIDENCES USING SUITABILITY MODELING WITHIN THE BUILT ENVIRONMENT AT TERRACE, UTAH: A CASE STUDY

by

Kelly N. Jimenez

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ABSTRACT

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by

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Utah State University, 2021

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Suitability modeling is a useful approach for exploring human interactions with their environments (Mitchell 2012; Malczewski 2004). Within a geographic information system (GIS) environment, locations are weighted relative to applied criteria, resulting in a landscape hierarchy that displays regions coded from least to most suitable. Suitability modeling is used in various disciplines, from urban planning to natural resources, but a gap exists in research concerning social human behavior. This method can especially contribute to the investigation of social inequality at archaeological sites by quantitatively assessing multiple attributes at an intra-site level. Examining intrasite spatial association and material distributions can inform on human behavior, including social organization (Earle et al 1984; Carr 1984).

In this thesis, I discuss the use of this method for determining social inequality at the historic townsite of Terrace along the Transcontinental Railroad in Utah, focusing on historic and archaeological evidence gathered in past research. My analysis shows that Chinese railroad workers lived amongst the least suitable regions of the site while Euroamerican railroad workers lived amongst the more suitable regions. By investigating social inequality at Terrace, I address various overarching questions: First, how does archaeological material within the site indicate segregation between the Chinese and Euroamerican cultural groups, and what is the nature of this segregation (voluntary vs. forced)? Second, how can spatial patterning of residential segregation at Terrace inform on nineteenth century urban planning and ethnic interactions within a larger context of American West expansionism along the Transcontinental Railroad.

Due to ongoing research on the Chinese occupation along the Transcontinental Railroad during the late nineteenth century, there is a multitude of historical and archaeological evidence supporting the presence of segregation and social inequality between the Euroamerican and other cultural groups, including Chinese immigrants (Voss 2018; Merritt et al 2012). By developing a spatial analytic method for documenting social inequality at Terrace, I hope that archaeologists can apply this technique in similar settings. In doing so, archaeologists can expand the suite of methods and theory used for analyzing social inequality and social hierarchies at archaeological sites.

(68 pages)

PUBLIC ABSTRACT

Examining Segregation Between Chinese and Euroamerican Residences Using Suitability Modeling Within the Built Environment at Terrace, Utah: A Case Study

Kelly Jimenez

Suitability modeling is a useful approach for exploring human interactions with their environments. Within a geographic information system (GIS) environment, locations are weighted relative to each other, resulting in a landscape hierarchy that displays regions from least to most suitable. Suitability modeling is used in various disciplines, from urban planning to natural resources, but a gap exists in research concerning social human behavior. This method can especially contribute to the investigation of social inequality at archaeological sites by considering multiple attributes within a site. In this thesis, I use method to determine social inequality between cultural groups at the historic townsite of Terrace along the Transcontinental Railroad in Utah, focusing on historic and archaeological evidence gathered in past research. My analysis shows that Chinese railroad workers lived amongst the least suitable regions of the site while Euroamerican railroad workers lived amongst the more suitable regions.

By investigating social inequality at Terrace, I address various overarching questions: First, how does archaeological evidence indicate segregation between the Chinese and Euroamerican cultural groups, and what is the nature of this segregation (forced vs. voluntary segregation)? Second, what can spatial analyses of cultural segregation tell us about urban planning and cultural interactions during the nineteenth century in the American West? Due to the large amount of ongoing research on the Chinese

occupation along the Transcontinental Railroad during the late nineteenth century, there is a multitude of historical and archaeological evidence to support the presence of segregation and social inequality between the Euroamerican cultural group and other ethnic groups, including Chinese immigrants. By developing a spatial analytic method for documenting social inequality at Terrace, I hope that other archaeologists can apply this technique in similar settings. In doing so, archaeologists can expand the methods and theory used for analyzing social inequality at archaeological sites.

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I would like to thank my committee, Drs. Anna Cohen and Ken Cannon, for all the advice and patience they have given me during the process of preforming this project, especially Dr. Molly Cannon who supported the development of my ideas and provided to construct this suitability model. I would also like to show my deepest gratitude for my graduate cohort, Cayla Kennedy, Paige Wilcox, Alix Piven, and Gideon Maughan, who gave me the encouragement to continue when I felt discouraged. Lastly, I would like to thank Canon Heritage Consultants, the Utah SHPO, Christopher Merritt, and archaeologist, Michael Polk, for providing data and knowledge to complete this thesis.

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Chapter I: Introduction

In the late nineteenth century, the United States set out to gain control of western lands and untapped natural resources with the construction of a transcontinental railway (Allen and Maniery 2016). The transcontinental railroad was considered to be a "technological marvel," a feat of design that would be very difficult to complete in that time period. Despite these doubts, the railway was completed but it came with important social, political, and economic effects on American society, indigenous cultures, and immigrant populations (Polk 2015).

The railroad stretched from Omaha, Nebraska to Sacramento, California and connected the eastern and western US railway systems. Due in part to poor documentation in the late 19th century, Chinese railroad workers, and their significant contribution to the development of the railroad, are often overlooked. Through archaeological investigation, questions about the lives of Chinese railroad workers can be answered by analyzing the wealth of material remains they left behind (Voss 2018). In the following study, I will provide a brief history of the development of the transcontinental railroad, an overview of previous research conducted at sites along the grade, and how archaeologists use various methods to investigate social inequality in similar settings. Secondly, I will outline and describe the process of creating a raster surface displaying least to most suitable regions of Terrace via a suitability model, evaluating quality of living spaces at the historic townsite of Terrace located on the Central Pacific Railroad grade in Utah, and the results that follow. Lastly, I will discuss how these results impact our current understanding of social inequality at sites in similar settings, the overall effectiveness of using a suitability model to understand social inequality, and how this research can inform on broader questions surrounding nineteenth century urban planning and ethnic interactions.

A Feat of Design

On May 10, 1869, the transcontinental railroad was completed at Promontory Summit, Utah with the driving of the Golden Spike, the last spike to be hammered in place connecting the east and west rails. Until the construction of the transcontinental railroad, the western US primarily consisted of scattered, isolated settlements across a vast landscape. The railroad linked these towns and cities allowing for the transport of goods, livestock, people, etc.

The American Civil War caused an influx of railroad system construction across the eastern part of the country, and by the year 1865 the east was filled with rails connecting most major metropolitan areas. The western US, however, still relied on a few wagon roads to travel across the expansive terrain, taking months to trek. Two companies came together to build the transcontinental railroad: The Union Pacific Railroad (UPRR) starting in Omaha, Nebraska heading west across the Great Plains, and the Central Pacific Railroad (CPRR) starting in Sacramento, California heading east across the Sierra Nevada mountains and western deserts.

The UPRR had a ready supply of displaced Civil War veterans, Irish immigrants, African Americans, and, once in Utah, members of the Church of Jesus Christ and Latter-Day Saints as the majority of its labor force (Raymond and Fike 1994; Merritt et al. 2012; Polk 2015). The CPRR, however, had difficulties hiring a sufficient number of workers to construct the western part of the railroad (Voss 2018). The company turned to the Chinese, known already to be hard-working and reliable miners and railroad workers in the US, and decided to bring even more workers from China (Cummings et al. 2014; Voss 2018).

Additional workers were recruited from Guangdong Province, China, which had been experiencing many years of economic and societal hardship (Voss 2015; Khor 2016; Allen and Maniery 2016). The CPRR hired independent businesses to recruit workers from the area and negotiate with other representatives to persuade residents to leave for California. The CPRR lent each worker money for passage to the US, an amount that took each man approximately two and a half years to pay back (Maniery and et al. 2016). Workers were grouped anywhere between twelve to thirty individuals to form a team of laborers. Some served as construction vanguards tasked with preparing the grade by breaking rocks, shoveling dirt to form cuts, and piling up soil for fill areas. Others followed behind lain tracks, hammering down spikes and finishing the grade.

Estimating he total number of Chinese laborers is difficult due to several reasons including, loss of historical financial legers of payments to and from Chinese employers and employees due to negligence, destruction of documentation listing names and numbers of Chinese laborers. Historic accounts and documents report around ten thousand Chinese workers in total, but many scholars believe the number to be much larger, between fourteen and twenty-three thousand workers (Voss 2015). Regardless, the Chinese formed the majority of the labor force for the construction of the western part of the Transcontinental Railroad.

The Life of the Chinese Railroad Worker

Natural Environments Constructing a railroad is dangerous and labor intensive. Many workers died or were seriously injured during the course of construction (Merritt et al. 2012; Heffner 2015). Environmental hazards of the job such as explosions, cave-ins, avalanches, and severe climates claimed the lives of many railroad workers, over a thousand of which were Chinese (Merritt et al. 2012, Voss 2018). Diseases and illnesses were often only treated using informal "folk medicine," or medical practices passed down through generations within a cultural group, due to the lack of access to modernized medical practices (Heffner 2015). Workers in northwestern Utah contended with arid conditions, the unique salt and mudflats, and desert fields of sagebrush and juniper of the Great Salt Lake region, an environment that was unfamiliar to many workers. Previous research found that many Chinese workers adapted to the desert conditions by building rock-lined dugouts with canvas provided by their employers and supplementing them with sagebrush and juniper coverings (Maniery et al 2016). The lack of natural water sources created a dependence on water deliveries from more than forty miles away arriving via rail or wagon. These adaptations left behind visible archaeological traces of a built environment.

Built Environments Construction of the Transcontinental Railroad required large numbers of workers who lived in temporary "line camps" along the grades (Merritt and et al. 2012). Housing, or housing materials, was provided by employers in most cases, but were frequently supplemented by the workers themselves. Structures such as tents, cabins, and even boxcars were adapted and used as housing by workers (Allen and Maniery 2016; Merritt et al. 2012) (Figure 1 and Figure 2). Workers crossed a topographically diverse part of the US and faced extreme weather conditions of both cold and heat. Their built environments were constantly adapted and changed as an attempt to accommodate the changing geographical and meteorological conditions. Cabins were found to be essential for colder conditions, but tents were commonly provided otherwise. In the summer months, the Chinese lived in tents and dug into the sand to escape the extreme heat (Maniery and et al. 2016). In the winter months, the workers contended with a low supply of materials and slept in groups inside a few cabins or other sheltered structures. Once the railroad was completed and section stations were established for continued railroad maintenance, Chinese workers began to build more permanent living structures. Previous research on this topic suggests that these more permanent built environments along US railways leave behind material remains that suggest the Chinese populations' living quarters were often positioned within the less habitable parts of town (Merritt et al. 2012; Sunseri 2015; Laundreth and Condon 1985).

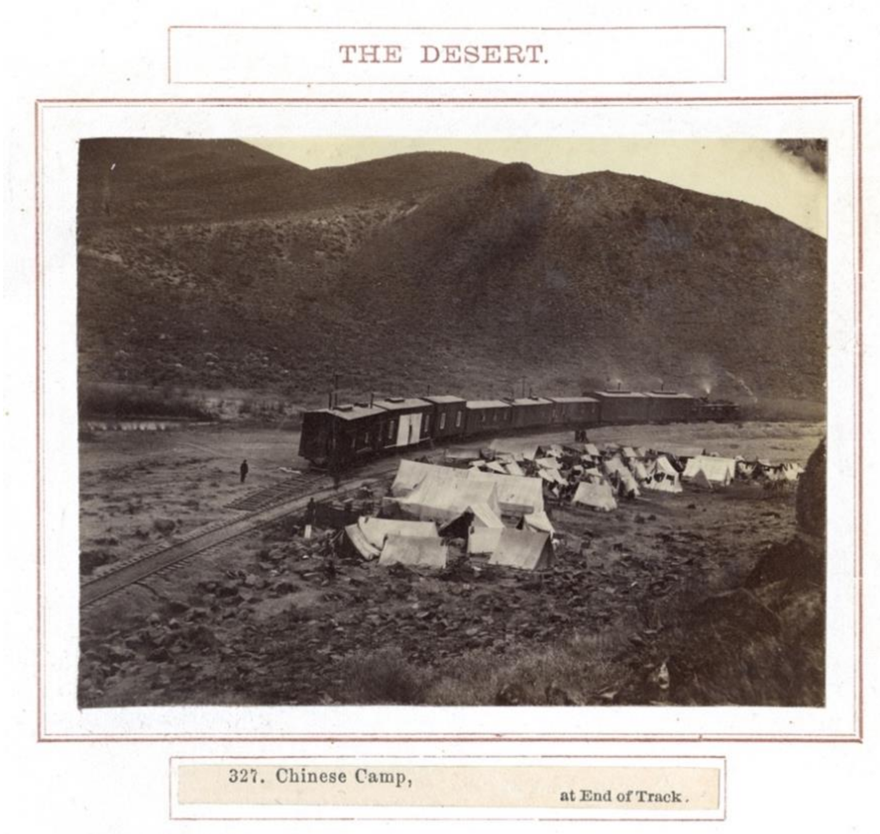


Figure 1 Chinese Camp at End of Track." ca. 1862-1869 (Stanford University Libraries).
The historic image above illustrates an example of social segregation between Euroamerican and Chinese laborers along the rail.
Here, the boxcars provided by the CPRR.

Figure 2 "Chinese Camp, Brown's Station." ca. 1865-1869 (Library of Congress).

Social Inequality Manifest within the Built Environment along the Railroad

The topic of social inequality and segregation of cultural groups at sites along the American West railroads has been explored in previous research (Boswell 1986; Gardner 2003; Sunseri 2015) and spatial analyses were conducted to show evidence of segregation between ethnic and non-ethnic railroad workers (Merritt et al. 2012; Voss 2015, 2018). For example, Sunseri (2015) discusses the presence of multiple "Chinatowns" and spatial evidence of consistent segregation between cultural communities amongst several railroad sites in Nevada. Chinese workers, many of which had to seek out other forms of employment after the completion of the Transcontinental Railroad, were subject to racial violence and marginalized to the peripheries of many larger section stations and mining towns. Many of these Nevada towns, such as Bodie, experienced an influx of Chinese seeking employment or escaping racial tension in nearby areas and reported some of the largest growing Chinatowns in the southwestern US. In Mono Mills, Nevada, Sunseri (2015:93) describes a distinct separation between ethnic communities, specifically the Mono Valley Paiutes and the Chinese, from Euroamerican residences. This segregation can be seen through spatial analyses of sheet refuse excavated at the site; Chinese affiliated ceramics and food containers were prevalent in Chinese households and not common elsewhere.

Merritt and colleagues (2012) conducted a systematic archaeological investigation at Cabinet Landing, Idaho—a townsite along the Northern Pacific Railroad occupied in 1882—and reported evidence of segregation by both socioeconomic classes between supervisors and laborers, as well as a cultural division between Euroamerican and Chinese railroad workers. Supervisory personnel, such as engineers and inspectors, and their families lived in a "quiet, clean, and orderly" camp on the north side of the Clark Fork River. Laborer camps were located on the southside of the river near landings, supply roads, and a warehouse. Further segregation is present between Chinese laborers (approximately 2,600 workers) in what is referred to as the "Front Town" of Cabinet Landing, while non-Chinese lived separately. Additional studies at Cabinet Landing (Laundreth and Condon 1985) reported a clear spatial separation between Chinese and non-Chinese workers via sheet refuse, specifically a division between Chinese and non-Chinese tableware.

Merritt and colleagues (2012) explored further, suggesting that spatial inequalities also existed via the locations of camps across the landscape. It is noted that Chinese encampments were frequently found within the least desirable regions of the landscape along the railroad grade. An example of this phenomenon is presented at a "Front Town" on the Thompson River along the Northern Pacific Railroad in Montana. Natural topography allowed for a division between the Chinese and Euroamerican camps, and archaeological evidence shows that Chinese camps were in a more topographically difficult terrain and a mosquito infested line camp. These studies reinforce the notion of ethnic hierarchies among railroad workers and the practice of preferential treatment of Euroamerican workers, specifically in relation to location of living space within the built environment.

The research summarized in this section has explored the cultural segregation between ethnic groups along the railroad at the turn of the twentieth century in the western US, specifically the separation of Euroamerican railroad workers and other ethnic worker groups, including the Chinese, via the physical landscape and/or archaeological material remains. There is a gap, however, in research discussing the social behaviors instigating this segregation and how this segregation affected the ethnic railroad workers, specifically if these marginalized communities are found in undesirable or less habitable environments than Euroamerican workers. Archaeological methods provide a unique look into the lives of Chinese laborer, as much of their social practices and experiences were not well documented by either historians or the laborers themselves. I take a deeper look at this type of segregation by developing a GIS method that specifically analyzes spatial data showing segregation and social hierarchies at archaeological sites, and by examining the results of this method through a multi-disciplinary lens to understand the social inequality resulting from this phenomenon along the Transcontinental Railroad. By doing so, this study will contribute to the growing body of knowledge about the lives of the Chinese railroad workers and the social hardships they faced in the American West during the late 1800s.

Chapter II: A Brief History and Description of Terrace, Utah

Background

The historic townsite of Terrace is located in the high-desert region of northwestern Utah where environmental conditions are arid and often accompanied by moderate to extreme temperatures. The original CPRR grade, which ran though Terrace, transects the basin of Pleistocene Lake Bonneville and is situated within a landscape of alternating basins and ranges—between the Raft River Range and the Grouse Creek Mountains. The modern climate consists of very warm summers and moderately cold winters. The land possesses no significant natural water sources (Cannon et al. 2016).

Terrace was a small settlement along the CPRR founded on April 1st, 1869. Terrace was the largest settlement along the CPRR in the state of Utah and served as the repair and maintenance headquarters for the Salt Lake Division between 1869 and 1904 (Raymond and Fike 1994). In 1987, the site was listed on the National Register of Historic Places as a contributing component of the Central Pacific Railroad Grade Historic District under criteria A and D, by retaining integrity of location, setting, and feeling, as well as being associated with important events of the late nineteenth and early twentieth centuries (Cannon and et al. 2016; Dodge 1986). The archaeological information embedded at Terrace has the potential to address multiple research questions including inquiries about the living and environmental conditions railroad workers faced, the interactions between the different cultural groups that occupied the town, and community organization (Dodge 1986; Voss 2015, 2018).

At the height of occupation during the 1880s, according to census data, approximately 50 residents lived in Terrace (Polk et. al. 2019). Census data report that there were twenty-two male Chinese occupants residing at Terrace in 1870. The population increased to fifty-five Chinese males and one Chinese female in 1880. The majority of the men worked for the railroad (~75%), but other men held occupations such as cook, tailor, and storekeeper (Manson et al. 2020). USU Archaeological Services (USUAS), now Cannon Heritage Consultants, conducted research at Terrace in 2015 that involved georeferencing a 1988 BLM map of the town to identify major features, and the investigation into the Chinese occupation at the site with an intensive pedestrian survey of Chinese-affiliated material culture remains (Cannon et al. 2016). The majority of artifacts collected during this investigation were related to Chinese culture with minimal documentation of Euroamerican artifacts.

Figure 3 View of Terrace looking west at the business district, ca 1875 (Utah State Historical Society).

Figure 4 View of Terrace business district looking west towards the Grouse Creek mountains, circa 1875 (Utah State Historical Society).

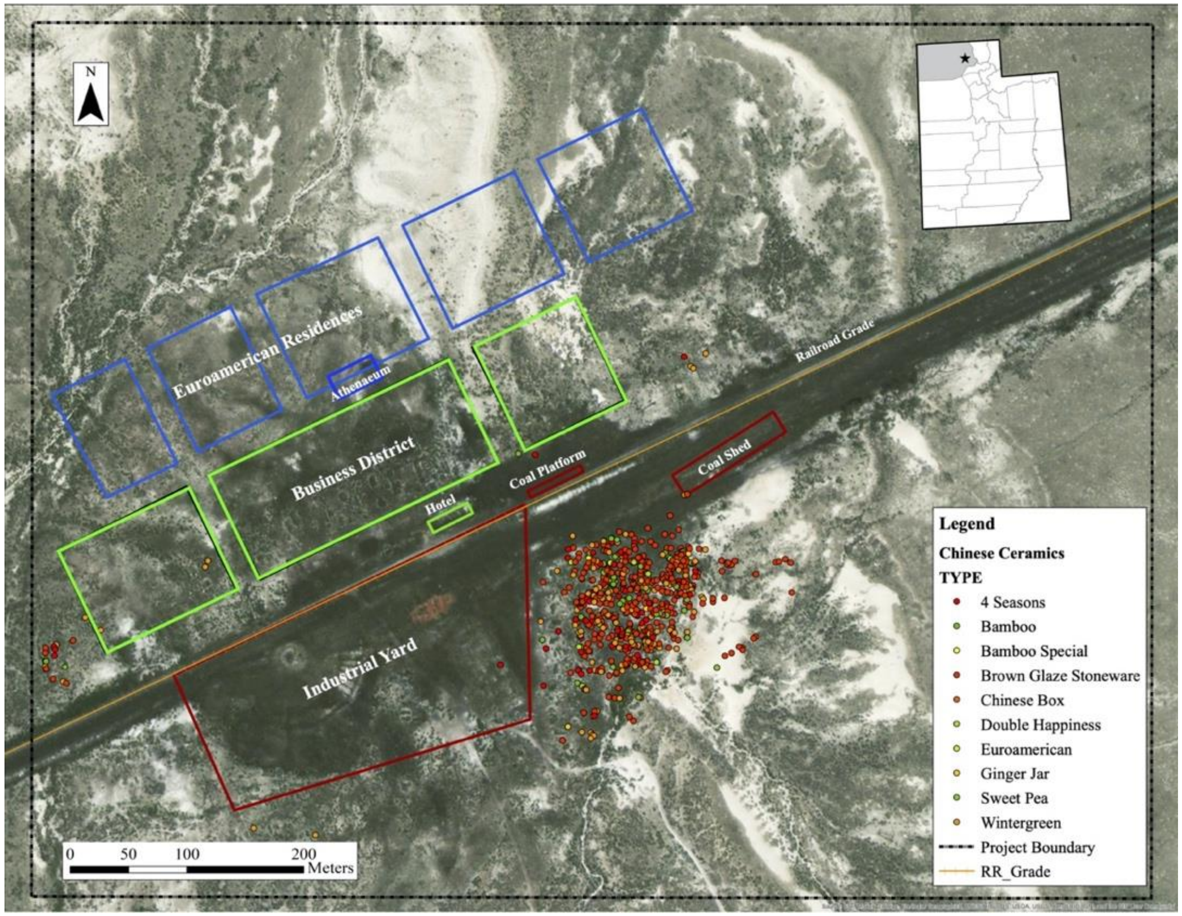


Figure 5 Pedestrian Survey conducted by Cannon Heritage Consultants in 2016 of the Chinese affiliated artifacts across the surface of Terrace. This map which shows an accumulation of Chinese ceramics in the southeastern part of the site.

The Built Environment at Terrace

Terrace consists of several notable surface features that are still visible today. Unfortunately, many structures across the site are not easily discernible due to several possible factors, including looting, environmental stresses, and a fire that ravaged the town in the early 1900s (Raymond and Fike 1994). The features described here were used in the suitability model but are not inclusive of every feature that once occupied the site. It is important to detail the built environment of Terrace as these features provide the infrastructure of the suitability model presented in this study. Understanding the primary use and locations of major features, such as the railroad grade or water source locations, inform on the discussion of whether or not Chinese residences were located within a region of the site that was less conducive for human habitation.

The historic town of Terrace was described by Raymond and Fike (1994) as having a business-lined avenue north of the tracks and scattered residences south of the tracks (Figure 3 and Figure 4). Archaeological evidence indicates that Chinese residents lived in the eastern end of town on the southeast side of the railroad, based on significant clustering of Chinese affiliated ceramic material documented during survey work in 2015 (Figure 5). Additionally, recent PIT excavation projects undertaken by the Bureau of Land Management and the Utah Historic Preservation Office in 2020 and 2021, revealed housing structures in the same vicinity (Christopher Merritt personal communication 2021).

Located in the southwestern section of Terrace, the industrial portion of the site contains features that pertain to railroad maintenance and construction (Figure 6). It is located in the southwestern section of the site. A roundhouse, a structure that was used to house engines that were unused or receiving maintenance, is a major feature of Terrace and is visible in the top left corner of the industrial yard. Other features within the industrial yard include a blacksmith and machine shop for metal working, and two of the towns store houses, most likely for storing various types of equipment used in railroad maintenance. A coal shed, used to store coal for engine use, was identified along the eastern part of the grade on the southside. A coal platform was located just west of the coal shed along the northside grade and was used as a staging platform for shoveling coal into the engines. The railroad grade was digitized within the boundary of Terrace to use in the suitability model.

A hotel, most likely for travelers coming through Terrace, is located near the center of the site on the north side of the grade. North of the hotel lies side-by-side structures along a lane that has been described as the "business-lined avenue" (Raymond and Fike 1994). These features most likely held various goods for sale, a saloon, offices, and other commercial parts of Terrace.

From historical documents and previous archaeological survey, the site of Euroamerican residences was located and is indicated by a set of structures north of the businesses, extending to the east along the north side of the grade. Within this set of buildings is a smaller structure labeled "athenaeum" on the 1895 historic map. An athenaeum is traditionally for housing important documents but was also a source of clean water for Terrace residents which is necessary for human subsistence (Raymond and Fike 1994: 50). More clean water sources may exist but have not yet been identified.

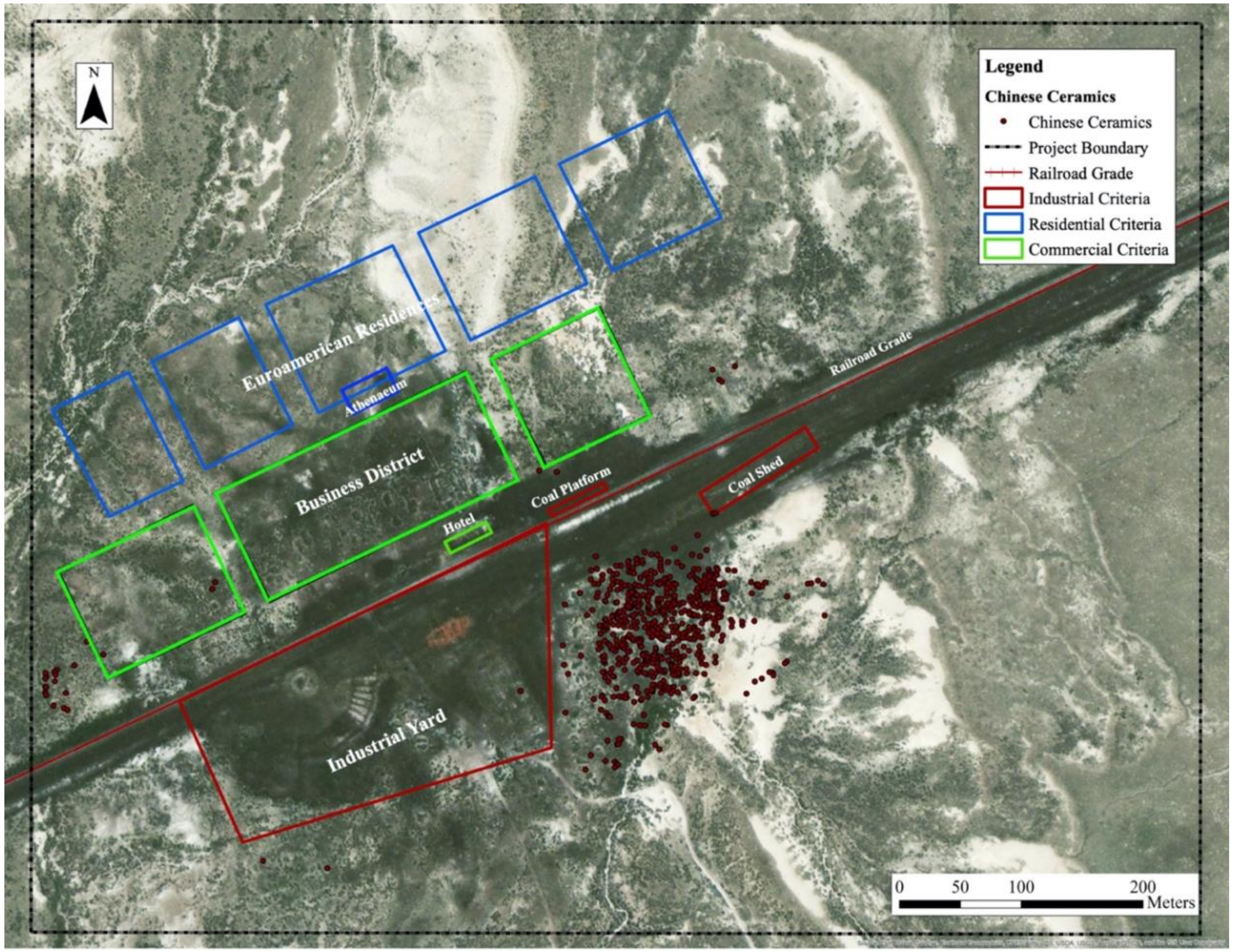


Figure 6 Terrace features included in the suitability model, excluding the coal slag which obstructed the view of other features but visible in the aerial basemap as the dark regions along and adjacent to the grade (see Figure 11b).

Chapter III: Maslow's Hierarchy of Needs: An Adapted Theory for Urban Design

Building a suitability model requires creating a set of criteria that are weighted on a scale from least to most suitable (Mitchell 2012). These weights are based on prior knowledge and research into the subject of the suitability model. Prior examples of suitability modeling used accumulated knowledge of which criteria would affect the subject of the model more or less in order to determine how to assign criteria weights (Wren and Burke 2019 and Oheim 2007). Wren and Burke (2019) used suitability modeling to investigate habitat suitability during the Last Glacial Maximum and the impacts of ecological risks to the human population, and weighted criteria based on the greater or lesser effect that specific criterion had on human survival ability. This project draws on Maslow's Hierarchy of Needs, and the adaptations of the theory for urban design, for the theoretical basis for what constitutes a less or more suitable setting for human habitation at Terrace.

A.H. Maslow published his theory of a *hierarchy of needs* in "A Theory of Human Motivation" (1943) outlining a pyramid of motivational factors that provide a description of basic human needs and stimuli for human development (Figure 7). Each layer of human motivation, once fulfilled and satisfied, build upon one another and are as follows: physiological needs, safety and security, love and belonging, self-esteem, and self-actualization. Physiological needs encompass basic human needs, such as breathing, water, food, shelter, clothing, sleep, etc. Safety and security needs are good health, employment, property, family, and social stability. Maslow describes further in the higher tiers: the need for love and belonging, a need for a connection and intimacy; self-esteem, a need for confidence and a sense of achievement and to be unique in some way; and finally, self-actualization, a need for a moral code, acceptance, meaning and inner potential, and a purpose in life. Scholars have applied the Hierarchy of Needs theorem to a diverse range of social issues from advancements in water management infrastructure (White 2020) to assessments of motivations behind religious behaviors (Brown and Cullen 2006).

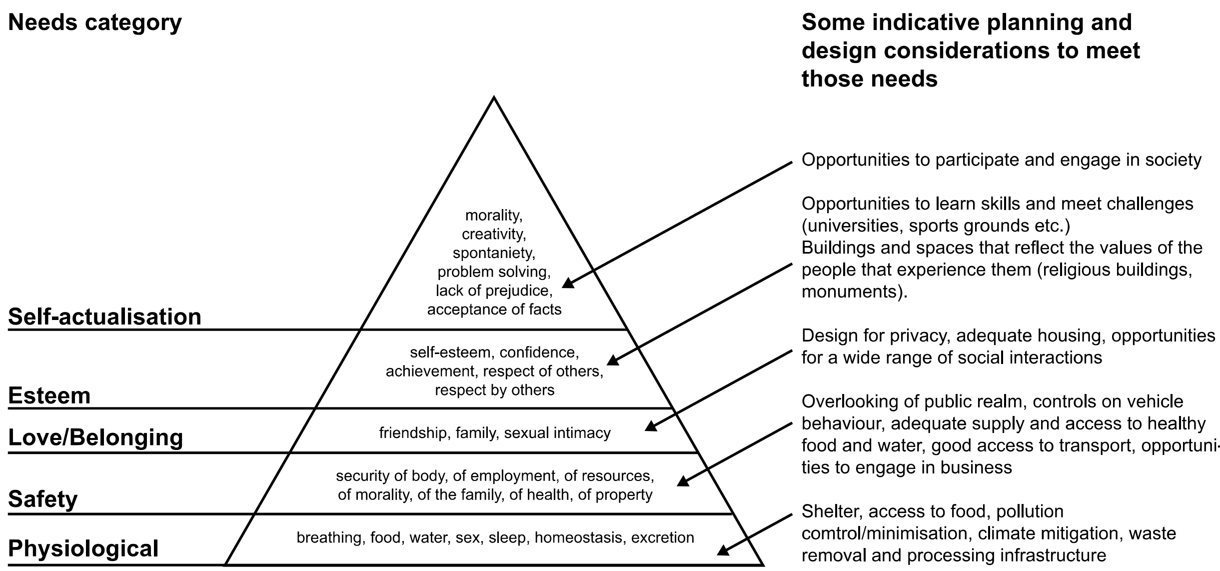


Figure 7 Maslow's Pyramid of Needs adapted for use in urban planning and design by Donovan (2010: Figure 1).

The hierarchy of needs have been adapted and applied to urban design and community planning (Donovan 2010; Putnam 1995; Jacobs 1961). These adaptations shift focus from the human person to the human built environment and communities and provide a broader look at the development of human habitation. For example, Donovan (2010) includes the control and minimization of pollution and climate mitigation in the physiological needs tier and accounts for opportunities for social interactions as an essential necessity. Putnam (1995) uses Maslow's theory to take a broader look at the progression on American society and what he explains to be a decline in social capital and social disassociation, or a lack of cohesive societal behaviors, during the 1990s. By adapting Maslow's theory to modern urban development, engineers and architects have a guide to constructing cities and towns that meet not only basics human needs but provide opportunities for people to participate and engage in society as well, a more humanistic approach to city planning (Jacobs 1961).

The present study applies the concepts outlined in the bottom two tiers of the hierarchy of needs, physiological needs and safety and security, to analyze the suitability of features across Terrace for human habitation. Though the upper tiers can inform on broader questions about social inequality and segregation, the present goals for a suitability model describe the overall physical habitability of the landscape at Terrace and whether or not the Chinese population lived within the less suitable regions of the historic site. Additional research of the emotional or social well-being of the Chinese residents at Terrace may benefit from exploring Maslow's theory and applying it to questions of segregation and social inequality.

Chapter IV: Methods

Much of the suitability model construction process was trial and error. Though researchers apply suitability mapping in a variety of contexts, information about using the model to map social inequality is lacking (Healy et al. 2017; Oheim 2007; Wren and Burke 2019). For the purpose of this study, the goal is to show a possible method of studying social inequality via suitability mapping in historic and archaeological settings, using variables from the built environment. In this section, I provide a description of data sources and how those data were manipulated and classified for inclusion in the suitability model, and an outline of the suitability model construction process. I conclude with an overview of the issues encountered and changes made to create the final suitability surface.

Description of Data Sources

ArcGIS ArcMap v10.7.1 was used to create and manipulate spatial data, and to construct the suitability model. Cannon Heritage Consultants (formerly USU Archaeological Services) provided spatial data, including point data for Chinese affiliated ceramics and identified structures, for Terrace from previous surveys performed at the site, as well as historic maps gathered from previous research. Other feature shapefiles were digitized into polygons using ArcMap from the georeferenced 1988 BLM map of Terrace, the historic plat map of eastern Terrace, and the 1895 CPRR map of the town (Figure 8, Figure 9, and Figure 10) (Cannon and et al 2016: Figure 12, Figure 13, Figure 14).

Figure 8 1988 BLM Map (Cannon et al. 2012).

Figure 9 Historic plat map of eastern portion of Terrace (Cannon et al. 2012). This map represents an "idealized" plan for Terrace which was never fully implemented.

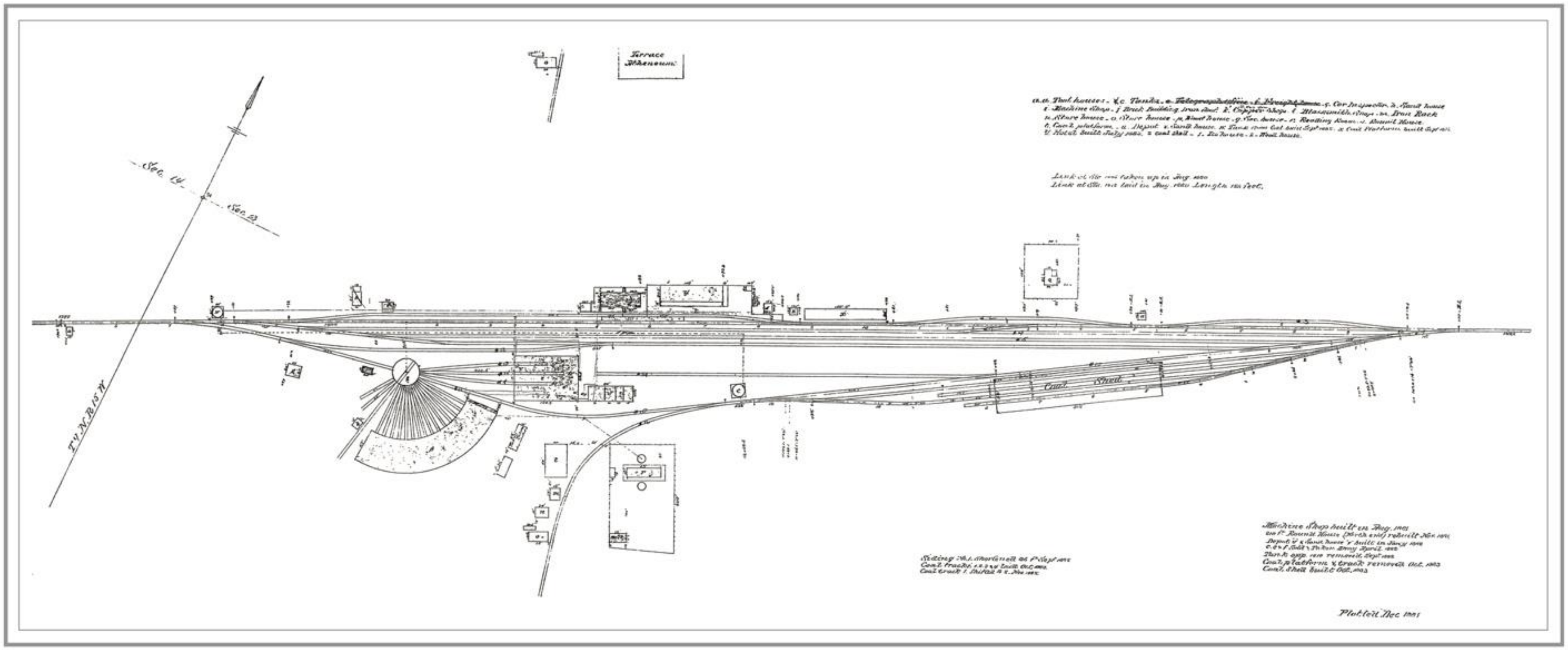
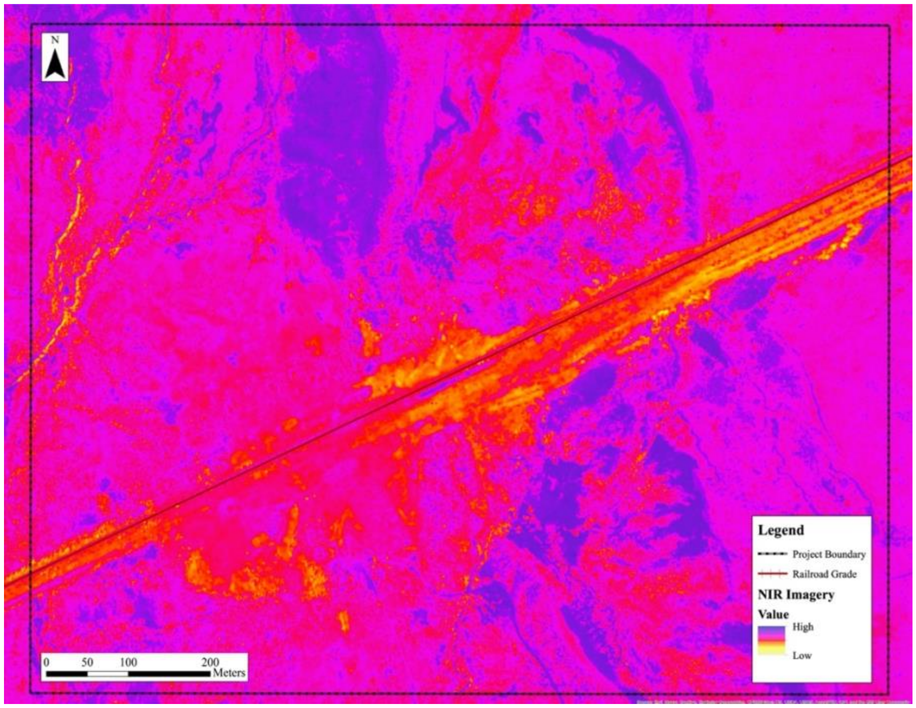


Figure 10 Central Pacific Railroad map plotted December 1895 (Cannon et al. 2012).

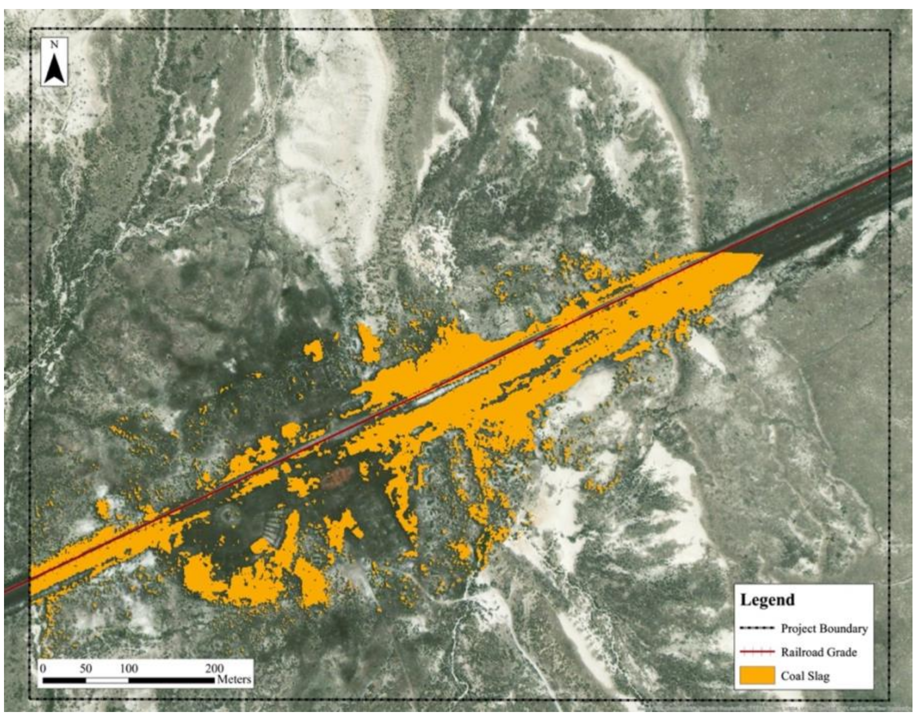
Many features at Terrace were not discernible from historic maps, and any other maps of the site are not available or lost due to a fire at Terrace in the early 1900s. The most applicable structures were identified and digitized for use in the model and include: the industrial yard (blacksmith, machine shop, roundhouse, etc.), railroad grade, coal shed and platform, hotel, business district, Euroamerican residential district, and an athenaeum where a clean water source was located. Other features include coal slag, areas across the surface of the site heavily saturated with slag (a by-product of burning coal). Coal slag features likely represent areas of Terrace with higher-than-average air and soil pollution. Though the coal slag is not part of the built environment, it is a result of that environment and associated behaviors and is an important aspect of understanding quality of life at Terrace. This feature was extracted from infrared imagery and clipped to the boundary of the site.

The coal slag was identified and extracted from a 2018 near-infrared (NIR) raster surface of Box Elder County, Utah from the National Agriculture Imagery Program (NAIP) (AGRC 2018) and clipped to the boundary of the site. NIR, also known as color infrared imagery, uses a false color composite to display information about the landscape that may otherwise be unseen by the naked eye. The NIR map displays separate regions of vigorous vegetation and weak soil or bare soil. The NIR surface was inputted into ArcMap and the symbology was modified to display darkened areas, places across the site that have been heavily saturated with coal slag. The value representing those areas was isolated and extracted using the *Extract By Mask* function and clipped to the boundary of the site (Figure 11a and Figure 11b). More structures were identified but not included in the model as those data were not applicable to the project at this time (i.e., section house).

The above features form the criteria for the suitability model and were placed in four weighted sub-categories based on primary function (Table 1): industrial, residential, commercial, and environmental.



(a)



(b)

Figure 11a (Top): NAIP Color Infrared imagery of Terrace. High values (reds and purples) are areas of vigorous vegetation. Low values (oranges and yellows) are areas of poor to no vegetation. The lowest values were interpreted as coal slag saturation.

Figure 11b (Bottom): Extracted NIR value to isolate coal slag saturated regions.

Industrial Criteria 30%					
Built Environment Feature	**Data Source**	**Data Type**	**Contribution to the Model**	**Transformation**	**Assigned Suitability Scale Value(s)**
Industrial Yard (*Roundhouse, Machine Shop, Blacksmith, Store and Tool Houses*)	Digitized from historic maps	Polygon	Areas of Terrace that negatively impacts essential human habitation needs. The Gaussian function was used due to the need to be close enough to maintain a feasible distance for employment.	Gaussian	1-2 (Least Suitable)
Coal Shed					
Coal Platform					
Railroad					

Commercial Criteria 15%					
Built Environment Feature	**Data Source**	**Data Type**	**Contribution to the Model**	**Transformation**	**Assigned Suitability Scale Value(s)**
Business District	Digitized from historic maps	Polygon	Areas of Terrace that negatively impacts essential human habitation needs depending on proximity.	Gaussian	2-5 (Less to Moderately Suitable)
Hotel					

Residential Criteria 30%					
Built Environment Feature	**Data Source**	**Data Type**	**Contribution to the Model**	**Transformation**	**Assigned Suitability Scale Value(s)**
Euroamerican Residences	Digitized from historic maps	Polygon	Areas of Terrace that is considered most suitable for human habitation within the project boundary.	Small	9-10 (Most Suitable)
Athenaeum/Water Source					

Environmental Criteria 25%					
Feature Name	**Data Source**	**Data Type**	**Contribution to the Model**	**Transformation**	**Assigned Suitability Scale Value(s)**
Coal Slag	NAID infrared raster (2016)	Raster	Area of Terrace that is saturated with slag, a by-product of burning coal, and negatively impacts essential human habitation needs.	Large	1-2 (Least Suitable)

Table 1 Schematic of weighted variables and how they contribute to the suitability model.

1 2 3 4 5 6 7 8 9 10

Least Suitable | Moderately Suitable | Most Suitable

Figure 12 Suitability value scale.

Following the identification of data, the criteria are derived and defined in terms of suitability using a continuous scale. This suitability scale defines the criteria from least to most suitable on a scale from 1 to 10—1 being least suitable and 10 being most suitable (Figure 12). This scale is applied during the modeling process. The scale is informed by Maslow's Hierarchy of Needs, where subcategories are organized from least to most suitable based on primary function and how that function affects human habitation needs within the theory. For example, the industrial criteria are considered least suitable among the identified built environment features at Terrace because the industrial features are associated with a small range of human needs and adversely affect the basic need of providing a safe place to live.

The industrial criteria were rated as least suitable. These criteria affect both the first and second tier of Maslow's Hierarchy of Needs: physiological needs for pollution control (both air, noise, and soil) and safety needs (safe shelter and healthy surroundings). Residential criteria were rated as most suitable. Since there is consistent evidence elsewhere (Merritt et al 2012) that Euroamerican railroad workers resided in more favorable conditions, for the purposes of this study, it is assumed that Euroamerican Terrace workers and later Euroamerican residents received the same accommodations.

Additionally, a close proximity to a clean water source is imperative for human habitation needs (tier one) and the residential water supply at Terrace resides within the residential regions of the townsite. Commercial criteria were rated moderately suitable. Living within a commercial district is not ideal but it has a lesser effect on human habitation needs. The environmental criterion was rated as less suitable. Coal slag, though harmful with prolonged exposure and/or close proximity, does not cause immediate danger to residents.

Kernel Density Analysis of Chinese Ceramics

A kernel density analysis was conducted using the Chinese ceramics locations data gathered from Cannon and colleagues (2016) to ensure that significant clustering was present. The *Kernel Density* tool in ArcMap assesses the distribution of Chinese ceramics across the site and calculates a pattern displaying areas of high ceramic populations (ESRI 2016). The results illustrate an area of greater density of ceramics in the southeast portion of the site, reinforcing the idea that this region hosted the residential site of Chinese workers (Figure 13). Further, an excavation was conducted in September 2020 and May 2021 that unearthed a Chinese housing structure in this region of the site with indicators that more exist in the area (Christopher Merritt personal communication 2021).

The Chinese ceramics are used as a proxy for the location of Chinese residences. These data will be overlain on the final suitability surface to determine any differences in habitat suitability between where the Chinese and Euroamerican workers resided.

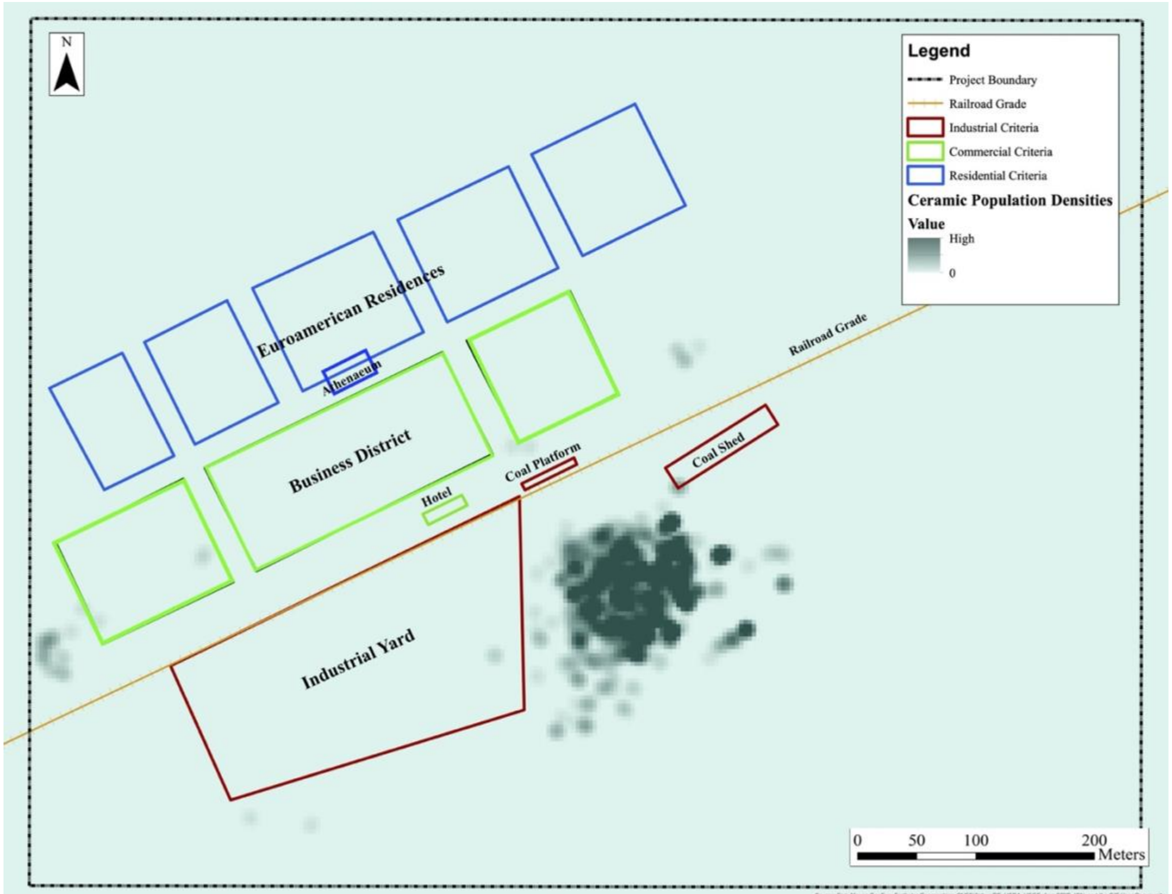


Figure 13 Kernel Density analysis of the Chinese ceramics at Terrace showing ceramic population densities.

Encountered Obstacles and Modifications During the Modeling Process

The model underwent many rounds of evaluation. Initially, a more comprehensive suitability model was proposed that included environmental data such as slope, vegetation, soil composition, and wind direction that would inform on how additional environmental conditions may have affected ways of life at Terrace, as well as how site formation processes effected the present locations of material remains. However, available DEM, soil, and vegetation data did not display data with a fine enough resolution to assess changes in slope, vegetation type, or depth of soil across the site, and wind direction point data was not available for this region of Box Elder County. Consequently, the model moved forward using the features of the built environment and the NIR imagery.

Several obstacles were encountered trying to discern structures across Terrace using the few historic maps available. Written testimonies, or other such written historic accounts, are few and far between, and were perhaps lost in the Terrace fire. The historic plat map of Terrace (Figure 9) displays no legend, and the 1895 historic map is faded and possesses only a crudely written legend that made it difficult to identify corresponding structures (Figure 10). Locating additional structure and features at Terrace and including them in future versions of the model may provide a more comprehensive look into social inequality at the townsite.

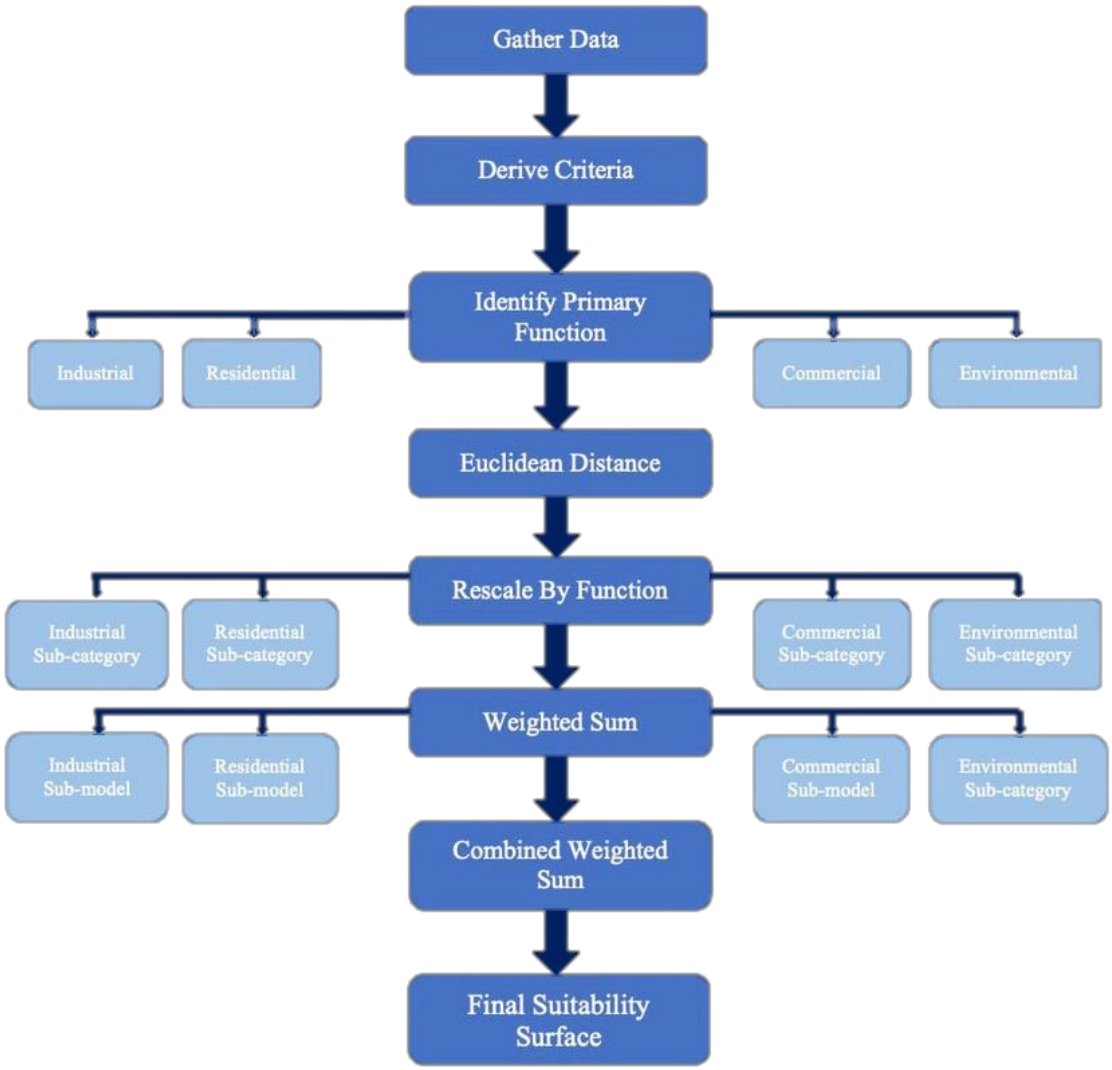


Figure 14 The figure above outlines the sequence of geospatial analyses for constructing the suitability model.

Constructing the Suitability Model

Described in the following sections are the steps taken within ArcGIS ArcMap 10.7.1 to produce a final suitability surface using the data and theoretical concepts discussed above.

Feature polygons, representing the structures identified across Terrace, were inputted into the *Euclidean Distance* tool to classify those data by increasing the distance from the center of the polygon, in a straight line, to a specified boundary. In this model I created a project boundary based on the previous archaeological site boundary of Terrace from Cannon Heritage Consultants. The archaeological site boundary was modified to include the Euroamerican Residences and Business District and constrained to minimize empty space within the model. This process was repeated to produce a raster surface for each built environment feature at Terrace (Table 1 and Figure 15). This calculation derives from the Euclidean Distance, or the straight-line distance between two features, and produces a raster that contains the measured distance from every cell to the nearest source feature (in meters) (Mitchell 2012). *Euclidean Distance* is often used in suitability mapping when data representing the distance from a certain object is needed, as is the case at Terrace. Once raster datasets are produced, suitability values can be assigned along a continuous scale.

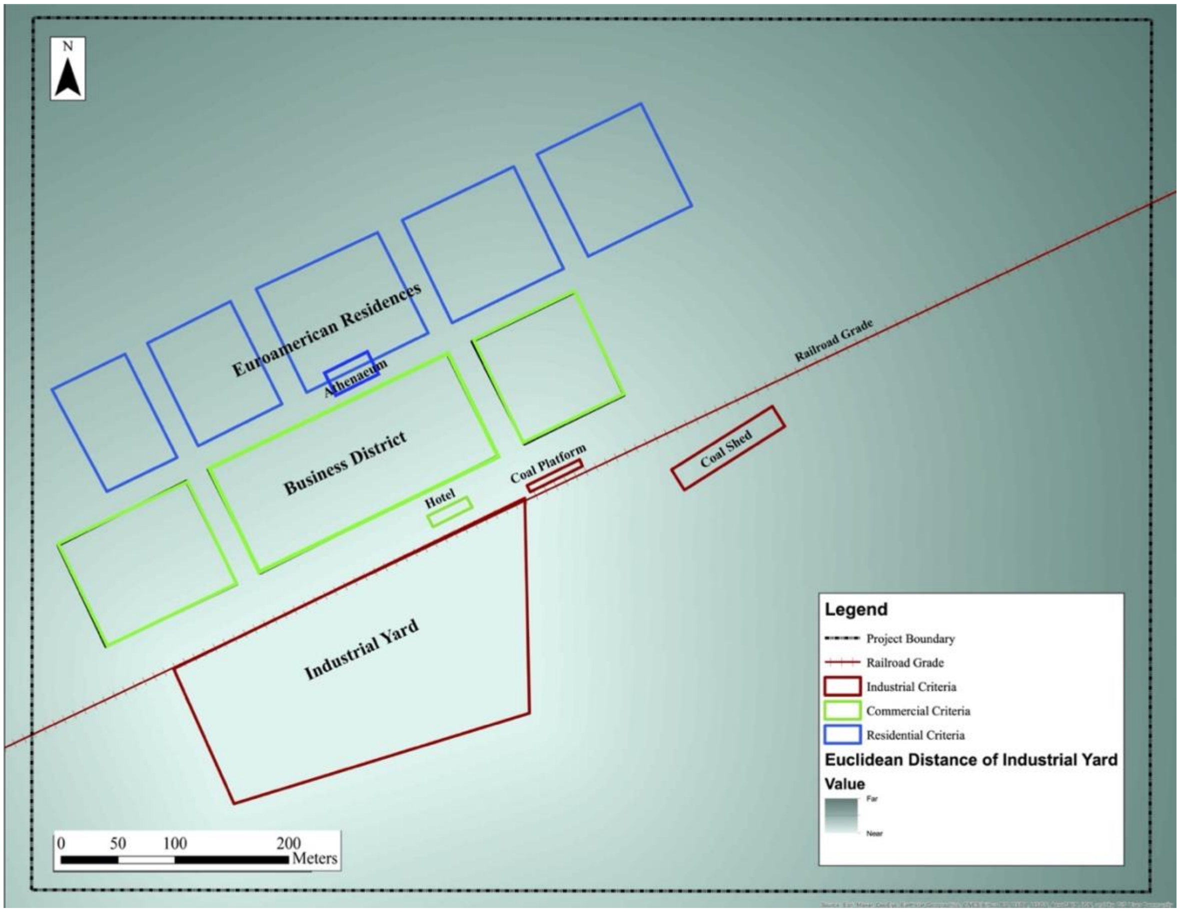


Figure 15 An example of how the Euclidean Distance tool was used on the Industrial Yard feature of Terrace.

The raster outputs from the *Euclidean Distance* tool were inputted into the *Rescale By Function* tool, which uses a mathematical function to transform the values of an input raster to a continuous scale, or *suitability scale* (Figure 14 and Figure 16). Suitability of a criterion changes values continuously, and often in a non-linear manner (ESRI 2016). For example, cells closer to a water source are more preferred as the cost of time and labor of obtaining clean water decreases. I used three different mathematical functions during the course of this step to transform the values for the four different criteria: Gaussian, Small, and Large. The Gaussian function transforms data to make the midpoint the most preferred area of the raster, where a value decreases in suitability as it increases or decreases from the midpoint (Figure 17) (ESRI 2016).

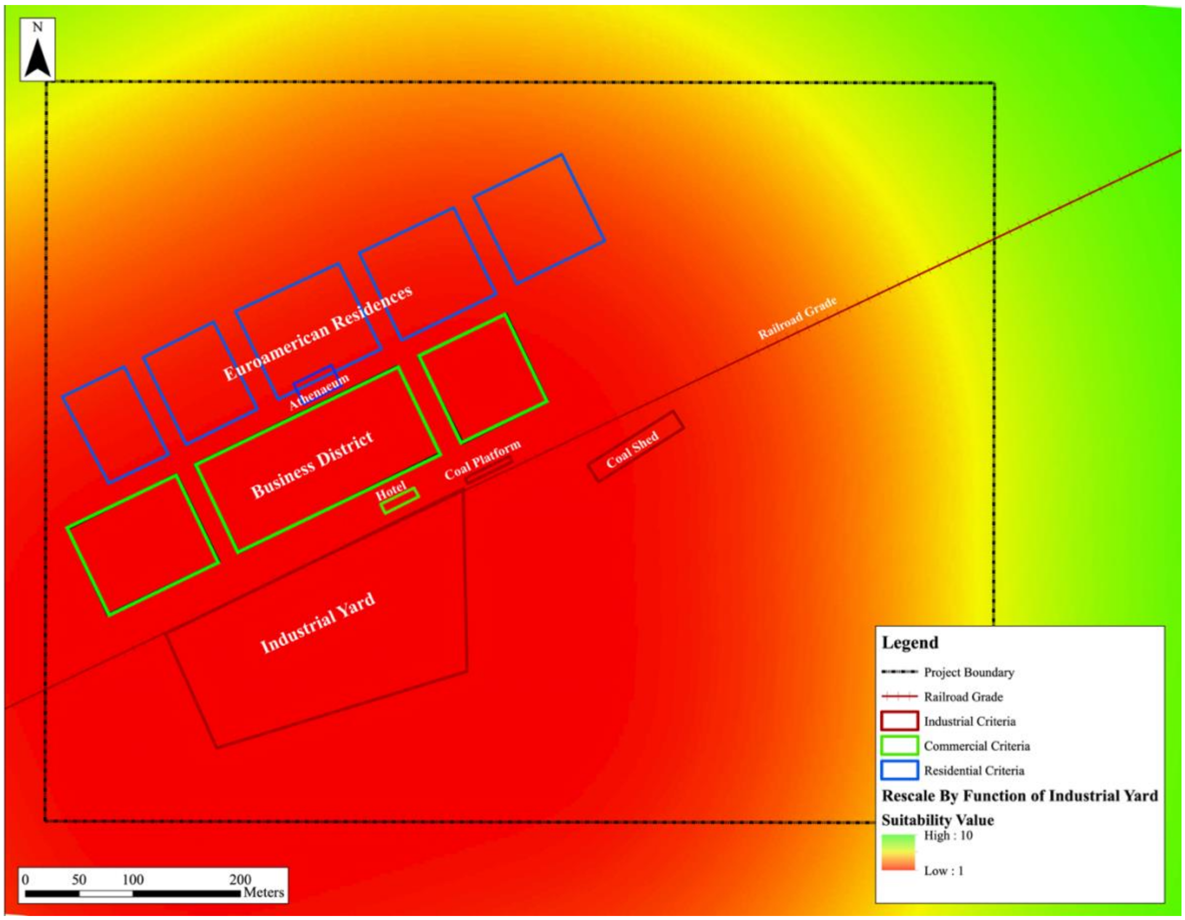


Figure 16 An example of how the Rescale by Function tool (Gaussian) was used on the Industrial Yard feature of Terrace.

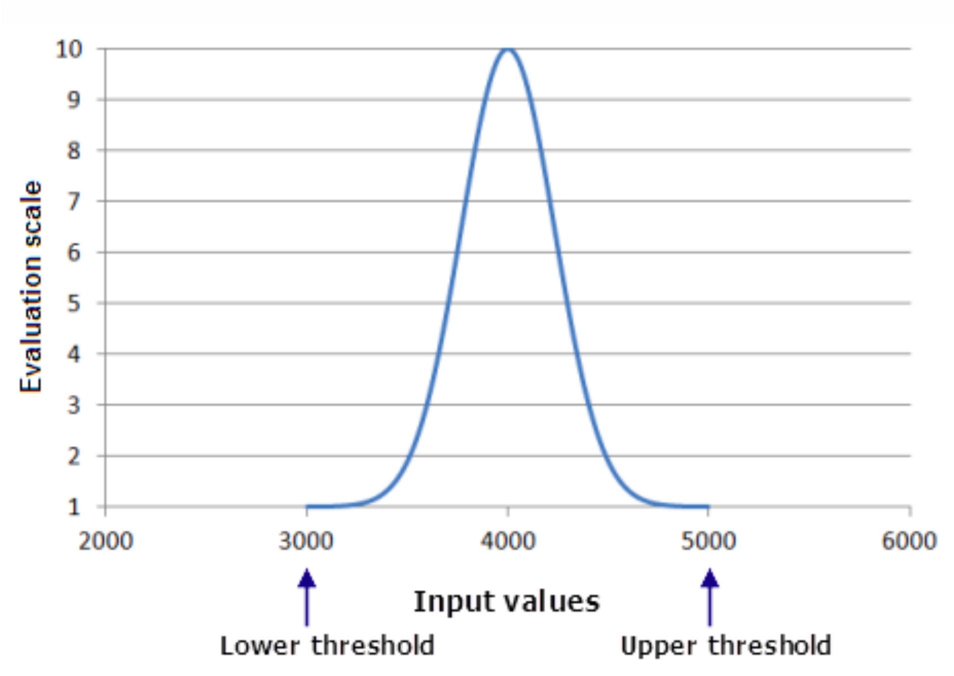


Figure 17 A visual representation of the Gaussian function used on the Commercial and Industrial criteria. The midpoints (peak of the bell curve) are considered most suitable. (ESRI 2016)

The Gaussian function was applied to the industrial and commercial sets of criteria. Living in close proximity to a business or an industry is not ideal but living too far away from either feature may cause lack of employment or access to vital goods, i.e., food and clothes. The Small function was applied to the residential criteria. The Small function transforms the data so that the cells closest to the feature are most suitable, decreasing in suitability as the cells become further from the source (ESRI 2016). Residential criteria make up the "most suitable" regions of the site and include the only known water access, a tank filled with water piped via a 12-mile aqueduct from the Grouse Creek Mountains to the north (Polk et. al. 2021). Close proximity to these features equate to more suitable areas. The Large function works conversely and applies the lowest suitability to close cells which increase with distance from the source (ESRI 2016). The coal slag feature was transformed using the Large function. Coal fumes, and other industrial pollutants that make up slag, are hazardous to the health of individuals within close proximity and should be avoided. The *Rescale By Function* tool transformed the data to a common scale of suitability based on the above transformations (Figure 18). The data must then be weighted and combined to form a final suitability surface (Table 1).

The *Weighted Sum* tool is used to assign weights to criteria and combine the criteria into a single raster surface (ESRI 2016**)**. This function weights the outputs from the *Rescale By Function* tool based on percentage (XX out of 100). Changing these percentages causes one criterion to affect the outcome of the suitability surface more or less than other criteria. Sub-models were created to combine criteria based on the criteria categories from the table above (Table 1, Figure 18a, and Figure 18b): 1) Industrial Sub-model, 2) Commercial Sub-model, 3) Residential Sub-model, and 4) Environmental Sub-model. The criteria within each of these sub-models were weighted equally and produced a raster dataset for each sub-category of criteria. This process was repeated to combine the sub-models into a final suitability surface. Weights were given to the sub-models according to positions within Maslow's Hierarchy of Needs. Sub-models that are associated with tier one, physiological needs, were weighted a higher percentage than those associated with tier two, safety and security. Additionally, criteria associated with both tiers were weighted higher assuming that those criteria have more of an effect on overall human habitation needs.

Many of the criteria could be considered a part of either tiers, or even both. The Industrial and Residential Sub-models were weighted at 30%. The residential criteria directly impacts the physiological needs of human habitation, i.e., clean water. The industrial criteria directly impact both tier one and two, and have significant impacts on health, safety, and security leading this sub-model to have a greater effect on suitability. The Environmental Sub-model (coal slag) was weighted at 25%. This sub-model impacts the vital needs of tier one. The Commercial Sub-model was weighted the least, at 15%. While living in close proximity to a business may not be ideal, it does have a lesser effect on tiers one and two and may have more effect on feeling of privacy and emotional well-being, the higher tiers n the Maslow's Hierarchy of Needs and not evaluated with these data.

Once weighted, the sub-models were combined to create the final suitability surface (Figure 19) which displays rated regions of suitability across Terrace. These results are discussed in the following section.

Chapter V: Results

The final suitability surface presents interesting results for furthering our understanding of social inequality at Terrace. The results inform questions regarding whether the marginalized Chinese railroad workers were living in the least desirable regions of the built environment at Terrace and provide evidence that this new spatial method can contribute to other archaeological sites, settings, and investigations concerning social inequality and cultural segregation. Figure 18d displays the final suitability surface. The features highlighted in blue represent the Euroamerican residences and the point features are Chinese-affiliated ceramics used as a proxy for Chinese residences at Terrace. The least suitable region within the project boundary is concentrated in the center of the site just to the west of the industrial yard and the more suitable regions reach out towards the north and southeast boundaries of the site. It is important to note that the majority of Terrace lies within the lower suitability values of the scale. This is not surprising as the majority of features at Terrace have a negative impact on suitability and make up a large portion of the site. The most suitable regions of the landscape lie outside of the boundary of the site making the average suitability of Terrace moderate to very low.

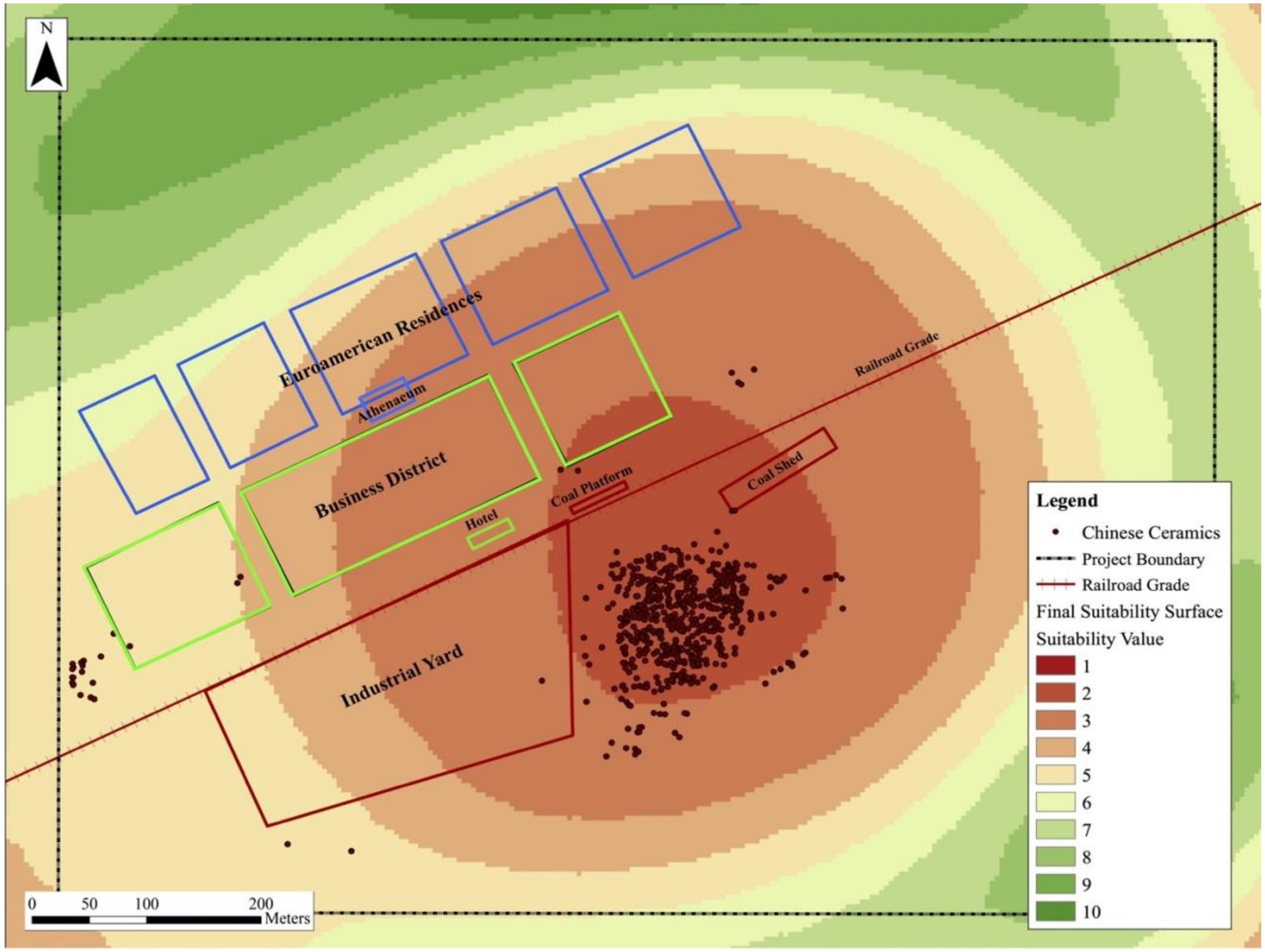


Figure 18 Displayed is the final suitability surface of Terrace. The majority of Chinese-affiliated ceramics is within the least suitable region of the site. Site suitability is reflected in the higher values (green shading).

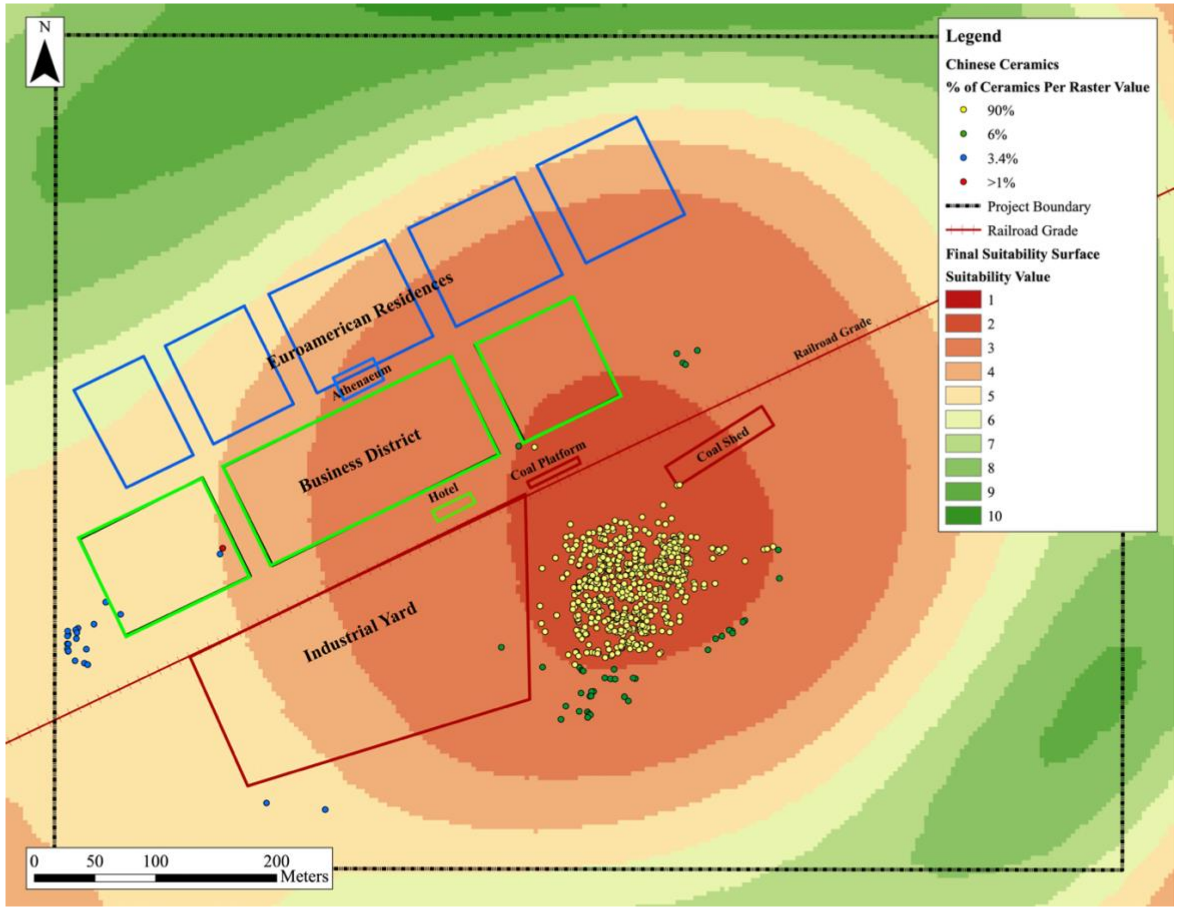


Figure 19 Shown is the percentage amount of Chinese affiliated ceramic within each corresponding suitability value zone. The majority, ninety percent, of the concentration of Chinese ceramics is within the least suitable region of Terrace. Six percent of the Chinese ceramics are with the less suitable range while less than four percent remain are within the moderately suitable range. Site suitability is reflected in the higher values (green shading).

The point data for the Chinese-affiliated ceramics was lain over the suitability surface to compare its location with that of the Euroamerican residences. The majority of the Chinese ceramics (~90.4%) are located within the least suitable range of the suitability surface, whereas the Euroamerican residences are located within the less to moderately suitable range. This pattern mostly likely emerges from the closer proximity of the Chinese living space to the industrial and environmental features.

While the Euroamerican residences are within less suitable areas of Terrace, the Chinese living space remains within a lesser to the least suitable areas of the site. The results of the suitability model, therefore, supports the original hypothesis that Chinese railroad workers lived amongst the less suitable regions of Terrace than other cultural groups at the site.

The results of the suitability model confirm that Chinese residents were located within the least suitable region of Terrace for human habitation. Figure 19 shows that the accumulation of Chinese ceramics lies within an area coded in red, the second lowest value of suitability (value 2). Conversely, the Euroamerican residences, though still affected by the less suitable criteria, are located in higher suitability value ranges (values 3-6). The results of the model indicate that the original hypothesis, that Chinese railroad workers lived in a less suitable region of Terrace than Euroamerican railroad workers and other residents of Terrace, remains valid.

Chapter VI: Discussion

This study presents additional evidence to the growing body of literature on the Chinese occupation along the Transcontinental Railroad and the social inequality that they encountered. The findings of this study not only support the segregation of Chinese from Euroamerican workers at Terrace (via the kernel density analysis of ceramic material and previously stated evidence of this type of segregation at similar sites along the grade, see Sunseri 2015) but also reinforces prior evidence of social inequality between cultural groups at Terrace and other similar sites across the American West railways (Merritt et al 2012; Sunseri 2015; Laundreth and Condon 1985; Voss 2015, 2018). Previous studies (Merritt et al 2012; Sunseri 2015) used sheet refuse as evidence of segregation between Chinese and Euroamerican laborers (presence/absence of Chinese affiliated material remains) or used environmental attributes, such as mosquito infested camp sites (Merritt et al 2012:681), to compare Chinese living space with that of Euroamerican workers. I have taken these methods and built upon them taking a deeper look at the nature of this segregation using material remains, such as sheet refuse, as well as the relation of town features to habitation areas and how proximity to hazardous features or distance from necessary resources impacts quality of life for Chinese workers.

Further, this study presents an innovative, effective spatial analytic method of investigating social inequality in historical and archaeological settings. Suitability modeling has been used by researchers in many disciplines, but the method has yet to be utilized to its fullest potential, especially in regard to questions about past human behaviors revolving around social inequalities and social hierarchies at historic sites (Oheim 2007; Wren and Burke 2019; Healy et al. 2017). I present this study as an example of an effective use of suitability modeling to explore social inequality at archaeological settings. Using this type of spatial analysis adds to additional evidence of cultural segregation found among similar sites to Terrace along the railway and bolsters claims of social injustice between Euroamerican population and other marginalized cultural groups, such as the Chinese and Native American populations working for railroad companies. For example, physical barriers, such as the railroad grade, were often used to separate Euroamerican and Chinese workers (see Figure 1) and using these types of visual data in conjunction with a spatial analytic method, like suitability modeling, provides both tangible (able to see clearly across the landscape) and intangible (not clear to the naked eye, i.e., hierarchical levels of suitability across a site) evidence of social inequality. For historical archaeology in the U.S. west, suitability modeling, specifically using the methods described in this study, can provide a statistical and analytical line of evidence demonstrating social inequality between different cultural groups via analyzing the physical landscape, built environment, and material remains—within a single model—at historic archaeological sites across the U.S. West.

Mapping social inequality between cultural groups along the Transcontinental Railroad using suitability modeling holds much promise. Future research should consider developing similar models for other sites along the CPRR using the methods described above. A comparative analysis between the results from Terrace and other towns along the grade may strengthen the outcome of the present study and provide stronger evidence of the effectiveness of suitability modeling for this purpose. Additionally, including more diverse criteria into the model would create a more comprehensive investigation into social inequality at Terrace, or other sites. For example, DEM, vegetation, soil, wind direction, and other environmental data could add insight into the site formation processes that may have disturbed original locations of material remains at Terrace. These data were not available at a high enough resolution for the current study but may be available for future research with additional fieldwork or at different locations.

Maslow's Hierarchy of Needs, specifically the adaptations of the theory for use in urban design and community planning (Jacobs 1961), can provide a theoretical infrastructure for studying social inequality in historical and archaeological settings, especially in settings that include material evidence of socio-economical hierarchies. Combined with suitability modeling, Maslow's theory can inform on social and spatial patterning of residential segregation and nineteenth century urban planning and ethnic interactions during American West expansionism using both qualitative—presence or lack of basic human needs—and quantitative—spatial analytic methods—analyses.

The results of this study expand our current understanding of the living conditions of, and the hardships faced by, the Chinese railroads workers during the construction of the transcontinental railroad, and their epic contributions to the American Industrial Revolution. At Terrace, much of the documentation of lifeways was lost during the fire in the early 1900s. The suitability model presented here serves as a new perspective and method for looking at which regions of Terrace were less suitable than others for habitation, as well as a deeper look into social hierarchies that existed during the occupation of the site. For Western Archaeology, this study presents evidence that suitability modeling is an effective spatial analytic method for examining social behavior, social hierarchies, and social inequality at similar archaeological sites.

Broader Questions

The present study exists under a broader shadow of questions concerning the concept of self-segregation. Segregated cultural groups are recognized in historic and modern urban settings, such as Chinatowns present in many major metropolitan areas (Gardner 2003; Yuan 1963). Scholars have explored the motives behind cultural segregation by attempting to distinguish the act as either involuntary (forced) or voluntary (self) segregation. Yuan (2003) applies these two concepts to San Francisco's Chinatown and discusses the possible causes of culturally segregated groups. Voluntary segregation may be the result of a need to be amongst culturally-like groups, a shared culture, to feel safe, secure, and familiar. Maslow's Hierarchy of Needs theory can attest to this interpretation as feeling safe and secure as a basic need for human development. Involuntary segregation often is associated with racial violence or tension from other cultural groups and societal pressures that make it difficult to live comfortably without a cultural support system. Yuan proposes that self-segregation, or a gathering of culturally-like individuals, is a result of both voluntary and involuntary segregation. Villalpando (2003) explores self-segregation in smaller cultural groups in modern educational settings and reiterates that these groups tend to gravitate to others with shared cultural backgrounds and practices for support and engagement. These studies provide interesting reasonings behind why we often see cultural groups gravitate toward one another in urban settings.

There has been little documentation found authored by Chinese laborers themselves (Voss 2015). Archaeological methods provide direct evidence of how Chinese railroad workers lived during the construction of the transcontinental railroad and the social inequality they encountered. This study contributes to the collaborative research on the

Chinese occupation of the transcontinental railroad by presenting both a new spatial analytic method for examining social inequality at other historic railroad sites, but also a new theory, Maslow's Hierarchy if Needs used in conjunction with suitability modeling, for exploring quality of living space at archaeological sites. These concepts may provide a foundation for exploring and contextualizing similar phenomena in historical and archaeological settings. Investigations into self-segregation of Chinese groups from Euroamerican groups in historical settings is not a new notion (Gardner 2003), but using archaeological datasets with spatial analytical methods, such as suitability modeling, may provide additional insight into these historical sites, lending voice and understanding of lived experiences for marginalized groups.

Chapter VII: Conclusion

The results presented above provide a glimpse into the conditions in which railroad workers lived, and, specifically, an example of inequality of living spaces between cultural groups at railroad sites. Chinese railroad workers were marginalized and gathered in segregated groups to escape racial tension in order to live more comfortable lives (Sunseri 2015). Based on the current available data at Terrace, the average suitability of the townsite is low, with the Chinese railroad workers congregated in the least suitable region of the site, though the reason behind this segregation is unknown at this time. Several investigations are underway to collect more data about past lifeways at Terrace and more features are being unearthed every year. Collecting more data and creating additional versions of this suitability model will provide a more conclusive and holistic view of social inequality between the cultural groups the lived at the site. The Terrace suitability model presents an example of how investigating suitability provides insight into historic lifeways, particularly at historic archaeological sites that have little information other than what can be seen archaeologically and should be considered when investigating similar sites along the Transcontinental Railroad.

Using this type of spatial analytic method will reinforce the presence of social inequality, particularly at archaeological sites investigating cultural segregation, by providing an intangible line of evidence—evidence unseen by the naked eye, i.e., a hierarchy of suitability levels across a landscape—along with material evidence left behind in similar archaeological settings. Additionally, the results of the suitability model present a prelude to further study into the social behaviors and motivations behind cultural segregation in similar historic settings. Further application of Maslow's pyramid of needs to Terrace and other section stations along the CPRR will enrich our understanding of the motivations behind segregating from Euroamerican groups, regardless of living space quality. Further investigations into the social inequality encountered at Terrace, the application of suitability modeling to similar sites to Terrace, and the replication of this study with both new evidences uncovered about Terrace and with similar sites can provide a better understanding of the social tension between the Euroamerican cultural group and marginalized cultural groups, such as Chinese. Once we have a better understanding of social inequality during this time, we can apply broader questions about the nature of this social inequality and cultural segregation, such as the differences and connections between voluntary and involuntary segregating between cultural groups.

The overlooked contributions made by the Chinese railroad workers to the construction of the Transcontinental Railroad are being unearthed by archaeologists across the American West. Using archaeological methods, the lives of, and challenges faced by, the Chinese immigrants along the railroad are becoming clearer. The present study contributes to this growing body of knowledge by providing a spatial analytic method for investigating segregation and social inequality between cultural groups via living spaces along western US railways. Suitability modeling is adaptive and can be easily manipulated to fit historical settings similar to that of Terrace, Utah, to inform archaeologists, historians, and other scholars about the quality of living at historic railroad towns. In conjunction with Maslow’s Hierarchy of Needs, suitability modeling proposes an effective way to explore social inequality in urban historic settings.

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