University of Nevada, Reno

Unmanned Aircraft Systems (UAS) and Photogrammetrics as a Tool for Archaeological Investigation in 19th Century Historic Archaeology

A thesis submitted in partial fulfillment of the
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by

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Abstract

Unmanned Aircraft Systems (UAS) and photogrammetrics are a growing part of the archaeological toolkit. They provide a low cost tool to aid in the collection and analysis of aerial imagery. To test the applications of this technology, I completed a partial survey of Aurora, Nevada. Using a UAS, I collected images for three city blocks during the summer of 2015. Using photogrammetric software, I have analyzed the collected image data by creating orthophotomosaics and 3D models of the site. With these models, I have been able to examine topography, foundations, and house lot locations to explore the relationship between historic building material and the remains currently seen on the ground. This thesis shows the methods employed in the collection of aerial imagery and data processing, and the multitude of ways researchers can analyze this data to evaluate archaeological sites.

Dedication

To my father, Gary Lee Calkins. Thank you for teaching me the value of hard work.

Acknowledgments

Many people helped make this thesis possible. First, I wish to thank Dr. Christopher von Nagy. Dr. von Nagy, thank you for introducing me to UAS and teaching me how to fly. Without your ceaseless support, this thesis would never have been possible. You have proven an inspiration to me throughout the completion of this thesis. Thank you. I also wish to thank Dr. Carolyn White. She has read numerous drafts, and put up with endless questions, thank you. I also wish to thank Dr. Paul Starrs. He has read numerous drafts and kept me focused on the road ahead. Thank you. I wish to thank my field crew Leo, Melody, Lauren, Erika, and Emily. Without your help, I could have never collected the data for this project. I also wish to thank Cliff Shaw and Bob Stewart. They have both proven to be an invaluable source of information on Aurora and have shared that wealth of knowledge with me. Thank you both. I also wish to thank all of my colleagues and instructors at the University of Nevada, Reno. Your names are too many to mention, but I am grateful for the valuable feedback and experiences we have shared together. Thank you all.

Last, I wish to thank my wife Megan and my children Beth and Graham. Megan, thank you for working endless hours to put me through graduate school. I know I do not say thank you enough. Beth and Graham, thank you for being the best children I could ask for. I love you all.

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Figures and Tables

Chapter 1: An Introduction to Aurora, Nevada, Unmanned Aircraft Systems, and Photogrammetrics

Unmanned aircraft systems (UAS) and photogrammetrics are a growing part of the archaeological toolkit. Archaeologists have used UAS to record excavations, sites, and generate photogrammetric models. This thesis adds to the existing literature and explores the applications of UAS and photogrammetrics in historic archaeology. I use the collected data to examine the distribution of building materials on three partially surveyed blocks of Aurora, Nevada. Through an analysis of Aurora and its building location and materials, I will show that UAS and photogrammetrics are a valuable tool for archaeological data collection and interpretation.

To complete this thesis, I partially recorded three city blocks of Aurora, Nevada with a UAS. The collected data was used to create photogrammetric two and three-dimensional models. I used these images to analyze the recorded blocks, looking for patterns in the distribution of building remains. My goal is to understand why certain locations exhibit a wide variety of structural debris while debris is absent in other places. I argue that structures made from milled lumber and brick were more difficult to remove, thus they left more structural debris on the landscape. Homes made from logs, canvas, and stone were easier to remove in their entirety by 19th-century miners. Consequently, these structures left behind little or no structural debris.

This chapter is an introduction to Aurora, Nevada and UAS technology. First, I discuss the previous research that has taken place at Aurora. Second, I look at the ideas of building function, aesthetics, and material type and the role they played in Aurora.

Third, I provide a history of Aurora, its people, and places. Fourth, I introduce current UAS and photogrammetric technology and applications.

Previous Research

Several researchers have conducted fieldwork to study various archaeological themes in Aurora. The first researcher to conduct fieldwork at Aurora was Jessica Kinchloe (2001). She studied the foodways of the Exchange Hotel in downtown Aurora. Emily Dale (2011, 2016) analyzed Aurora's Chinese population, and individual agency through the Chinese who lived in and around Aurora and Bodie, California.

As a part of the Aurora Neighborhoods Project, two previous researchers have conducted fieldwork in Aurora. The Aurora Neighborhoods Project is a partnership between the Humbolt-Toiyabe National Forest of the United States Forest Service (USFS) and the University of Nevada, Reno (UNR) to conduct archaeological studies of Aurora's neighborhoods and households. Dr. Carolyn White (UNR) directs the project in cooperation with Fred Frampton and Eric Dillingham (USFS). Ashley Younie (2014) and Katee Withee (2015) were the first to conduct fieldwork as part of this partnership. Younie examined food use of several Block C residents, while Withee examined family construction through the artifact assemblages of the Kaufman and Levy households. The 2015 UAS survey is the latest research in this ongoing partnership.

The data provided by Kinchloe, Dale, Younie, and Withee helps researchers learn more about the people of Aurora through an analysis of lifeways and foodways. Younie and Withee focus their theses on the Kaufman and Levy households of Block C. My research incorporates these lots, as well as the lots surrounding them. I hope to provide a clearer picture of life on Block C through a discussion and analysis of the house lots omitted by Younie and Withee. Part of my survey area also included the area of Spring Street excavated by Dale in 2010. While Dale focuses on the Chinese occupation of Spring Street, I look at the Euro-American occupation of Spring Street from 1863-1864. Kinchloe provides valuable background information about Aurora and the foodways of the Exchange Hotel. Her excavation area was not part of the 2015 UAS survey.

The History of Aurora

Situated in the west central part of Nevada, the town of Aurora is three miles east of the California border. Aurora is located on the eastern slope of the Sierra Nevada Mountains at an elevation of 7,441 feet. Figure 1.1 shows Aurora's location.

In August 1860, three prospectors—J.M. Braly, E.R. Hicks, and J.M. Cory—set out in search of new mining claims around Mono Lake, California (Williams 1987:24). On August 25, 1860, they discovered ore deposits just south of what is now Aurora. They named the area Esmeralda, later changed to Aurora (Stewart 1996:6). Word of their discovery spread quickly, and prospectors poured into the area on a "silver wave" (*Daily Alta California* [DAC], 21 September 1860:1).

Figure 1.1. Location of Aurora, Nevada. Image courtesy of bing maps.

By October 1860, surveyors had platted Aurora, and on November 11, the first shipment of ore departed Aurora (*Mining and Scientific Press* [MSP], 30 November 1860). By February 1861, six months after the first gold discovery, Aurora's population ha grown to over 300 people (DAC, 10 February 1862:1). The population continued to climb, and by 1863 Aurora boasted a population between 3,000-5,000 people and was the second largest city in the Nevada Territory

(Kinchloe 2001:13). The *Daily Alta California* describes this growing desert metropolis:

> [Aurora] is now improving very rapidly, and the sound of the mechanic's hammer is heard in every direction from morn till night, and buildings, from the small miners' cabin up to the splendid brick store–house, family residence or spacious saloons, are being erected on lots that a short time since were lying vacant and considered almost worthless. Money seems to be more plenty and business seems to be prosperous. The health of the citizens generally, good, and all seems happy and flourishing. (DAC, 27 October 1862, 1:3)

While this newspaper article paints a vivid picture of content and growing Aurora, life was not always easy. It was difficult to get staples like flour, rice, and beans. One reporter described it this way, "We are suffering for want of flour and other necessaries. This town is bare of everything but whiskey, cigars, tobacco, and some clothing. We, as well as our neighbors, are living on beef and coffee straight: no flour or corn meal, no beans." (*Sacramento Daily Bee* [SDB], 6 June 1862:2). Not only was it challenging to obtain a steady supply of food, but winters proved exceptionally harsh. In the winter of 1861-1862, the first snowfall began in September and continued to May (SDB 10 October 1862). The heavy snowfall closed down roads, reducing travel and supply trains into and from the city.

Good lumber yielding trees were not locally available around Aurora (Shaw 2009:55-57). Aurora's residents used nearby resources such as pinyon pine and juniper to create firewood and charcoal to power the kilns in the Aurora brickyards. Nevertheless, many residents did import lumber for use on homes and businesses. Alternatively, the materials needed to make bricks were locally available, making it an inexpensive alternative to lumber. At its peak, Aurora had five brickyards creating bricks for Aurora's growing population (Shaw 2009:28-29). Figure 1.2 is an image taken of Aurora circa 1890. Residents constructed many of the buildings seen in the image from locally made brick and imported lumber.

I place emphasis on building material here because it will play an important role in my analysis of the photogrammetric data. I argue that structures made of milled lumber and brick were more difficult to remove for 19th-century miners. Scavengers removed Aurora's brick buildings during the post-World War II building boom in Nevada and California (Stewart 2004:83). Because it is more difficult to remove these materials, scavengers left behind more debris. Today, none of the buildings on the survey blocks remain standing.

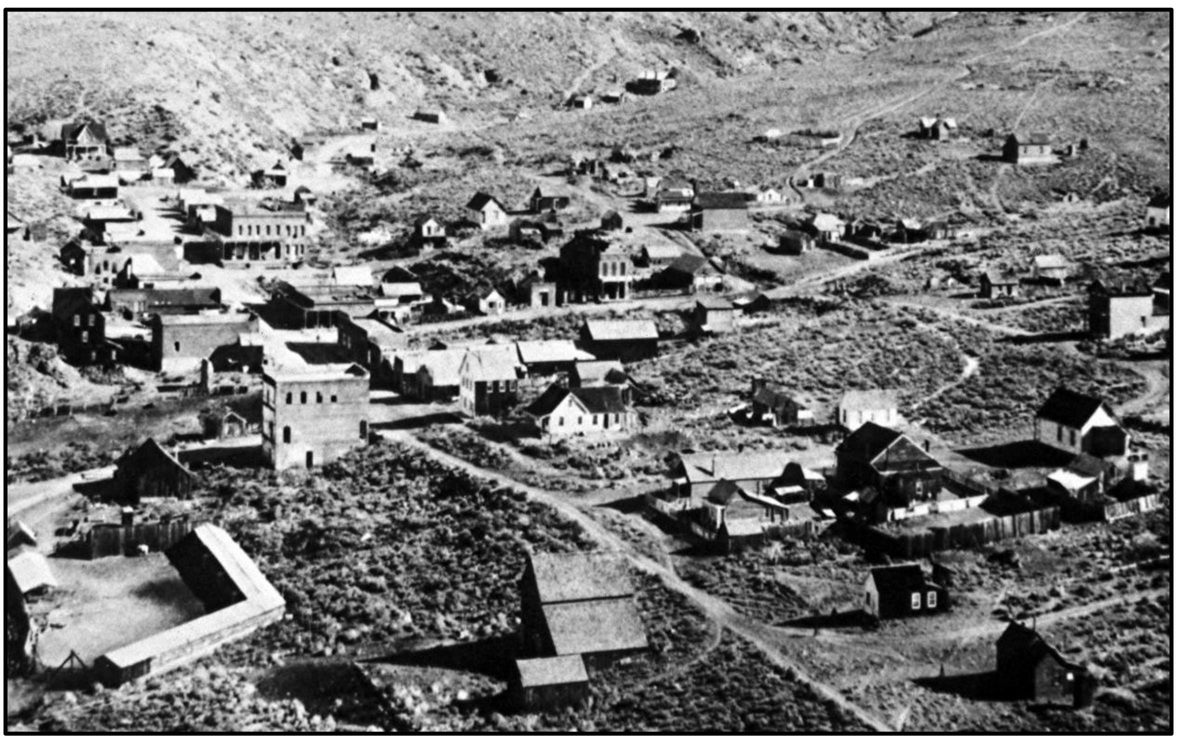

Figure 1.2. A view of Aurora looking southeast ca. 1890. Photograph courtesy of the Nevada Historical Society.

By the autumn of 1863 Aurora was a growing and prosperous city with a population between 3,000-5,000. However, the boom was short-lived (Stewart 2004:2; Shaw 2009:14). By early 1864, the mines began to dry up after yielding around $3 million in gold and silver (Shaw 2009:156). In 1865, 14 of the 17 stamp mills closed (Kinchloe 2001:17), and by 1870, the town's population had fallen to less than 300 (1870 Census). By 1900 the population had decreased to less than 100, and in 1930, Aurora was a ghost town.

Aurora is too large to effectively record with the small rotary wing UAS in the provided time frame. Therefore, I chose to focus my research on three town blocks, Block 3, Block C, and Spring Street. They were chosen because they represent the economic diversity of Aurora, and provided a way for me to build upon the work of previous researchers.

I refer to each block by the name given in the 1862 Brady Fire Map of Aurora (Figure 1.3), which lists all the city blocks by number or letter. The map is more schematic than spatially accurate. The 1864 Esmeralda County Tax Assessment Roll Map is more spatially accurate, and I use it to understand block and lot dimensions.

By surveying three different blocks, I was able to examine many different building materials and how they relate to the overall picture of life in a 19th-century mining community. Block 3 was commercial and residential. The commercial buildings were made of brick and fronted Pine Street, one of Aurora's main roads. Residents placed the residential structures behind the commercial buildings and were wood cabins. Block C was residential, where some of the town's merchants and businessmen lived. This block also bordered Pine Street, and these families' homes were made from a mix of brick and lumber. Spring Street was a working class area, where miners and mill workers lived. The residential buildings on Spring Street were recorded as cabins.

This chapter does not discuss each surveyed lot. With Blocks 3 and C, there are too many surveyed lots to discuss each one effectively. Therefore, I limit my discussion in this chapter to the individuals and buildings with the largest amount of primary material found in newspapers, official documents, and diaries. I determined these individuals and buildings had the most primary material after a thorough search of the Special Collections at the University of Nevada, Reno, the Nevada Historical Society, and numerous communications with Aurora researchers Clifford Shaw and Robert Stewart. I found very little information about the lot owners on Spring Street. The names of the lot owners are recorded on the 1864 Esmeralda County Tax Assessment Roll, but no other information was found. For this reason, I only discuss the lot of Calvin Higbie. Samuel Clemens discusses him in first-hand accounts, though Clemens account of life in Aurora may be questionable.

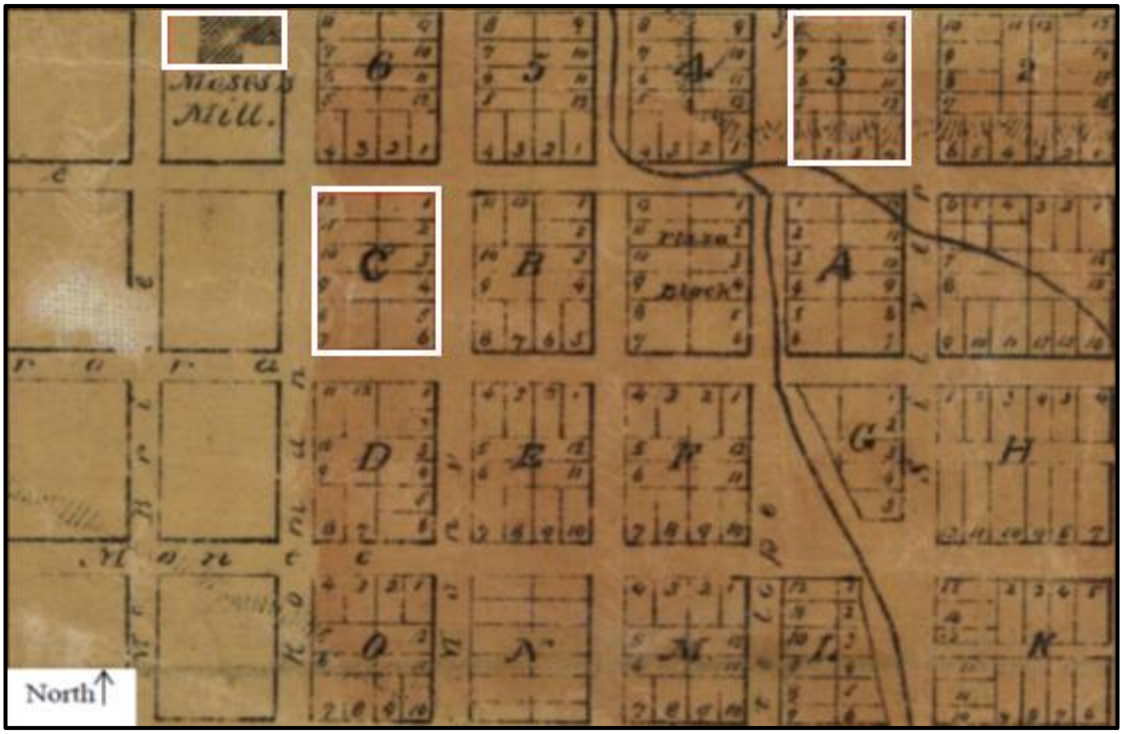

Figure 1.3. The 1862 Brady Fire Map. The surveyed blocks are outlined in white. Courtesy of the Nevada Historical Society.

Block 3

Block 3 is a heavily sloped block in downtown Aurora. The south side of Block 3 fronted Pine Street, one of Aurora’s main thoroughfares. Silver Street borders on the east and North Antelope Street on the west. North Antelope Street is the main road to Carson City, Nevada. To the south, east, and west were residential blocks of Aurora. Also to the east were the mines, such as the Wide West and Del Monte. North of Block 3, up the sloped topography, was the edge of the platted town.

In this section, I will not address each lot specifically because there is not enough information on all the lot owners and residents. The lots discussed had the largest amount of primary source information. Therefore, the only lots discussed in detail are the Beckett and Frainor, Wingate Hall, Molineaux & Dodd, Dreyfus & Laurel, and Mono County

Jail. I first discuss the lots that face Pine Street, working in a counterclockwise manner across the entire block.

Block 3 was a mix of residential and commercial properties. The south end of the block, along Pine Street, were shops, saloons, and residences. Of the seven lots facing Pine Street, six were commercial. Gasson is the only residential lot. Of the six commercial lots, Beckett & Frainor’s lot contained four buildings, and S. Jones’ lot contained two buildings each with different occupants. The Neidy lot contained one building that housed two businesses and the Wingate lot (Wingate Hall) contained one building with three businesses. The Dreyfus & Laurel and Molineaux & Dodd lots each contained one building with one business.

As the block continued north and away from Pine Street, the lots were less commercial and more residential. The lot owners fronting Silver Street, North Antelope Street and the north end of the survey area were residential. Of the lots on Silver Street, the Wingate lot was the only commercial lot. It is also the closest to Pine Street. The lots of Keefer, W. Jones, and Wheeler were all residential. Each lot contained one wood structure. Structures on the north end of the block were almost exclusively residential. The Dr. Sill, and McBride lots were all residential. Each lot contained a single wood house or cabin. The Mono County Jail is the single commercial property in the area. It was constructed of brick, stone, and lumber.

Table 1.1 and Figure 1.4 show the information presented above in more detail. Table 1.1 provides information on residents, lot size, and the assessed lot values, including furniture and buildings. The table shows the location of the businesses, even if occupant did not own the respective lot or building. Figure 1.4 is a redrawn portion of the

1864 Esmeralda County Tax Assessment Roll Map. This map only shows the lot owners; it does not show the building occupants.

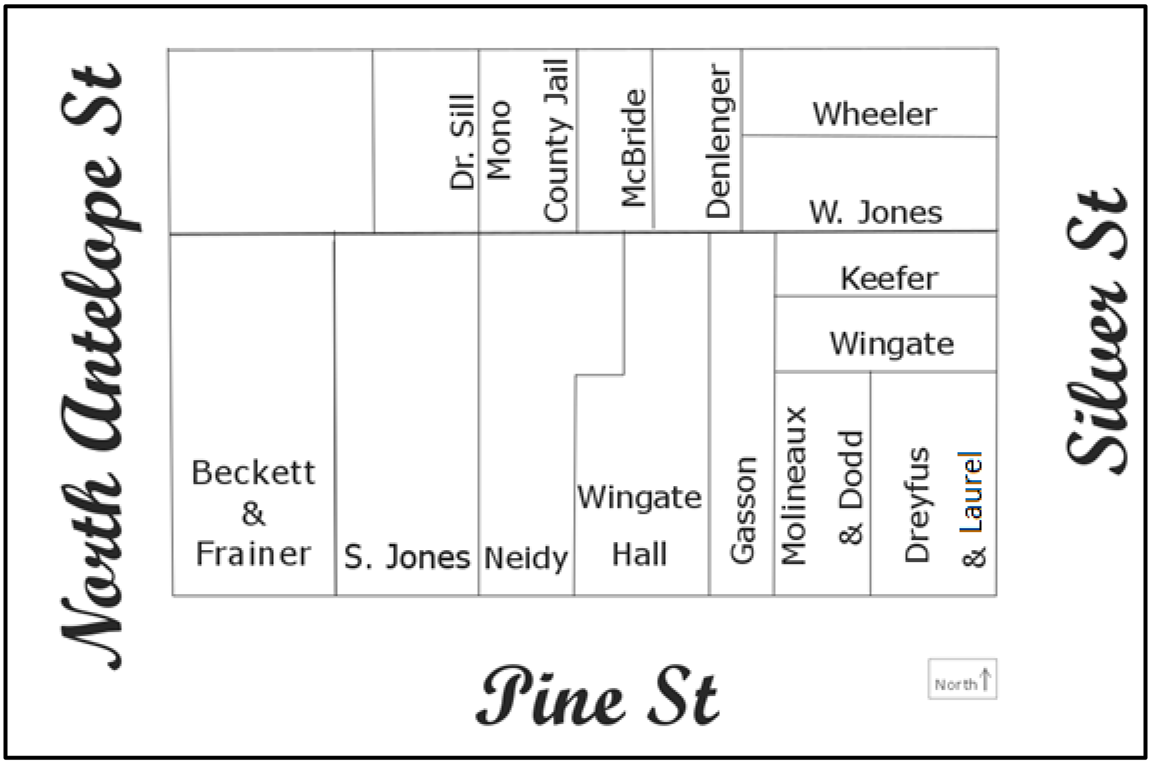

Figure 1.4. Map of the Block 3 survey area redrawn from the 1864 Esmeralda County Tax Assessment Roll Map. The solid lines are the extent of the survey area while the dashed lines indicate the extension of the block not surveyed.

Table 1.1. Block 3 lots surveyed in 2015. Data from the 1864 Esmeralda County Tax Assessment Roll and Map.

Owner	**Value**	**Lot size**	**Occupant (if other than owner)**	**Occupation**
Beckett & Frainor	Lot Value=$3500	40ft x 100ft with four structures		
	Building 1=$1225		Gem Saloon (Hoey and Davis)	
	Building 2=$300		Bee Hive Saloon (J. Levison and Co.)	
	Building 3=$150		Judge Chase	Lawyer
	Building 4=$200		Judge Beckett	Lawyer
Wm Jones	$250 with one wooden building	25ft x 60ft		Works at Winters Mill
Henry Keefer	$250 with wood cabin	20ft x 50ft		
H.C. Wheeler	$300	25ft x 80ft		
Dr. Sill	$300 with a wooden house	25ft x 100ft		Physician
S. Jones	Lot value=$2200	40ft x 10ft with two structures		
	Building 1=$850		Levy and Bro. Saloon	
	Building 2=?			
John Neidy	$5000 with a one story brick building	21ft x 100ft with two occupants in building		
	$800 furniture/merchandise	Basement	Dannis Saloon (A.J. Dannis)	
	$3500 store merchandise	1st Floor	Haas and Finlayson Store	
Wm. McBride	$300 with house	20ft x 50ft		County Surveyor
Jacob Denlenger	$650 with house	50ft x 50ft	J. Miller	
A.M. Wingate	$10500 with brick	25ft x 100ft		

(Wingate Hall)	building	three building occupants		
	$300 furniture/merchandise	Basement	Glenn Brothers Saloon (Basement)	
	$4000 store merchandise	1st Floor	Wingate Store	
	$3600 furniture/merchandise	2nd Floor	Sazerac Saloon (Steiner and Gaige)	
A.M. Wingate	$300 with wood building	20ft x 50ft	S.M. Van Wyck- Assay Office	
Paul Gasson	$1300 with one wood building	16ft x 100ft		
Dreyfus & Laurel	$4500 with one story brick store $1200 merchandise	27ft x 60ft basement		
Molineaux & Dodd	$6000 with two story brick building $4000 merchandise	25ft x 60ft		

F.K. Beckett and U.B. Frainor owned the corner lot between Silver Street and North Antelope Street. The lot was 40 x 100ft, with four structures: two saloons and two law offices. Beckett was an attorney and public notary who played an important role in early Aurora (1864 Esmeralda County Tax Assessment Roll). On August 23, 1861, Aurora's residents voted Beckett Vice President of the Aurora and Monoville Union Club, and Chairman of the Esmeralda County Central Committee (*Sacramento Daily Union*, 27 August 1861:2). He also served as the first delegate to the Nevada Territorial Assembly from Esmeralda County (Thompson and West 1881:402).

A.M. Wingate owned two lots on Block 3. The lot on Silver Street housed the S.M. Van Wyck assay office. The lot on Pine Street was Wingate Hall. Wingate Hall played an important role in the social and economic life of Aurora. Constructed in the fall of 1863, Wingate Hall was a spacious two-story building that housed two saloons, a store, and a large meeting space (Shaw 2009:151). The Glenn Brothers Saloon was in the basement. Wingate's store, which specialized in "Groceries and Miners Goods," occupied the first floor (1864 Esmeralda County Tax Assessment Roll). The Sazerac Saloon and Barnum's Cigar and Tobacco store were on the second floor along with a large meeting space. Aurora's citizens used the meeting space for several town social events including an 1864 Christmas and New Year's party (*Esmeralda Union*, 30 December 1864). The following excerpt describes the design of Wingate Hall:

> A large number of new buildings have been contracted for. The most prominent and beautiful one in Aurora is A.M. Wingate's large three story brick building, fronting on Pine Street twenty-two feet. The [sic] Basement story is built of dressed stone-the wall two feet thick. The main store room is thirty-two by fifty feet, the ceiling thirteen feet, six inches high from the main floor, and is supported by heavy iron columns. The third story forms a large and beautiful hall, of thirty-two by fifty feet, and is well adapted for a lecture room or billiard saloon- ceiling thirteen feet high. On the north end of the main building is added an L, twenty-four by twenty-four feet, three stories high, and is well arranged for a family residence. The interior of the main and front building is beautifully finished–all of the openings being enclosed with heavy iron doors, and the front is handsomely decorated with a splendid bracket cornice, making a happy combination of durability and beauty (DAC, 4 September 1863).

Three other mercantile stores were present on Block 3: Dreyfus & Laurel, Molineaux & Dodd, and Haas & Finlayson (1864 Esmeralda County Tax Assessment Roll). Each mercantile that fronted Pine Street was in a brick building. Haas &

Findlayson placed an advertisement in the *Aurora Daily Times* promising, "Clothing, boots, shoes, hats, and caps; which they offer at such prices that will defy the competition" (*Aurora Daily Times* [ADT] 27 November 1863). In another advertisement, Molineaux & Dodd advertised "Hardware, stoves, [sic] tinware, iron, steel, gas pipe, lead pipe, window glass, putty, oils, &c" (ADT 27 November 1863). I found no advertisement for the Dreyfus & Laurel store.

Each store's goods were assessed at a similar value. Haas & Findlayson, Wingate's Store, and Molineaux & Dodd had their goods valued at $3,500, $4,000, and $4,000 dollars respectively. The Dreyfus & Laurel mercantile had goods valued at $1,200. It is difficult to know why the county assessors gave each lot their specific value. Without store ledgers, it is difficult to make an accurate judgment on why certain values were given. The difference in assessment value could be due to the amount of inventory each business had at the time it was assessed or the quality of goods offered by each business. Figure 1.5 shows the Block 3 mercantile businesses as they appeared around 1900.

The Mono County Jail was located on the northern slope of Block 3. Its location must have been difficult to reach because it did not have street access. Rather, other lots surrounded it. Figure 1.4 shows this location. It was poorly constructed, and considered to be of little benefit for detaining prisoners (*Esmeralda Star* [ES], 23 August 1862). As a public building, this structure played a role in the unconventional election of 1863.

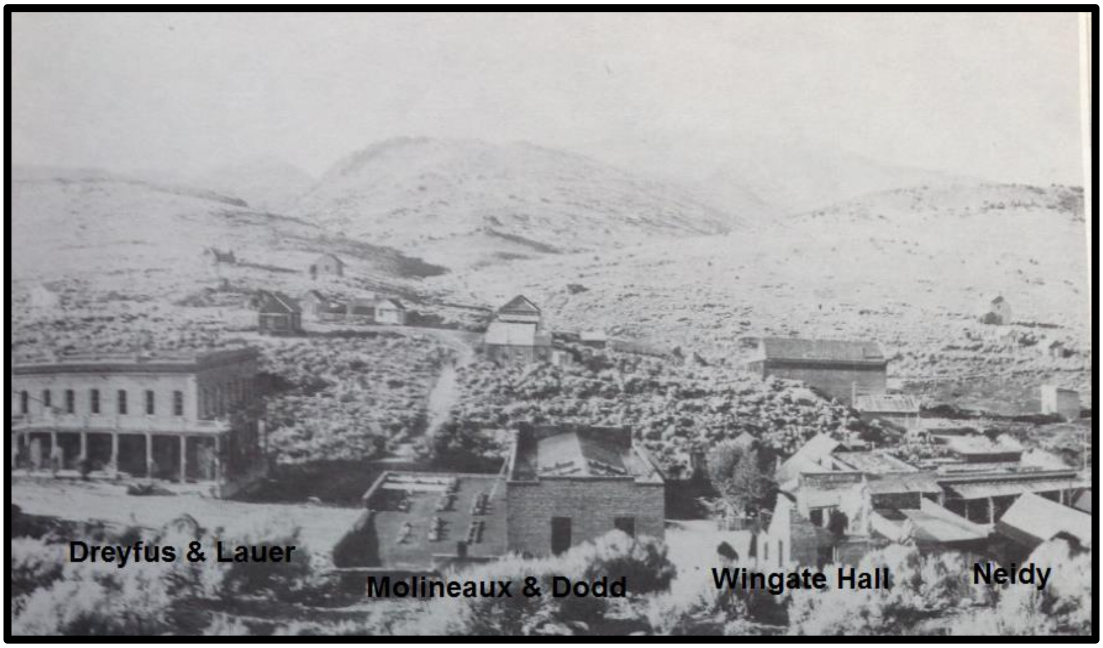

Figure 1.5. View of the southern half of Block 3 taken ca. 1900. The camera faces south. Photograph courtesy of Nevada Historical Society.

Shortly after its discovery, Aurora's citizens disputed whether it was located in California or Nevada. Both states wanted access to Aurora's vast mineral resources. To lay claim to Aurora and its resources, California established Mono County in June 1861, with the county seat in Aurora. In August 1861, Nevada followed suit and established Esmeralda County with the county seat in Aurora.

By the election of 1863, government surveyors had not reached Aurora to determine where it belonged. To solve the problem of state elections, residents decided to hold a dual election. It was agreed that when the surveyors reached Aurora, the elected officers of that state would preside. Armory Hall held the elections for Esmeralda County, Nevada, while the Mono County Jail held California's elections (Thompson and West 1881:403). In September 1863, surveyors reached Aurora and settled the boundary dispute, placing Aurora in Nevada (Thompson and West 1881:401-402).

Block 3 housed a variety of businesses, from mercantile stores to law offices. It gave residents a place to live, socialize, and purchase needed supplies. The south end of the block along Pine Street housed commercial brick buildings such as Wingate Hall, Molineaux & Dodd, and Dreyfus and Laurel. As the block progressed north, the lots were more residential. The lots on the north end of the block, on the steepest slope, were wood cabins, including the lots of Dr. Sill, Wheeler, and Keefer (1864 Esmeralda County Tax Assessment Roll). Block 3 is unique among the surveyed blocks for its mix of commercial and residential. The surveyed areas of Block C and Spring Street were residential.

Block C

Block C was a residential area located two blocks west of Block 3 along Pine Street (Figure 1.3). Pine Street borders Block C to the north and Mono Street to the east. Other residential lots were on the blocks to the east and south. The block to the west had very few structures, and Spring Street is north with several small houses and cabins.

The homes on Block C were a mix of brick and lumber. The Kaufman and Levy residences were made of brick and were the two most expensive homes on the block. Besides these homes, the Block C lots were modestly assessed (1864 Esmeralda County Tax Assessment Roll, Shaw 2009:163-201). The lot and property assessments on the Iovanovitch, Radervitch, Porter, and Pebelie lots range from $700 to $150 (1864 Esmeralda County Tax Assessment Roll). These homes were constructed of wood. Table 1.2 lists the lot owners and values, and Figure 1.6 illustrates the residential lots on Block C as they appeared around 1890.

Six of the seven lot Block C lot owners also owned a business in Aurora; this includes Radervitch, Porter, Fleishman-Kaufman, Levy and Co., and Pebelie. The business interests of these individuals were varied, and the specific businesses can be found in Table 1.2. This section will focus on the Porter, Kaufman, and Levy lots. I focus on these lots because there is the largest amount of primary documentation on these individuals, and I hope to build on the research done on the Kaufman and Levy lots by past researchers Younie (2014) and Withee (2015).

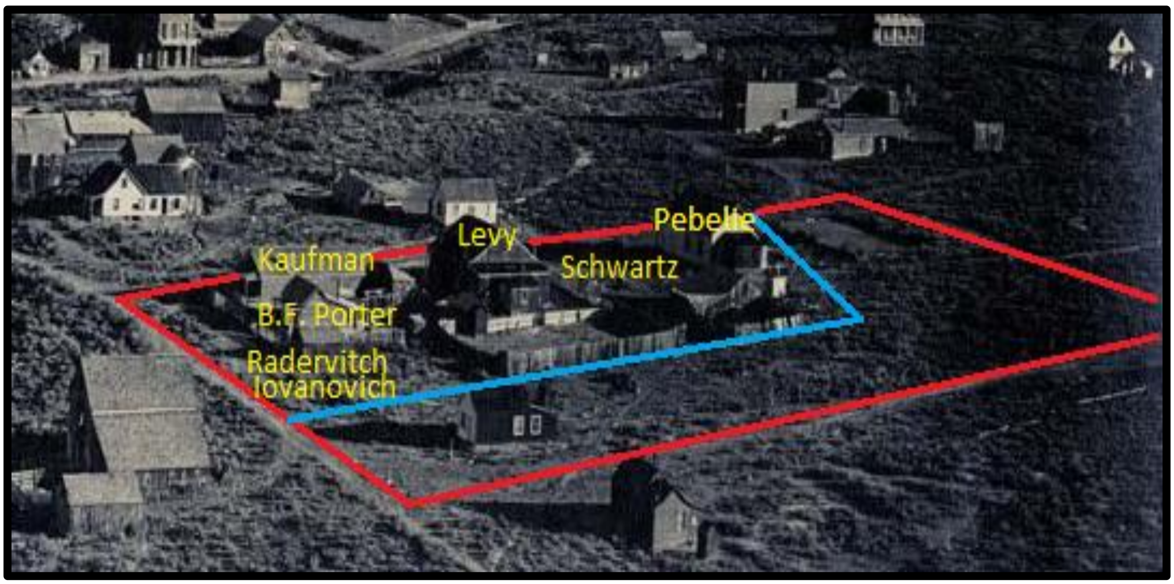

Figure 1.6. Block C looking northeast from Lover's Leap ca. 1890. The red outline is the full extent of Block C. The blue outline shows the area surveyed in 2015. Photograph courtesy of the Nevada Historical Society.

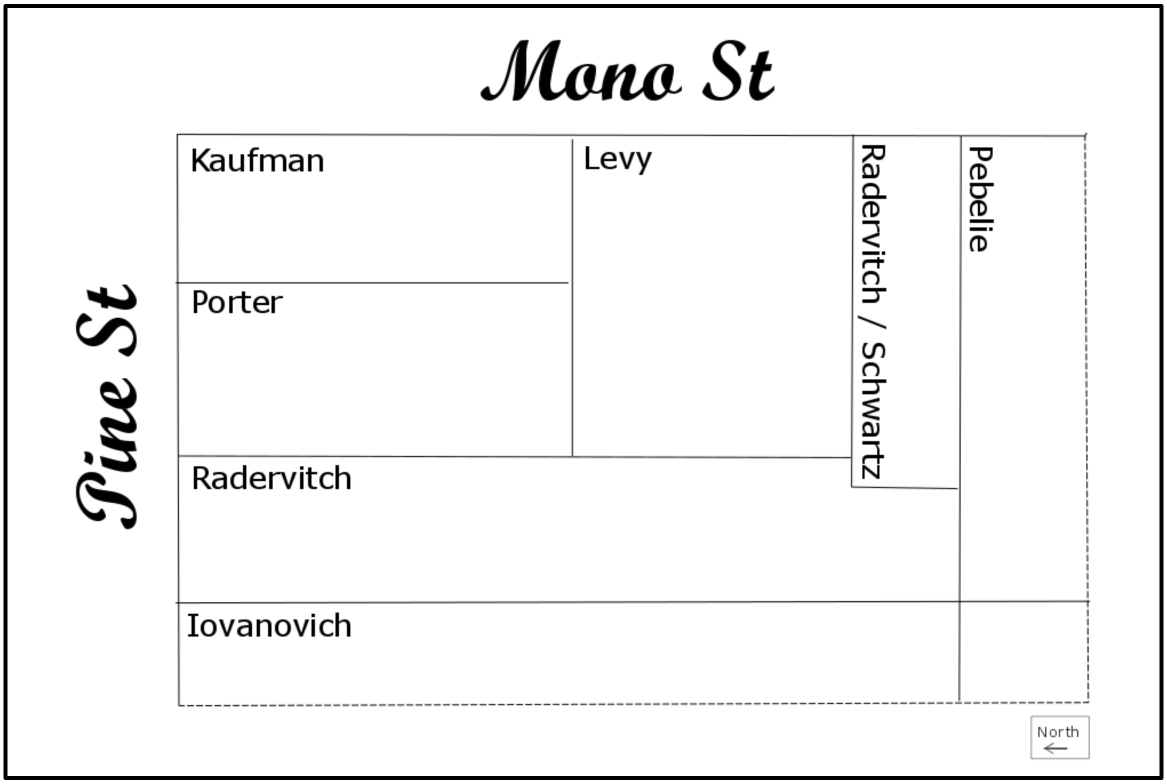

Figure 1.7. The Block C survey area redrawn from the 1864 Esmeralda County Tax Assessment Roll Map. The solid lines are the extent of the survey area while the dashed lines indicate the extension of the block not surveyed.

The Porter lot fronts Pine Street, one of Aurora's main streets. Porter's home was a single story wood 'saltbox' structure (Figure 1.6). To the east was the Fleishman-Kaufman lot, to the south the Levy and Co. lot, and the west the Radervitch lot (Figures 1.7). All of Porter's immediate neighbors owned businesses in Aurora (Table 1.2). Porter was the owner of Porter's Saloon on the corner of Antelope and Aurora Streets.

Gabriel Kaufman moved to Aurora in 1861. He married shortly after his arrival. They were members of Aurora's small Jewish population in the peak period of 1863-1864 (White and Younie 2014:8). Kaufman and his family lived a prosperous life in Aurora. They ran a successful dry goods store and lived in a permanent brick home on Block C. While living in Aurora, Gabriel Kaufman and his wife Jetta, welcomed two children, Sophie and Bettie (Withee 2015:53). Jetta became good friends with Laura Sanchez, who wrote about “Mrs. K” at length to her sister Nannie Crittenden. From these letters, we learn many things about the Kaufmans, including their appearance, work ethic, and businesses practices (Withee 2015).

Table 1.2. Block C lots surveyed in 2015. Data from the 1864 Esmeralda County Tax Assessment Roll.

Owner	Value	Lot size	Occupant (if other than owner)	Occupation
V. Iovanovich	$250 with improvements	30ft x 50ft		
Fleishman-Kaufman and Co.	$2200 with a brick residence	30ft x 75ft		Owner of the Pioneer Brick Store
Levy and Co.	$2700 with brick residence	66ft x 70ft		Owners of the Aurora Emporium
J. Pebelie	$350 with house	25ft x 100ft		Co-Owner of Washington Baths
B.F. Porter	$700 with wood house	40ft x 75ft		Owner of Porter’s Saloon
P. Radervich	$250 with board cabin	25ft x 100ft		Owner of Tremont Hotel
P. Radervich	$150 with cabin	21ft x 75ft	M. Schwartz	

The Kaufman home was a single story brick residence set on a foundation (1864 Esmeralda County Tax Assessment Roll). The home faced north on Pine Street and was completed in late 1862 (Laura Sanchez to Nannie Crittenden, September 1, 1862). It abutted the Levy home to the south and the Porter home to the west. The location of the Kaufman home is seen in Figures 1.6 and 1.7.

Shortly after coming to Aurora, Kaufman opened the Fleishman, Kaufman, and Co. Mercantile Store (Withee 2015:52). He owned and operated the store with his brother-in-law Benjamin A. Fleishman. The store, located a short distance away from his home, sold a variety of goods including groceries, clothing, hardware, and cookery (ADT 11 December 1863:2). Laura Sanchez called the Fleishman-Kaufman store "the best general store in town" (Laura Sanchez to Nannie Crittenden, August 15, 1862). In 1865, a fire destroyed the Fleishman, Kaufman, and Co. store (SDU, 27 November 1865). Kaufman did not rebuild, and the family soon moved from Aurora (White and Younie 2014:8).

The Levy family came to Aurora in early 1862. Upon arriving in town, Baruch and Nathan Levy established the Levy, Dreyfus and Co. Dry Goods Store on Antelope Street (Shaw 2013:2). Isaac Levy arrived in Aurora sometime after his older brothers. In 1863, Isaac bought out Dreyfus' and Coblentz' shares of the company, renaming it Levy and Co. Aurora Emporium (1864 Esmeralda County Tax Assessment Roll; Shaw 2013:2).

The Levy home was a single story brick structure set on a foundation. The house fronted Mono Street a short distance from Pine Street. The lot was valued at $2,700 and was the most expensive lot on the block (1864 Esmeralda County Tax Assessment Roll). To the north were lots owned by the Fleishman-Kaufman family and the Porter family. The Radervitch/Schwartz lot was to the south, and the Radervitch lot was to the west.

It is unknown how long Baruch and Nathan lived in Aurora, but the historical record suggests they came and went over the next decade, as each represented the company in different locations (White and Younie 2014:10-11). Isaac and Nathan were the most consistent occupants from 1863-1864 (Shaw 2013:4). The Levy home provided a place for the mobile Levy family to reside.

Block C was home to some of Aurora's business owners (Table 1.2). This section focused primarily on the Porter, Fleishman-Kaufman, and Levy and Co. lots. These lots represent a sample of the building type and material present on Block C.

Spring Street

Spring Street was the main thoroughfare out of town towards Bodie, California. Spring Street passed through town, down a gully, and into California. It was home to multiple stamp mills, brickyards, stables, a brewery, by mid to late 1863 through 1864, and residential lots mostly occupied by miners in 1861 and 1862. (Shaw 2009 and 2003). Traffic heading to and from the mines, and to and from Bodie and Bridgeport, California often left Spring Street congested. With the constant noise from the mills and brickyards, Spring Street was a less than desirable location to live (Dale 2011:113).

The topography of Spring Street is steep, increasing in elevation to the south. The area of Spring Street near the intersection with Roman Street was not favorable to large buildings and structures due to the topography. Nevertheless, this did not prevent residents from building small houses and cabins on the flat sections that fronted Spring Street (Figure 1.8).

I surveyed five Spring Street lots in 2015. The assessed worth for each one of these lots was relatively modest, each lot was valued at less than $400. The 1864 Esmeralda County Tax Assessment Roll describes four of the surveyed lots, Thompson & McDonald, Miller, Schwinerger, and Elstner. The Thompson & McDonald and Miller lots had two structures, described as houses or wood cabins. The Elstner lot contained a single cabin and the Schwinerger lot contained improvements (usually indicates a structure of some sort). The assessment roll does not provide information on the Higbie lot. Beyond the information provided in the assessment roll, I was only able to find information on the cabin occupied by Calvin Higbie. His cabin, lot, and experiences are described in this section.

Table 1.3. Spring Street lots surveyed in 2015. Data from the 1864 Esmeralda County Tax Assessment Roll and Map

Owner	Value	Property size	Occupant (if other than owner)	Occupation
Joe Schwinerger	$300 including improvements	50ft facing Spring Street running through Pine Street		
M.R. Elstner	$200 including a cabin	50ft x 100ft		
C. Higbie	$150	50ft x 100ft		Miner
Thompson and McDonald	$250 including improvements	25ft x 100ft	2 houses of unnamed Chinese	
J.W. Miller	$400 including two wood cabins	25ft x 100ft		

In the following section, I use a firsthand account provided by Samuel Clemens of his life in Aurora. While this information is valuable, it may not be entirely accurate. Clemens is known to have embellished facts to make them more entertaining to his readers (Mac Donnell 2012:26). For that reason, I do not discuss some of the experiences he describes in *Roughing It*. I only focus on facts that can be validated from multiple sources including statements by Higbie himself regarding his life in Aurora.

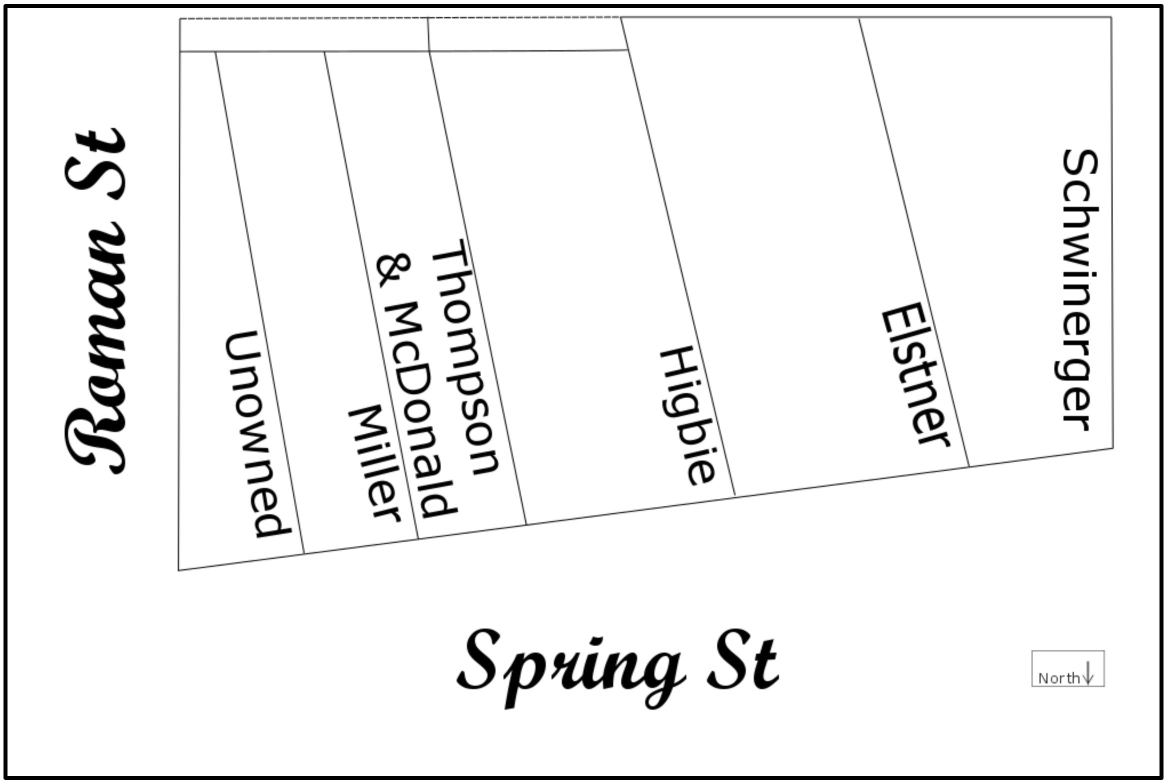

Figure 1.8. Redrawn survey area from 1864 Esmeralda County Tax Assessment Roll Map of Spring Street.

In April 1862, a young Samuel Clemens arrived in Aurora (Williams 1987:22). Soon after arriving in town, he began to share a cabin with Calvin Higbie (Twain 1913a). In the summer of 1862, Clemens moved into Higbie's cabin. Clemens lived in Aurora for several months where he tried his luck at mining. He found he did not enjoy the work and did not make any money. At this time, he began sending letters to the *Territorial Enterprise* in Virginia City, Nevada. In October 1862, he accepted the position of City Editor and left Aurora for Virginia City (Twain 1913b:3-4). While writing for the *Territorial Enterprise*, he adopted his more famous pen name, Mark Twain. Higbie continued to live and work in Aurora until he departed for California in 1864 (Dale 2011:70).

The Higbie cabin lay on a 50 x 100-foot lot of sloped ground on Spring Street. To the south, up the slope, was Pine Street. According to Higbie, the cabin was no more than a few log walls with a canvas roof and provided for the barest of physical needs (*Saturday Evening Post* 11 September 1920:23). Higbie's cabin was probably similar to the other structures occupied by miners in 1862 on Spring Street. Figure 1.9 shows Higbie's cabin as presented by Clemens in *Roughing It* (Twain 1913a). The following quote is Clemens description of his Spring Street cabin.

> Higbie and I were living in a cotton-domestic lean-to at the base of a mountain. It was very cramped quarters, with barely room for us and the stove - wretched quarters, indeed, for every now and then, between eight in the morning and eight in the evening, the thermometer would make an excursion of fifty degrees (Twain 1924:257).

Information collected from the 1864 Esmeralda County Tax Assessment Roll indicates the residents of Spring Street lived in modest homes. The assessment roll provides information on the Miller, Elstner, Schwinerger, and Thompson & McDonald lots describing them as wood cabins or houses. Higbie's home is not described. The homes on Spring Street were most likely similar to other homes occupied by Aurora's miners.

The 1864 Esmeralda County Tax Assessment Roll lists two types of residential wood structures on the three surveyed blocks, wood cabins and wood houses. In this section, I wish to offer an explanation for each term, and how that correlates with its respective assessment values. Each lot known to have a wood cabin was assessed at less than $250. Wood cabins would have been highly variable in their construction, would have lacked proper framing, and were built quickly to serve the needs of the occupant.

Figure 1.9. Calvin Higbie's cabin as pictured in *Roughing It* (Twain 1913a).

Explanation of Building Type

Alternatively, the lots containing a wood house were listed between $300 and $350. Wood houses valued in this range had a little more structure, were variable in their construction, may have exhibited proper framing, and more architectural details. Wood houses, and cabins are present on all the surveyed blocks in different forms.

Conclusion

The buildings on Aurora's landscape were a mix of brick, lumber, log, and stone. The style of home residents lived in varied by location and occupation. Residents who owned businesses were more likely to live in wood framed or brick structures than residents who worked in the mines. Structures built on the flat ground were more likely to be framed or brick, while structures on steep topography are described as “cabins” or simply “houses” in the 1864 Esmeralda County Tax Assessment Roll. This is seen at Block C, Block 3, and Spring Street.

I will use the data presented in this section as a lens through which to interpret the photogrammetric data in Chapters 3 and 4. Information discussed in this section is important to identify the location and type of structures present in Aurora’s peak period of 1863-1864. This information allows me to create expectations about the influence building material and structural form had on the way buildings were removed from Aurora’s landscape. The photogrammetric data allows me to examine building debris to understand why certain building material is still present on the landscape, while other material was removed.

Unmanned Aircraft Systems and Photogrammetrics in Archaeology

Unmanned aircraft systems (UAS) and photogrammetry are expanding the uses of aerial photography in archaeology. Today, archaeologists can create large-scale photogrammetric two and three-dimensional models of landscapes, buildings, and excavations using unmanned aircraft (Rua and Alvito 2011:3297). This section introduces the history, techniques, and methods of UAS and photogrammetry.

History of Aerial Photography in Archaeology

Early archaeologists used manned balloon flights to capture aerial photography. In 1899, Giacomo Boni took a series of aerial photographs of the Roman Forum. These are the first known aerial images intentionally taken of an archaeological site (Verhoeven 2009:233). These images did not have a large or immediate impact on archaeology; in fact, it was not until after World War I that aerial photography became popular in archaeology.

In 1914, with the beginning of World War I, many world governments halted recreational aerial photography (Barber 2011). As the war progressed, the need to take aerial photographs of enemy positions led to improvements in existing technology such as airplanes and cameras (Orlando and Villa 2011:147). In the aftermath of the war, many experienced pilots returned home and used their new skills for aerial landscape photography (Barber 2011:200).

In the 1920s to 1930s, archaeological aerial photography became an important tool for archaeological prospection in Palestine, Egypt, South America, and the United States (Reeves 1936). In 1932, W.S. Webb and W.D. Funkhouser published a report on the aerial photography of the Great Plains where they used aerial images to locate archaeological sites. Similar projects were conducted in Europe and the Middle-East. In subsequent years, Dache Reeves (1936, 1937) wrote two articles about the usefulness of aerial photography in *American Antiquity* stating, “aerial photography furnishes a rapid, inexpensive and accurate source of topographic information” (Reeves 1936:107).

In 1939, World War II interrupted most recreational flying across Europe. As in World War I, military innovations in technology paved the way for improved civilian photography. For example, the ability to perceive vegetation differences through infrared photography was one major development (Orlando and Villa 2011:147). Manual photogrammetrics (aligning image sets by hand to create maps), computers, and smaller cameras with higher resolution were developed. These advancements paved the way for the current technological revolution, including automated photogrammetrics and UAS technology.

After World War II, aerial photography became increasingly important to archaeology. T. E. Huddleston (1948) and Ralph Solecki (1957), among others, used aerial photography for archaeological prospection. Kites, balloons, and manned aircraft were the most popular means of aerial photography. Technology did not drastically change for almost 30 years (Verhoeven 2009:236). Researchers continued to use balloons and kites because advances in autonomous systems and satellites were not available to the public. In the early 1980s, archaeologists used model aircraft to acquire aerial imagery. Wester-Ebbinghaus (1980) began attaching cameras to model airplanes for mapping terrestrial landscapes.

Since the 1980s, remote-controlled (R/C) technology has advanced exponentially. Today, fixed wing and propeller-driven unmanned aircraft are smaller, lighter, faster, and less expensive than in the past. They come equipped with video and high-resolution cameras unheard of 30 years ago. The technology continues to advance, and today UAS have longer battery life and higher image resolution. Advances in battery life, camera resolution, and autonomous flight has allowed for an increase in the use and productivity of UAS in 21st-century archaeology.

Aerial Imagery and Photogrammetrics

Before discussing the methods and tools used to collect aerial imagery, it is important to discuss the terms of aerial photography and photogrammetrics. Many of the case studies described in the following section use photogrammetric terms. Aerial photography comes in two forms, low altitude aerial photography (LAAP) and high altitude aerial photography (HAAP). LAAP refers to any image taken less than 300 meters from the ground surface, which is the type of imagery recorded by an UAS. HAAP is imagery recorded flying above 300 meters, such as that of manned aircraft or satellites (Martinez-del-Pozo et al. 2013:228). LAAP has become intricately linked with photogrammetrics. Together, they generate models of landscapes, features, and sites. Unless otherwise noted, all case studies in this thesis use LAAP imagery.

Photogrammetry is the process of extracting data from two-dimensional (2D) images to create 2D or three-dimensional (3D) models (Remondino 2014:63). Images are stitched together to create accurate depictions of landscapes, excavations, features, and sites. While photogrammetric 3D models are named, simply, 3D models, photogrammetric 2D models are referred to as orthophotos or orthophotomosaics. Photogrammetric 3D models illustrate depressions and topography not obvious in 2D images or orthophotos (Remondino 2013). Orthophotos provide researchers with a complete geometrically correct site model; this allows researchers to identify, locate, and plot site features.

UAS Platform Types

Unmanned aircraft systems (UAS) are any aircraft flown without the use of an onboard pilot (Nex and Remondino 2014:73). Currently, platforms employed in aerial photography include kites, balloons, satellites, and propeller driven systems like UAS. Although researchers call all of these systems UAS, here UAS will refer only to a propeller driven system; all other systems are called by their proper names, such as balloon or kite. With the increase in unmanned propeller driven systems, this terminology has become common practice.

Table 1.4. Table examining attributes of different aerial systems (Nex and Remondino 2013:3). For this table, a higher number equals a more favorable rating.

	Kite/ Balloon	**Fixed Wing Electric**	**Fixed Wing ICE**	**Rotary Wing Electric**	**Rotary Wing ICE**
Payload	3	3	4	2	4
Wind Resistance	4	2	3	2	4
Minimum Speed	4	2	2	4	4
Flying Autonomy	-	3	5	2	4
Portability	3	2	2	3	3
Landing Distance	4	3	2	4	4

UAS are an emerging component of archaeological investigation. Coupled with Global Positioning Systems and compact high-resolution digital cameras, UAS provide an inexpensive platform for aerial photography. Aerial image sets allow archaeologists to create photogrammetric models. As UAS platforms continue to improve payload, battery life, and camera systems, they will become an increasingly important tool for archaeological investigation. These improvements will allow UAS to fly longer, take higher resolution images, and carry heavier sensors such as thermal imagery and LiDAR.

As of 2016, the cost of UAS platforms start around $500 and increase depending on the type (multicopter, fixed wing), payload, instruments, and technology employed in its design and use (Nex and Remondino 2013:2). Nex and Remondino's (2013:3) table lists the attributes of UAS types (Table 1.4) and allows researchers to determine which system is most effective for their project.

Table 1.4 is divided by aircraft type and further divided by propulsion system: internal combustion engine (ICE) and electric. Each type of craft (kite, ICE fixed wing, etc.) is given a rating across categories of payload, wind resistance, portability, etc. A higher number is a more favorable rating. For example, if LiDAR were part of an UAS survey, an internal combustion engine (ICE) provides higher payload needed to carry larger sensor systems (4) and would be more beneficial than an electric aircraft (3/2). Since the Aurora project only required image capture, a small electric aircraft was a more affordable option.

Current UAS Applications

There are many uses for UAS in archaeology. These include site recording, excavation recording, and site monitoring. The next section provides a summary of these uses. It will discuss the pros and cons of kites, balloons, satellites, and UAS platforms. I discuss one or more case studies showing their applications with each platform.

Mozas-Calvache et al. (2011) and Rinaudo et al. (2012) used UAS to recorded excavations. They used the photogrammetric models to locate features and determine focus areas. After the excavation they used this data to view the site level-by-level, examining artifact and feature context.

In addition to data collection, archaeologists use UAS imagery to create highly accurate photogrammetric models. Photogrammetric orthophotomosaics and 3D models allow researchers to examine sites and features. After recording the site of Cempoala, Mexico, Mouget and Loucet (2014) used their photogrammetric model as a site map to locate and plot features. Verhoeven et al. (2012) created a photogrammetric model accurate to 0.1 meters. Researchers use these models to locate features on the ground, after identifying them on the images.

Kites. Kites allow rapid data collection because they are easily portable and simple to control (Verhoeven 2009: 237). A major drawback of kites is that without the wind they cannot fly. Researchers still employ kites on archaeological sites; nonetheless, with the increase in affordable unmanned fixed-wing and rotary-wing aircraft, kites have ceased to be a main source for collecting LAAP imagery.

Verhoeven et al. (2012) used a large kite to survey the Roman Quarry site of Pitaranha on the Spain-Portugal border. High winds at the site made a kite more appropriate than UAS. Verhoeven and colleagues systematically collected image sets and then created photogrammetric models. Their models are accurate to 0.1 meters (Verhoeven et al. 2012:1116).

A high level of accuracy (0.1 meters) allows archaeologists to produce geometrically accurate orthophotos and 3D models. Geometrically accurate models allow archaeologists to correctly identify features on the model and their exact locations on the ground. Photogrammetric models allow archaeologists to measure the distance between features on the selected images instead of being physically present at the site. This can save researchers time because this work can be conducted by a single person quickly in a laboratory instead of multiple people in the field.

Balloons. Current balloon aerial photography for archaeology primarily comes from unmanned flights (Verhoeven 2009:238). Balloons are relatively inexpensive and easy to maneuver, making them an effective tool to collect aerial imagery. However, balloons are highly susceptible to the wind, and in some countries, it can be difficult to purchase the necessary amounts of helium or hydrogen (Mozas-Calvache 2011:524). In addition, archaeologists must tether balloons to a single location, limiting their ability to record large areas. Like kites, balloons have decreased in use as UAS have become more affordable.

In 2004, Vassilis Fotinopoulos used a balloon to survey the Gates of Nafplio and Arapoporta in Greece (Fotinopoulos 2004). After he had collected the image sets, Fotinopoulos created a series of orthophotomosaics and 3D models that were complete site maps, providing researchers with a digital record of each site to assist in preservation. Researchers can use the models to see changes to the site and track that change over time. At the time of publication, the plan was for future researchers to periodically redo this project (Fotinopoulos 2004); but there are no additional publications on later examinations at these sites.

Martinez et al. (2014) conducted a photogrammetric project similar to Fontinopoulos (2004). Martinez et al. located damaged historic paving stones through their photogrammetric models of the historic streets of Santiago de Compostela, Spain, and tracked their deterioration over time. When a stone became damaged, they measured the stone's dimensions (diameter, volume) directly on the photogrammetric model. This gave them the dimensions for a replacement stone (Martinez et al. 2014:7).

The high level of accuracy in the models created by Martinez et al. and others, allows researchers to track the structure's deterioration, and measure the size of features to understand their context and association. A single person can do this digitally in the lab, as opposed to two or three people required to collect the same measurements in the field. Measuring distances and objects on a photogrammetric model reduces labor and saves time and money.

Satellites. Archaeologists use satellites to examine landscapes, monitor cultural resources and discover unknown sites (Lasaponara and Masini 2011:1995). Satellites provide a vast array of photographic data in a variety of spectrums, including natural light (GeoEye and Worldview-1 satellites) and hyperspectral imagery (AVIRIS satellite) (Orlando and Villa 2011:151). Different types of sites create different landscape signatures, and multiple sensor systems provide more data types to examine those signatures. While satellite imagery is an excellent source for locating and recording archaeological sites, it has drawbacks. Satellite photography is dependent on weather conditions, is unable to penetrate thick vegetation, and can be difficult and expensive to procure images in close range and high resolution (Lasponara and Masini 2011:1997).

Parcak (2015) used satellites to discover and record archaeological sites in Egypt. She identified and monitored looting at Egyptian archaeological sites following the 2011 uprising. With high-resolution, HAAP imagery from the GeoEye, Quickbird, and EROS-B satellites, she examined pre- and post- 2011 imagery from three sites: Saqqara, Lisht, and el Hibeh. She recorded over 5,400 looting pits at these sites, an increase of nearly

540% since 2009 (Parcak 2015:201). In this way, satellites provide access to landscapes otherwise unavailable to archaeologists. Satellites allow researchers to monitor archaeological sites in areas that cannot be reached by remote-controlled balloons, kites, and UAS.

Unmanned Aircraft Systems (UAS). Unmanned aircraft systems are an affordable option to locate and record archaeological sites. In 2013, researchers from the University of Toulouse constructed an octocopter (eight bladed UAS) to locate archaeological sites using thermal imagery (Poirer et al. 2013). Since UAS are not tethered, archaeologists can use them to survey a large area. Because buried structures exhibit a different thermal signature than the surrounding environment, Poirer et al. used the UAS platform to carry thermal sensors and locate buried archaeological features. During post-processing, they identified several buried features, demonstrating that UAS are a useful tool to locate sites using thermal imagery.

Archaeologists can use standard imagery (red, green, and blue spectrums) and UAS to find and record archaeological sites. Mancini et al. (2013) conducted a cultural vulnerability assessment of Italy's Adriatic Coast. Their goal was to develop methods to locate and record at-risk archaeological sites. The authors did an experiment on a 200-meter section of coastline, recording the area with an electric hexacopter (six bladed UAS). They processed the images into an orthophoto and 3D model with an accuracy of 0.3 meters. After examining the generated imagery for archaeological sites and features, the authors found their methods to be an effective way to locate and record archaeological sites. They noted that UAS are particularly useful due to the rapidity of data collection and low cost (Mancini et al. 2013).

Recording archaeological excavations is one of the most effective applications for UAS. Archaeologists can create photogrammetric models to track excavation progress, map archaeological features, and create time-lapse models of the excavation. Orthophotomosaics and 3D models allow archaeologists to examine features that span several units to understand their overall context. Unlike a standard hand drawn excavation map, photogrammetric models provide a high-resolution image of each artifact or feature in its original context. LAAP imagery provides archaeologists with a complete picture of an excavation that can be duplicated at the conclusion of each day or level by level to analyze features as they change at different depths.

The following two case studies are useful illustrations of the value of UAS in mapping excavations. The first study shows how archaeologists use photogrammetric models during an excavation to evaluate progress. The second study shows how photogrammetric data helps analyze a site after excavation.

Via Gemina is the ancient Roman road linking Aquileia and Emona. In 2012, the Polytechnic University of Turin and the University of Trieste excavated portions of this road. As part of this project, Rinaudo et al. (2012) recorded the excavation's progress using UAS. Each day, they recorded the entire site and generated a photogrammetric orthophotomosaic, creating a digital excavation record. Archaeologists used these models to evaluate each day's progress and determine which area(s) needed further attention (Rinaudo et al. 2012). Before publication, they planned to use these models to examine features and artifacts in situ at different levels.

Mozas-Calvache et al. (2011) completed a similar project to Rinaudo et al. (2012). Using UAS and LAAP photography, the authors captured the progress of excavation at Cerrillo Blanco, Spain. They wanted to record their progress to serve as a digital excavation record. Periodically, they captured image sets of the excavation, showing feature changes at different levels.

Mozas-Calvache et al. processed the collected images into a series of photogrammetric models to create a digital excavation model. The model merged separate excavation units into a single image, creating a high-resolution image map of the entire site. This map allowed them to examine all the excavation units level by level, observing changes to features and artifacts simultaneously across the entire site on a single high-resolution image (Mozas-Calvache at al. 2011).

One advantage of photogrammetrics is the ability for easy data sharing. Researchers in multiple locations can compile photogrammetric data, and then transfer it to a single place and organize two or three data sets into one. Once collected, researchers can share their data across platforms around the world.

Martin Sauerbier and Heri Eisenbiess (2010) are German researchers who have researched the applications of UAS extensively. In 2009, they used UAS to record the East and West Courtyards and Main Plaza of Copán, Honduras. After collecting the data, they created a series of photogrammetric models for each mapped location. Researchers in different institutions used these models to create an interdisciplinary 3D model of Copán (Eisenbiess and Sauerbier 2010). The German Archaeological Institute published the results in 2015 (mayaarch3d.org).

According to their website “The MayaArch3D Project has built a virtual research environment for the documentation and analysis of complex archaeological sites — specifically, it is a web-based, 3D-GIS that can integrate 3D models of cities, landscapes, and objects with associated, geo-referenced archaeological data” (mayaarch3d.org). The international and interdisciplinary project provides professional and amateur researchers with a 3D model of Copán. The project’s website mayaarch3d.org, allows anyone to take a virtual walkthrough of current and reconstructed Copán. The website provides an unprecedented view of an archaeological site while providing a new way for public engagement.

Mouget and Lucet (2014) undertook an UAS mapping project at the archaeological site of Cempoala, Mexico. The project objective was to use UAS to record the site and then use the image sets to create a high-resolution 3D photogrammetric model of the site. With a mean error of 0.57 meters, they accurately placed features on an orthophoto, creating a complete site map. The geometrically accurate models allowed them to calculate the dimensions of the recorded structures. Since Mouget and Lucet used high-resolution LAAP, the resulting model has limited pixelation at high magnification, which allows them to examine monuments in detail (Mouget and Loucet 2014). Even at high-resolution, a simple 2D HAAP image taken from a manned aircraft will not provide this level of detail.

Many archaeological sites have features that are inaccessible to traditional survey and recording. Mark and Billo (2016) used UAS to record rock art in the American Southwest. In their survey, several prehistoric images were located on large boulders or high cliff faces. To record the art safely, Mark and Billo used UAS technology and did not damage the resource. These authors also recorded several sites where multiple resources were near one another. UAS permits them to record the panels and combine them into a single orthophoto (Mark and Billo 2016). As seen in this case study, UAS provide a way to record sensitive and difficult to access resources without damaging the site.

Aerial photography platforms provide numerous applications in archaeology. Researchers can use unmanned platforms to record archaeological sites, locate features, document excavations, monitor sites for environmental and human impacts, and record difficult to access sites. The examples cited here show the utility of UAS and photogrammetrics for archaeological investigation.

Conclusion

This chapter discusses the town site of Aurora and introduces a variety of UAS platforms. This introduction focuses on the people, places, and buildings that had an impact on life in Aurora. The UAS case studies describe the general applications of unmanned aircraft systems and photogrammetrics. What follows is my contribution to the archaeological examination of Aurora.

Research Questions

This thesis revolves around three research questions:

1. What does this study contribute to a knowledge of the deconstruction processes at Aurora?
2. Are UAS an effective tool to record historical archaeology sites?

3. Is photogrammetric modeling an effective tool for site interpretation and recording?

Ashby and Johnson (2010:4) assert that residents create buildings to be both functional and aesthetic. This includes both commercial and residential structures. A large amount of functional and aesthetic variation does take place within a community. This variation is based on income of the residents, and the location and function of the structure. Aurora demonstrates a large amount of aesthetic and functional difference between the three city blocks, and within the blocks themselves. The goal of the first research question is to examine why there is such a large amount of variation, and what role the large amount of structural types played in the deconstruction of Aurora.

The last two questions address the effectiveness of the technology employed to collect and process the aerial image data for archaeology. Through an examination of the photogrammetric data, and a discussion on research methods I will review the effectiveness of UAS and the roles they can play in archaeological investigation.

This thesis has three more chapters. Chapter 2 discusses the methods of image collection and the steps to process the data into photogrammetric models. Chapter 3 is a presentation of the photogrammetric data and what the data informs about 19th-century Aurora. Chapter 4 is a discussion and conclusion. I discuss the research questions posed in Chapter 1 and future research for the field.

Chapter 2: Methods

Researchers use Unmanned Aircraft Systems (UAS) to acquire aerial imagery. There are many published articles on the applications of UAS for archaeology (e.g., Poirer et al. 2013; Mancini et al. 2013; Mozas-Calvache et al. 2011, Mouget and Loucet 2014). Nevertheless, published approaches to data collection are irregular, with varying levels of detail, making it difficult to create a research design and establish methods to conduct UAS survey.

I adapted the UAS survey approaches outlined in Martinez et al. (2012), Turner et al. (2012), Sauerbier and Eisenbiess (2011), and Remondino (2014) to construct a method for data collection in Aurora, Nevada. I present that methodology here. This methodology outlines procedures for pre-flight, flight, and post-flight UAS survey and photogrammetric processing. By adopting different methodologies, I created a concise approach for collecting and processing UAS image sets.

Research Design

Since I was unable to find a succinct methodology for UAS survey, it was necessary to use ideas presented by several authors, and combine them into a single research design. This section is my research based on the ideas presented in Turner et al. (2012), Martinez et al. (2012), Rinaudo et al. (2012), and Eisenbeiss and Sauerbier (2011).

Figure 2.1. An image of the Iris+ in flight at Aurora.

Unmanned Aircraft System and Camera

In order to decrease the chance of UAS crashes, UAS operators and assistants should become familiar with their unmanned aircraft before beginning a project. They should practice flying the UAS, learning the throttle, yaw, pitch, and roll. Researchers must also learn and follow local and federal UAS guidelines.

The UAS flown during the Aurora project is an Iris+ by 3D Robotics (3DRobotics 2015, Figure 2.1). The Iris+ is a small quadcopter platform with a maximum payload of 400g. I chose the Iris+ because it is compatible with android software. This compatibility allowed the anthropology department to purchase a less expensive tablet to run the autopilot software. Figure 2.1 shows the Iris+ at Aurora. Due to the small payload, smaller cameras like a GoPro provide the best mix of flight time and image resolution. I used a GoPro Hero3 White with a 5MP camera.

Image Overlap

In building a research design, it is necessary to determine the amount of image overlap desired. According to Martinez et al. (2012:521), each photograph collected by UAS should have 30–40% overlap with the surrounding images. Overlap ensures that the entire site is recorded without missing any part of the landscape (Rinaudo et al. 2012:586). Without a complete image set the photogrammetric software will generate incomplete site models.

Image overlap is attained in two ways, acquire more images, and decrease the distances between transects. At Aurora, the Iris+ captured images every second. Depending on the size of the survey section, the UAS completed 4-6 transects. These methods ensured the acquisition of enough images for photogrammetric processing.

Flight Modes

After determining the amount of desired overlap, researchers must determine the flight mode to collect the image sets. Eisenbeiss and Sauerbier (2011:401-402) outline three flight modes for UAS survey: manual, semi-autonomous, and autonomous flight.

Manual Flight Mode. Manual flight mode allows the operator to control all aspects of the flight. This mode does not utilize a ground lock (GPS positioning to keep the craft stable) and the UAS can be adversely affected by wind. Manual flight is the most difficult to use and is not recommended.

Semi-autonomous Flight Mode. Semi-autonomous flight is similar to manual flight. The operator controls many aspects of the flight including speed and altitude. However, the UAS uses a ground lock (GPS positioning) to keep the craft stable. With a ground lock, the UAS is less susceptible to wind. Semi-autonomous flight does not ensure a complete image overlap, since the operator determines the transect size. If the transects are too large it can result in insufficient overlap. Nevertheless, this flight mode is still more desirable than manual flight because of the GPS lock.

Autonomous Flight Mode. In autonomous flight mode, the on-board navigation unit controls all aspects of the flight. Using a ground station (computer or tablet with an autonomous flight application), a flight path is preprogrammed for the UAS, and it flies the predetermined route with no control from the operator. Autonomous flight is the most effective mode for image collection. Because the UAS will fly at predetermined transect distances, it ensures proper overlap.

At Aurora, the initial plan was to use autonomous flight. This would ensure proper image overlap by flying predetermined transects (Eisenbeiss and Sauerbier (2011:401-402). I achieved autonomous flight using a tablet, telemetry radios, and the open source software *andropilot*. During the second day of flights, the telemetry radios failed. The flights were undertaken using semi-autonomous flight mode because I was unable to acquire replacement radios until after the field session ended.

Fieldwork

This section discusses the methods employed in the field to collect the UAS image sets. I discuss the flight and data checklists, and the methods adapted from Turner et al. (2012) to create a grid system for each block. The grid system is described in detail in this section. Also described are the flight paths and how proper image overlap was achieved.

Checklists

Before beginning the Aurora project, I created detailed checklists to prepare the UAS for data collection and the steps required to download the image sets from the camera. The pre-flight checklist outlines steps to inspect the UAS, gimbal, camera, and batteries before each flight. The UAS examination makes sure all the parts (propellers, legs, arms, lights, etc.) are in working condition. I made sure that no wires were loose, and that everything was installed properly. An examination of the gimbal would show any loose screws, or camera attachments. This is important to make sure that the camera does not fall off the UAS during flight. The camera should be inspected for scratches, and proper attachment to the UAS and/or gimbal. Finally, the batteries should be inspected to look for improper wear, damage to the connectors, and charge level. This ensures that the UAS will function properly and fly for the alloted time. A failed battery can destroy a UAS or cause a significant crash. These steps, while tedious, ensured the UAS was in proper working condition facilitating successful data collection in a constrained timeframe.

Turner et al. (2012) recommends creating a detailed information sheet to ensure that the camera images are downloaded and saved in the same way after each flight. I used the same file path so save each image. Each file path contained folders detailing the date, block, and flight number. The image is then saved in the flight number folder (Figure 2.2). I employed two external hard drives at Aurora to ensure that the data was properly backed up. Upon returning to the lab, each image was backed up again on an external server in the Anthropology Department at the University of Nevada, Reno following the established protocol. The preflight and image download checklists are found in Appendix A.

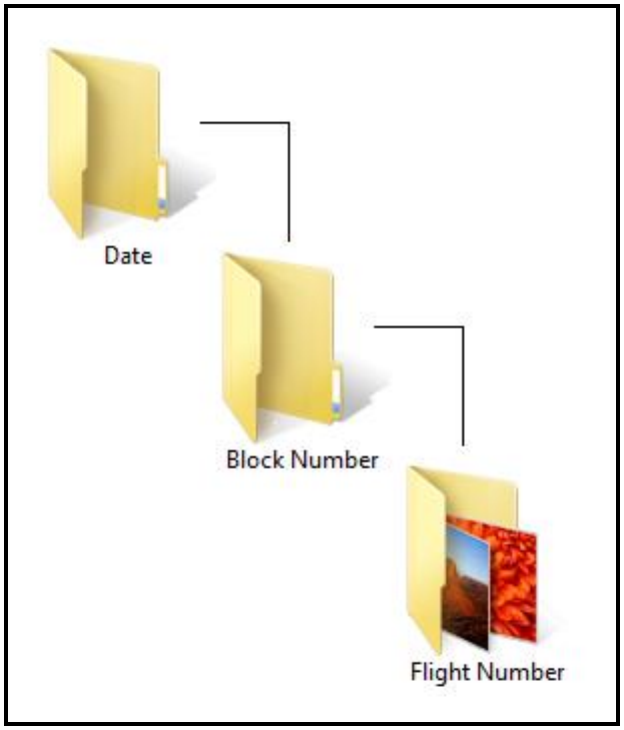

Figure 2.2. This figure shows the file path for saving the images each day.

Site Preparation

The original research goal was to record three complete blocks in the town of Aurora (Block C, Block 3, and Spring Street). Once on the ground, this plan was overly ambitious, so I reduced the size of the survey area. Turner et al. (2012) divided their UAS survey area into smaller sections using a grid system. A grid allowed them to collect image sets in a systematic way by flying one section per flight. I followed this method to survey each block at Aurora. To record each block, the team placed a grid to control flight patterns and data acquisition. The grid provided a systematic way to collect the data on each block.

The survey team placed markers on the north-south and east-west lines and the interior transect lines of each grid. To differentiate between locations, each point received a number and a colored piece of paper. To distinguish between points, I developed a numbering system that gave each point a unique number designation. Each point received a number, a north or west location, and a block identifier. For example, the first point on Block 3 was 1N3 (point number, direction, and block number). To mark each location, the survey team placed an 8½ x 11 piece of colored paper. Three different colors were used for each block. The colored paper helped distinguish between locations on the aerial images.

After placing the markers, the team took a Global Positioning System (GPS) location at each grid point. These locations serve as Ground Control Points (GCPs) to aid in the creation of photogrammetric models. GCPs are Universal Transverse Mercator (UTM) coordinates that researchers upload into the photogrammetric model. They allow the model to be geometrically accurate. Figure 2.3 is an example of what each point looked like at each location. It took approximately three hours to create each survey grid.

Figure 2.3. A point marker located on Block C.

GPS Accuracy

Currently, there are no standards for spatial accuracy in archaeology. However, there is an implied expectation of sub-meter, even sub-centimeter accuracy. Due to the accuracy of GPS, it is possible for archaeologists to record locations with sub-meter accuracy. Total Stations and differential GPS can provide archaeologists with even more accurate models.

When placing Ground Control Points, differential GPS, and Total Stations are preferred because they provide an increased spatial accuracy. Handheld GPS units often have a high margin of error, up to 10 meters in some cases (esri.com 2016:1). This can make it difficult, if not impossible to build geometrically accurate photogrammetric models. The use of differential GPS or Total Stations when creating GCPs allows photogrammetric models to have the highest degree of accuracy. Higher accuracy makes it easier to measure features, overlay historical maps, and identify features on the photogrammetric models.

Two types of differential correction are available to increase GPS accuracy with nearly identical results. The first is using a differential GPS unit in the field. This takes into account the correction from a base station and accurately records the location in the field. The second type of differential correction is done during data processing. Using a differential correction software such as GPS Pathfinder (trimble.com 2016), data is sent from the base station, and the uploaded coordinates are corrected.

Total Stations are another way to collect accurate GPS locations. They provide sub-centimeter accuracy. However, as noted by Pierdicca et al. (2016:82), these are expensive and not always feasible when the project requires archaeologists to move equipment by hand over a large area. While more accurate, they do not provide the flexibility of handheld GPS.

Many photogrammetric articles published over the last several years display sub-meter accuracy: Mouget and Loucet (2014), Mancini et al. (2013), and Rinaoudo et al. (2012) as examples. Martinez et al. (2014) created a photogrammetric model of the historic streets of Santiago de Compostela, Spain. Their models recorded an error of 0.10 millimeters. Their models were accurate enough that they could measure the dimensions of historic stones for replacement based on the 3D model. This is the standard archaeologists should strive to attain. Nevertheless, this level of detail is not always possible, and sub-meter accuracy will provide archaeologists with accurate GCPs.

Differential GPS provides archaeologists with sub-meter accuracy, and in many cases sub-centimeter accuracy. Total stations provide sub-centimeter accuracy with each reading. However, they are larger and more expensive. As a minimum, archaeologists should use differential GPS to acquire GCPs. When possible, archaeologists should use a Total Station to acquire readings that are even more accurate. The models presented in this thesis display sub-meter accuracy, generated from differential GPS points. While sub-meter accuracy is not an official standard, I propose that it should be, because it is easily attainable. Due to the rapid advances in GPS technology, even this recommendation may soon be out of date.

During my 2015 fieldwork, a differential GPS unit was not available. The GPS unit used in 2015 was a Garmin 60CSx, which does not guarantee accuracy greater than 9 meters. To create the most accurate models possible I used a series of differential GPS locations placed by the U.S. Forest Service in 2012. The U.S. Forest Service placed a series of brass caps marking differential GPS points, recorded with sub-millimeter accuracy. The survey grids incorporated three brass caps as GCPs for Block C, two for Block 3, and one for Spring Street. This provided a more accurate grid, and balanced out the potentially high level of inaccuracy from the Garmin GPS.

Block C

In consultation with Dr. Carolyn White, we decreased the survey area of Block C from 86 meters x 79 meters (the complete block) to 57 meters x 46 meters. In 2012, the U.S. Forest Service placed a series of brass caps marking differential GPS points on Block C, recorded at sub millimeter accuracy. To ensure the highest accuracy possible for my GCPs, two brass caps were incorporated into the survey grid at Block C. The dimensions of the survey area reflect the distances from the datum to the brass caps, not the dimensions of house lots.

The area surveyed on Block C runs 57 meters south along Mono Street and 46 meters west along Pine Street. Parallel lines run south through the Ivanovich lot and west through the Porter lot. A map of the Block C survey area can be seen in Figures 1.8 and 1.9. The block was subsequently broken into smaller grid sections by placing markers at intervals on the perimeter and interior transect lines of the survey area creating four 20 meter x 20 meter sections, two 17 meter x 20 meter sections, one 17 meter x 6 meter section, and two 20 meter x 6 meter section. Figure 2.4 shows the survey grid of Block C.

Once the grid was established and the GCPs were acquired, I began the flights. Each flight began at a predetermined location on the block. After takeoff, the UAS flew 4–6 transects over a section of the survey grid. Each UAS flight was at approximately 15 meters of altitude. It took 13 flights to record Block C, because of camera and UAS malfunctions. The dashed lines in Figure 2.4 divide the survey grid into flight sections. Refer to Table 2.1 for details on each flight.

Figure 2.4. The survey grid of Block C. The dashed lines represent the UAS flight sections.

Table 2.1. Flights taken at Block C.

Flight #	Take off Location	Take off UTM North	Section Size (m)	Paper Color	Transects	Comments
1	1NC	4239342	20 x 20	Pink	4	
2	1NC	4239342	20 x 20	Pink	2	UAS Crashed
3	2WC	4239342	20 x 20	Yellow	6	Camera Battery Died
4	2WC	4239342	20 x 20	Yellow	6	
5	3WC	4239346	57 x 6	Yellow	3	Camera Malfunction
6	3WC	4239346	57 x 6	Yellow	3	Gimbal Malfunction
7	2NC	4239327	20 x 20	Yellow	6	
8	3NC	4239302	17 x 20	Yellow	6	
9	5WC	4239286	17 x 20	Yellow	1	UAS Battery Died
10	5WC	4239286	17 x 20	Yellow	6	Gimbal Malfunction
11	5WC	4239286	17 x 20	Yellow	6	
12	3WC	4239346	57 x 6	Yellow	3	
20	7WC	4239330	20 x 20	Blue	6	
21	1NC	4239342	N/A	Pink	N/A	Video

Block 3

I followed the same process on Block 3 as on Block C; create a grid, collect GCPs, and conduct flights. To keep uniformity between survey areas, Block 3's grid is also 57 meters x 46 meters (Figures 1.3 and 1.4). Point 1N3 is located on the corner of Pine Street and Silver Street. From this location, the perimeter runs 46 meters north along Silver Street and 57 meters west along Pine Street. Parallel lines run north through the Beckett & Frainor lot and west through the Wheeler, McBride, Jail, and Sill lots. This created four 20 meter x 20 meter sections, two 17 meter x 20 meter sections, one 17 meter x 6 meter section, and two 20 meter x 6 meter section. Figure 2.6 shows the grid created for Block 3— the dashed lines show each flight section.

The slope of Block 3 increases to the north on Silver Street, (Figure 2.5). This slope provided a challenge to capture the image sets at a consistent above ground level. To accomplish this, I steadily increased the UAS's altitude to 25 meters as it flew north, and then decreased it back to 15 meters as it flew south. This change in altitude kept the UAS at a constant 15 meters above the ground. Each flight was conducted in semi-autonomous flight mode.

Figure 2.5. This image shows the topography of Block 3. The image is looking north. As the UAS flew north the altitude was increased, as the UAS flew south the altitude was decreased.

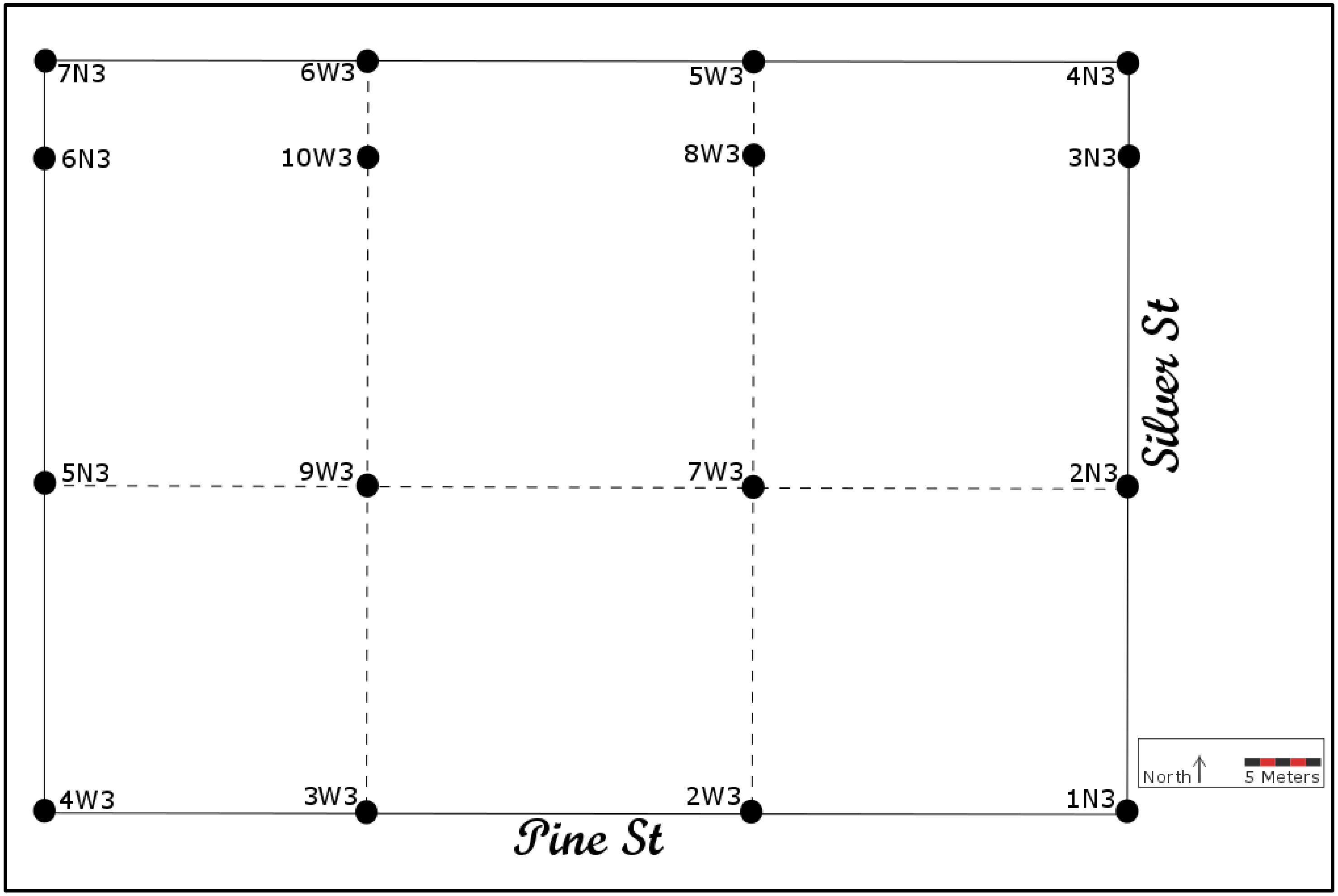

Figure 2.6. The survey grid of Block 3. The dashed lines represent the UAS flight sections.

Due to the difficult terrain of Block 3, two different methods were used to collect the data. Flights 13–15 are single 20 meter x 20 meter or 20 meter x 17 meter sections, taking off from Pine Street. Because of the difficult terrain, there was no place to safely take off or land on the north end of the survey area. This required an adjustment in the approach to data capture. Instead of collecting data in smaller units (flights 13-15), I conducted flights 16-19 over multiple grid sections. This created two 20 meter x 26 meter sections and one 17 meter x 26 meter section. This created a safe way collect the required image sets, because the UAS only had to take off from the sloped topography three times instead of six. The flight sections are on Figure 2.6 and represented by the dashed lines. Table 2.2 provides details on each flight at Block 3.

Table 2.2. Flights taken at Block 3.

Flight #	Take off Location	Take off UTM North	Section Size (m)	Paper Color	Transects	Comments
13	1N3	4239337	20 x 20	Red	6	
14	2W3	4239339	20 x 20	Yellow	6	
15	3W3	4239338	20 x 17	Yellow	6	
16	2N3	4239354	20 x 26	Yellow	6	Gimbal Malfunction
17	2N3	4239354	20 x 26	Yellow	6	
18	7W3	4239360	20 x 26	Purple	6	
19	9W3	4239357	17 x 26	Purple	6	

Spring Street

The north-south extension of the Spring Street block is 30.5 meters (1864 Esmeralda County Tax Assessment Roll Map). To stay within the block’s boundaries, I decreased the grid size to 30.5 meters x 57 meters. Point 1NS is on the corner of

Spring Street and Roman Street. From this location the grid moved south 30.5 meters along Roman Street, and 57 meters west following Spring Street. Parallel lines run south through the Schwinerger lot and west along Pine Street. The survey area and lots are shown in Figure 1.8. To keep the grid sections uniform I created four 20 meter x 15.25 meter sections and two 17 meter x 15.25 meter sections. Figure 2.7 shows the Spring Street grid.

The south end of Spring Street is at a higher elevation than the north end (Figure 2.8). The change in elevation did not provide a safe place for the UAS to takeoff or land at the southern grid points (2NS, 7WS, 8WS, and 4NS). Because the UAS could only takeoff and land at points 1NS, 2WS, 3WS, and 4WS. I altered my data collection strategy. Instead of having six flights, one for each grid section, the six survey sections were combined into three, creating three flight sections. The UAS flew two 20 meter x 30.5 meter sections, and one 17 meter x 30.5 meter section. Each flight flew an entire north-south grid section, making three flights. In Figure 2.7, the dashed lines show the flight sections.

Once again, I adjusted the altitude of the UAS as it flew north to south. Taking off at Spring Street, the UAS flew at 15 meters altitude until it reached the midpoint of the grid. I then increased the altitude to 25 meters to account for the slope. As the UAS returned to Spring Street, I decreased the altitude back to 15 meters. The flights are summarized in Table 2.3.

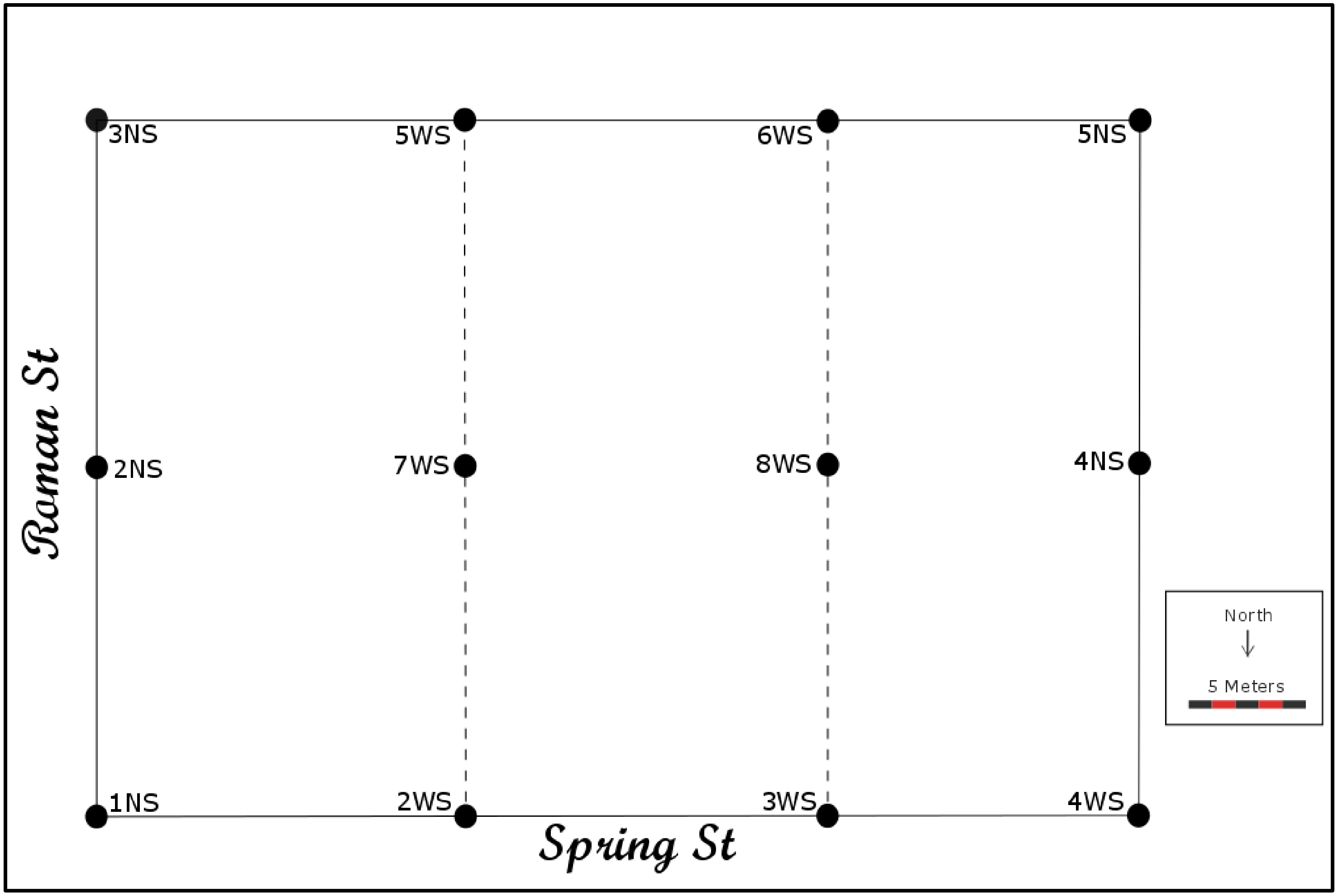

Figure 2.7. The survey grid of Spring Street. The dashed lines represent the UAS flight sections.

Figure 2.8. A view the Spring Street block looking south.

Table 2.3. A recording of the flights for Spring Street.

Flight #	Take off Location	Take off UTM North	Section Size (m)	Paper Color	Transects	Comments
22	1NS	4239421	20 x 30.5	Blue	6	
23	2WS	4239397	20 x 30.5	Red	6	
24	6WS	4239377	20 x 30.5	Red	6	

Reflections on Field Methods

It took three days to collect the image sets. Laying the grid on the landscape proved to be time consuming, but important. The grid made it possible to capture the data in small controlled areas. Since the image sets were properly collected, the photogrammetric models could be generated without losing any data. Nevertheless, creating the grid was time consuming and would not be feasible on a larger survey area. Researchers can explore the best methods to collect data over a large space. This will help archaeologists use UAS for larger landscape survey, and not limit their applications to smaller known sites. A comprehensive methodology for UAS survey in archaeology is needed.

The largest problem faced in the field was UAS battery life. According to the 3DRobotics website, the Iris+ should experience 16 to 22 minutes of flight time when flying without a gimbal, and below 2,000 feet above sea level (3DRobotics 2016). In Aurora at over 7,000 feet above sea level, flying with a gimbal and camera, each battery lasted between 5 and 8 minutes. This allowed one flight per battery before recharging. With only four batteries, I spent a considerable amount of time waiting for batteries to charge. On future projects, more batteries will be required. With more batteries, all the flights can be conducted in a single day, increasing the effectiveness of UAS for site recording.

Unmanned Aircraft Systems have the ability to benefit the archaeological community. Currently, small off the shelf, UAS are limited to the use of standard imagery (red, green, blue). Sensors such as LiDAR, multispectral and thermal imagery are unavailable for most small UAS platforms. Platforms that do employ a variety of sensors are expensive, and often require specialized training, making them impractical for most projects (Parcero-Oubiña et al. 2016:17). Over the next several years, advanced camera sensors will become more accessible to researchers for use with UAS technology. When these systems become available archaeologists should examine the effectiveness of UAS equipped with these sensors to locate and record archaeological sites.

Laboratory Methods

Following fieldwork, I processed the images and created the photogrammetric models. Photogrammetry is the process of extracting data from 2D images to create 2D and 3D models (Verhoeven et al. 2012). Two types of models were completed for each block, orthophotomosaics, and 3D models, as described in Remondino (2014).

I completed the data processing in the Historic Archaeology Laboratory at the University of Nevada, Reno. I used a Python script (python.org 2016), which employed OpenCV algorithms for geometrically correcting the images (opencv.org 2016), and Agisoft PhotoScan (agisoft.com 2016) for the creation of the photogrammetric models.

Photogrammetric Processing

Photogrammetrics work through the employment of Structure from Motion (SfM) algorithms. Developed in the 1990s, SfM estimates the 3D structures from a 2D image. The software will reproduce that structure as a photogrammetric 3D model (Westby et al. 2012). Together with GPS and ground control points, SfM generates a geometrically accurate representation of the surveyed surface. SfM allows researchers to create highly accurate reconstructions of landscapes, excavations, and artifacts (Biermann 2013).

I adapted the photogrammetric processing steps outlined in Remondino (2014). According to Remondino, there are three steps in photogrammetric modeling: point cloud generation, mesh generation, and texturing. Because of the project needs, I added image correction and orthophotomosaic generation as steps in this process. These steps are described in this section.

Image Correction. As cited above, the camera employed in Aurora was a GoPro Hero3 White (GoPro 2015). A stock GoPro lens creates a "fisheye" distortion on the acquired images. Depending on the photogrammetric software, this distortion may need to be corrected before processing. Dr. Christopher von Nagy of the University of Nevada, Reno, created a Python script to geometrically correct camera images using OpenCV, a computer vision library.

Geometrically corrected images can lose around 30% of the image's outside border (Remondino 2014). To adjust for this loss, a higher overlap is required when collecting images and when selecting images for processing. During the Aurora UAS project, more transects were completed during each flight, and the images were acquired more rapidly to ensure proper overlap.

After correcting the images, the next step is to generate photogrammetric models using PhotoScan. To create the models, I applied the photogrammetric techniques discussed in Remondino (2014): point cloud generation, mesh generation, and texturing. These steps are explained in detail later in the chapter.

Each flight in Aurora collected between 100 and 200 images. Due to a large amount of image data, I generated an independent model for each flight, creating 17 separate chunks with PhotoScan. In PhotoScan, a chunk is a single workable file that can be combined to form a larger model, or used as a single data set. After completeing each individual chink, I merged them into one model to create a complete photogrammetric model of each block. For example, Block C had eight flights with usable image data. I used PhotoScan to create eight separate chunks, one for each flight. PhotoScan then merged the eight separate chunks into one model, creating a complete photogrammetric model of Block C. I applied this same technique to each block. One chunk per flight gives greater control over the model generation, and used fewer images per processing chunk, expediting the photogrammetric process.

Ground Control Points. The first step in photogrammetric modeling is to assign geographic coordinates to the uploaded images, giving them an accurate location in space. After importing the images into PhotoScan, I manually mapped the GCPs onto the images. After placing a GCP on a single image, the software automatically recognizes this exact location on all other uploaded photographs in the same chunk. The GCP points aid in the creation of a point cloud by giving the software known locations to match, as well as finding points on its own through SfM algorithms. Without these points, the model will not be geometrically accurate.

Point Cloud. The software generates a point cloud after the images are uploaded and the GCPs defined. The point cloud is a matrix of aligned points; each one represents a matched location in multiple photographs (Turner et al. 2012). A point cloud is a representation of the 3D geometric surface of the surveyed object. Point clouds are not a complete model because they do not give texture or an accurate representation of the model's surface (see texture below). Rather, they are a representation of points in space. The remaining steps in the modeling process utilize the point cloud to build the mesh and texture. Table 2.4 shows the point cloud values for all the flights/chunks, and Figure 2.9 is a point cloud for the Block 3 model.

Table 2.4. GCP and Point Cloud values for each flight.

Flight #	GCPs	Number of Images	Point Cloud Value
1	4	34	46,013
2	–	–	–
3	4	24	47,899
4	–	–	–
5	–	–	–
6	4	42	29,859
7	4	38	37,510
8	–	–	–
9	–	–	–
10	–	–	–
11	4	16	22,368
12	4	24	45,876
13	4	27	17,020
14	5	36	23,346
15	5	28	19,332
16	4	26	17,843
17	4	42	24,648
18	4	60	19,652
19	5	52	32,552
20	5	26	43,576
21	–	–	–
22	6	36	28,722
23	6	18	17,954
24	6	46	23,595

Mesh. After generating the point cloud, the next step is to create the polygonal mesh. The mesh matches the point cloud into a series of polygonal triangles, almost like a large and intricate game of connect the dots. The triangles created through meshing come in different shapes and sizes and create the framework of the model. By connecting the point cloud, the mesh creates a series of faces that represent features displayed in the images. Each triangle forms a part of the larger picture, that when textured becomes the physical topography of the landscape (Remondino 2014). Figure 2.10 is the polygonal mesh for Spring Street. The mesh polygons are visible on the image.

Texture. Once the polygonal mesh is generated, the final step is to texture the model. Texturing provides the model with the full geometric appearance of the object it is recreating (Remondino 2014). Texturing is the process of overlaying the images onto the frame created through meshing. This gives the once 2D shapes a 3D visualization. A textured model is the most accurate representation of the physical surface. Textured models allow researchers a perspective of the object as if it was physically in front of them. Figure 2.11 is an example of a fully textured 3D rendering of part of Block C.

Orthophotomosaics. After generating a 3D model, PhotoScan can create an orthophotomosaic of each 3D model. Orthophotos are geometrically accurate 2D renderings of the surveyed surface. Orthophotomosaics are multiple orthophotos stitched together to show a larger landscape. To generate the orthophotomosaics, PhotoScan applied an algorithm to each processed 3D model, creating a 2D rendering of the surveyed surface.

Reflections on Laboratory Methods

To generate the photogrammetric models, with the methods discussed here took three days. I spent the majority of that time selecting images for processing, and properly placing the GCPs on the images. The batch process function saved lots of time. Batch processing (completing several steps at once without user involvement), allowed me to run all the required steps overnight without being present. Upon returning to the lab, the models were completed. This step saved time and provided a rapid turnaround on the data after collection.

Conclusion

The methods discussed in this chapter allowed me to collect the image sets required to generate photogrammetric models, and in turn, create photogrammetric models of Aurora, Nevada. By adapting the methods of Martinez et al. (2012), Turner et al. (2012), and Sauerbier and Eisenbiess (2011), I created a process for UAS survey. These methods allow for a swift collection of aerial images. Also used are the photogrammetric methods discussed in Remondino (2014). Through the steps outlined here, the photogrammetric models of Aurora were generated in three days. Using these models, features not observable on standard 2D imagery are visible.

To collect the image sets, each block was broken into smaller sections, which allowed for the systematic collection of data. With semi-autonomous flight mode, the Iris+ recorded each survey section through multiple transects. This provided 30 to 40% overlap on each image. Proper overlap allowed the photogrammetric models to be produced without the loss of any data.

To generate the photogrammetric models, I followed the steps outlined by Remondino (2014) for point cloud generation, polygonal mesh generation, and texturing. I added my own methods of image correction and orthophoto generation to this process. With these methods, six models were created, three orthophotomosaics, and three 3D models. The orthophotos and 3D models are discussed in Chapter 3.

I use the photogrammetric models generated of Aurora, Nevada to examine building debris on Aurora's landscape. The photogrammetric models allow me to examine features such as building foundations, material type, and building location to understand more about the deconstruction processes of Aurora's buildings. In Chapter 3, I present the photogrammetric data, and in Chapter 4 I discuss what the data shows about Aurora's deconstruction.

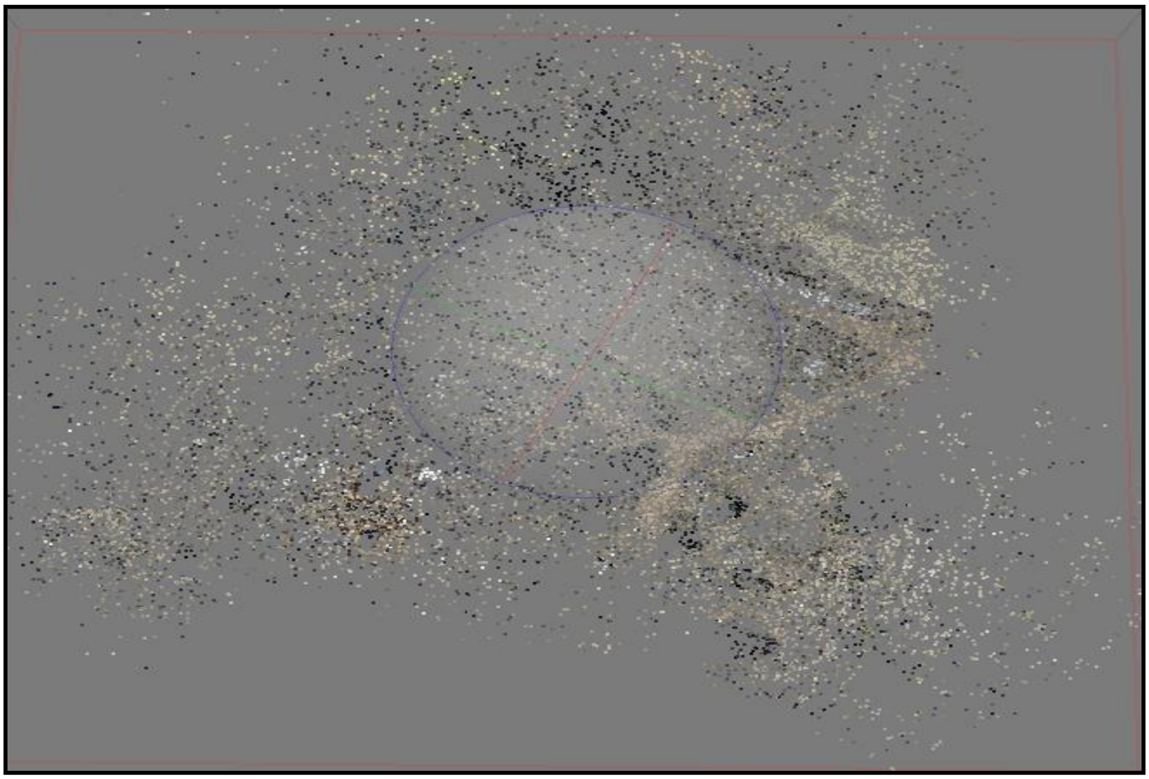

Figure 2.9. A generated point cloud for Block 3.

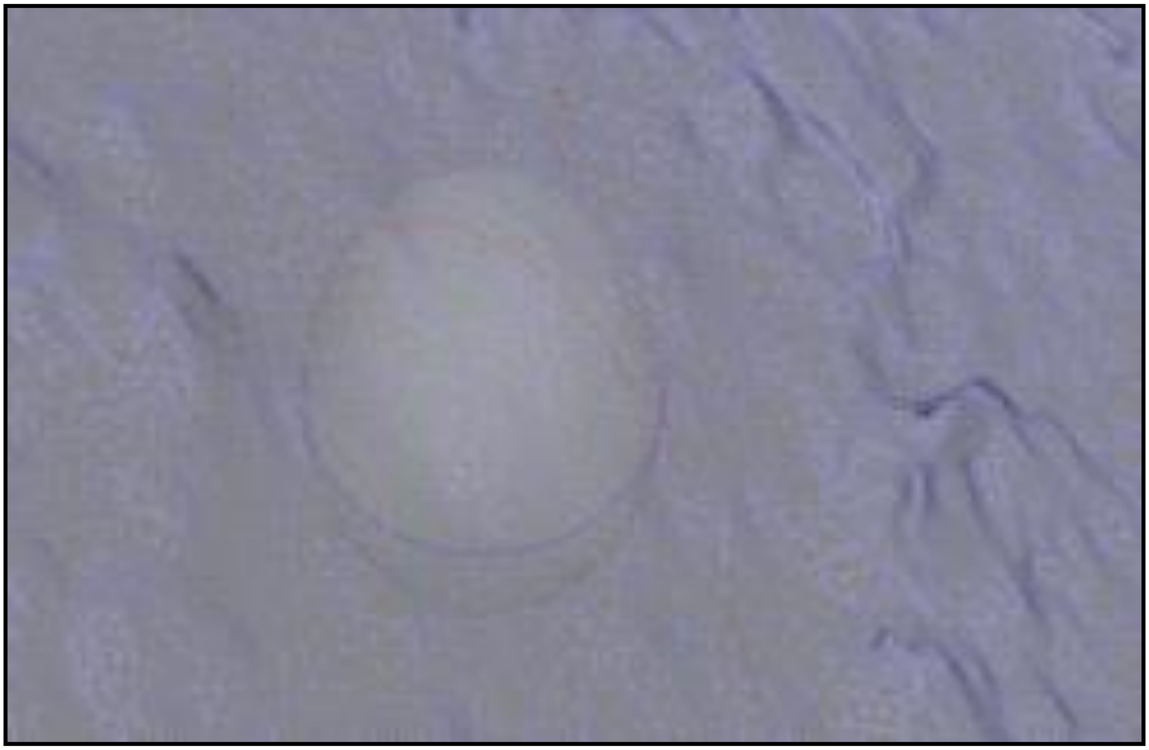

Figure 2.10. Meshed portion of the Spring Street model.

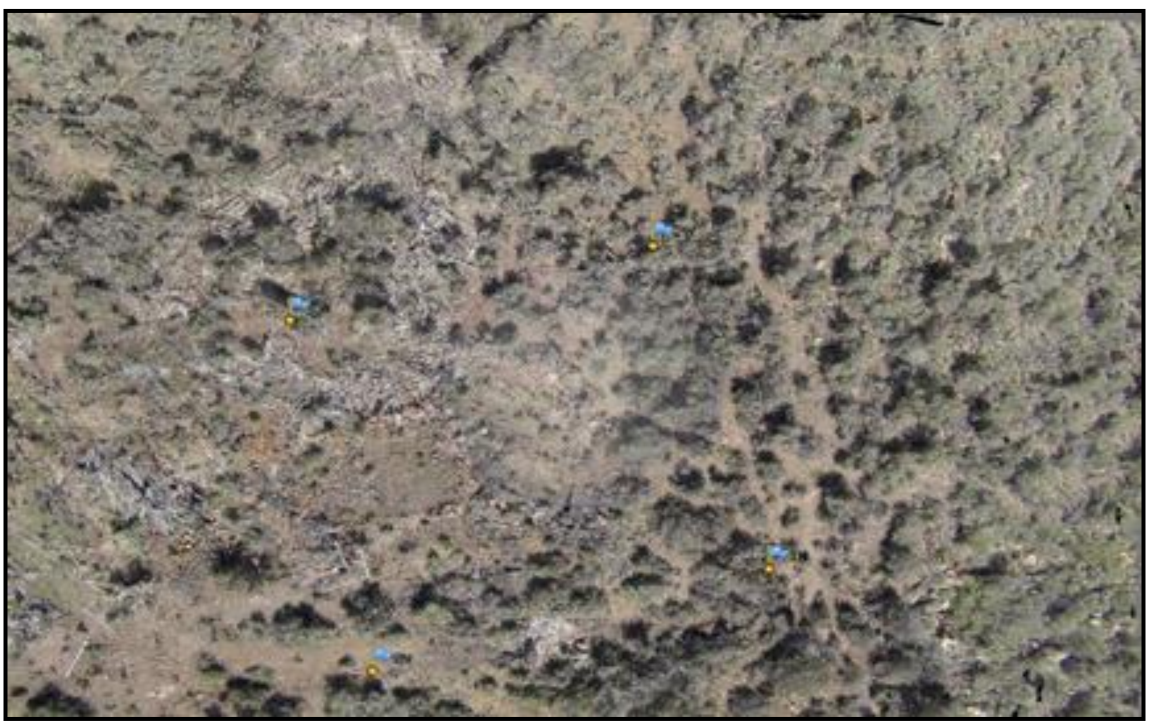

Figure 2.11. Textured portion of the Block C model.

Chapter 3: The Archaeology of Aurora, Nevada in the Light of Orthophotomosaics and Three-Dimensional Models

The focus of this thesis is to explore three of Aurora's city blocks through photogrammetric data. This chapter looks at photogrammetric data in two ways. The first way I photogrammetrically examine the city blocks is through orthophotomosaics, and second way is through the three-dimensional (3D) models. I use the orthophotomosaics to examine each house lot that displays structural debris and discuss the type and distribution of the remains. I use the 3D models to examine slope and features such as building foundations. The goal of this chapter is to provide a quantitative look at the building debris in Aurora.

Orthophotomosaics

Orthophotomosaics are geometrically accurate two-dimensional (2D) reconstructions of a surveyed surface. In this section, I provide two types of analysis with the orthophotomosaics. The analysis focuses on first, overall context of each block, and second, structural debris present on each individual lot. I create this analysis based on the process of transferring the 1864 Esmeralda County Tax Assessment Roll Map directly onto their surface. By transferring the assessment roll map, the orthophotomosaic becomes a high-resolution aerial map of each block. With these maps, I am able to present the whole block and show the relationship between each lot. These maps also allow me to analyze the lots individually. Each lot is magnified on the orthophotomosaic to show the structural debris.

Block 3

The Block 3 orthophotomosaic shows the lots surveyed in 2015 (Figure 3.1). The model is geometrically accurate with the Ground Control Points (GCPs). The measurements to determine accuracy were conducted in Agisoft PhotoScan (Agisoft 2016). According to these measurements, Block 3 is accurate to 0.5 meters.

Block 3 was both commercial and residential. Each lot's location depended on the purpose of the structure. Structures like Wingate Hall, Molineaux & Dodd, and Dreyfus & Laurel were commercial and located on the south end of the block along Pine Street. Each one of these lots had access to Pine Street, one of Aurora's main thoroughfares, and would have provided the businesses with access to the supplies required to operate. At the north end of the survey area, the block changed from commercial to residential. Residents like Dr. Sill, McBride, and Wheeler owned "single wood cabin" lots (1864 Esmeralda County Tax Assessment Roll). These lots do not have access to any street and are on the heaviest slope of Block 3 (Figure 3.1).

Many of the commercial buildings were made of brick and the residential buildings were made of wood (1864 Esmeralda County Tax Assessment Roll). The orthophotomosaic shows several sets of structural remains. Structural remains are seen on the Neidy, Wingate Hall, Gasson, Molineaux & Dodd, and Dreyfus & Laurel lots. Structural remains on the Beckett & Frainor, S. Jones, Dr. Sill, Mono County Jail, McBride, Denlenger, Wheeler, Wm. Jones, Keefer, and Wingate lots do not exist in large enough quantities to be seen on the orthophotomosaic or aerial images.

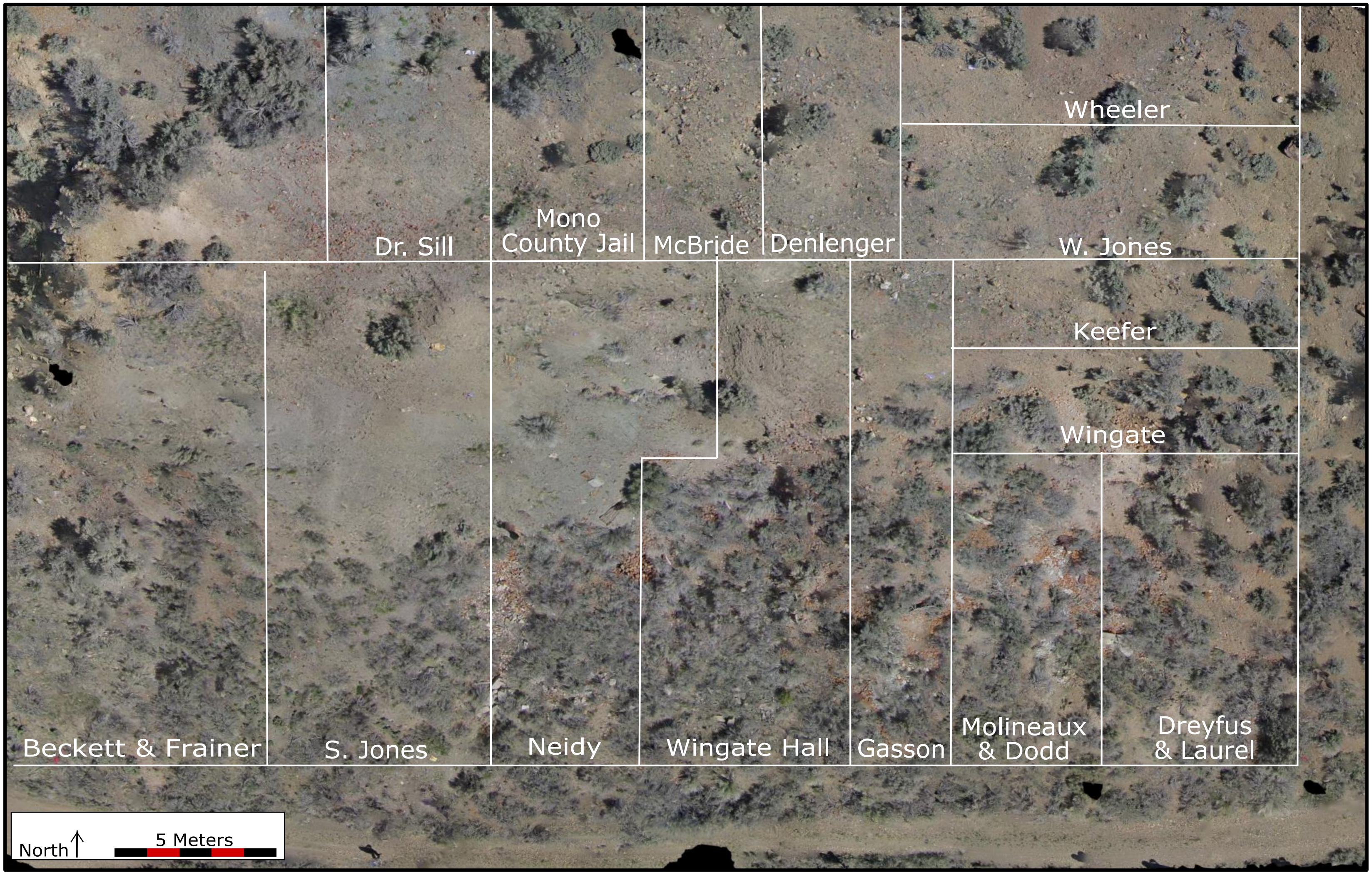

Figure 3.1. The orthophotomosaic of Block 3 with the transferred 1864 Esmeralda County Tax Assessment Roll Map

Figure 3.1 is the Block 3 orthophotomosaic. Because of the scale of the image, the structural remains are not seen in detail. To better show the details on each lot, I have increased the magnification of the original orthophotomosaic for each lot. The increased magnification clearly shows the structural remains present, such as type and quantity. Each lot with quantifiable remains is discussed in conjunction with its orthophotomosaic.

Figure 3.2. A detail of the Neidy lot. The red box indicates a concentration of brick.

Neidy. Figure 3.2 is a magnified image of the Neidy lot on the Block 3 orthophotomosaic. The Neidy lot runs north to south and fronts Pine Street. According to the 1864 Esmeralda County Tax Assessment Roll, the Neidy lot contained a “single story brick structure.” At the northeast end of the lot a small concentration of brick exists. Since this brick overlaps with the Wingate Hall lot it cannot be clearly determined how much of the brick is from the Neidy building, and how much is from Wingate Hall. It is likely a combination of both.

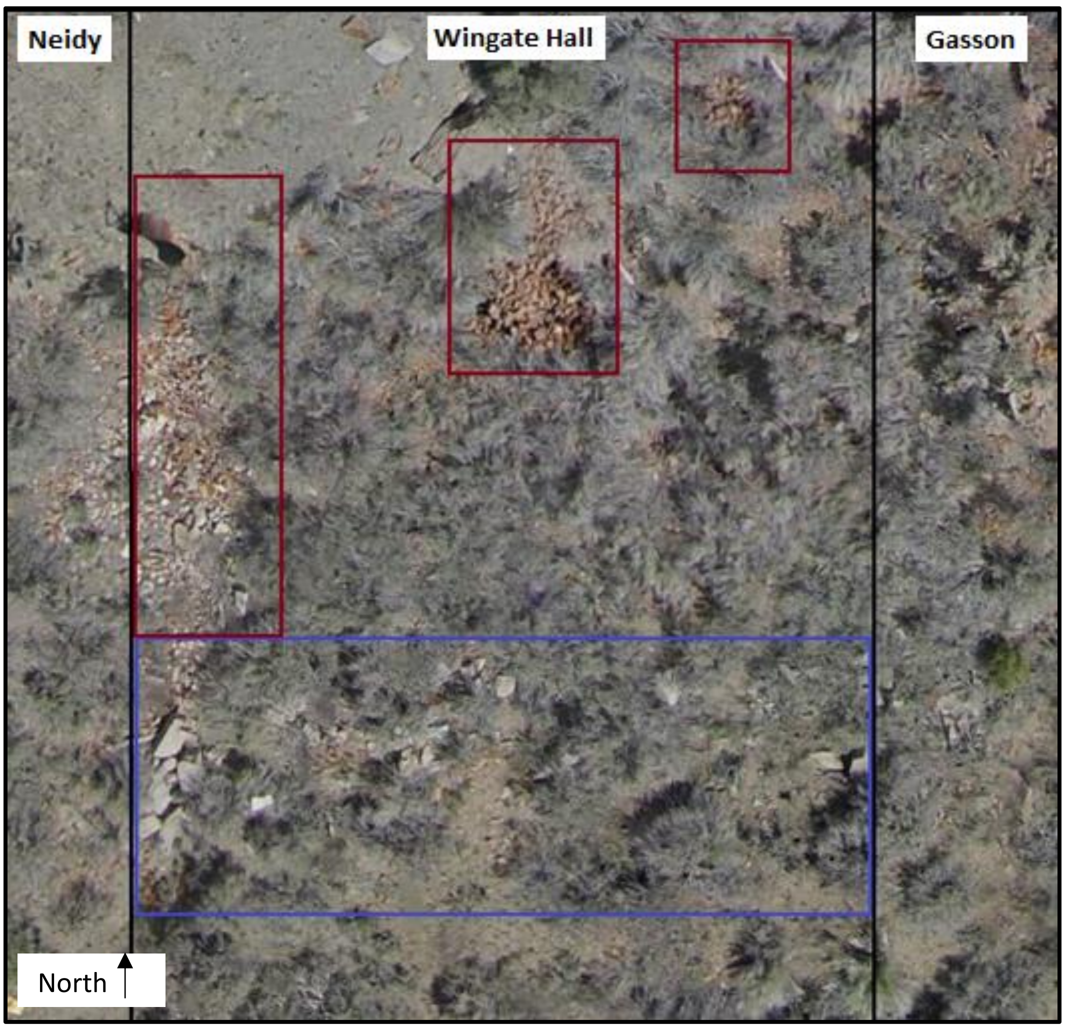

Figure 3.3. A detail of the Wingate Hall lot. The red boxes show concentrations of brick and the blue box shows a concentration of stone.

Wingate Hall. Figure 3.3 is a magnified portion of the Wingate Hall lot. This lot has three separate piles of brick. The first is in the northwest corner and overlaps with the Neidy lot. The second is in the middle of the lot, while the third is in the northeast corner. The second and third piles likely contain almost exclusively Wingate Hall bricks, while the first pile likely contains both Wingate Hall and Neidy bricks.

The Wingate Hall lot also contains a large amount of dressed white stone. The *Daily Alta California* states "[Wingate Hall's] Basement story is built of dressed stone-the wall two feet thick" (4 September 1863). The dressed stone at the south end of the lot is most likely the stone referred to in the newspaper. Small quantities of brick and stone are scattered across the rest of the lot.

Gasson. The Gasson lot is represented by Figure 3.4. The structural debris on the Gasson lot do not coincide with the description provided in the 1864 Esmeralda County Tax Assessment Roll. According to the assessment roll the only structure on the lot was made from wood. However, no wood debris remains on the lot. There is a scattered pile of brick on the Gasson lot. The brick could be remains of a brick feature such as a chimney, or remnants of the Wingate Hall and Molineaux & Dodd lots. Nevertheless, I cannot confidently say which lot it came from.

Molineaux & Dodd. Figure 3.5 shows the Molineaux & Dodd lot. Like Wingate Hall, this lot also has three piles of brick and one section of dressed stone. The brick piles are at the northwest, northeast, and west sections of the lot. A small pile of dressed white stone is on the west side of the lot, with stone scattered throughout the rest of the lot. The three piles of brick are probably from the building itself. The stone is probably from the Molineaux & Dodd lot, though some of the stone is on the Dreyfus & Laurel lot. No historical documents describe a stone foundation. However, the 3D model indicates a foundation was present, and Molineaux & Dodd most likely had a stone foundation similar to Wingate

Dreyfus & Laurel. Figure 3.6 shows the Dreyfus & Laurel lot. The Dreyfus & Laurel lot contained a single story brick building (1864 Esmeralda County Tax Assessment Roll). A single pile of brick exists on the northwest section of the image. This brick is probably from the Dreyfus & Laurel lot. A small pile of dressed stone appears on the west side of the image but overlaps with the Molineaux & Dodd lots. It is difficult to discern which lot the stone belongs to. It is possible it belonged to both Molineaux & Dodd and Dreyfus & Laurel. Hall.

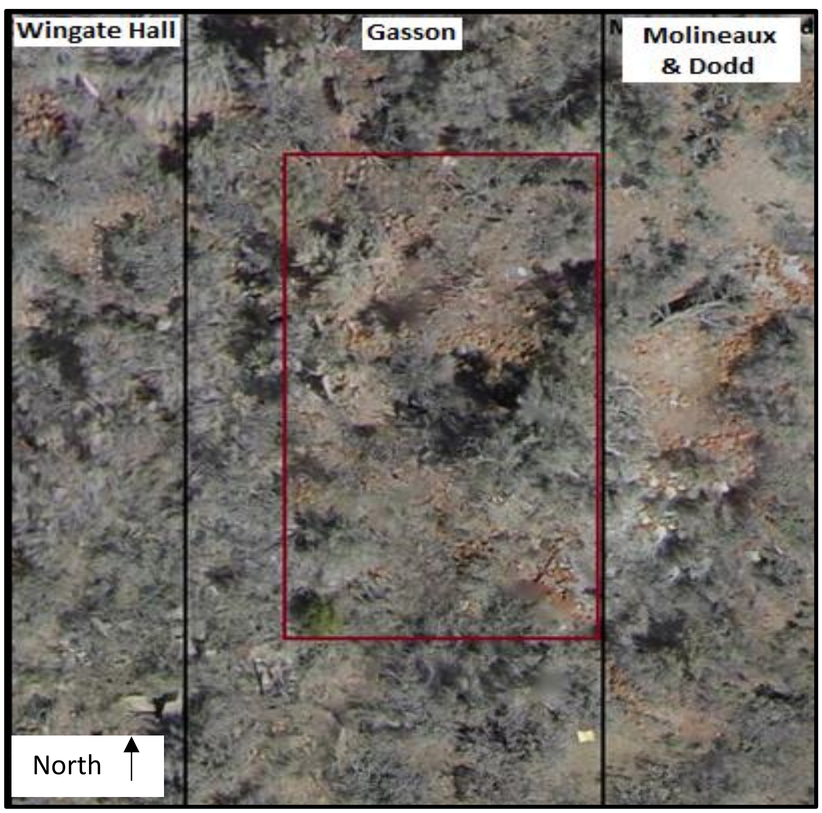

Figure 3.4. A detail of the Gasson lot. The red box shows a concentration of brick

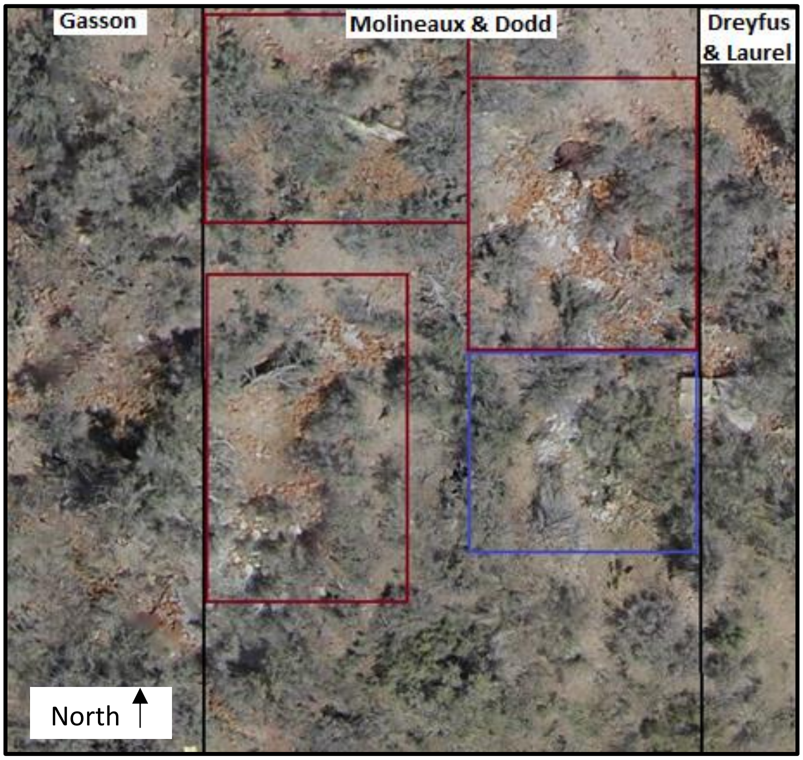

Figure 3.5. A detail of the Molineaux & Dodd lot. The red boxes show concentrations of brick and the blue box shows a concentration of stone.

The orthophotomosaic of Block 3 shows several important details. The lots facing Pine Street contain a large amount of structural debris, while the lots on the north end of the model do not hold structural material. In addition, the structural debris did not stay on the original lot during deconstruction, as the Gasson lot has brick debris, yet the original structure was made from wood.

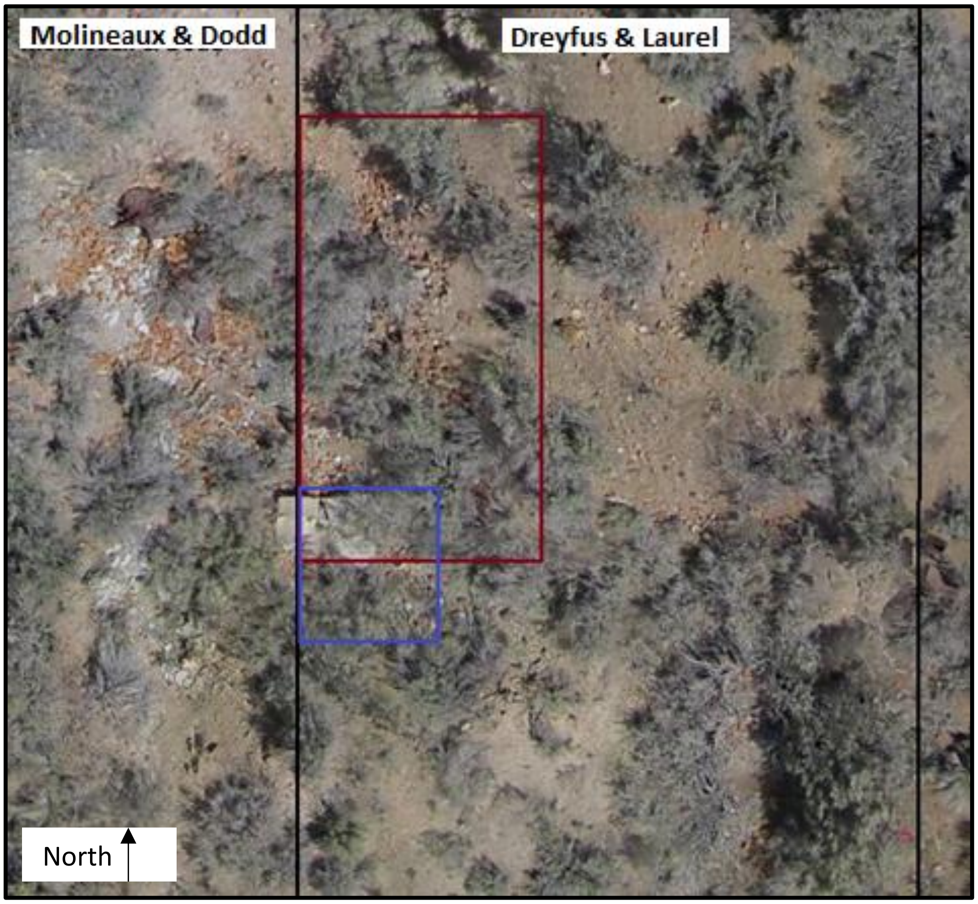

Figure 3.6. A detail of the Dreyfus & Laurel lot. The red box shows a concentration of brick and the blue box shows a concentration of stone.

Block C

To create a true orthophotomosaic, it must be geometrically accurate. I used the same method to test the Block C orthophotomosaic I used to test Block 3s. This measurement provided a mean inaccuracy of 0.6 meters.

Structural remains are dense on Block C, which makes it is difficult to see the dividing line between each lot on the aerial photographs. Several sets of remains, the Porter-Kaufman and Porter-Radervitch lots, have merged into single sets of remains. To show the location of each lot, and which remains were associated with each lot, I transferred the 1864 Esmeralda County Tax Assessment Roll Map onto the surface of the orthophotomosaic (Figure 3.7).

With the orthophotomosaic divided by lot, I can examine each set of remains. The Levy, Kaufman, Porter, and Radervitch lots each display a different amount of structural remains. However, with the orthophotomosaic at this scale, it is difficult to see the structural debris on each lot clearly. As with Block 3, I have magnified each lot and will discuss the remains associated with each lot individually.

Levy. The Levy home had a brick exterior with interior wood framing. The majority of remains on the Levy lot are wood lumber (Figure 3.8). The debris is heavily concentrated in the center of the lot, but scatters are found in the northwest, south, and southwest corners. The central feature appears to be made from framed and boarded timbers. Small amounts of brick are present along the edges of the wood framed timbers. Looters have removed most of the brick from the Levy lot.

Figure 3.7. The orthophotomosaic of Block C. The 1864 Esmeralda County Tax Assessment Roll Map is overlaid on the image.

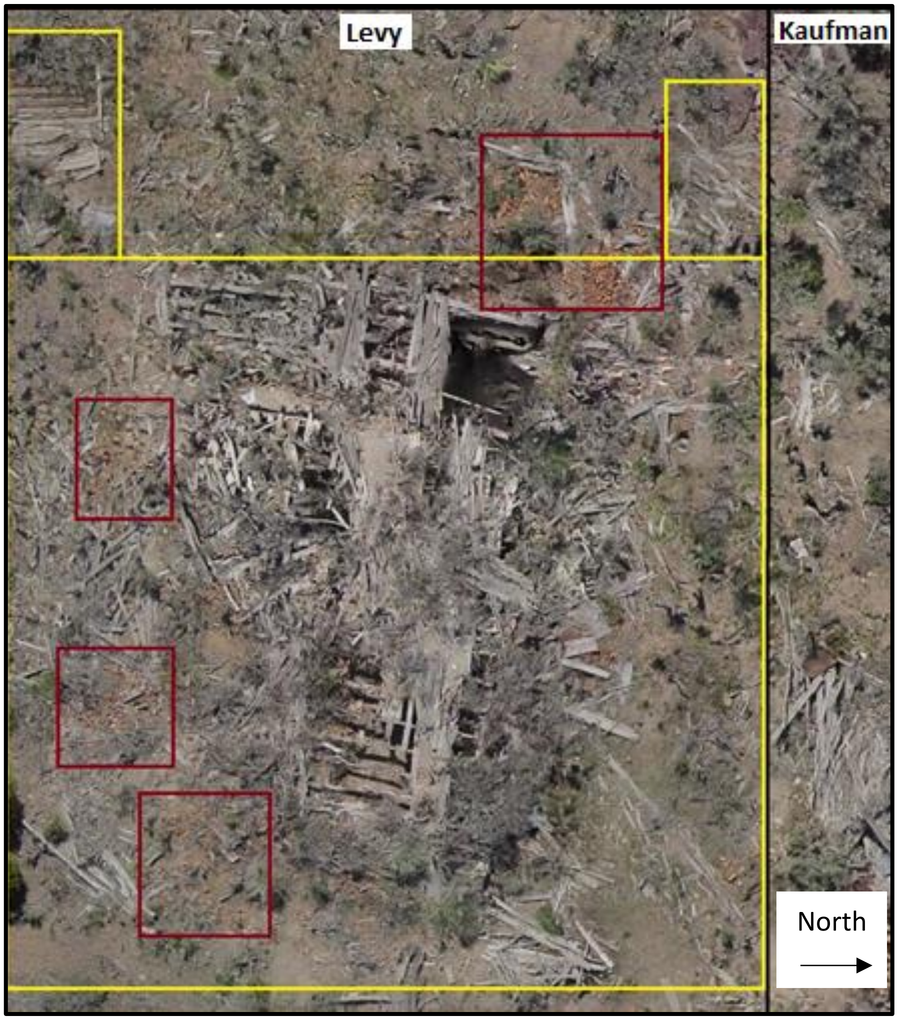

Figure 3.8. A detail of the Levy lot. The yellow boxes show a concentration of wood and the red boxes show a concentration of brick.

Kaufman. The Kaufman lot shows three types of building material: brick, wood, and stone (Figure 3.9). The Kaufmans made their home from brick, probably with interior framing like the Levy home. The most prevalent building material on the Kaufman lot is milled lumber. This material is most prevalent in the southwest, central, and east portions of the lot. A small amount of brick is present at the west end of the lot. Large piles of stone, dressed and undressed, are located on the north and southeast portions of the lot. Kaufman used the stone as the foundation. The lumber would have fallen away from the main structure during collapse, or looters could have moved it.

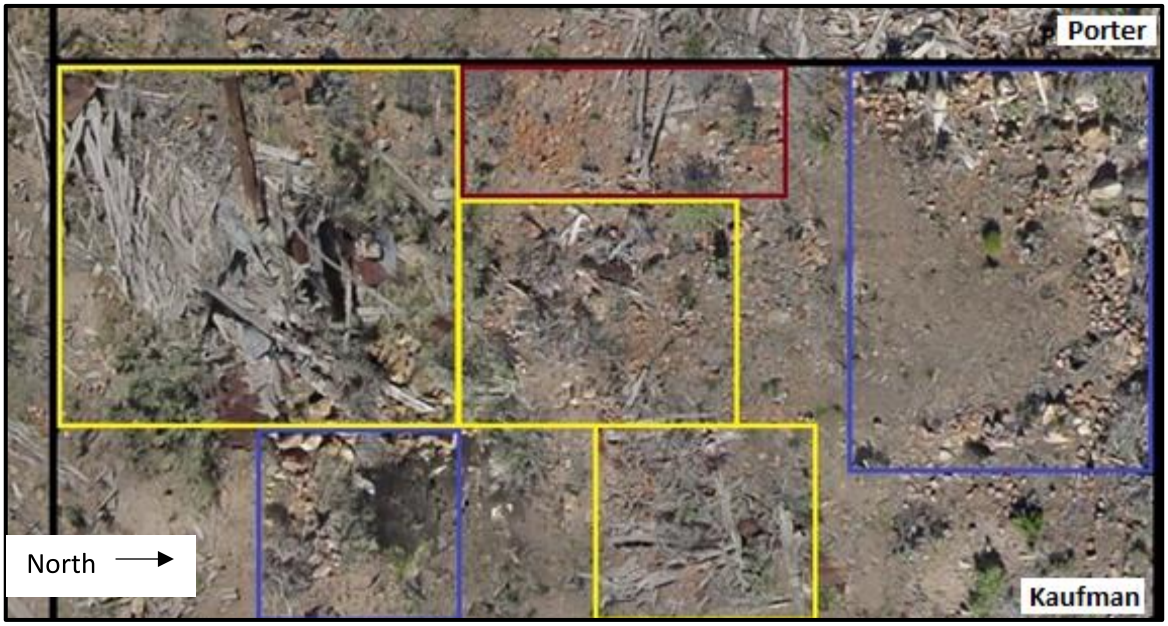

Figure 3.9. A detail of the Kaufman lot. The yellow boxes show concentrations of wood, the red box shows a concentration of brick, and the blue boxes show concentrations of stone.

Figure 3.10. A detail of the Porter lot. The yellow box shows a concentration of wood.

Porter. The Porter home was a small 'saltbox' style home. According to the 1864 Esmeralda County Tax Assessment Roll, the Porter home was made from wood. Figure 3.10 shows the Porter lot. The only building material present in large quantities is milled lumber. The debris is scattered around an empty opening, suggesting the structure fell outward not inward.

Radervitch. The structural remains of the Radervitch lot are very similar to those found on the Porter lot. Milled wood is the only structural debris (Figure 3.11). It is also scattered around an opening, suggesting that the structure fell outward rather than inward.

Figure 3.11. A detail of the Radervitch lot. The yellow box shows a concentration of wood.

Spring Street

As with Block C and Block 3, it is important to test the accuracy of the orthophotomosaics. I followed the same steps outlined above. With these methods, I determined that the Spring Street orthophotomosaic is accurate to 0.8 meters.

Unlike the other two blocks, there are no structural remains in the Spring Street survey area. Because there are no structural remains, it is difficult to provide a locational reference in the field. To help provide a locational reference I transferred the 1864 Esmeralda County Tax Assessment Roll Map on the model's surface. This map shows the lot locations on Spring Street (Figure 3.12).

Figure 3.12. The Spring Street orthophotomosaic with the 1864 Esmeralda County Tax Assessment Roll map transferred on the surface.

With Block 3 and Block C, I examined and discussed each lot that displayed large amounts of structural debris. None of the lots surveyed on Spring Street have structural debris. Therefore, I do not discuss the lots on Spring Street because there are no structural remains present.

The amount of structural material left in Aurora varies by block and lot. The orthophotomosaics allow me to examine the distribution of structural debris on each lot and block. Lots on Block C and the southern half of Block 3 all show structural remains; the northern half of Block 3 and Spring Street do not. Why there is a difference in the presence, or lack, of structural debris is answered in Chapter 4 as I discuss my research questions.

3D Models

Three-dimensional (3D) models are an accurate representation of the surveyed object. They show the x, y, and z-axis, as compared to the x and y-axis shown on orthophotomosaics. Photogrammetric 3D models can show the entirety of a site. By utilizing 3D models, archaeologists have the ability to create spatially accurate maps, and see features not visible on a 2D image. A 3D model, in conjunction with orthophotomosaics, enhances archaeologist’s ability to interpret archaeological sites.

This section looks at the photogrammetric 3D models of each recorded block at Aurora. This section focuses on features only visible on a 3D rendering, such as depressions and slope. I use the 3D models to look at structural foundations on Block 3, topography and slope on Block 3 and Spring Street, and I present a different view of the structural remains at Block C.

Topography is an important feature in landscape archaeology. I argue that Aurora's residents placed structures in particular locations because of topography. This is no more evident than Block 3 and Spring Street. On Block 3, the commercial buildings were placed facing Pine Street. Many of these structures were made from brick. The residential lots were placed on a heavy slope and contained single wood houses or cabins. This area would have been difficult to build a large brick structure. The more level the ground, the more intricate the building. Spring Street is similar to Block 3. The block is also heavily sloped. However, the leveled area is smaller and less suitable for large buildings along its eastern end. Residents placed small wood cabins here. Chinese and American laborers occupied these homes.

Some of the buildings on Block 3 were built on an excavated foundation. These buildings were made of brick and required a foundation for stability and strength. The 3D model shows these foundations. By analyzing each foundation, it is possible to determine the building's actual location.

When a building collapses, or is taken down, the walls do not fall in perfect order. Building walls crumble and fall in a variety of ways. On an orthophotomosaic, it is difficult to see the exact layout of the collapsed walls because they are only visible in two dimensions. With a 3D model, all three dimensions are visible and allow researchers see the structural remains at different angles. I apply this technique at the Levy home on Block C.

Block 3

Block 3 was a heavily sloped commercial and residential block. The commercial buildings fronted Pine Street, and some were built on a foundation. Residential buildings were on the north end of the survey area on the heaviest slope. Building foundations and slope are difficult to see on an orthophotomosaic because it only shows two dimensions. In this section, I discuss the topography and foundations of the buildings on Block 3. Figure 3.13 is a still image of the 3D model and shows the slope of Block 3.

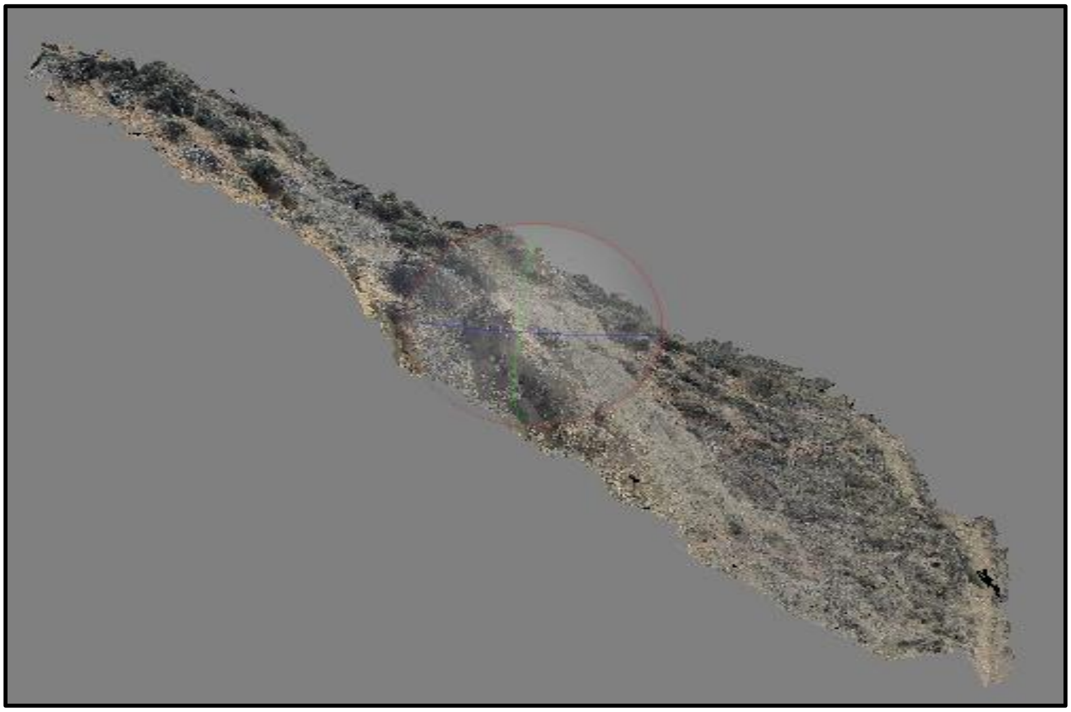

Figure 3.13. A still image from the 3D model of Block 3. This image shows the slope of the block. The figure is oriented looking east.

All of the buildings on the north end of the Block 3 survey area were placed on a heavy slope. This includes the Denlenger, Dr. Sill, Mono County Jail, McBride, Harvey, Wheeler, W. Jones, and Keefer lots. While all of these lots were on a slope, I use the Mono County Jail, as an example to illustrate how researchers can see a lot’s topography on the photogrammetric 3D model. The Dr. Sill and McBride lots bordered the Mono County Jail. Residents constructed the jail from brick, stone, and wood. With the orthophotomosaic, I was able to identify the location of the Mono County Jail on Block 3. This location was transferred to the 3D model. The 3D model can be rotated to look at the slope of the lot, after the jail’s location was identified. Figure 3.15 shows the Mono County Jail on the Block 3 model. This same process can be repeated across the block to determine a building's location on the topographic landscape. While pedestrian survey can be used to find a structure's location, it is time consuming and requires multiple people. I was able to do this in less than five minutes on a computer.

Other important features visible on the 3D model include building foundations. To locate the building foundations, I rotated the 3D model to show a variety of angles. Multiple angles show features in different ways, and can help identify features that may not be visible from a single angle. This enhances researcher's ability to look at depressions and building remains. I located foundations on the Wingate Hall, Molineauex & Dodd, and Dreyfus & Laurel lots using this technique. In this section, I will discuss the relationship between each foundation and the building material distribution on each lot.

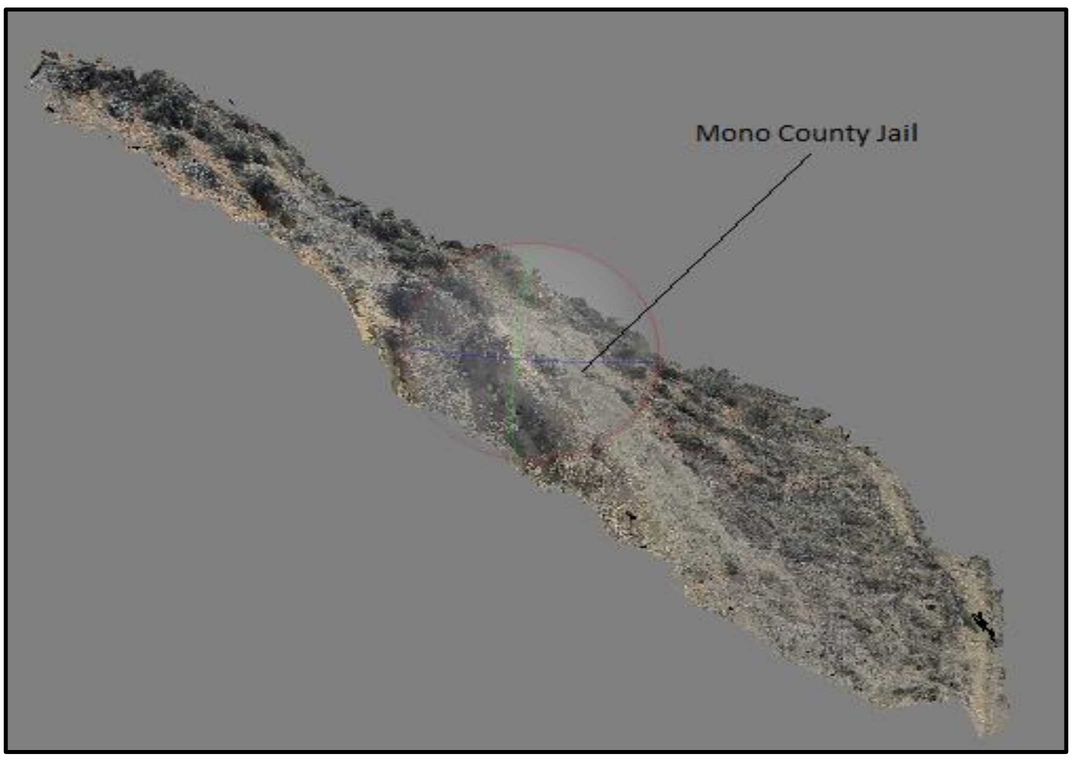

Figure 3.14. A still image taken from the Block 3, 3D model showing the location of the Mono County Jail. The figure is oriented looking east.

Wingate Hall. A.M. Wingate built Wingate Hall on a stone foundation. The dressed stone used in the foundation is shown in Figure 3.3. The Wingate Hall foundation is seen in Figures 3.15 and 3.16. Having identified the building material type on the orthophotomosaic, and the foundation on the 3D model I can create a correlation between the distribution of building material and the building's location.

Two building materials were identified on the Wingate Hall lot, brick and stone. Brick is found in the northwest, central and northeast sections of the lot. The south end of the lot displays a large amount of stone. The building foundation is located in the southwest section of the lot (Figure 3.14). This suggests that the dressed stone is still in its original location, while the brick has been scattered across the lot. Since brick is only found north of the foundation, it suggests that the structure fell north and not south onto Pine Street. Any material that did fall south onto Pine Street would have been removed.

Figure 3.15. A still image taken from the Block 3, 3D model. The Wingate Hall foundation has been identified. This foundation can be identified by rotating the model at different angles.

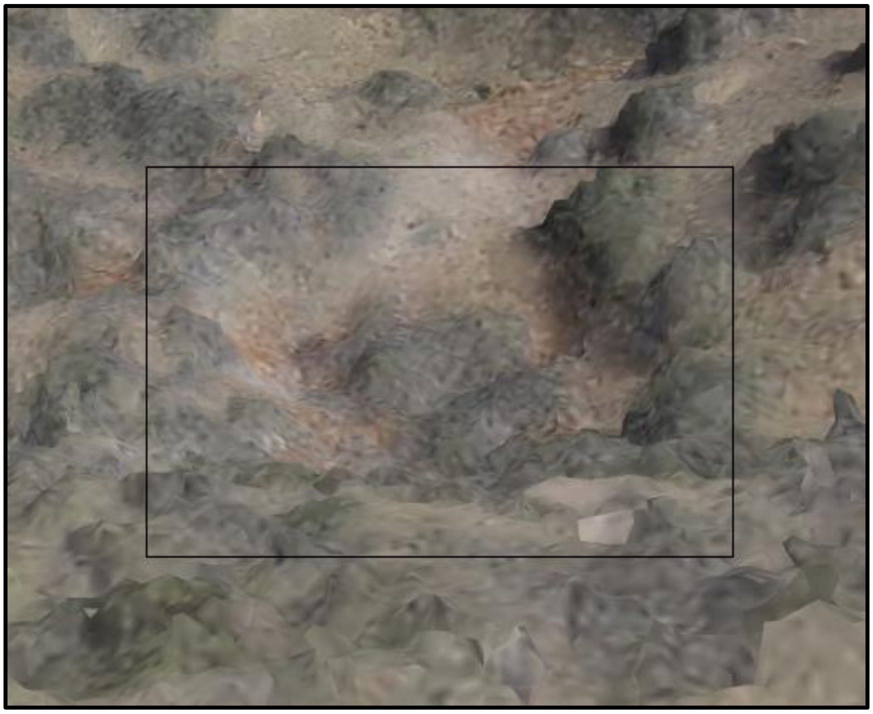

Figure 3.16. A still image taken from the Block 3, 3D model. The Wingate Hall foundation has been identified. The figure is oriented looking north.

Molineaux & Dodd. The Molineaux & Dodd lot contained a two-story brick building built on a foundation. By rotating the 3D model to different angles, I located the building's foundation. The foundation is in the east and central portion of the lot. Dressed stone and brick are both found in and around the foundation. The builders probably used dressed stone for the foundation as it is the most abundant material in the foundation today. The brick probably fell into its current location as the building was torn down by looters in the 20th century. Figure 3.17 shows the Molineaux & Dodd foundation.

Dreyfus & Laurel. The Dreyfus & Laurel foundation is in the south and central part of the lot (Figure 3.18). The foundation does not show any building material. Dressed stone is located north of the foundation and looters may have moved it to this location during deconstruction. Because no building material is located in the foundation, I cannot say what type of material the occupants used. In addition, a lack of material in the depression could indicate a foundation was not present and the depression is natural or served another purpose. The dressed stone could have been used on the Molineaux & Dodd lot and moved onto the Dreyfus & Laurel lot later.

Block 3 Conclusion

On each lot with a visible foundation, the majority of building material is located north of the foundation. Why? I speculate that during deconstruction, building material fell north and south. Scavengers probably took more of the material from the south because it was easier to access. It would have been near a main road and would have required less effort to remove. This would cause the building material distribution to appear disproportionate today, when it was originally spread across the entire lot.

I use the Block 3 3D model to show two things. First, is the relationship between a lots location and topography. Buildings described as cabins in the 1864 Esmeralda County Tax Assessment Roll, or those that are poorly constructed are placed on a heavier slope than those made of brick. I used to the Mono County Jail to illustrate this point. Second, I showed the relationship between the building foundations and the distribution of building material. This comparison showed that all three buildings had a similar material distribution of brick and dressed stone, centered around their foundation. Without the 3D model, it is difficult to understand these features.

Figure 3.17. A still image taken from the Block 3, 3D model. The Molineaux & Dodd foundation has been identified. The figure is oriented looking east.

Figure 3.18. A still image taken from the Block 3, 3D model. The Dreyfus & Laurel foundation has been identified. The figure is oriented looking west.

Block C

Since Block C is built on a gentle slope, and is devoid of depressions, I want to discuss how complex structural remains can be evaluated with a 3D model. On the orthophotomosaic, the structural remains can only be seen from one perspective. With the 3D model the remains can be manipulated to show the structural debris from multiple angles.

The Radervitch, Porter, Kaufman, and Levy lots display structural remains. The structural remains on the Radervitch and Porter lots focus around a central opening. This suggests that the structures collapsed outward rather than inward. While looting may have taken place on both these lots, it does not appear as severe as the Kaufman and Levy lots since the remains are still intact in a uniform way. The Kaufman remains are scattered across the lot. The remains are a mix of wood, brick, and stone. They are scattered in relatively small flat piles. The Levy remains are scattered around a large central feature. This type of scatter suggests heavy looting for building material and artifacts.

The Levy lot best shows the detail that can be understood from the 3D models, because the building remains show the most detail. I use it as an example here. Most of the visible remains center around a large feature of collapsed lumber. The orthophotomosaic of the Levy lot shows the presence of framed walls (Figure 3.8). The orthophoto only shows the presence of these features, it does not show the different layers of building material and how the walls are deposited onto one another.

The 3D model of Block C enhances the interpretation of the structural remains. They are transformed from flat two-dimensional objects to complex three-dimensional shapes. By rotating the model, I can view the feature as layers, not flat objects. Figure 3.19 shows a portion of the Levy lot. This image shows the presence of a framed and partially paneled wall with a small opening underneath. The framed wall is resting on other pieces of structural debris creating the small opening. The opening cannot be seen on the orthophotomosaic.

The Block C 3D model shows different layers of structural debris. The Levy lot is the most complex set of structural remains on the block. With the 3D model, I was able to manipulate the image to show the Levy remains from multiple angles. This shows that the Levy lot is made from complex layers, lying on top of one another to form the structural remains. The other features on the block do not display the same complexity as the Levy lot, so I did not discuss them in detail.

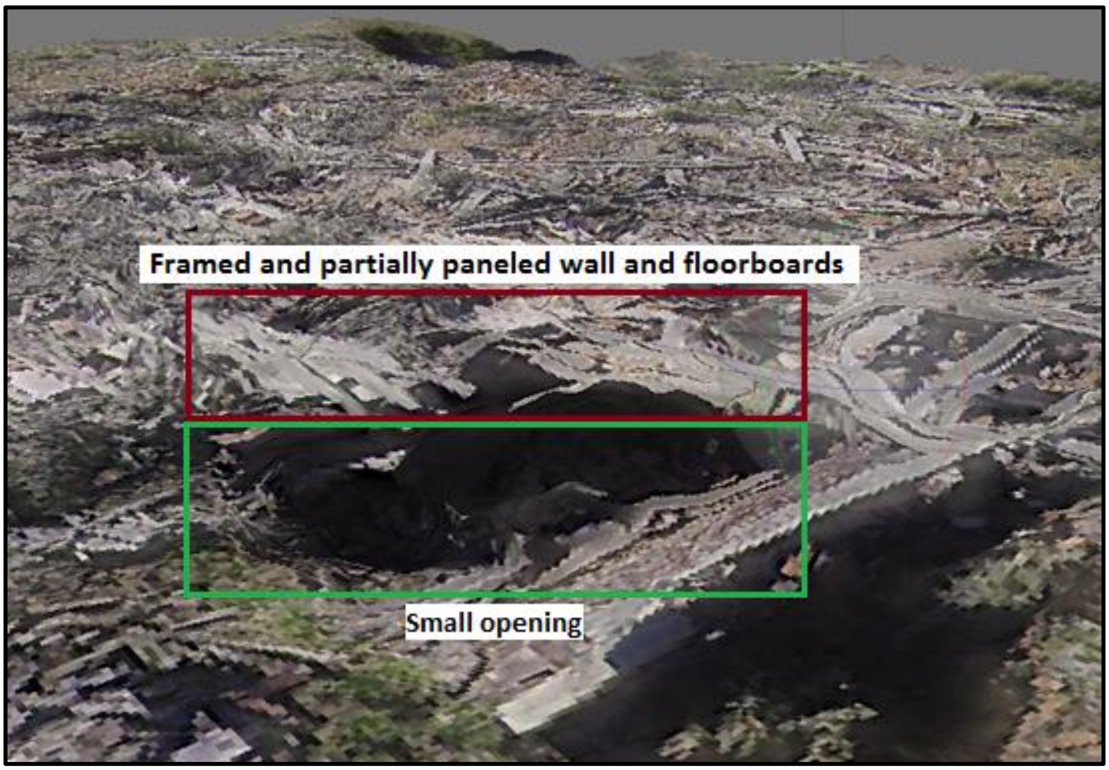

Figure 3.19. A still image taken from the Block C 3D model of the Levy lot.

Spring Street

Spring Street is located three blocks west of Block 3 and one block northwest of Block C (Figure 1.3). Many of the residential structures built on Spring Street were miner’s cabins (1864 Esmeralda County Tax Assessment Roll). They did not have foundations and did not leave structural remains such as stone, brick, or wood on the landscape. Because Spring Street is heavily sloped, the relationship between location and slope can be determined; much like Block 3.

The steep slope of Spring Street, coupled with the industrial buildings made this area undesirable for Aurora's citizens. It would be difficult to construct a large brick or wood frame home on these lots. Aurora's residents would have preferred places like Block C with favorable topography and lack of industry for building this type of domestic structure. Visualizing the topography of the block helps researchers understand why residents lived in wood cabins as opposed to larger framed homes.

This idea of low desirability is supported by a viewshed analysis conducted by Emily Dale (2011:113-116). With Geographic Information Software (GIS) ArcMap 10, she conducted a viewshed analysis of Aurora to see if Spring Street was visible from the Courthouse on the corner of Silver Street and Pine Street and a second point further down Pine Street. Her test concluded that Spring Street was not visible from either location, and therefore not visible from Block 3 or Block C. Lack of visability coupled with steep topography and a large amount of industry would have all contributed to Spring Streets lack of appeal to bussiness owners and merchants for residential structures.

I follow the same process here that I followed to locate the lots on the Block 3 model; determine the location on the orthophotomosaic, and then plot it on the 3D model. The Miller, Thompson & McDonald, Higbie, Elstner, and Schwinerger lots were all on the same slope. Figure 3.20 shows the location and slope of the Higbie lot.

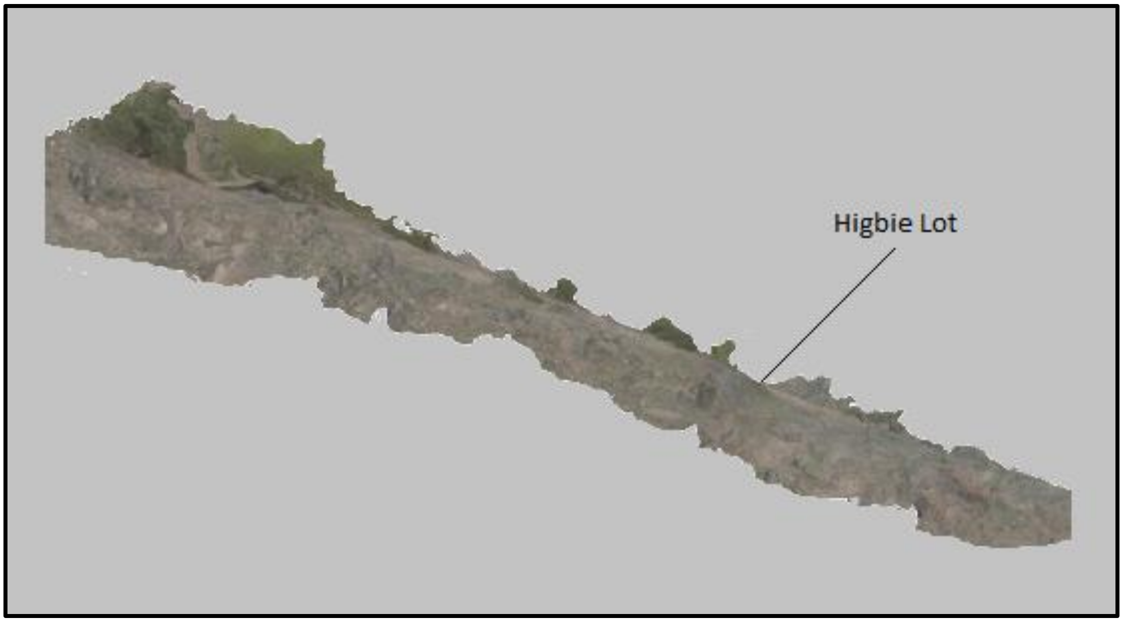

Figure 3.20. A still image taken from the Spring Street 3D model to show the Higbie lot. The figure is oriented looking west.

The Higbie lot is on a steep slope and would be a difficult location to build a large home. Samuel Clemens describes Higbie's cabin as a few log walls and a canvas roof (Figure 4.2). Higbie was a miner and laborer. Clemens accounts that he and Higbie were often short of money and he records writing his brother for funds several times (Clemens 1913a). Higbie did not have the funds for a home on Block C. Possibly he could have afforded a home on Block 3, but even those on the north end of the block were assessed at a higher value than his lot. The other Spring Street residents probably faced a similar financial situation.

I argue that the homes on Spring Street were small, and built of temporary materials such as log, canvas, and stone. Miners and other laborers lived in this area because it was affordable. The affordability was probably due to the topography of the area, and the noisy and busy industrial buildings to the west. To understand the topography of the area allows me to make assumptions about the type of structures present, and why miners and laborers were living here as opposed to business owners and merchants.

Conclusion

Orthophotomosaics and 3D models are an important tool for archaeological investigation. The 3D models expand the way researchers understand each block. The 3D models show features like slope and foundations that are not visible on the orthophotomosaics. By understanding each block's slope, it allowed me to make a judgment about why residents placed certain buildings in certain locations. When I looked at the foundations on Block 3, it became easier to understand the materials and distribution of the structural debris on the Wingate Hall, Molineaux & Dodd, and Dreyfus & Laurel lots.

In this chapter, I transferred historic maps onto the surface of each orthophotomosaic. These new models show each lot's physical location on the modern landscape. Archaeologists can examine the relationship between lots, their location, and their relationship to each other. I also magnified each lot to discuss the remains seen on each lot and their distribution.

By examining the 3D models and orthophotomosaics, I was able to recognize a pattern between building remains and topography. It became clear that structures placed on a heavy slope no longer had structural debris, while structures placed on a gentle slope still show building material. The amount, type, and distribution of the remains plays an important role in understanding the deconstruction processes at Aurora. Chapter 4 is a discussion of these ideas.

Chapter 4: Discussion and Conclusion

In Chapter 1 of this thesis, I posed three research questions to frame the data collection, processing, and analysis of this thesis. The first three chapters have focused on the people, places, methods, and data used to answer those questions. This chapter answers the three original questions through an analysis of the collected data.

Research Questions

1. What does this study contribute to a knowledge of the deconstruction process at Aurora?

As I examined the photogrammetric data two patterns emerged. First, residential lots that were on heavily sloped ground did not have structural remains present. Second, lots with structures made from brick and milled lumber left a large amounts of debris on the landscape; while structures with no description, or described in the historical records as wood cabins left no structural materials. Why are there differences in the amount, type, and location of structural remains at Aurora? To answer this question, I will draw on two ideas.

Ashby and Johnson (2010:4) state that materials and design are chosen to serve a specific purpose. According to them, all structures are functional and aesthetic. Nevertheless, the degree to which a structure is functional or aesthetic can vary greatly, even within a single community or block. Structures exhibit these designs through material and features.

The second idea is presented by Palmer and Naeverson (1998:19). According to them, industrial workers chose buildings and materials based on availability. This includes placing buildings in a certain location with certain materials. This leads to the idea that simple structures, unframed cabins and houses, were easily portable and thus experienced movement from one town to another on a regular basis. Permanent structures, such as brick buildings and expensive framed houses, were more likely to remain in place because they were difficult to move.

During the boom and bust cycle of 19th century Nevada, many people moved from town to town looking for work. The most mobile residents were often miners and other laborers. They were not tied down with expensive homes or businesses, making it easy to move from boom town to boom town. Samuel Clemens and Calvin Higbie are two examples of temporary residents discussed in this thesis. The living structures enjoyed by these residents were often crude and temporary. Those that could afford it lived in boardinghouses, while most lived in dugouts or cabins (California Department of Transportation 2008:130). Their living quarters were certainly more functional than aesthetic.

Many of Aurora's other residents were more permanent. They brought in schools, churches, and businesses to the growing mining communities (Hardesty 1992). For example, as Aurora's citizens became more permanent residents established three churches, two newspapers, and five brickyards, with 13 physicians (Shaw 2009). The presence of so many businesses indicated that Aurora was moving from a mining camp to the status of mining town. Aurora's business owners and merchants also lived in structures that were more permanent, built from milled lumber or brick. These homes, while still being functional, also displayed various amounts of aesthetic details. The Levy, Kaufman, and Wingate residents all display these ideas.

In this section, I discuss evidence that shows miner’s cabins were made from more portable materials, and the permanent residents built from brick or milled lumber. Due to the portability of the miner’s cabins, they were moved to other communities, reused on other structures within Aurora, or simply reused as firewood. The permanent residences were not moved to other communities because they were made from less portable materials. I will present this evidence through an analysis of the photogrammetric models and the 1864 Esmeralda County Tax Assessment Roll.

Temporary Residences

The orthophotomosaics and 3D models indicate two areas with no structural debris present: Spring Street and the north end of Block 3. What are the similarities and differences between these lots? Both areas are on heavily sloped topography, and were occupied by individuals and groups where there is little information in the historic record. When there is a description of the residence it is limited to “wood house” or “wood cabin” (1864 Esmeralda County Tax Assessment Roll). The difference between these areas is what was around them. The south end of Block 3 was commercial with large mercantile buildings and other businesses. The area around Spring Street was industrial with brickyards and stamp mills.

The historic record for Aurora does not give great detail on the types of structures present along Spring Street during the 1863-1864 peak period. The 1864 Esmeralda County Tax Assessment Roll lists a structure on the Schwinerger, Elstner, Thompson &

McDonald, J.W. Miller lots (see Table 1.3). The structure on Higbie's lot is described in 1864 Esmeralda County Tax Assessment Roll, but is described in detail by Samuel Clemens and Calvin Higbie. According to these sources, all the residential structures were either wood cabins or improvements.

None of the lots on Spring Street were expensive. The J.W. Miller lot, with two cabins, was the most expensive, assessed at $400. Lots on Block C and Block 3 are also assessed around $400, however they only contained a single structure. The lots on Spring Street with a single structure are valued no higher than $300. The low assessment values in conjunction with descriptions of wood cabins or 'improvements' is further evidence that these structures were probably made from simple materials and hastily built. Figure 4.1 is an image taken of the Higbie cabin on Spring Street. The cabin is made from log walls with a canvas roof. It would have served the barest of functional needs. Other structures on Spring Street probably closely resembled Higbie's cabin, and were more functional than aesthetic.

The house lots at the north end of the Block 3 survey area also lack structural remains. This area includes the Dr. Sill, Mono County Jail, McBride, Wheeler, W. Jones, and Keefer lots (see Figure 3.1). This section of Block 3 displays similarities to Spring Street. While some of the lot owners were skilled, Dr. Sill and McBride, the other lot owners/occupants were laborers. Notwithstanding the occupation of the owner, the homes were all inexpensive.

According to the 1864 Esmeralda County Tax Assessment Roll, each one of these lots contained a wood house or cabin worth less than $300 (see Table 1.1). This is the only documentation from the historic record that describes the structures present in this area. No photographic evidence has been found that shows the house lots on Block 3. Therefore, it is difficult to make a determination about what type of structures were present on the block. I rely solely on my interpretation of the 1864 Esmeralda County Tax Assessment Roll and the photogrammetric data to support these ideas.

Figure 4.1. Calvin Higbie and friends in front of the Higbie Cabin on Spring Street. Image courtesy of the United States Forest Service.

I argue there are two reasons for a lack of building debris on Spring Street and Block 3. The first is that the structures themselves were not meant to be permanent. They were meant to be functional for a short period of time. Since it was typical for miners and other laborers to move from mining town to mining town, while only staying for a short period; I would maintain many of the owners and occupants of these structures did not intend to stay for an extended period and they built their residences accordingly (Paher 1970:8). The second reason is an effect of the first. Because these structures were poorly built, they were easier to transport from location to location. They would have lacked proper framing and materials as seen on Block C and the south end of Block 3. Johnson and McQueen (2014: 181) and Bansby et al. (1980:47) note that buildings were frequently moved between mining towns. In many parts of Aurora this was not possible, due to the reliance on brick for many of the commercial and residential structures. However, if the structures on Spring Street and Block 3 were hastily built and made from more portable materials, miners could easily move them from town to town.

Spring Street's structures may have been particularly vulnerable to such movement due to its location. Spring Street was the main thoroughfare between Aurora and Bodie, California. Bodie experienced a mining boom several years after Aurora. If miners were looking for available residences, why look further than Aurora, only 15 miles away. Spring Street would have been the first place they came to upon entrance into Aurora. It would have required less effort to remove structures from Spring Street than any other location in Aurora. Corri Jimenez who has done extensive research on Bodie's buildings believes that some structures in Bodie were taken from Aurora (Corri Jimenez personal communication 9/21/2016).

Lack of debris on Spring Street is an indicator of building movement. If the buildings merely collapsed due to natural processes, there would be some type of remains present. The lack of debris indicates careful deconstruction, to preserve as much of the material as possible for future use. If the buildings were portable and easy to move, they would need to be constructed from a material that provided for easy portability.

The lack of building debris points to temporary wood structures as the building material of choice along Spring Street. Wood cabins and other temporary structures were the perfect choice for Aurora's transient miners. Wood gave them a functional rather than aesthetic shelter for their meager incomes. If their homes were made with portable materials such as logs and canvas they could reuse their homes again at a different location. Or, if the owners and occupants left the original structures, the buildings would have been available to anyone who could move them to another site. People chose buildings and material that were convenient. Moving a structure from Aurora to Bodie is more convenient than finding local building material; especially in locations where building material is scarce.

While I argue many of the structures and debris on Spring Street were removed by 19th century miners, some of the surface could have been cleaned by natural process such as erosion. Heavy snow and rain coming down the slope from Pine Street could have moved some of the materials off the level surface. Still, this would not have been able to completely clear the area of all structural debris.

The 1864 Esmeralda County Tax Assessment Roll indicates that the structures on the north end of Block 3 were also wood houses or cabins. The assessment value given to the properties was very low, and the lots (including structures) were worth very little. The occupations of the area's residents varied, the laborers making between $3-4 per day (*Daily Alta California*, 29 October, 1862). Like Spring Street, it would have been difficult to construct large buildings, like those seen on the south end of the block. Thus, the area was limited to the construction of small wood houses and cabins.

Like Spring Street, no structural debris is located on the Dr. Sill, Mono County Jail, McBride, W. Jones, Wheeler, and Keefer lots of Block 3 (Figure 3.1). The lots on the north end of Block 3 were placed on the steepest slope (Figure 3.13). Most or all of the material would have been carefully removed, to be reconstructed in a new location by 19th century miners.

I argue that there is a lack of material because these structures were transported from Aurora to a new location. They were easy to transport because of their simple design. Aurora's residents, and the residents of surrounding mining communities, would have seen these building materials as reusable and carefully transported them accordingly. The functional and temporary elements of these structures are in contrast to the structures built at Block C and the southern portion of Block 3. On Block C and the southern half of Block 3, structures were meant to convey a sense of permanence by blending function and aesthetic through material and design.

Permanent Residences

The residential and commercial structures built on Block C and the south end of Block 3 represented a different type of building than those on Spring Street and the north end of Block 3. These structures were made of brick or lumber, and were typically framed as opposed to the cabins or 'improvements' discussed earlier. With the brick materials, residents displayed elements of prosperity (Marschall 2008:22). Because these buildings were larger and made from less portable material, their remains left a larger impact on the landscape when the buildings were removed. The photogrammetric models show this difference.

Figure 4.2. A picture of the Levy home taken ca. 1905. Note the decorative details such as the bargeboard, false balcony, gabled windows, and two chimneys. Image courtesy of the Nevada Historical Society.

When the Levy family constructed their home in 1862, they had a different view of space, than did the residents of Spring Street. The Levy family owned a prosperous business and had the ability to build a home that reflected that success. These social differences are evidenced by the architecture of the home. Withee describes the Levy home: “The Levy home was a handsome brick structure that contained architectural elements reminiscent of Greek Revival style, including Doric columns, and Gothic Revival style, expressed in the presence of a gable window, a false balcony, decorative bargeboard along the roofline, and two chimneys” (2015:16). An image of the Levy home ca. 1905 is seen in Figure 4.2.

The Levy home was a mix of function and aesthetic. It served a functional purpose by providing a place for the fluid Levy family to reside. Because the home was built functionally it was able to stand into the 20th century. The Levy home was also built to convey aesthetic details. Decorative bargeboard, a false balcony, and a gable window are aesthetic features. This home would have been expensive to build and demonstrated the prosperity of the family.

The Kaufman family also built their home in 1862. Kaufman was a successful businessman and co-owner of the Pioneer Brick Store. Like his neighbors the Levys, he had the ability to project success and wealth. The Kaufman home was made from brick and had a single chimney. The Kaufman home appears to have been built with more function in mind than aesthetics. Nonetheless, an image of the façade does not exist, so many of the decorative elements could have been present and just not known from the historical record.

Other residents of Block C included Porter and Pebelie. The Porter home was a wood 'saltbox' style home with a porch. The Pebelie home was also wood framed, with a back addition and chimney (Figure 1.6). The Porter home was assessed at $700 and the Pebelie home was assessed at $350. Both homes were assessed at a lower value than the brick homes of Levy and Kaufman, but higher than the wood cabins and homes on Spring Street which were assessed at $300 to $150 (see Table 1.2 and Table 1.3). Since they were wood framed homes, they would have been more difficult to move than the wood cabins on Spring Street and Block 3 (Johnson and McQueen 2014:181).

The orthophotomosaic of Block C shows large amounts of building material still present on the Levy, Kaufman, Porter, and Radervitch lots. The Levy lot displays a large amount of structural debris. Much of the debris shown is wood (Figure 3.8). The brick was scavenged during the 20th century leaving behind the wood building segments, mostly floor material. The Kaufman lot displays similar structural debris. Despite being made of brick, much of what remains on the Kaufman lot is wood structural debris. A stone foundation is also present on the ground surface. Brick is still present, but most of the brick was scavenged in the 20th century (Stewart 2004:83). Figure 3.9 is the orthophotomosaic of the Kaufman lot at high magnification.

Only two of the surveyed homes on Block C were made of brick, the rest were made of lumber. I argue the material made just as much of a difference as building style. The homes on Block C were not easy to transport because they were framed, and made of less portable materials. The Kaufman and Levy homes were made from brick which is a difficult material to remove and reassemble; it is heavy, and cracks and breaks easily when removed from its original structure. Miner's cabins, like those seen on Spring Street, were much easier to move due to their construction than the brick or framed homes seen at Block C.

Like Block C, the south end of Block 3 also supported brick buildings. Wingate Hall, Molineaux & Dodd, and Dreyfus & Laurel were all built of brick (Table 1.1; 1864 Esmeralda County Tax Assessment Roll). These buildings housed a variety of businesses including mercantile stores and saloons. These structures were a mix of function and aesthetic.

They were designed to be functional and aesthetic through their material choice. Brick was a sign of permanence, wealth, and insurability (Marschall 2008:22). The buildings were also functional in design; several stories to house several business types. With Wingate Hall, there was also a large amount of aesthetics in the design. Wingate

Hall had bracketed cornices and heavy iron details throughout the exterior (Daily Alta California, 4 September 1863). These details were more aesthetic than functional.

To create a more secure structure, Wingate Hall, Molineaux & Dodd, and Dreyfus and Laurel were all placed on a foundation with an excavated basement. These foundations provided a more secure building, especially since they were made of a heavy brick or stone material. Each foundation varied in size and can be seen on the photogrammetric 3D model (Figures 3.15-3.18). The current foundation size could be in part to initial building size, or natural erosion and deposition processes that have occurred since the buildings were deconstructed. The foundation of Wingate Hall was "…built of dressed stone-the walls two feet thick" (DAC, 4 September 1863). Many of the stones from this foundation are visible in the orthophotomosaic of Wingate Hall (Figure 3.3). Through an examination of the 3D model and orthophotomosaic it is clear that the foundation stones are still located on the original foundation (Figures 3.3, 3.15 and 3.16). The foundation of the Molineaux & Dodd lot shows that stone is still present, and the Dreyfus & Laurel lot does not show any stone in the foundation.

The photogrammetric 3D model and orthophotomosaic of Block 3 shows large amounts of brick on each one of these lots (Figures 3.3, 3.5, and 3.6). The brick is scattered on each lot. During building deconstruction in the 1930s-60s the bricks fell where they currently reside. Many of the bricks are partial, probably left behind by looters because they were incomplete.

The buildings on Block 3 were not removed after the initial peak of 1864-1865, but later in the 20th century. The Molineaux & Dodd, Neidy, and Dreyfus & Laurel stores can be seen in two photographs taken ca. 1890-1900. (Figures 1.2 and 1.5). As noted by

Shaw (2009:14) and Stewart (2004:83), the removal of most of Aurora's brick did not begin in earnest until a post-World War II building boom in California and Nevada.

One reason the brick structures on Block 3 were not removed during the 19th century may have been building size; multi-story brick buildings are difficult to move. Another reason may have been that brick was difficult to move in large enough quantities to build a new structure, as opposed to wood logs or boards. By the time the buildings were looted in the 20th century they had already begun to fall apart, making them easy prey for vandals.

The buildings at the south end of Block 3 were intentionally designed. They were designed with a mix of functional and aesthetic details. They exhibit this by a combination of size, material, and decoration. They were made from brick which served the function of being permanent and 'fireproof'. Brick also provided an aesthetic feeling of wealth and prosperity to homes and businesses. The size of these building demonstrated a sense of permanence to the residents of Aurora, and the owners themselves. The combination of size and material made the buildings more difficult to move and left more remnants on the ground.

The structures along Pine Street on Block 3 and Block C were purposefully designed to provide a mix of function and aesthetic. Buildings like the Levy home were made from brick with decorative elements such as gabled windows and bargeboard. These details provided for function (material) and aesthetic (brick, bargeboard, false porch). Similarly, Wingate Hall was functional through its use of brick and aesthetic through its use of iron decorative elements.

The photogrammetric models helped me understand building location, setting, and materials. With these images I created maps of each block to see the lots in detail. The 3D models show building foundations, which helped determine the building's actual location on the landscape and the landscape's topography. I use this information to make judgments about structure type based on the materials and topography of the lot.

Conclusion

This study contributes to our knowledge of Aurora by providing evidence on why there is an absence of structural material on the north end of Block 3 and Spring Street. Because of their material type, it was easier to move these structures than those on Block C and the south end of Block 3. Structures made from framed lumber and brick were more permanent and difficult to remove. It was not until the 20th century that many of these structures were torn down for use in other cities. Many were already in disrepair. They were not removed as carefully leaving behind a great deal of material.

The next section answers the second and third research questions. In this section, I move away from a discussion about the structures of Aurora. Instead, I focus on the effectiveness of unmanned aircraft systems and photogrammetrics to record and analyze historic archaeology sites.

2. Are UAS an effective tool to record historical archaeology sites?

Case studies by Mouget and Loucet (2014) and Eisenbiess and Saurbier (2010) demonstrate that UAS can effectively record archaeological sites. Nevertheless, until this thesis, a published study focused on UAS technology and 19th century historic archaeology has not occurred.

One of the largest benefits of UAS is their ability to record sites quickly and accurately. Even with the setbacks I encountered, the blocks were still recorded in less than three days. A study conducted by Boston University (Olson et al. 2013) found that UAS collected data faster than traditional mapping techniques. Subsequently, the photogrammetric models were produced to a higher geometric accuracy than the traditional hand drawn maps (Olson et al. 2013:250). UAS allow researchers to conduct field studies with limited personnel, while acquiring highly accurate photographic data. The Aurora project further demonstrates the conclusions reached by Olson et al. (2013) through the creation of accurate photogrammetric models in less than three days.

The Aurora project encountered several setbacks with the UAS, notably poor battery performance, flights without usable data, and a malfunctioning flight radio. These problems caused me to decrease the size of my project area to ensure I collected data from all three blocks. With autonomous flight the project could have been completed in less time. Likewise, longer battery life, or more batteries, would have expedited the recording process.

The most time consuming setback, was the amount of flights that did not yield usable data at Block C. Six of the twenty flights did not produce usable data, either from a camera, gimbal, or UAS malfunction. These problems caused me to repeat flights which increased the survey time. I rectified the problems encountered at Block C and collected the data quickly at Block 3 and Spring Street.

UAS are an effective tool for archaeological site recording. They are inexpensive and create a complete photographic record of each surveyed location. The setbacks encountered at Aurora were minimal, and did not affect the overall outcome of the project. With limited personnel, each block was gridded and recorded in less than a day. The collected images provide a permanent, geometrically accurate record of each city block.

3. Is photogrammetric modeling an effective tool for archaeological site interpretation and recording?

Photogrammetrics are an effective tool to interpret and record archaeological sites. This has been demonstrated by the work of Rinaudo et al. (2012), Mozas-Calvache et al. (2011), and Poirer et al. (2013). Unlike traditional mapping and photography, photogrammetric models offer a three-dimensional view of an excavation, building, or landscape. Photogrammetric modeling is easy to do, and anyone can learn this skill in a matter of hours. Nevertheless, the more time invested in learning photogrammtrics, the higher quality models that will be produced.

Photogrammetric modeling presents researchers with an unprecedented look at the landscapes and artifacts, through both 2D and 3D reconstructions. Three-dimensional reconstructions provide researchers views of artifacts or landscapes from different angles, enhancing their understanding of the subject. Two-dimensional reconstructions provide large scale, high resolution maps to examine archaeological landscapes. Both model types are used in this thesis.

I used photogrammetric modeling to understand more about Aurora, its people, and its places. Photogrammetric models allowed me to create high resolution, accurate aerial maps of each block in a limited time. Traditional mapping methods would have taken several days per block, and been less spatially accurate. I used the orthophotomosaics to analyze each block collectively and then individually to determine the location and types of structural remains present. With the 3D models I looked at foundations and exact building placement. This allowed me to draw conclusions about Aurora as a whole and its deconstruction processes, as discussed previously in this chapter.

Photogrammetric modeling is more affordable now than any time in the past. Researchers have demonstrated the benefits of this technology, and I argue it will continue to change the way researchers conduct archaeological investigation. Photogrammetric models have become an important tool for archaeologists.

Conclusion

Unmanned Aircraft Systems are an effective tool to record archaeological sites. I have successfully used UAS to partially record three blocks of Aurora, Nevada. The collected data was used to generate photogrammetric orthophotomosaics and 3D models of each surveyed block. I used these models to examine building location and material type.

I found that structures on Spring Street and the north end of Block 3 did not leave behind structural debris. I argue this is because they were more functional and made from more portable building materials such as logs and canvas. The structures on Block C and the south end of Block 3 were less portable. They were framed lumber or brick homes. This made them difficult to transport. These buildings were removed in the 20^{th} century, and because of the material type a large amount of debris was left behind.

This thesis demonstrates the ability of UAS to rapidly collect data for photogrammetric processing. I present methods for the rapid acquisition of photographic data, and how to process that data into photogrammetric models. This thesis shows that UAS and photogrammetrics are a valuable tool to examine 19^{th} century mining communities.

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Appendix A: Flight Checklists

Pre-Flight Checklist

1. Check for lose parts/unconnected wires
2. Examine propellers, legs, arms
3. Examine gimbal
4. Examine camera/gimbal attachment
5. Check UAS battery
6. Check camera battery

Flight

1. Clear any debris from the takeoff/landing area
2. Inform bystanders you are preparing to take off
3. Make sure the flight area is clear of bystanders
4. Make sure the controller is in loiter (LTR) mode
5. Turn on controller
6. Connect UAS battery
7. **Do not touch the UAS until the warning light turns green**
    a. If the warning light does not turn green after two minutes, repeat steps 4-6
8. Press safety button (located on top of battery compartment)
9. Take off
10. Land

Post-Flight

1. Disarm motors
2. Turn off the controller
3. Press safety button
4. Disconnect battery

I*mage downloading Instructions*

1. Remove sd card from camera
2. Connect sd card to computer
3. Download images into folders
    a. Project name
        i. Aurora UAS
    b. Date images were acquired
        i. 6/10/2016
    c. Block number
        i. Block 3
    d. Flight number
        i. Flight 1
4. Repeat step 3 on second storage device
5. After returning to the lab, download the data onto the external server