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The Legacy of Mining in Southwest Missouri: Past and Present Conditions of the Tri-State Mining District

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THE LEGACY OF MINING IN SOUTHWEST MISSOURI: PAST AND PRESENT CONDITIONS OF THE TRI-STATE MINING DISTRICT

A Master's Thesis

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In Partial Fulfillment

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Master of Science, Geospatial Science

By

Anastasia Marie Cox McClanahan

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ABSTRACT

The historic Tri-State Mining District (TSMD) of southwestern Missouri, southeastern Kansas, and northeastern Oklahoma has a history of lead and zinc mining that extended over a hundred years. During the district's peak production period, the TSMD was one of the world's largest producers of lead and zinc. The mining activities in the TSMD produced economic growth that supported the local communities and were essential to the victory of the Allied Forces during World War I and World War II. Beginning in the 1920s, the mining activities in the district slowly began to cease due to depletion of metal ores and competition from imports. The last mine in southwest Missouri closed in 1957. Unfortunately, the negative consequences of the mining industry have had a lasting effect in the environment. Abandoned mining sites caused lead and zinc contamination in the soils, sediments, and streams throughout the district. Due to the high level of contaminants present, remediation efforts began in the 1980s and are still on-going today. This study assists in identifying sites with contaminated levels of heavy metals in the sediment due to over a hundred years of lead and zinc mining centers in southwest Missouri. The metal content of sediments reported in literature were collected and added to a database used to build maps that would highlight their spatial distribution. The purpose of this study is to (1) provide an historical description of the mining activities in the Missouri part of the TSMD, (2) aid in further understanding the extent of contamination caused by the historic mining activities, and (3) aid in an understanding of the effectiveness of remediation.

KEYWORDS: Tri-State Mining, lead, zinc, contamination: remediation

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I would also like to thank my family, including my parents- Cindy and Russell Cox- and my siblings- Guinevere, Richard, Matthew Cox- whom have provided me with love, emotional support, and many hours of babysitting to help me to complete this degree. I appreciate each and every one of you. The success of this research is as much my victory as it is yours.

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I dedicate this thesis to my son, Spencer McClanahan, and the memory of the mother, Cindy Cox.

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CHAPTER ONE: INTRODUCTION

1.1 Content and Organization

The history and legacy of the Tri-State Mining District (TSMD) involves several clearly defined periods of discovery, mining, booming, decline, contamination, and remediation. The character, purpose, and ambitions of the region have shifted in response to each of these stages. This study is divided into four sections;

1) physiographic description of the study area and the geology of the mineral deposits,
2) history of the mining development in the district,
3) local histories and modern conditions of six historic mining sites, and
4) post-mining conditions, with an emphasis on the effectiveness of remediation.

The four parts of this study are self-contained and describes where the documents and data for the section were acquired and how they were integrated into the study. This study is organized in this format to give the reader a clear understanding of the history and legacy of the TSMD. Initially, in chapter two, this study describes the physiography and geology of the TSMD. This includes the geographic location of the district, as well as the location of the historic and modern towns, counties, rivers, and historic mining sites within the district. In addition to the physical geography of the study area, this chapter describes the major ore and gangue minerals mined throughout the TSMD, what formations and rock types were the ores located within, and the major theory on how the ore deposits were formed.

Chapter three covers the history of mining activities throughout the TSMD. These includes early mining activities, the introduction of commercial mining, improvement in mining methods, the growth and decline of the mining operations throughout the district, the

establishment Mercy Hospital, the generation of mining waste, and the related health hazards due to the abandoned mining waste.

Chapter four focuses on the history and modern conditions of six mining sites in southwest Missouri, as a representative sample of towns within the TSMD shaped and influenced by mining. Each of these mining towns has endured a different fate and had to adapt to the decline and disappearance of mining and thus replace this economic activity with other activities in order to survive.

Chapter five of this study discusses the enduring consequences in the post-mining era throughout the district. The creation of Superfund sites, previous remediation efforts, challenges encountered and the state of remediation at the present time are addressed.

1.2 Significance of the Study and Specific Objectives

Mining for metals, coal, and other minerals has been a crucial asset to every major civilization since prehistoric times. Mining has contributed to increased production of goods, energy, and building materials around the globe (Hudson-Edwards et al. 2011; Spitz and Trudinger 2009). However, unregulated or poorly designed mining activities cause wide-spread chemical contamination of soils, sediments, and waterways, as well as physical hazards near mining sites. Mining in the United States began before the Pre-Columbian era with copper mines in the Great Lakes region as early as 3,000 B.C.E. (Sloane and Sloane 1970). Europeans began small-scale mining in the United States for coal and metal ores beginning with the first settlements. Later, the development of commercial mining led to the exploitation of larger quantities of valuable ores. Unfortunately, the consequences of a lucrative mining industry have come at a cost to local ecosystems (Hudson-Edwards et al. 2011). Mining sites, such as the

TSMD in southwestern Missouri, southeastern Kansas, and northeastern Oklahoma, have experienced environmental degradation from mining activities and the accumulation of contaminated mining waste. Mining waste that was improperly disposed throughout the district produced physical hazards (shafts and cavities). Whereas the mine tailings contain high concentrations of heavy metals that pose serious risk to the surrounding environment and human health (Gutierrez et al. 2016; Hudson-Edwards et al. 2011). However, the mining activities of the TSMD also had a positive effect on the local communities. The historic mining provided steady jobs and income for miners and their families, especially during times when there were few other jobs in the region, and when farming in the region was not producing enough profit to support the economic demands of the local residents. Additionally, mining activities provided valuable metal ores essential to the United States military during the Civil War, World War I and World War II. The TSMD was a leading producer of lead and zinc in the United States. The amount of zinc excavated in the TSMD represents half the total zinc and about a tenth of the lead excavated in the United State prior to 1972 (Gibson 1972).

This study builds on previous research to explore four aspects of mining in the TSMD from the middle 1800s to the present time. Specifically, (1) provides a historical description of where the mines were located and what ores were being mined at various locations and time periods, (2) provides an understanding of the excavation, milling, and smelting processes at various locations and time periods in order to understand how contamination of heavy metals occurred, (3) aids in understanding the effectiveness of remediation, and (4) encourage and build the interest of the local community in the history of mining in the Tri-State Mining District.

CHAPTER TWO: PHYSIOGRAPHY AND GEOLOGY OF THE TSMD

2.1 Physiographical Setting

The TSMD encompassed over 2,500 square miles and expanded across southwest Missouri, northeastern Oklahoma, and southeastern Kansas, shown in Figure 2.1. This study primarily focuses on the historic lead and zinc mining activities in southwest Missouri but some history of the mining in other regions of the TSMD is needed to better understand historic facts that occurred in Missouri. Figure 2.2 shows the geographic distribution of the known lead and zinc mining activities in the Missouri part of the TSMD. The map shows that the highest concentration of mining sites in southwest Missouri occurred in the western part of the region in Jasper and Newton Counties around Joplin, Missouri. However, noticeable concentrations of mining activities also occurred around Aurora and Granby, and lesser satellite deposits were mined as far east as Texas and Howell Counties in Missouri.

This study concerns the history of mining and the state of remediation after mines were closed, told by the metal content of sediments collected adjacent to six historic lead and zinc mining towns in southwest Missouri. Two major urban areas that developed within the study area include Joplin and Springfield. However, smaller urban centers in Granby, Neosho, Aurora, and Oronogo also were influenced by the lead and zinc mining of the region. The historic mining district lied predominately within the Ozark Plateau and within the topographic sub-region of Springfield Plateau (Rafferty 1980; Brockie et al. 1968). This area was part of the larger known "Ozark" that covers parts of most of southern Missouri, a small part of northeast Oklahoma, and parts of northern Arkansas (Rafferty 1980). The Springfield Plateau has a karst topography with

an abundance of springs, streams, and creeks. The topography of the Springfield Plateau varies and includes prairies, glades, forest, and rolling hills (Rafferty 1980).

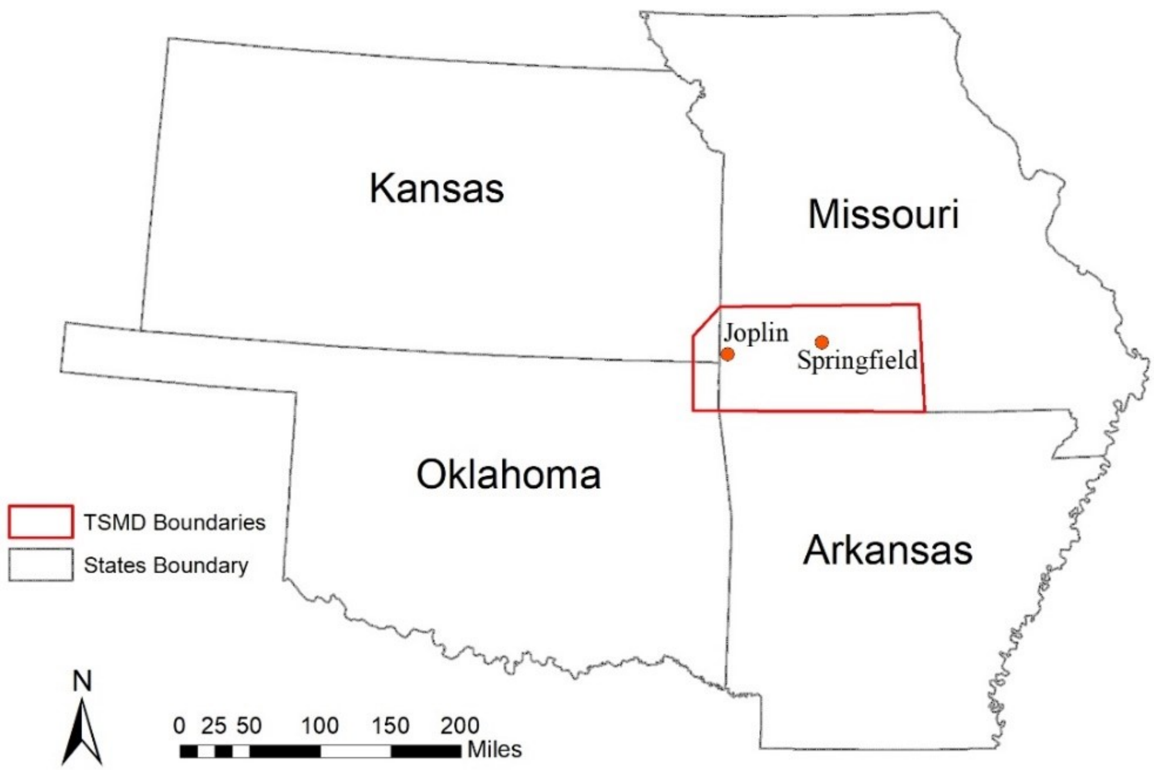

Figure 2.1. TSMD boundary encompassing all formerly scattered mined ore deposits and the two largest urban centers in Missouri within the district.

The two major watersheds within the Missouri part of the TSMD in the area include the Spring and the James watersheds, shown in Figure 2.3. However, portions of the Sac, Pomme de Terre, Niangua, Elk, Bull Shoals, Beaver, North Fork, Big Piney, Lake O' The Cherokee, and Upper Gasconade Watersheds overlay the study area (Edmond and Daniel 1997). Due to the numerous unregulated mining sites, multiple waterways in the study area have been documented to have mining contaminants present. Chapter five of this study maps the lead and zinc

contaminants present in Turkey Creek, Joplin Creek, Honey Creek, Center Creek, Chat Creek, and James River.

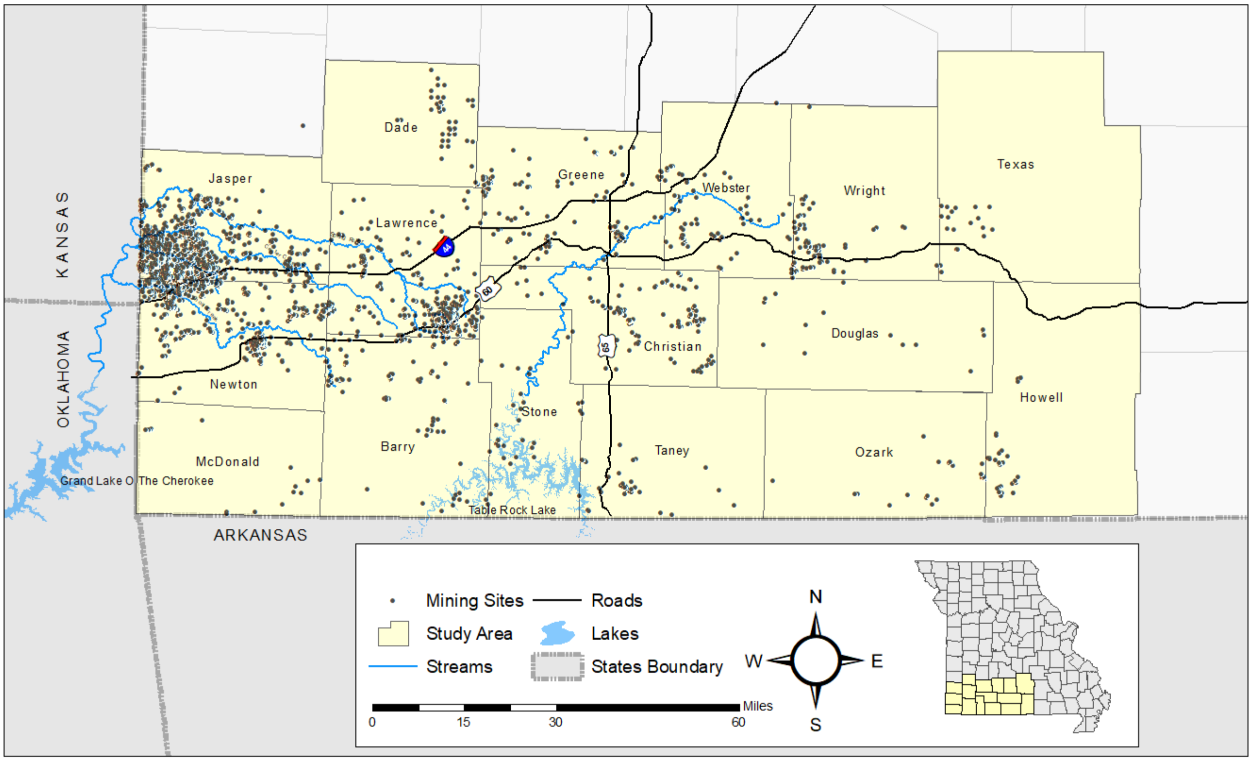

Figure 2.2. The geographic distibution of lead and zinc mining activities in southwest Missouri (data obtained from the Department of Natural Resources).The highest concentration of mining activites occurred in the western portion of the mining district around Joplin, Missouri, but extented to the satellite depoists that were mined as far east of Texas and Howell Counties.

2.2 Geological Setting

The emplacement of the TSMD produced isolated, scattered sources of lead and zinc ores that are found in long, irregular shaped deposits in the Mississippian-age limestone which contained an abundance of chert and jasper (Johnson et al. 2016; Rafferty 1980; Gibson 1972; Brockie et al. 1968). The lead and zinc bearing ores were deposited in the Paleozoic sedimentary rocks in the Reeds Spring, Keokuk, Warsaw, and Chester formations (Johnson et al. 2016; Brockie et al. 1968). However, most of the lead and zinc bearing ores were found in the Keokuk

and Warsaw formations (Johnson et al. 2016; Brockie et al. 1968). In their natural state, lead and zinc ores occurred together and miners could not excavate one without excavating the other. However, larger lead deposits were generally found close to the surface, while larger zinc deposits were found at greater depths (Gibson 1972).

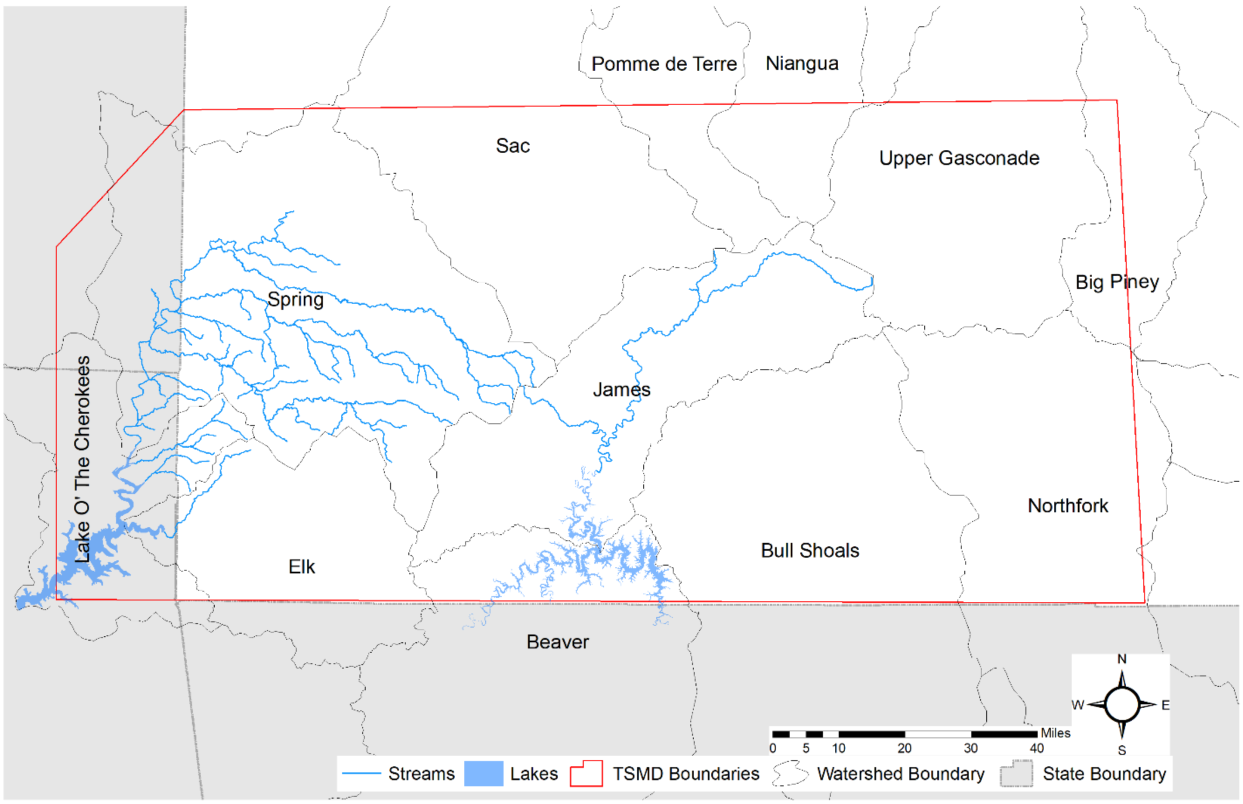

Figure 2.3. Map of Watersheds and Streams

Ore bodies varied in size and shape. Ores were deposited in three general categories (MDNR 2019; Gibson 1972; Brockie et al. 1968). First, pocket formations deposits were ores that disconnected from the main metal bearing ore formation. Pocket formations were generally shallow, circler in shape, and often associated with sinkholes. Generally, pocket formations produced very little zinc and lead bearing ores. However, there were exceptions and some pocket formations produced rich zinc and lead deposits. For example, the Oronogo Circle Mine was a

pocket formation that produced a large amount of metal bearing ores (MDNR 2019; Gibson 1972). Second, sheet-ground bodies deposits were deposits that varied in thickness and could cover from 40 to 200 acres (MDNR 2019) Although sheet-ground bodies are generally easy to excavate, the deposits produce have a low-concentration yield of metal bearing ores. The best-known metal bearing ores excavated from a sheet-ground body deposit in the TSMD was discovered in 1908 near Webb City, Missouri. This ore bed stretched for about twelve miles (Gibson 1972). Third, runs deposits typically ranged ten to five hundred feet wide, five to over one hundred feet in height, and from a few hundred to several thousand feet in length (MDNR 2019). Run deposits were typically found linked with factures or fissures where zinc and lead bearing ores deposits were able to concentrate. The run deposits were the most abundant ore producers in the TSMD (MDNR 2019).

The mineralization of lead and zinc bearing ores in the TSMD were most likely formed when the geological formation of the Ozark Uplift caused substantial faulting, flexing, brecciating, and folding in the existing rocks (Cosatt 2011). These physical geological movements resulted in structural deformities in the strata throughout the district (Johnson et al. 2016; Gibson 1972; Brockie et al. 1968). Subsequently, hydrothermal solutions that carried heavy metal ions in solution, migrated into the structures where they eventually cooled, and the heavy metal ions precipitated into the Mississippian limestone beds (Johnson et al. 2016; Gibson 1972).

Zinc and lead were the dominant metals present throughout the district. Zinc bearing ores are five to six times more abundant than lead bearing ores in the study area (Brockie et al. 1968). However, lead contaminants are the primary pollutant studied in the district because of lead's high toxicity level that continues to negatively affect the residents and the surrounding

ecosystem (Johnson et al. 2016). Other metals occurred in lower concentrations through the district (Johnson et al. 2016; Gibson 1972). Most notable of these metals is cadmium. Cadmium is closely associated with zinc due to the chemical similarities between zinc and cadmium. Cadmium often occurred in sphalerite; the primary mineral mined for its zinc contents. Although cadmium occurred in lower concentrations than zinc, cadmium poses a higher risk due to its high toxicity level. Therefore, cadmium remains a metal of concern throughout the historic mining district (Johnson et al. 2016; Andrews et al. 2009).

Lead and zinc metals are found deposited in several mineral forms throughout the district (Johnson et al. 2016; Gibson 1972; Brockie et al. 1968). As stated above, sphalerite (zinc sulfide) was the most important zinc mineral mined in the district due to its high concentration of zinc. Sphalerite contained approximately sixty-three percent zinc. Other forms of zinc mined in the district included smithsonite (zinc carbonate) and calamine (zinc silicate) (Beyer et al. 2004; Gibson 1972). The most important lead mineral mined was galena (lead sulfide). The galena in the district was non-argentiferous lead, meaning the galena was a peculiarly pure form of lead ore that had little or no silver associated with it. This made the lead ore relatively easy to smelt and produced a high-quality lead after smelting. (Gibson 1972; Brockie et al. 1968). Other forms of lead mined in the district included cerussite (lead carbonate), pyromorphite (lead phosphate), and anglesite (lead sulfate) (Gibson 1972; Brockie et al. 1968). Additionally, numerous gangue minerals were present including calcite, dolomite, marcasite, pyrite, chalcopyrite, limonite, and quartz (Gibson 1972; Brockie et al 1968). The predominate rocks throughout the district included Paleozoic sedimentary rocks positioned unconformably over Precambrian igneous rocks (Johnson et al. 2016; Brockie et al. 1968). Included in the Paleozoic rocks were the ore bearing Mississippian limestones.

CHAPTER THREE: HISTORY OF MINING IN THE TSMD

3.1 Archival Research and Literature Review Methodology

The history of lead and zinc mining in southwest Missouri has been preserved by many individuals throughout the region. Often these histories have been documented in locally published books, articles, and digital archives, which are not easily accessed through online searches. Therefore, it took many long hours of reading through old and rare documents to adequately research the history of the TSMD. Many of the local books and articles were obtained with the help of the librarians at the Springfield- Green County Library. The librarians' wisdom and patience were much appreciated throughout this research. Additionally, the Missouri Secretary of State's Missouri Digital Heritage archives provided most of the high-resolution images found throughout this study of the TSMD (MORH 2011).

This study strives to document the past and current events of the TSMD to make this information more accessible to individuals interested in the history of mining and its consequences in southwest Missouri. However, there remain many gaps in knowledge in the pre-mining, mining, and post-mining eras of the TSMD. These gaps in information are present in both space and time, since previous studies do not cover the entire chronology the TSMD. Also, some locations within the TSMD have been extensively studied, while other locations have not been studied in any depth.

In addition, a literature review was conducted to better understand the biological and ecological effects of activities during the mining and post mining eras throughout the study area. The relevant literature has been generated by academic professionals, government agencies, and independent researchers, as cited below.

3.2 Early Mining History

One of the earliest known European American explorers of the Ozarks was Henry Schoolcraft. In 1818, Schoolcraft set off on an expedition from Potosi, in the eastern part of Missouri, to confirm reports of lead deposits found on the James River (Rafferty 1996). During Schoolcraft's expedition, he confirmed that he found high quality lead ores in a creek bank on the eastern edge of present-day Springfield, Missouri. Schoolcraft also reported that he found evidence of shallow mining activities and simple log furnaces that he presumed were by used by Native American to excavate and refine lead ores to produce ammunition for personal use (Rafferty 1996; Rossiter 1992; Gibson 1972). Around the late 1830s, the first permanent settlements in the future TSMD were established (Gibson 1972). It was not the prospect of mining though that drove pioneers into the region. Westward expansion drove American settlers into the area with dreams of homesteading a rich, new land (Rafferty 1980; Gibson 1972). However, many of these pioneers found poor cherty soil that were not very productive. As a result, the pioneers in the area struggled to provide a marginal living on family farms (Rafferty 1980; Gerlach 1977).

Although the first settlers in the TSMD were not mining metals commercially, pioneers would often collect exposed lead in surface deposits along river banks to melt into bullets for personal use (Rossiter 1992; Gibson 1972). However, as more settlers found high quality lead ores, the mining activities began to slowly shift away from the mining of small quantities of lead deposits for personal use towards commercial mining of lead deposits. By the late 1840s, commercial mining camps had appeared in numerous locations around southwest Missouri (Gibson 1972). Figure 3.1 shows the geographic location of two of the earliest commercial mining camps that appeared right outside present-day Joplin in Leadville Hollow, Missouri. The

Reports of the Geological Survey of Missouri refer to these first two commercial mines as the Turkey Creek Mines of Jasper County (VanGilder 1975; Gibson 1972). Figure 3.2 shows an early mining operation in the TSMD.

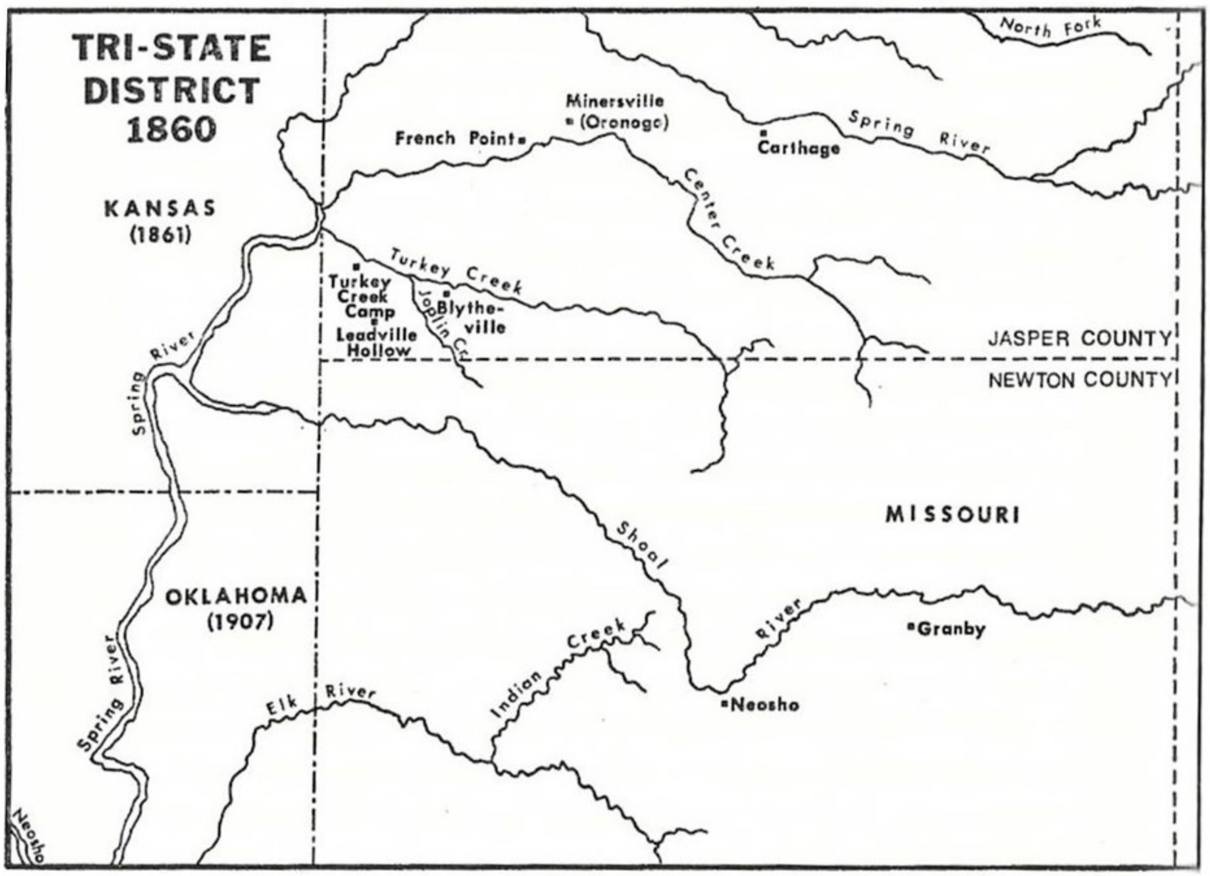

Figure 3.1. Geographic location of the Leadville Hollow, Missouri and the Turkey Creek Mining Camp (Gibson 1972).

Simultaneously with the discovery and start of the mining activities at the Turkey Creek Mines, miners began to establish lead mining camps around present day Oronogo, Granby, and Neosho, Missouri (Gibson 1972). These initial mining operations were often operated as partnerships, or family operations, with little or no hired help and used rudimentary mining techniques to extract the lead from the ores. Early miners would excavate near- surface deposits of lead bearing ores in shafts that rarely extended fifty feet in depth (Gibson 1972). Due to the

shallow nature of the lead deposits, early mining camps in the TSMD were known as "poor man's camps", because miners could work the shallow shafts with just basic tools, such as shovels, picks and man-powered windlass and bucket to bring the ores to the surface (Rafferty 1980; Gibson 1972; Brockie et al. 1968).

Figure 3.2. Early mining partnership TSMD. The unidentified miner in the center is standing on a board that was placed over the open shaft. Ores were placed in the bucket by the miner below and lifted to the surface through the shaft using the windlass and hand power of the miners above (MDHP 2011).

Although zinc ores were present at a five to one ratio to lead, little zinc was processed during the mid-1800s because of the difficulty in smelting zinc, the low cost for the zinc concentrate, and the lower depth at which zinc ores primarily occurred compared to the lead ores

(Smith 2016; Pope 2005; Rafferty 1980; Gibson 1972; Brockie et al. 1968). Before 1870, zinc excavated during lead mining were often thrown out with the waste rocks during the milling process (Rafferty 1980; Gibson 1972; Brockie et at 1968). Once the lead bearing ores were excavated and brought to the surface, the miners had to mill them in order to separate the waste rocks from the metal ores. Early methods of milling consisted of hand crushing the crude ores. Last, the milled ores were smelted in order to refine the lead. Initial methods of smelting included melting the ores using primitive log furnaces to separate the lead from gangue rock (Gibson 1972). These rudimentary techniques of milling and smelting led to a low percentage of lead ores being recovered and a high percentage of lead ores remaining in the mining waste.

The lack of transportation limited the growth of the initial mining operations throughout the district. Once the lead ores were excavated, milled, and smelted adjacent to the mine shafts, they needed to be transported to market on the east coast. Without railroad lines near-by, lead ores had to be either floated down Spring River on rafts towards New Orleans or transported by wagon to Missouri River (Wannenmacher 2013; Renner 1985; Gibson 1972). Both methods of transportation were expensive and time-consuming. Consequently, mining remained limited in the TSMD before the railroads were extended into the area during the post-Civil War era (Renner 1985; Gibson 1972).

Due to the scattered and shallow nature of the ore deposits, the initial miners developed a unique system of mineral leasing (Gibson 1972). Typically, partners would lease small tracts of land, generally two hundred feet square, from landowners. If a profitable mineral was excavated, a portion of minerals discovered belonged to the landowner. Therefore, the miners would pay the landowner a royalty for his portion of the mineral rights. Miners who lacked the money to pay the lease and royalty to landowners, would sometimes form a “paying partner” with a local

merchant. In doing so, the miners would work the lease and share the profit with the merchant, while the merchant furnished the miners with their necessities, such as food and gun powder (Gibson 1972).

3.3 Civil War, Railroads, and Improved Mining Methods

The start of the Civil War, in 1861, restricted the development of mining operations within the district. The mining camps that were slowly and steadily growing before the Civil War, were often abandoned or destroyed during the war due to the conflicts between the Union and Confederate forces. Both the Union and Confederate forces, including guerilla bands from both the north and the south, fought to control the mines in order to provide the lead needed to produce ammunition for their armies (Renner 1985; Gibson 1972). Moreover, guerrilla bands would often kill the local men and leave the women and children to operate the farms and run the family. This left little time or resources for mining operations and most of the population of southwest Missouri fled the area to escape the violence (Renner 1985). However, the end of the Civil War, in 1865, led to a growth in the commercial mining industry of the TSMD.

In addition to the new-found stability within the district, the railroads extended lines into the TSMD starting in the 1870s. In the United States, the development of a railroad system began in the 1830s with small private investors who constructed short passenger lines to connect areas within the eastern coast of the United States (“Library of Congress” n.d.). The idea of a transcontinental railroad that connected the east to the west coast of the United States grew out of an idea that began in the late 1840s (“Library of Congress” n.d.). In Missouri, the construction of the St. Louis- San Francisco Railways, known as Frisco, under the Pacific Railroad Company, began in St. Louis in 1851 and was constructed to connect St. Louis, Jefferson City, Sedalia,

Independence, and Kansas City, Missouri. In 1855, a southern line, called the Southwest Branch of the Pacific Railroad, began construction with the intent to connect to Springfield and southwest Missouri ("History of the Frisco" 1962). The Southwest Branch of the Pacific Railroad was completed to Rolla when the Civil War began in 1861. However, construction of the rest of the rail ceased until the end of the Civil War in 1865 ("History of the Frisco" 1962). As Figure 3.3 shows, by June 1870, the railroad line was extended into Springfield, Missouri and later the same year it reached Neosho, Missouri ("History of the Frisco" 1962).

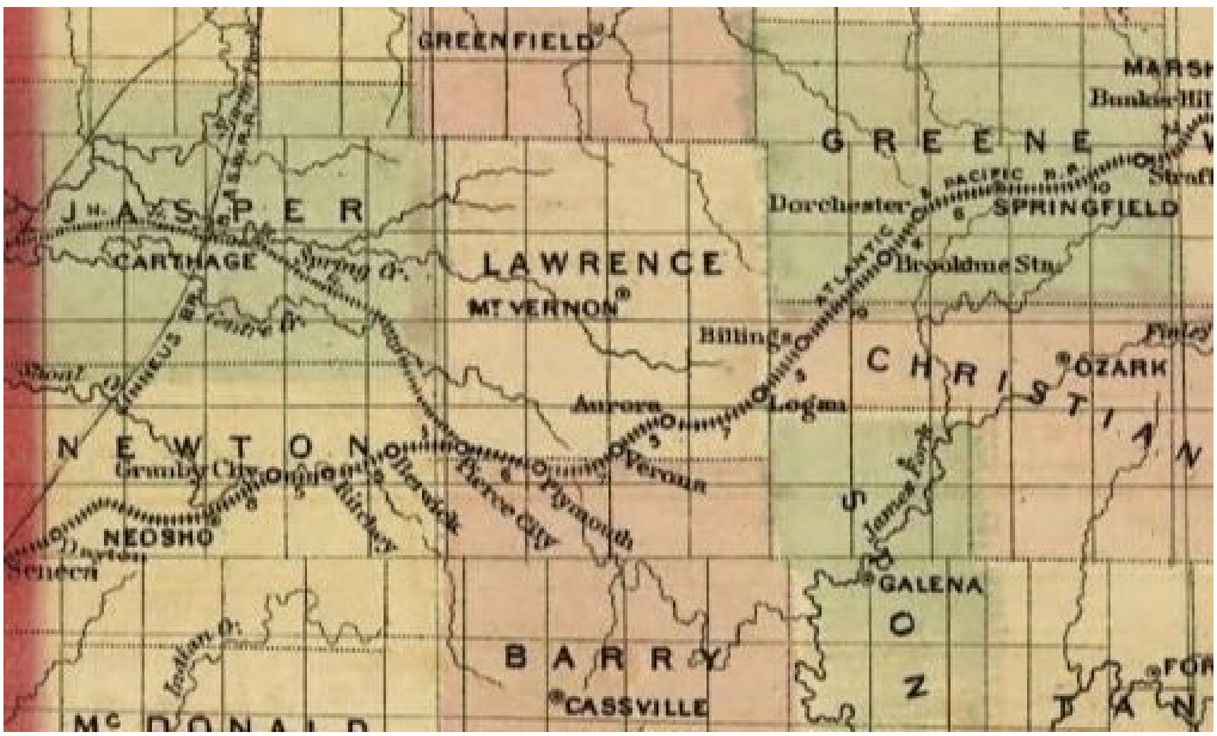

Figure 3.3. Fragment of map of railroad lines and stations in southwest Missouri, from Springfield (east) to Joplin and Neosho (west). Circa 1872 ("Library of Congress" n.d.).

With the development of the railroad lines, steam-powered equipment became accessible to the mining industry and led to the mechanization of the mining operations, Shown in Figure 3.4 (Pope 2005; Rafferty 1980; Brockie et al. 1968). Initially the steam-powered equipment was fueled by charcoal, but by 1880 coal was imported from the surrounding coal mines in southeast

Kansas to fuel the steam equipment (Wannenmacher 2013; Rafferty 1980). While the metal mines in the TSMD were worked by local farmers or miners, the coal mines of southeast Kansas were predominantly worked by immigrants from Eastern Europe. Many of the immigrant miners' descendants still live close to the historic coal mines (Wannenmacher 2013).

Access to steam powered equipment permitted mining the deeper ore deposits (Pope 2005; Brockie et al. 1968). The size of the district expanded exponentially during the post-Civil War era due to the use of drills, hoists, and pumps needed for larger mining operations (Pope 2005). These improvements led to new methods of excavating metal ores. Around the district shallow, near-surface mining operations grew to larger, deeper room and pillar methods of mining that incorporated excavating large underground cavities that were supported by pillars of unexcavated rock (Figure 3.4). Underground rooms would sometimes reach heights of upwards of 100 feet (Smith 2016; Pope 2005). Mining below the water table required using steam powered pumps to pump the groundwater out of the mines to keep the mines dry and workable (Smith 2016).

As the mining operations grew in the area, wealthy investors began to capitalize on the mining operations in the TSMD. The "poor man's camps" that had been scattered through the district before 1870, were beginning to be consolidated by larger mining companies in the post-Civil War era (Wannenmacher 2013; Pope 2005). For example, the Granby Mining and Smelting Company and the Joplin Mining and Smelting Company were both established in the post-Civil War era. Additionally, after 1865, the rudimentary mining techniques began to be replaced by significant improvements in the mining methods. Each process of mining including; excavating, milling, and smelting of metal ores became highly specialized and technical. Therefore, each of these processes began to be carried by individuals who were specialized in a particular phase of

the mining process (Pope 2005; Gibson 1972). Consequently, milling and smelting were no longer carried out adjacent to the mine shafts, but rather in centralized locations through the district (Pope 2005; Gibson 1972).

Figure 3.4. Miners in large underground mine cavity in Jasper County. Circa 1915 (MDHP 2011).

With new, improved methods of mining and smelting, along with the increased market value of zinc, commonly referred to as “blackjack” or “jack”, zinc mining became more profitable than lead mining in the district starting in the 1870s. As a result, zinc began to replace lead as the predominate metal mined in the district (Smith 2016; Pope 2005; Gibson 1972). The market for zinc expanded due to its use in brass and bronze production, its anti-corrosive

properties on steel and iron, and its use in industrial products, such as paints, rubber, ceramics, and medicines (USGS 2019; Wannenmacher 2013).

3.4 Growth and Decline of the Mining Operations

The mining camps and towns continued to grow in southwest Missouri through the late 19th century. As the mining industry continued to grow in the district, Joplin grew to be the largest metropolis area and was the business and financial hub of the TSMD. Joplin was home to most of the mining companies' offices, research facilities, and facilities that manufactured and supplied the mining equipment used throughout the district (Renner 1985; Gibson 1972). Figure 3.5 shows workers of the Leckie Foundry and Machine Works in Joplin. Leckie Foundry and Machine Works was one of the first companies to make mining equipment in Joplin (MDHP 2011).

In addition to the developing industry in Joplin, a large percentage of the miners of the district resided in Joplin and traveled to the multiple mining sites daily. Eleven mining towns were located within a ten-mile radius of Joplin. Railways, electrical trolley systems, and eventually roads provided transportation for miners to easily live in Joplin and travel to the surrounding mines for work (Renner 1985; Kirkman and Stinnett 1981). In 1893, Alfred H. Rogers placed the first interurban trolley system, shown in Figure 3.6, known as the Southwest Missouri Electric Railway Company, in Joplin (Renner 1985). Figure 3.7 shows the trolley system that grew to be an elaborate system that served most of the mining district and provided a cost-effective way for miners to get from Joplin to their jobs at various mining sites and allowed families an economical way to travel within the TSMD (Wannenmacher 2013; Renner 1985). A trolley trip from Joplin to Picher would have cost a miner only fifty-five cents at the beginning of

the 20th century (Renner 1985). By the 1920s, highways were replacing trolleys. Miners would often be seen car-pooling in cars they then called "buddy cars" (Renner 1985). Starting in the late 1910s, John Malang began to use chat from the mining waste piles to build a concrete highway between Webb City and the Kansas state line. This was the first concrete road in the state of Missouri. Malang later was known as the Father of the Good Roads Movement (Kirkman and Sinnett 1981).

Figure 3.5. Men working at Leckie Foundry and Machine Works in Joplin. Circa 1880. The company was among the first mining industries to open their doors in Joplin (MDHP 2011).

Beginning in the early twentieth century, mining operations in the TSMD slowly began to shift from the eastern part of the district, in southwest Missouri, to larger, newly discovered ore deposits in southeast Kansas and northeast Oklahoma. The shift in mining activities was largely caused by the exhaustion of high-grade ore deposits and the high royalty rates charged to the

miners in southwest Missouri compared to the western portion of the district in Oklahoma and Kansas (Renner 1985).

Figure 3.6. Southwest Missouri Electric Railway Company's trolley. Circa 1905 (MDHR 2011).

However, the start of World War I (WWI) temporary increased the mining activities in southwest Missouri due to the increased demand for lead and zinc by the United States Armed Forces and its allies. During WWI, many mining operations in the district were opened extended hours in order to produce the large amounts of metal ores needed by the military (Jobe 1998). WWI erupted in Europe in 1914. However, it was not until 1917 that the United States officially entered WWI. Nevertheless, even before the United States officially entered WWI, the war

efforts overseas had increased the demand for lead and zinc coming out of the TSMD (American Institute of Mining Engineers 1917). This high demand for war minerals led to more extensive mining practices throughout the district. Thousands of acres of mining land were developed in both the eastern and western portion of the district. Prospects, mills, and smelters were being established on a weekly basis. The increased mining was so extensive that by 1915 the TSMD had increased its output of lead and zinc by over eighty percent (American Institute of Mining Engineers 1917). As WWI came to an end in Europe the demand for lead and zinc decreased, resulting in a decrease in the mining activities in the TSMD, particularly in southwest Missouri.

The start of the Great Depression in November 1929 brutally affected the TSMD. Lead and zinc prices dropped even more during the Great Depression. The already limited mining jobs in the area became even scarcer. Unemployed miners would often try to rework an old digging with primitive equipment with often little or no success, shown in Figure 3.8 (Renner 1985).

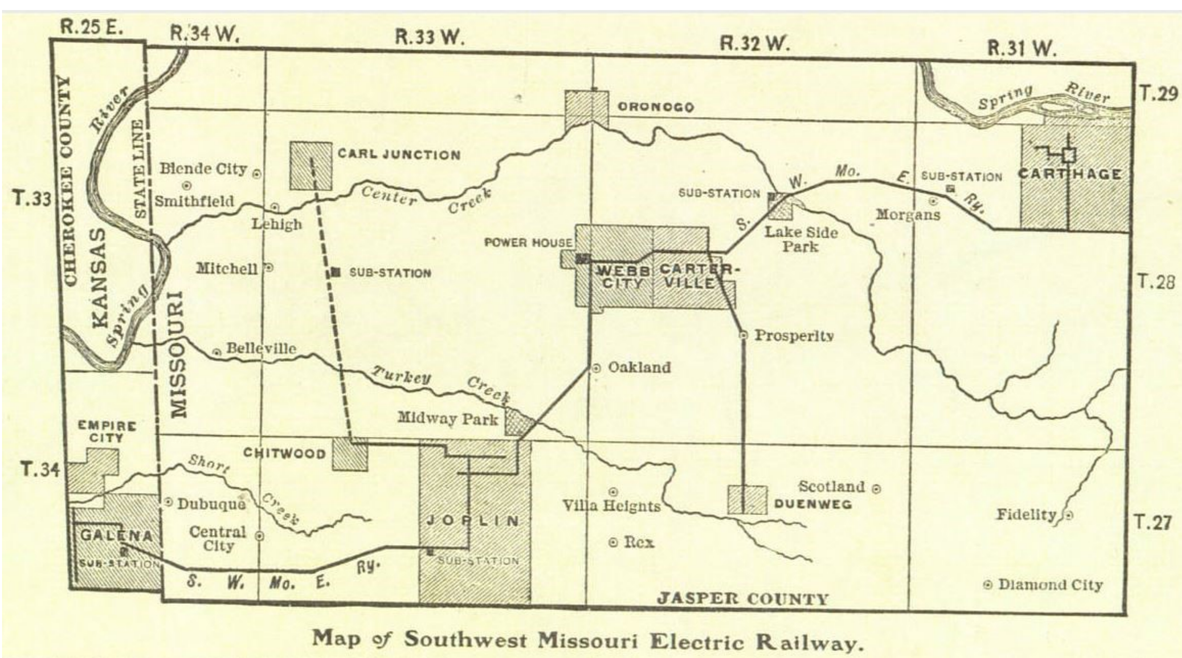

Figure 3.7. Map of Southwest Missouri Electric Railway Company lines. Circa 1905 (MDHR 2011).

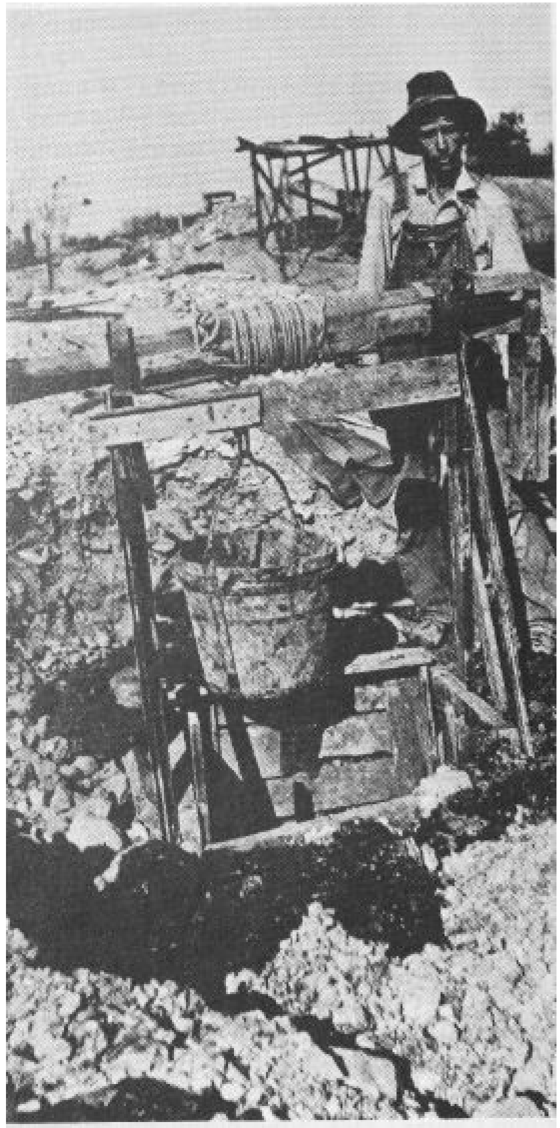

Figure 3.8. Miner during the Great Depression reworking an old prospect with 1870s equipment. Circa 1932 (Renner 1985).

However, the start of World War II (WWII) temporary increased the mining activities in southwest Missouri again due to the increased demand for lead and zinc by the United States Armed Forces and its allies. Mining operations reassumed in a few of the mines in the area that had previously been closed. For example, in 1940, the Federal Mining and Smelting Company reopened the mines in Granby to meet the demands for lead and zinc during WWII, shown in Figure 3.9. The new federal government Office of Price Administration provided subsidies

during WWII to encourage the mining of marginal deposits. However, with the conclusion of WWII in 1945, these subsidies quickly ran out and the remainder of the mining operations permanently closed in the area by 1948 (Renner 1985).

The conclusion of WWII signaled the end of most of the mining in the TSMD. The mines slowly began closing due to the depletion of metal ores, competition from imports, loss of demand for lead and zinc, and loss of profitability of mining in the district (Pope 2005; Gibson 1972). The last mines in the Missouri portion of the district closed in 1957. The last mine closed in the TSMD near Baxter Springs, Kansas in 1970. With the closing of the mines, many miners and their families moved out of the region, resulting in a major population decline in many areas within the district (Gibson 1972).

The TSMD mined lead and zinc ores for over a century. During the district's peak production period, between 1885 and 1955, the TSMD was one of the world's largest producers of lead and zinc. The district exported an estimated 500 million tons of ores (Manders and Aber 2014; Andrews et al. 2009; U.S. Environmental Protection Agency 2007). The mining operations in the district accounted for over a billion dollars in economic growth and has continued to influence the lives of the residents (Gibson 1972; Brockie et al. 1968).

3.5 Sisters of Mercy and the Establishment of Mercy Hospital

During the mining era in southwest Missouri, mining jobs provided a steady income for miners and their families. However, there were many health risks associated with the mining. Even before the wide-spread studies of heavy metal pollutants from mining waste, the health risks associated with mining were obvious. Many miners developed lung disease, such as silicosis and tuberculosis (TB), due to the poor air quality in the mines and the large amounts of

contaminants dispersed during the excavating, milling, and smelting processes (Manders and Aber 2014; Wannenmacher 2013; Aurora Centennial Committee 1970). However, the risk of lung disease was not limited to the miners. Many family members of the miners also become ill with TB, because the miners would carry the mining debris home with them on their clothing and their families often lived within proximity of the mines (Manders and Aber 2014; Wannenmacher 2013). By the 1930s, the district's rate of TB was the highest in the country (Manders and Aber 2014).

Figure 3.9. Joplin area mine during the WWII. Many miners working the mines in the TSMD during WWI and WWII felt a sense of pride for contributing to the war efforts overseas. Circa 1941 (Renner 1985).

In addition to the spread of lung disease through the mining towns and camps, substandard housing in many mining camps often led to the spread of diseases and infections. Sometimes as many of six to eight miners would live together in a small shack (Manders and Aber 2014). This inadequate housing conditions further cause the spread of TB and other diseases throughout mining camps. Additionally, injures were very common within the mines. Young men, and even sometimes young boys, would be seriously and sometime fatally injured in the mines due to explosions, rock falls, and other accidents (Wannenmacher 2013; Aurora Centennial Committee 1970).

Before 1896, medical treatment was very limited throughout the district. If miners became sick or injured, they would have to be transported by either horse and buggy or train to the nearest hospital in Fort Scott, Kansas. The route to Fort Scott would have taken a minimum of several hours, during which time the miner's condition could have greatly worsened (Renner 1985). Then, in 1896, following a serious mining accident, the Sisters of Mercy, led by Mother Mary Francis Sullivan, understood the need for local medical care for the mining community in Joplin, Missouri. Mother Mary Francis Sullivan and the Sisters convinced a Joplin mine owner and businessman to donate a building in Joplin that became the temporary ten bed hospital, called Mercy Hospital (Sticklen 2015; Renner 1985). As the mining activities and the population grew around Joplin, the Sisters of Mercy quickly outgrew the ten-bed hospital. As a result, the Sisters and the Joplin citizens began to raise money to fund a larger hospital. In October 1900, a fifty-bed permanent hospital was opened on a site donated by Patrick Murphy, one of Joplin's founding fathers. The Sisters called the fifty-bed hospital Saint John's Hospital (Renner 1985). Figure 3.10 shows the original Saint John's around 1900. In 1903, the Saint John's Hospital School of Nursing was founded, and the nursing school was accredited in 1905 (Renner 1985).

To meet the growing medical needs of Joplin's citizens and the surrounding community, Saint John's Hospital continued to expand its facilities throughout the area during the twentieth century (Renner 1985). The hospital changed its name from Saint John's Hospital to Mercy Hospital in 2012; this hospital network continues to provide medical treatments to the citizens of Joplin and the surrounding community today.

Figure 3.10. The original Saint John's Hospital in Joplin. The hospital was founded by the Sisters of Mercy (MODH 2011). Circa 1900.

3.6 Generation of Mining Waste

A long-term major consequence of the historic mining activities on the TMSD has been the manufacturing of chemical pollutants produced by the large amounts of contaminated mining waste primary in the form of tailings and smelter fallout.

3.6.1. Tailings. The lead and zinc ores were excavated from the mine shafts and brought to the surface were considered crude ores. The crude ores had to be milled in order to separate the ores from waste rocks, eliminate soil and other impurities, and reduce the mineral to a uniform size (Gibson 1972). Tailings are the remaining waste rocks left after the milling process. Figure 3.11 shows a typical tailing pile that is produced after the milling process. Tailings contain significant concentrations of lead, zinc, cadmium, and other trace elements that are separated from the metal ores during the milling process. Tailing piles, locally known as chat piles, were then stacked and abandoned adjacent to the milling sites. In 1877, the Granby Mining and Smelting Company built the first central mill in the TSMD two miles north of Joplin. However, central milling was not common before 1930 throughout the district due to the scattered nature of the ore deposits and the lack of cost-effective transportation to a centralized mill (Gibson 1972). Early methods of milling consisted of hand crushing the crude ores and washing the ores in an inclined wooden sluice to remove the waste rocks and soil from the ores. This rudimentary method of milling resulted in a low percentages of recovered metal ores (Gibson 1972). Additionally, since zinc ores were not being recovered until 1880s, zinc ores were discarded into the chat piles during early milling operations (Gibson 1972).

As the shallowing excavation of ore deposits grew to larger, deeper excavations, the milling techniques began to improve. Starting in 1870, the development of jigging and tabling operations led to smaller amount of metals in the waste rocks and higher concentrations of ores being recovered (Gibson 1972). Within the deeper ore deposits, lead and zinc ores were found physically connected and often infused with limestone and chert rocks. Therefore, more efficient methods of crushing and separating the crude ores had to be developed. Figure 3.12 shows an early jigging operation within the district. Jigging operations used lead and zinc’s relative density

to separate the minerals from the waste rocks. By knowing that zinc blende was one and one-half times heavier than chert and lead was three times heavier than chert, an early jig operator could mill six to ten tons of crude ores by hand in a twelve-hour shift (Gibson 1972). In 1881, as more of the excavation labor was being substituted by steam- powered machinery, the Empire Milling and Smelting Company of Galena, Kansas introduced the first mill in the TSMD to use steam-power to clean and crush the crude ores. The new steam-powered jigs could mill fifty tons of crude ores in a twelve-hour shift.

Figure 3.11. Unknown milling site in the TSMD. Waste rocks being dumped by a mill's flume onto the tailing piles. Circa 1915 (MDHP 2011).

By 1902, improved milling technology allowed steam-powered jigs to mill up to one hundred tons of crude ores in a twelve-hour shift (Gibson 1972). In addition to increased

production, the steam-powered, and later the electric- powered, mills recovered a higher percentage of the metal ores during the milling process because of its ability to grind the tailings into a finer size (Gibson 1972).

Beginning in 1916, floatation was introduced in the TSMD. Floatation increased the amount of ore recovered in the milling process by using reagents to float out the mineral particles in tailings after the crushing process (Manders and Aber 2014; Gibson 1972). After being crushed, the fine grain rocks and minerals were transformed into a muddy slime and mixed to form air bubbles. Then, a reagent solution was added. This reagent forced the lead particles to adhere to the air bubbles and rise to the surface. Once the lead was recovered, another reagent was added to force the zinc to adhere to the air bubbles and rise to the surface to be covered. By 1925, floatation became a common practice throughout the TSMD. However, even with improved milling techniques significant quantities of lead and zinc ore were still discarded in the tailings (Manders and Aber 2014; Gibson 1972). Zinc was lost at a higher percentage than lead. Some mills reported one ton of zinc concentrates lost for every two tons saved (Gibson 1972). This increase loss of zinc was because zinc had a lower density than lead and was often associated with smaller particles of chert compared to lead. (Gibson 1972). Therefore, in order to recovery a larger percentage of zinc the crude ore had to be crushed or ground to a finer particle size and improved floatation had to occur (Gibson 1972).

Once the milling process was completed, the lead and zinc ores were called concentrates. The remaining waste after the milling process produced two forms of tailings that were discarded. First, chat was created by the disposal of medium to coarse waste rocks. Large chat piles were created near mining sites by using elevators and conveyer belts to stack the rock waste (Pope 2005). Second, tailing ponds were created by the disposal of fine- grain floatation tailings

in near-by ponds (Pope 2005). Generally, waste from tailing ponds have a higher concentration of contaminants than chat piles and pose a higher risk to the environment (U.S. Environmental Protection Agency 2007).

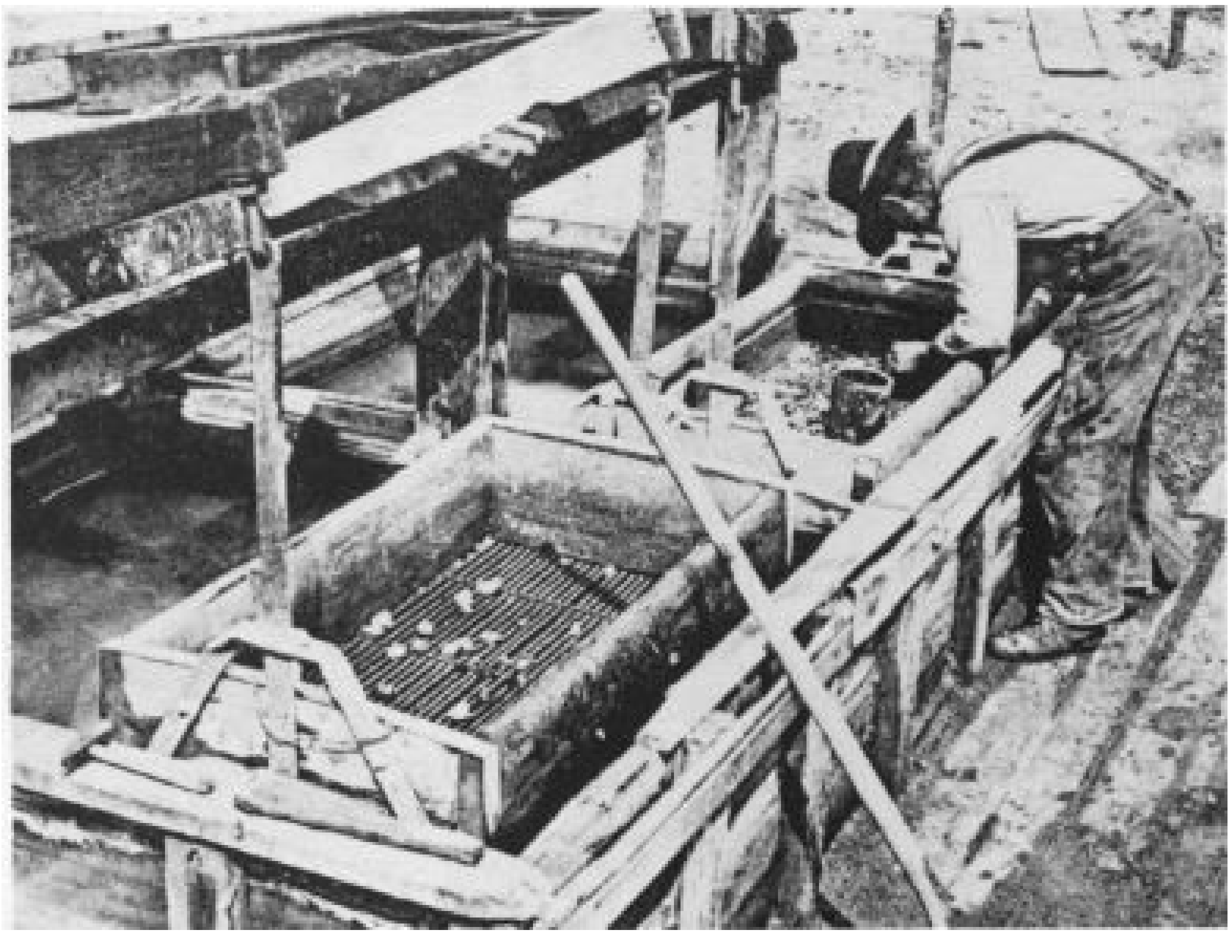

Figure 3.12. Early jigging operations in the TSMD. The jigging operator could mill approximately six to ten tons of crude ores in a twelve-hour shift (Renner 1985).

3.6.2 Smelter Fallout. Another source of chemical pollutant released from mining waste was the dust released through the smelting process. Once the mining process was completed, the lead and zinc concentrates were refined through smelting, shown in Figure 3.13. During smelting process the concentrates were heated which produced a chemical reaction. The chemical reaction freed the lead and zinc from the other trace elements such as sulfur (Gibson 1972). The earliest

smelting operations in the district were carried out through simple wood-fired furnaces. Since the galena discovered throughout the district was non-argentiferous, meaning it had very little or no silver associated with it, the lead ores were smelted relatively easily (Gibson 1972; Brockie et al. 1968). Early, rudimentary log-furnaces were built within close proximity of a shallow mine shaft, preferably on a hillside, and was only used a brief time before being deserted once the surface deposits of lead were sufficiently excavated. The hillside furnace allowed the molted lead to naturally flow downslope into a mold (Gibson 1972). However, the log-furnace was ineffective and time consuming in recovering lead ores. About fifty percent of the lead ore was lost in the residue, called slag, or through the lead fumes, called smelter fallout (Gibson 1972). A few of the earliest commercial mining operations in the district used log-furnaces before improvements in the smelting process permitted better smelting practices. Debatably the most successful log-furnace smelting operations in the district was worked by William Mosely on Shoal Creek near Neosho in 1850. Between April 1 and July 20, 1850, Mosely's mines were able to smelt about 3,000 pounds of lead a day (Gibson 1972).

Figure 3.13. Empire Smelter Works near Joplin, Missouri. Circa 1900 (MDHP 2011).

However, due to the high loss of lead through slag and smelter fallout, Mosely updated his smelter to a Drummond furnace in the 1850s. The Drummond furnace increased the percentage of metal ores being recovered to about sixty percent (Gibson 1972). As more commercial mining moved into the district, the smelting process continued to improve. In 1852, the blast furnace was introduced in the district. The blast furnace shortened the amount of time needed to smelt the metal ores by suddenly raising the temperature of the furnace with a blast of air. This accelerated the oxidation of sulfur and reduction of the ore at the same time (Gibson 1972). With the development of the Drummond and the blast furnace, the smelting process became highly specialized. Beginning in 1852, specialists in smelting began to emerge in the district and permanent smelters devoted to full time smelting were erected. By 1860, most of the ores excavated in the district were smelted by specialized smelting companies in centralized locations (Gibson 1972). Specialized smelting companies would purchase the ores from local, small mining operations and refine the ores in the centralized smelter.

With the conclusion of the Civil War, the water backed Scotch Hearth furnace was introduced in the district. The Scotch Hearth furnace increased the recovered percentage of ores to about seventy-five percent by maintaining a uniform heat throughout the smelting process. This assured complete oxidation of sulfur and caused less of the lead and zinc to volatize and be lost in slag and through smelter fallout (Gibson 1972). In addition to the improved Scotch Hearth furnace, the introduction of the slag furnace in 1865 to the district allowed slag that was formally thrown out, to be reprocessed and a higher percentage of ore to be recovered from the slag. In 1876, metallurgists discovered a process to reduce the chemical pollutants produced through smelter fallout. By capturing the fumes, formally lost in the chimney smoke as smelter fallout,

the converted the residue into white lead and pigment for paints. The resulting product was then marketed as Joplin White Lead. This process decreased the percentage of chemical pollutants released into the environment while allowing the residue to become an economic commodity. (Gibson 1972).

With further improvements in the smelting process, smelting became more specialized and the number of smelting operations decreased. Smaller smelting operations could not compete with the larger smelting operations that used advanced smelters to extract a larger percentage of metal ores and were able to extract metals from slag and fumes, formally considered to by-product of the smelting process, to make an additional profit (Gibson 1972). By 1873, coal replaced wood as the primary fuel for the local smelters. By 1900, natural gas replaced coal as fuel for the smelters (Gibson 1972). By the end of the nineteenth century, three main smelting operations remained in the TSMD. These smelting operations included the Granby Mining and Smelting Company at Granby, Picher Lead Company at Joplin, and Case and Searget Lead Company near Joplin on Shoal Creek (Gibson 1972).

3.7 Disposal of Mining Waste and its Consequences

By the time the mines closed in the 1970s, the district had produced over 500 million tons of contaminated mining wastes (Manders and Aber 2014; U.S. Environmental Protection Agency 2007). Today, approximately 100 million tons of mining wastes, with toxic levels of metals, primarily in the form of tailing and smelter fallout remain on the district and cause contamination of soil, sediments, and waterways through varies pathways (Gutierrez et al. 2014). The primary metals of concern are lead and cadmium. Although zinc occurs in higher concentrations, the toxicity level of lead and cadmium are much higher than zinc (Gutierrez et al. 2014). Abandoned

chat piles and tailing ponds continue to leach heavy metal contaminants, which eventually pollutes streams and groundwater throughout the district (Lynch et al. 2000). Furthermore, slag and smelter fallout caused large amounts of chemical pollutants to be released in the air and dispersed by wind into near-by-soils and into residential areas (Beyer et al. 2004).

3.8 Health Hazards

3.8.1 Human Health. Previous research in the TSMD has revealed the health hazards resulting from mining activities. Mining contaminants, including lead, zinc, and cadmium, have polluted the soils, sediments, and waterways in the district and have had an adverse effect on the health of the local residents and wildlife population. The toxic effects of lead exposure have been well studied. Lynch et al. (2000) investigated soil, household dust, and paint samples for lead in 208 houses within the Tar Creek Superfund Site in Oklahoma. Blood samples were also collected from children in the homes that participated in the study. The results revealed that elevated lead levels in soil and floor dust samples were strongly associated with elevated lead levels in children. Lynch et al. (2000) concluded children who lived within the Superfund Sites were 3.4 times more likely to have elevated blood lead levels than children who live outside the Superfund Site.

Lead poisoning causes damage to the central nervous system, peripheral nervous system, gastrointestinal tract, kidneys, reproductive systems, cardiovascular system, and neurological system. Children are particularly susceptible to lead poising. Children exposed to high levels of lead have a higher chance of experiencing developmental delays, as well as experiencing emotional problems (Duruibe et al. 2007). Zinc is an essential trace element within the human body. However, exposure to high concentrations of zinc causes damage to the gastrointestinal

tract (Plum et al. 2010). High exposure to cadmium causes damage to the respiratory system, kidneys, reproductive systems, and skeletal systems. Additionally, exposure to high concentrations of cadmium is associated with the development of cancer in the human body (Godt et al. 2006).

3.8.2 Terrestrial Wildlife. Mining contaminants have also had an adverse effect on local terrestrial and aquatic wildlife. Research by Beyer et al. (2004) confirmed a correlation between the high levels of lead, zinc, and cadmium in the TSMD and elevated levels of heavy metals in the blood and organs of wild birds. Elevated levels of heavy metals have been linked to impaired biological functions and exterior signs of heavy metal poisoning in wild birds. Beyer et al. (2004) also noted waterfowl deaths caused by exposure to lead poisoning from mining contaminants that were recorded as early as 1923 and lead pollutants continues to cause terrestrial wildlife fatalities and impaired biological function within the district. Van der Merwe et al. (2011) studied the effects of mine waste on Canada geese in the TSMD. The study concluded that geese exposed to mine contaminants within the TSMD consistently suffer from lead poisoning (Van der Merwe et al. 2011).

3.8.3 Aquatic Wildlife. Besser et al. (2014) studied the effects of heavy metal exposure from toxic sediments on juvenile mussel and amphipod populations in the TSMD and the southeast Missouri mining district. By comparing control groups of juvenile mussels and amphipods to groups exposed to heavy metal contaminated sediments, the study concluded that exposure to heavy metals affected the growth, biomass, and survival of mussels and amphipods. Additionally, the study revealed that the concentration of heavy metal contamination is strongly associated with the toxicity to the mussel and amphipod populations. Brumbaugh et al. (2005) analyzed fish from six heavy metal contaminated sites within the TSMD. The blood, caresses,

and liver of the fish collected within the contaminated sites revealed high levels of lead, zinc, and cadmium compared to samples collected from a control group (Brumbaugh et al. 2005). Juvenile mussel amphipod, and fish were chosen in these studies because these organisms are more sensitive to heavy metals exposure which makes them ideal to be indictor organisms to toxic and non-toxic conditions.

3.9 Discussion

The lead and zinc mining in the TSMD pre-dates European settlers in the area. However, the most extensive mining in the district occurred between 1885 and 1955. Early mining in the district began as small operations that mined shallow deposits of lead ores and grew to large corporations mining deep lead and zinc deposits. During the historic mining era, many prospectors and their families moved into southwest Missouri and established the local communities that still exist in southwest Missouri today. Although miners often suffered injuries and diseases due to their poor working and living conditions, mining jobs provided a respectable income for many families which grew the economy in southwest Missouri. As a result, miners developed a sense of pride and identity from their experiences in the mining field. Many residents have a strong emotional attachment to the mining history in the area.

The release of chemical pollutant led to wide spread contamination of the soils, sediments, and waterways throughout the TSMD. This caused elevated levels of lead, cadmium, and zinc documented through the district and have negatively affected aquatic wildlife, terrestrial wildlife, and human health.

CHAPTER FOUR: SIX MINING SITES

4.1 Methods

Due to the dispersed nature of the ore deposits several towns developed in places where there were richer ore deposits, and since the ore was scattered, so are the towns. Each mining town formed in the TSMD varied in its own history and its fate before, during, and after the mining boom ended. The six mining sites in this study, shown in Figure 4.1, represent the type of mining towns that were present during the mining boom and mining decline in southwest Missouri. The history and present condition of the mining towns are intertwined with many events other than mining.

Although the historic lead and zinc mining activities in southwest Missouri have remained a sense of pride and heritage to many local residents, there are limited resources published on the mining activities in this area. Documenting the history on the six mining sites in southwest Missouri was difficult because many of the towns are small and not very well studied. Additionally, many of the mining sites in the district were abandoned once the mining operations ceased. However, with the appreciated help from the staff at the Springfield- Greene County Library District, locally published books were found in the reference and rare books sections at Library Center and Library Station in Springfield, Missouri. Within local books and reports, the local history began to appear with pictures and information about the mining sites and the towns that grew up adjacent to the mining sites. Some of the earliest publications about the mining activities in southwest Missouri dated back to the post- Civil War era. However, the majority of the history of the mining was written in the nineteenth century. Sites that had extensive mining activities and developed into larger metropolitan areas, such as Joplin and Granby, had

significantly more publications with extensive pictures to document the area's development than, smaller metropolitan areas, such as Aurora and Oronogo.

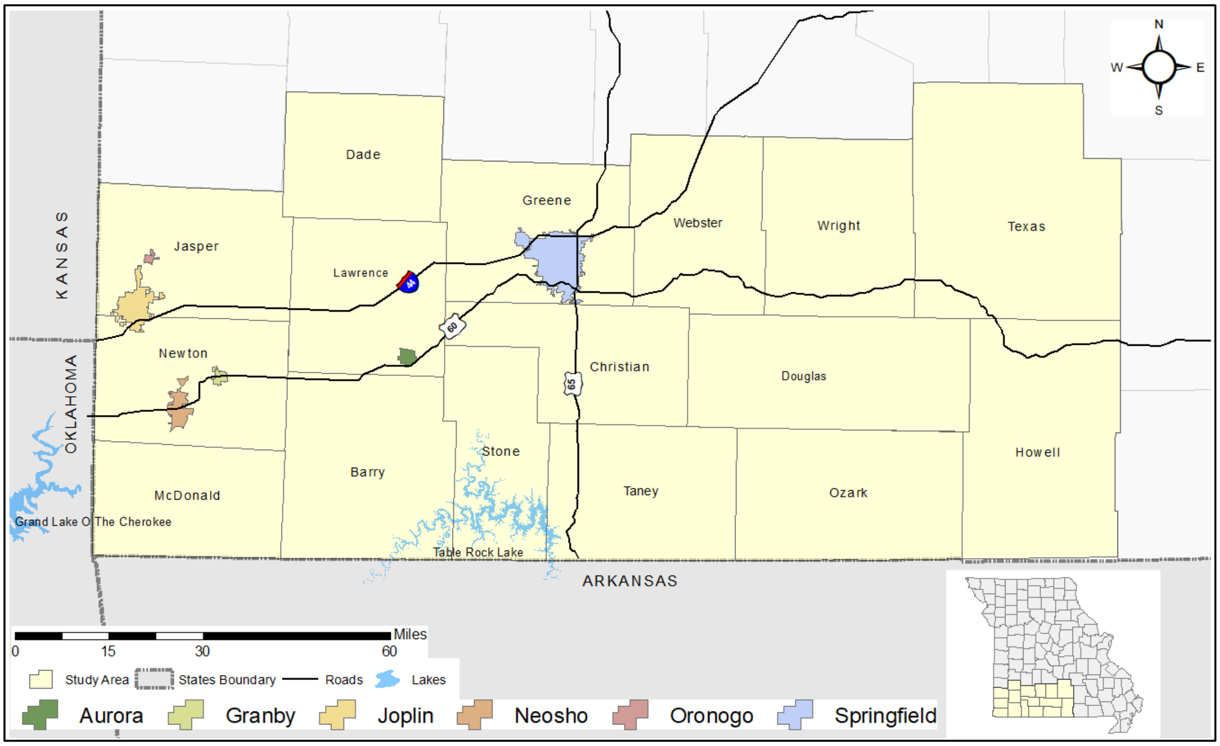

Figure 4.1. Geographic location of six historic mining towns and the major streams in southwest Missouri.

4.2 Joplin

The first European pioneer to settle Joplin was John C. Cox. He was attracted to the region because of explorer Edmund Jennings' description of the area. Jennings had spent fifteen years living among the Osages in the area and returned to Tennessee with many stories about the abundance of natural resources in the area (Renner 1985). Consequently, in 1838, Cox set-out with his young bride and sister to settle present-day Joplin, Missouri. Cox built a cabin on Turkey Creek and established a post office and small general store nearby. Cox named the store and post office, Blytheville, after a Cherokee Indian who lived along Shoal Creek (Renner 1985;

Gibson 1972). In 1839, Reverend Harris Joplin arrived in the area and built a cabin near a steam that holds his name-sake (Renner 1985). More pioneers continued to settle the area in the 1840s (Renner 1985; Shaner 1948).

These early pioneers would often collect small, shallow deposits of lead ores for personal use. However, there is no evidence of commercial mining in the area until around 1848 when two significant lead deposits when found simultaneously in the area. One discovery occurred when William Tingle and David Campbell, who was an experienced miner from the eastern part of Missouri, found a significant amount of lead ores two feet below the surface on Tingle's land (VanGiler 1995). Tingle and Campbell filed a claim and started a rudimentary mining operation in the area (VanGilder 1995). This discovery and the start of the mining operations on Tingle's land led other miners to set up similar operations on adjoining properties. These small mining camps grew to become known as Leadville Hollow (VanGilder 1995; Gibson 1972). By 1850, Leadville Hollow had grown to a population of over one hundred individuals (Gibson 1972).

Close to the same time period that lead ores were discovered on Tingle's land, significant quantities of lead were discovered by a young slave on Cox's land in the Joplin Creek Valley (Gibson 1972). Cox filed claim on the section surrounding the site, but the site was not developed until Cox leased the land 25 years later to Moffett and Sergeant (VanGilder 1995; Renner 1985; Shaner 1948). With the arrival of Campbell and other experienced miners, the mining operations in southwest Missouri grew. The arrival of professional miners increased the awareness of the potential for large lead deposits that could ultimately support full-scale mining operations (Renner 1985).

However, similar to other mining sites in southwest Missouri, the lack of transportation limited the growth of the mining operations in Joplin until the post-Civil War era. The lack of

efficient transportation resulted in mining only being a lucrative job when the lead prices were high on the market (Renner 1985). Mining operations in the Joplin area stalled during the Civil War due to the fierce guerilla warfare by both the Union and Confederacy. With the end of the Civil War in 1865, settlers began moving back into the area. By 1870, Jasper County had a population of almost 15,000, which was more than double the population from 1860 (Renner 1985). New pioneers quickly moved into the area due to the abundance of public land available and the recommencement of lead mining in the area (Renner 1985).

Beginning in 1867, the Granby Mining and Smelting Company encouraged development of mining operations in a mining camp, later known as Oronogo, by leasing tracts of land to miners to develop prospects. In 1870, to encourage further development, the Granby company offered a reward of $500 to the leaseholder who excavated the largest amount of lead in a certain amount of time. This reward went to Elliott Moffett and John Sergeant (Renner 1985; Shaner 1948). Moffett and Sergeant used their reward money to secure a lease from John C. Cox in October 1870 on about ninety acres along the Joplin Creek (Renner 1985; Shaner 1948). After almost exhausting their supplies, the partners discovered a rich body of lead ore about thirty-five to forty feet below the surface on the east bank of Joplin Creek close to the present-day Main Street Bridge in Joplin. The partners immediately erected a crude log-furnace close to the mine shaft to smelt the lead ores (Shaner 1948). This initial shaft reportedly produced about $60,000 worth of lead in the first ninety days in operation. After the discovery by Moffett and Sergeant, many prospectors quickly moved into the area with the hopes of getting rich quick from lead mining. By 1871, as many as 500 prospectors had moved into the Joplin Creek Valley. These prospectors lived in tents, pole shelters covered in brushes, makeshift box houses, and other rudimentary shelters (Renner 1985; Shaner 1948). These inexperienced prospectors did not have

adequate equipment to excavate the ores or knowledge for successfully mining the lead ores. These prospectors would sink a shaft anywhere they could get a permit from the land owners. When the prospectors could dig no deeper in a shaft, they would quickly move to another site. This resulted in hundreds of abandoned, shallow shafts along Joplin Creek in the 1870s (Renner 1985; Shaner 1948).

As more prospectors rapidly moved into the area, Cox decided to file for a plat of seventeen acres in July of 1871 for a new town he named Joplin City (Renner 1985; Shaner 1948). Shortly after the platting of Joplin City, Patrick Murphy, a Carthage merchant, platted the town of Murphysburg across the creek from Joplin City. The two new towns both grew rapidly, and rivalry grew intensely between the towns. Mining operations grew both in Joplin City and Murphysburg (Renner 1985). By the end of 1871, Joplin City and Murphysburg had multiple smelting furnaces and mining companies and were quickly fighting to secure leases for more mining rights (Kirkman and Stinnett 1981; Shaner 1948). During 1871 and 1872, lawlessness quickly became a problem as neither Joplin City nor Murphysburg had any local government or law enforcement. Many of the initial new-comers were men who were either single or married and had left their families behind in an effort to make quick money in the Joplin mines (Wood 2011). Gamblers, prostitutes, and other non-law bidding individuals poured into the area to take advantage of the lawlessness. Saloon and street fights became a common occurrence. This period became known locally as the Reign of Terror (Wood 2011; Renner 1985; Kirkman and Stinnett 1981; Shaner 1948). In February 1872, the citizens of both Joplin City and Murphysburg decided to join together and form Union City and J.W. Lupton was appointed marshal (Wood 2011; Kirkman and Stinnett 1981). This stabilized the law problems and ended the Reign of Terror (Wood 2011). With the new-found stability, married men began bringing their families to settle

in the area and permanent homes, schools, and churches were constructed (Renner 1985). However, rivalries continued between the east-side, Joplin City residences, and the west-side, Murphysburg residences. In December 1872, the incorporation of Union City was dissolved (Renner 1985). However, under the support of John C. Cox and Patrick Murphy the towns were once again incorporated in the spring of 1873 under the name of Joplin (Shaner 1948).

Joplin's population continued to grow from the early to mid-1870s, shown in Figure 4.2. However, in late 1877, significant lead ores were discovered in Webb City, Carterville, and Galena, Kansas. The local miners quickly abandoned working the Joplin mines, where the previously excavated shallow lead deposits were exhausted and the price to lease land was high compared to other locations, and began mining in newly discovered ore deposits (Renner 1985; Shaner 1948). This caused Joplin's population to grow comparatively slow in the late 1870s. However, by this time Joplin began to be seen as the central hub of the TSMD because of its access to trading, wholesale, and manufacturing mining machinery in the area (Renner 1985; Shaner 1948). Consequently, Joplin's manufacturing industry grew (Renner 1985; Shaner 1948).

Before 1877, several attempts were made to have a railroad line extent into Joplin. However, these attempts were unsuccessful because Joplin was perceived as a short-term mining camp. Then, in August 1877, the Joplin & Girard Railroad was completed. The completion of the railroad line gave Joplin reliable transportation to and from Girard, Kansas. Moffett, Sergeant, and other local Joplin investors built the railroad line in order to provide an economical way to transport fuel needed for the smelter in the Joplin area (Renner 1985). In 1879, the railroad line was sold to St. Louis & San Francisco Company, also known as Frisco. By the 1880s, other railroad lines were extended into Joplin and the transportation limitations were resolved (Renner 1985).

Figure 4.2. Bird's-eye view of Joplin. Circa 1877. Courtesy of Joplin Chamber of Commerce.

With access to transportation, the mining methods improved due to proving steam-powered equipment, and mining activities once again grew. As a result, Joplin's population to grow rapidly in the 1880s. Joplin experienced its most rapid growth in population between 1890 and 1900 and reached a population of 26,023 residents by 1900 (Renner 1985). Figure 4.3 shows the growing mining operations in the Joplin around 1900. With the population growth, businesses grew too. By the turn of the century, Joplin had listed seventy-five saloons, many churches, general stores, newspapers, an opera house, public cemetery, a library association, a theater, a hospital, a bakery, and a horse racing track (Kickman and Stinnett 1981). Additionally, city infrastructure grew to be more established. During this same time period, Joplin Water Works Company began providing clean water from Shoal Creek to Joplin and Joplin Gas and

Coke Company began providing gas for street lights and homes. Joplin also had a paid fire department and police department and an established public school system (Kirkman and Stinnett 1981).

Figure 4.3. Joplin, Missouri. Circa 1900. The growing mining operations are scattered across the forefront of the photo. The growing town of Joplin can be seen in the background (MDHP 2011).

Between 1910 and 1930, Joplin's population growth began to slow. This was caused by the exhaustion of high-grade ore deposits around the Joplin area and the newly discovered larger ore deposits found in Ottawa County, Oklahoma and Cherokee County, Kansas (Renner 1985). WWI temporarily increased the price of lead and zinc. Zinc reached a peak price of $100 a ton and lead reached a peak price of $130 a ton (Renner 1985). However, these prices plummeted sharply in the recession of the 1920 and 1921 (Renner 1985). Meanwhile, the newly discovered ore deposits in Picher Field caused most of mining operations throughout the TSMD to move into the Picher Field area (Renner 1985).

In the 1920s, Joplin growth and economy became less dependent on mining and more dependent on tourism and agriculture. The Joplin Chamber of Commerce began working closely with other farm organizations to encourage more fruit growing in the area and to cleanup old

mining land to be developed into new farmland (Renner 1985). Joplin was named the "Gateway to the Ozarks", because Joplin's business leaders worked to promote tourism in many towns and resorts in southwest Missouri and northwest Arkansas (Renner 1985).

The start of the Great Depression in November 1929 brutally affected Joplin. Lead and zinc prices dropped dramatically during the Great Depression. Consequently, mining jobs were scare in the area (Renner 1985). However, retail trade and agriculture-related industries in Joplin was able to hold up reasonably well during the Great Depression. Agriculture was promoted in the area with the construction of the stockyards, and retail promoted by expansion of the city market in the 1930s. Joplin's access to the expanding highway systems also contributed to Joplin becoming a hub for the livestock market and wholesale market (Kirkman and Stinnett 1981).

With the implementation of the New Deal in 1933, the federal government was able to fund relief projects in the Joplin area. One of these projects was through the Civil Works Administration (CWA) to improve and cleanup 101 acres of Landreth Park in Joplin (Figure 4.4). Landreth Park was the site of many early mining activities located along the Joplin Creek Valley and included the site of the historic Union Depot. Landreth Park had deteriorated rapidly once the mining had ended in the area due primarily to the abandonment of chat piles (Renner 1985). Although, Landreth Park was cleaned up in the 1930s other sites in the Joplin area remained covered in chat piles, as seen in Figure 4.5.

The start of the WWII impacted life in Joplin. Mining operations reassumed in a few of the mines in the area that had previously been closed. The new federal government Office of Price Administration provided subsidies during WWII to encourage the mining of marginal deposits. However, with the conclusion of WWII in 1945, these subsidies quickly ran out and the remainder of the mining operations permanently closed in the Joplin area by 1948 (Renner

1985). Additionally, at the beginning of WWII, the federal government recognized that the Joplin area had a large number of skilled mechanical workers because of their previous jobs in mining and related industries. Therefore, the government established a defense training school to instruct these skilled workers in sheet metal work for aircraft construction (Renner 1985).

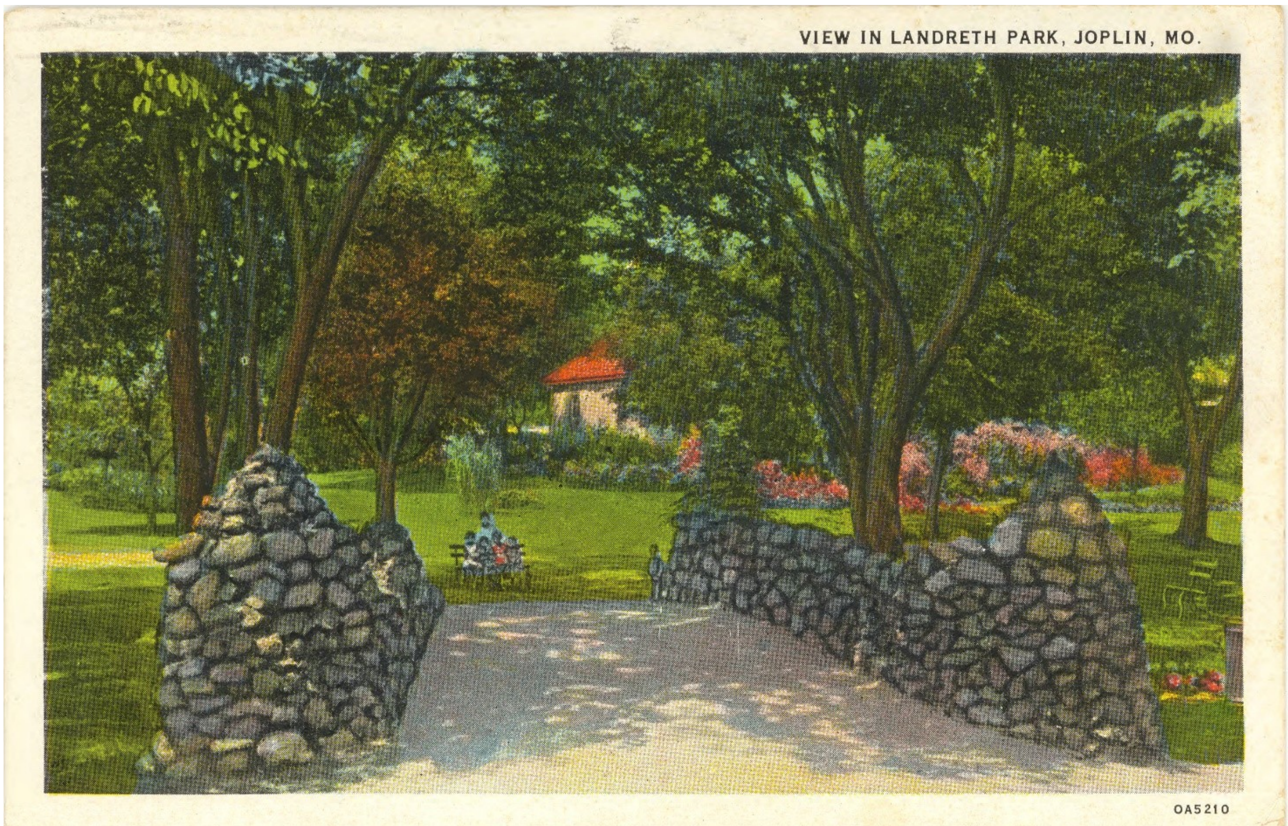

Figure 4.4. Postcard of Landreth Park in Joplin after the cleanup. Circa 1935 (MDHP 2011).

Today, the mining operations that had once fueled Joplin's economy have long been forgotten by many residents. Joplin's economy is now driven by local hospitals, schools, truck driving, and other miscellaneous manufacturing jobs. However, the unique and proud mining history in the area is well documented in the Joplin History and Mineral Museum. Figures 4.6, 4.7, and 4.8 shows some of the many changes to downtown Joplin through 1890 to 1970.

Figure 4.5. Aerial photo of northeastern edge of Joplin. Notice many tailing pilings standing. Circa 1940. Photo Courtesy of Tri-State Mineral Museum.

Figure 4.6. Joplin Main Street. Circa 1890. Photo Courtesy of Joplin Chamber of Commerce.

Figure 4.7. Joplin Main Street. Circa 1912. Photo courtesy of Joplin Chamber of Commerce

Figure 4.8. Downtown Joplin. Circa 1970. Photo courtesy of Joplin Chamber of Commerce.

4.3 Granby

Madison Vickery and his parents Abner and Rebecca Vickery were the first European settlers in Newton County in 1838. The Vickery family settled the town that would later be called Granby, Missouri. In 1849, Vickery discovered galena but did not develop his discovery. It is unclear why Vickery did not develop his discovery, but a possibility could be because of the lack of smelters in the area, the lack of transportation needed to move the ores to market on the east coast, or the lack of knowledge about the value of galena at the time (James 2013; James 2012). It was an additional three to four years before any significant amount of mining occurred in the area. The first significant mining in Granby was by William Foster, a Cornish man, who had previously been working in the Cedar Creek Mines, north of Neosho, Missouri. However, once the value of the galena was discovered in the area, many prospectors quickly moved into the area (James 2013).

Although it is debated whether the Granby area or the Joplin area was first to begin the commercial mining of lead ores in the TSMD, Granby was undoubtable the first location in the

district to build a blast furnace used to refine the lead ores. In 1850, John Ryan and George and William Mosely built the first blast furnace. Early blast furnaces, like one built by Ryan and Mosely, used water power and featured two pairs of bellows to blast oxygen which would cause the temperature in the furnace to raise rapidly. The result was a reduction in the amount of time it took to smelt the lead ores (Jobe 1998). With the development of the blast furnace, a majority of the smelting began to occur in centralized locations. Lead ores were excavated from many mine shafts throughout the TSMD and were transported to Granby to be smelted in the blast furnace (James 2015; Gibson 1972).

The development of Granby grew rapidly during the mid-late 19th century. In 1855, thousands of prospectors relocated to the Granby area. This large movement into Granby is known as the Granby Stampede (James 2013; Jobe 1998). By 1859, the population of Granby had grown to about 8,000 and was known as the largest lead mining and smelting area in the state because of the numerous mine shafts and smelting furnaces (James 2013). Like Joplin, the mining activities in Granby were growing, but limited transportation restricted the growth of early mining operations in the region.

Additionally, in Granby, land right disputes dramatically effected the mining operations. In June of 1852, congress granted land rights of approximately 1,040,000 acres in the Granby area to Pacific Railroad Company with the intent to develop the land to build railways. Included in the land grant was Section 6 in Granby. Section 6 was later known as the "Granby Section" because of the large amount of lead that was mined in the section (James 2012; Parker 1867). This land act made the early miners in the Granby area squatters, because they were illegally mining the lead ores. Therefore, conflicts arose between the railroad company and the miners in the region. These conflicts continued until 1857. In 1857, the first lease of land rights was

secured from the railroad by the Blow & Kennett Company. This made Blow & Kennett the legal land managers of section 6 and the surrounding areas in Granby, and gave ownership of all mines in this area to the company. By 1859, Blow & Kennett constructed the largest up-to-date smelter and closed all the old smelters in the area. Blow & Kennett began to employee over 200 men to work in the smelters and mines. Additionally, Blow & Kennett began to charge individual miners a two-dollar royalty on each 1,000 pounds of lead ores mined on the leased land. This gave Blow & Kennett a monopoly on the mining activities in the Granby area (Jobe 1998). This led to more conflicts, this time between the individual miners and the new land managers. Despite these conflicts, the mining operations continued to grow (James 2013; Jobe 1998; Parker 1867). Before 1861, Granby had the most extensive and enduring smelting establishment operated by Blow & Kennett Company (Gibson 1972). Large amounts of lead ores were being excavated, milled, and smelted at the Blow & Kennett furnace (Jobe 1998). According to James (2013), 35,414,014 pounds of lead were excavated and smelted at the Blow & Kennett smelter in Granby before the start of the Civil War.

The start of the Civil War delayed the growth of the mining operations in the Granby area. The Union and Confederate forces fought to control the lead mines in region with the aim of acquiring lead ores needed to produce ammunition (Jobe 1998; Gibson 1963). The Confederate forces initially held control of the Granby mines. The lead ores were an important resource to the Confederates army during the early part of the Civil War. In October 1861, the Granby Mines produced 32,000 pounds of lead that was shipped to the Confederate forces (James 2013). However, in October of 1862, a conflict between the Union and Confederate forces resulted in the Union forces taking control of the Granby Mines, but not before the Confederate Military was able to shut down the mines and blow up the smelters. The loss of the

smelters in Granby caused the Granby Mining operations to largely cease the remainder of the Civil War (James 2013; Jobe 1998).

With the conclusion of the Civil War in 1865, The Granby Mining and Smelting Company (Figure 4.9) was incorporated with Henry Blow as president and the mining operations were quickly resumed (James 2013). Originally following the Civil War, primarily galena and occasionally cerussite were mined in the area for lead ores, however zinc mining and smelting began in the region in 1869 when Mr. Adolph Von Weis recognized the value of sphalerite (James 2013; Jobe 1998; Buckley and Buehler 1906). By 1873, zinc replaced lead as the primary metal ore being mined. Additional development of the mining operations occurred when the railroad lines were extended into Granby in September of 1870 (Figure 4.10). This led to another boom in the mining activities in the region in the 1870s. During the summer of 1874, an estimated 600 new prospectors relocated to the Granby area (James 2013). During the next 40 years, the lead and zinc mining operations in the Granby area continued to experience years of growth followed by periods of reduction in the mining activities. Activities such as the Granby Fire in 1887, new ores discoveries on the prairie south of Granby in 1889, constriction of smelters in 1892, and new ore mills in 1889, all affected the mining activities in the area.

Additionally, in 1901, Ft. Scott and Central Railroad obtained land to build a railroad line between Joplin and Granby with the primary purpose to move lead ores. The railroad line only had one stop between Joplin and Granby in Diamond, Missouri (James 2013). Also, in 1900, The Granby Mining and Smelting Company began purchasing most of Section 6, which the company had previously been leasing, as well as Section 8. The Granby Mining and Smelting Company expanded by purchasing land elsewhere to grow the business. Overtime, the Granby Mining and Smelting Company purchased over 20,000 acres in Newton County, 2,000 acres in Jasper

County, 2,000 acres in Newton County, Arkansas, and 800 acres of oil and gas fields near Neodesha, Kansas (James 2013). Then, on June 9, 1916 the Granby Mining and Smelting Company was sold to the American Zinc, Lead and Smelting Company for $7,500,000. According to Larry James (2013), the deal made American Zinc, Lead and Smelting Company one of the largest zinc companies in the world. The American Zinc, Lead and Smelting Company continued to lease mining rights to individual miners and smaller companies (Jobe 1998).

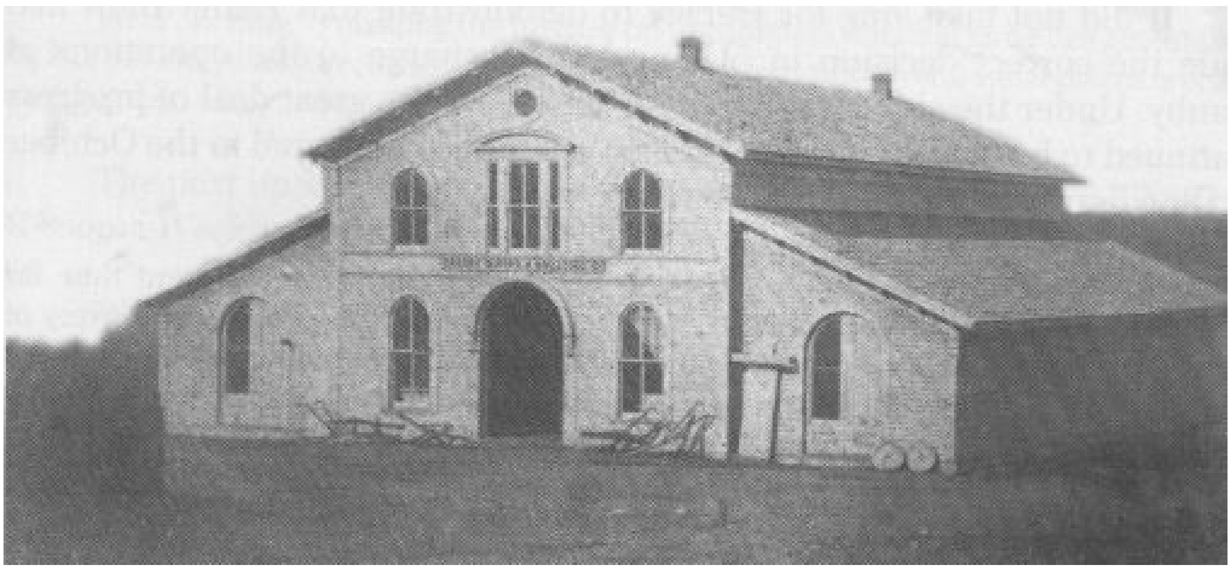

Figure 4.9. The Granby Mining and Smelting Company. Circa 1865 (James 2013).

Granby experienced another boom in the mining activates with the start of WWI in 1916. In 1918, the population of Granby was around 5,000 individuals and Granby had approximately 162 mines in operation. Figures 4.11 and 4.12 shows two of the mining sites that were operational during WWI in the Granby area. During this time, the mines were opened extended hours in order to obtain the metal ores needed by the military (Jobe 1998). In October 1930, American Zinc, Lead and Smelting Company was sold to the Federal Mining and Smelting Company. Soon after the sell, the mining operations came to a crash because of the Great Depression as lead and zinc prices dropping dramatically. During this time, no leases were

available to miners and only small mining operations continued (Jobe 1998). During WWII, a few mines reopened in the Granby area to meet the demand for lead and zinc. These mining operations were subsidized by the United States government. However, with the conclusion of WWII and the government subsides ended, the mining operations once again closed down, and in 1953, permanently closed (Jobe 1998). The land was sold to the American Smelting and Refining Company. The company then leased the land to local individuals. In 1961, the company began selling the land in and around Granby giving first chance to purchase the land to the home owners. By 1964, most of the old mining land had been sold (Jobe 1998).

Figure 4.10. Frisco Railroad Depot in Granby, Missouri. Circa 1890. (James 2013).

Figure 4.11. Home Stake Mine in Granby. Circa 1910 (James 2013).

Figure 4.12. Underground workings at the Klondike Mine in Granby. Circa 1910 (James 2013).

4.4 Neosho

Early European pioneers were attracted to Neosho, like many other towns that were established in southwest Missouri, because of the availability of rich vegetation and clean-fresh water. The name "Neosho" is an Osage name meaning clear or abundant waters and is in reference to the many springs in the area (Cozad 1965). The first European settlers began settling around Neosho in the 1830s. The first post office was established in August 1839 under the name of Newton C.H. and changed to Neosho four months later (Jobe 1998). In 1841, the first general store of Neosho was established by A.B. Anthony and the first tavern by William Elam (James 2001). Also, the first courthouse and jailhouse were built in Neosho in 1841 (Cozard 1965). The town was platted in 1846. The population of Neosho grew rapidly throughout the 1840s and 1850s. By 1856, the population of Neosho had grown to over 300 individuals (James 2001).

The first discovery of significant amounts of lead ores in the Neosho area was discovered in 1847. The lead ores were found on or near the surface in the area and were smelted nearby in primitive- log furnace. The largest amount of lead ores was discovered at the Mosley Mines which was northwest of Neosho. The Mosley mine was established by Thomas Shepherd and Simpson Oldham in the spring of 1847 (Cozad 1965). Shepherd and Oldham originally used a log furnace to smelt the ore adjacent to the mine shaft. However, by 1850, the first air-smelter was built four miles northwest of Neosho by Levi Gilstrap and his brother (Jobe 1998). In 1851, William and George Mosley, built a blast furnace on Cedar Creek near the Mosely Mines (Jobe 1998). Again, transportation limited the growth of the mining operations in Neosho. Lead mined from the Neosho area had to be transported by horse and wagon to the Grand River in Oklahoma, then to New Orleans by steamboats, and eventually on to Boston or New York (James 2012). This left little profit for the miners once the ores were transported to market.

The Civil War devastated Neosho. The guerrilla warfare that destroyed Granby also affected Neosho. Due to guerilla warfare, the local men were often brutally murdered, transportation and communication were destroyed, and homes and business burned (Cozad 1965). It is not clear if mining occurred during the Civil War. According to some reports, lead was continuously mined in the Mosely Mines throughout the Civil War, and the mines and the smelter were controlled of both the Union and Confederate forces at various times throughout the war. However, according to other reports, the lead mines were closed at the start of the Civil War and remained that way throughout the war (James 2012).

The end of the Civil War led to a period of recovery and rebuilding for the citizens of Neosho. By 1870, Neosho had built one hundred new buildings and railroad lines had been extended into Neosho, as seen in Figure 4.13. The railroad was built by the St Louis and San Francisco Railway, today known as Frisco, and connected Neosho to Pierce City. By 1871, more railroad lines were extended into the Neosho area (Cozad 1964). One of the new buildings erected in Neosho was a courthouse which was built to replace the old one destroyed during the war (James 2001). Additionally, the public school system was established and the school census stated that 219 children were attending (Cozad 1965). Many mercantile businesses were established in Neosho after the war including numerous dry goods stores, clothing store, drug stores, groceries stores, and a hardware store (James 2001; Jobe 1998). Manufacturing also grew in the area as planning mill, wagon factories, woolen mill, and flouring mill were all established in the 1870s (Jobe 1998). The Neosho Times was first published in 1869 and was the first newspaper of Neosho after the war (Cozad 1965). As a result of a fire that destroyed many businesses on the square in February 1870, a hook and ladder company was organized that acted as a city fire department (Jobe 1998).

Figure 4.13. Neosho looking north down Wood Street. Circa 1874 (James 2012).

In 1871, the mining activities at the Mosley Mines resumed, and in twelve months the Mosley Mines produced one million pounds of galena (James 2012). Shortly after 1871, the Mosley Mines were sold to Moffett and Sergeant of Joplin and the mining activities were suspended for several years at the site (James 2012). Additionally, in 1871, mineral ores were discovered on a farm owned by the Baxter family seven miles west of Neosho and on Cedar Creek eight miles northwest of Neosho. Multiple smelters began to be established in the area, including the Neosho Smelting Furnace and the W.H. Farr and Company Smelter (Cozad 1965; ("History of Newton" 1888).

The last two decades of the nineteenth century led to further growth in industry and population for Neosho. By 1890 that population of Neosho had grown to 2,198 from 875 in 1870, shown in Figure 4.14 (Cozad 1965). Many churches were established by the 1890s. In 1882, The Missouri Land and Livestock Company were incorporated, and land were purchased from Frisco five miles east of Neosho. Cattle was brought from Scotland and placed on the newly established ranch. In 1887, the first federal fish hatchery was established and covered

approximately thirteen acres. The fish raised at the hatchery were sold for stream stocking and shipped as far away as the Rocky Mountains (Cozad 1965). In the 1880s, two new strains of strawberries were developed by Hermann Jaeger. These strains known as the "Triumph", and "Newton County" and was the first development that kicked off the later successful strawberry industry of Neosho (Cozad 1965). In addition to the growth in industries, there was also growth in the city infrastructure. Public water lines were laid out in 1891. The original water system was made by ten-inch wooden water mains and transported clean water by Elm Spring. Later, iron pipes replaced the wooden pipes in 1897 (Cozad 1965). The first telephone company was organized in 1893 and electricity was introduced in 1897 (Jobe 1998).

In 1882, Matt Spurgeon leased the Mosley Mines and excavated 1,500,000 pounds of zinc in eighteen months, but shortly after he abandoned the lease (James 2012). In early 1887, the Mosley Mines changed ownership again and an additionally 1,000,000 pounds of zinc and 50,000 pounds of lead were excavated (James 2012). The ownership of the Mosley mines changed a number of times in the late nineteenth century, while the Mosley mine became one of the most productive in the area at the time (James 2012). In 1886, the Bass Lead Mines began operations. The Bass Mines were located two miles from the Mosley Mine and six miles from Neosho (Cozad 1965). In addition to lead and zinc excavation, the manufacturing of mining machinery boasted the economy in Neosho. The Neosho Foundry was founded and specialized in the manufacturing of mining machinery (Jobe 1998).

Neosho's economy in the beginning of the twentieth century began to shift away from the mining activities and towards agriculture. The strawberry industry began to grow. In 1910, Newton County was the second in the state for small fruit yield and included 1,677 acres. The strawberry industry reached its peak in the 1930s. After the 1930s, continued spring droughts

began to slow the yields (Cozad 1965). In addition to strawberries, apples, peaches, and grapes, sweet potatoes were often grown in Neosho. The dairy business that had begun in the 1870s grew rapidly in the early twentieth century. Neosho has numerous fine dairy farms and creameries (Cozad 1965). The poultry business, that is still significant to Neosho's economy, began in the early twentieth century. In 1911, the Stark Brothers Company moved their company to Neosho. In 1917, the Stark Brothers Company was purchased and the Neosho Nurseries Company was formed, operating until 1931.

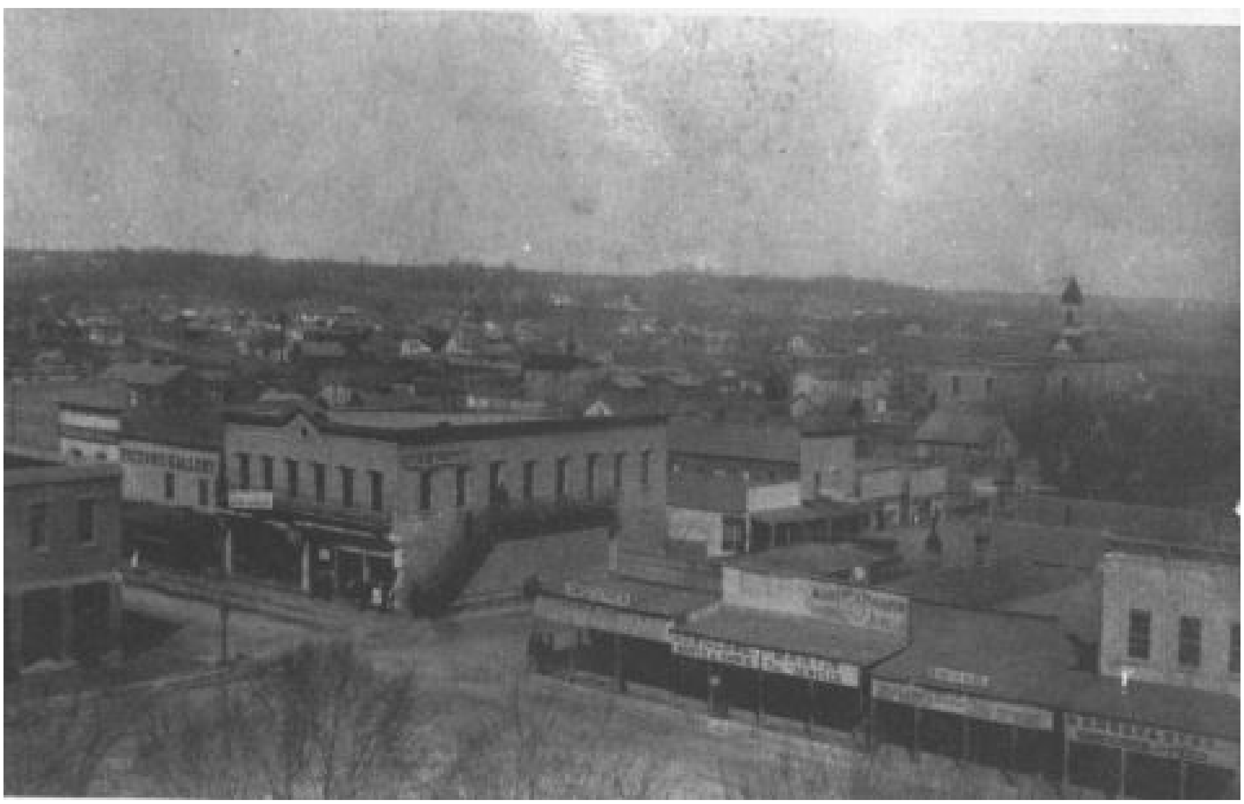

Figure 4.14. View of Neosho, Missouri. Circa 1890 (James 2012).

Neosho was home to many young soldiers who served overseas during WWI, shown in Figure 4.15. However, unlike lead and zinc mines in other locations around southwest Missouri, the start of WWI had little effect on the disappearing lead and zinc mining operations. There is

little recorded about the mining activities in the area during this time. In the 1920s, Neosho built its first public swimming pool, hospital, and roads improved as automobiles became more common (Cozad 1965). The 1930s, were a time of construction in Neosho. As a result of the New Deal, federal funds being allocated to keep citizens working during the Great Depression. A few of these construction projects included expanding the public schools, public library, a new post office, and a new courthouse (Cozad 1965).

Figure 4.15. Military Soldiers departing from Neosho to fight in WWI. Circa 1917 (James 2012).

The start of WWII also significantly affected on the daily life of the citizens of Neosho. Despite the objections of some individuals in Neosho, construct began for an army military base outside Neosho in August 1941. The army base was called Fort Crowder and the first troops arrived December 3, 1941. At any given moment, over 40,000 troops were being trained at Fort Crowder (Kirkman and Stinnett 1981). Neosho economy boomed as the large numbers of

soldiers were often seen in the streets of Neosho. Little lead or zinc mining occurred in Neosho during and after WWII. The last recorded time the Mosley Mine was open and operational was in 1940 (James 2012). The end of WWII led to the closure of Fort Crowder in 1945. Neosho's economy has since been largely due to agriculture and manufacturing (Cozard 1965).

4.5 Aurora

Aurora, Missouri was originally called Elk Horn Prairie. Some of the earliest European pioneers arrived in the mid-1850s and settled around present-day Aurora along Honey Creek. These earliest families included the Hillhouse, Young, Barrow, Gibson, McNatt, Liles, and Rinkers (Lawrence County Historical Society 1974; Aurora Centennial Committee 1970). The first house built within the city boundaries of Aurora was built by Joseph Rinker in 1840. However, the number of settlers remained low in the area until the 1870s (Lawrence County Historical Society 1974). Aurora was platted in May 1870 by Stephen G. Elliott on 40 acres that Elliott had bought from John McNatt. Additionally, in 1870, the first post office was established with Elisha Rinker as the first Postmaster, and the first train of the South Pacific Railway arrived in Aurora.

In November of 1885, workmen who were digging a well for Thomas G. Liles discovered large chucks of pure galena. Immediately following the discovery, mining operations began extensively in Aurora. Figure 4.16 shows one of the early mining operations in Aurora. Previous discoveries of galena were rumored by George Haley in 1873, but there is no evidence what these discoveries were ever worked (Aurora Centennial Committee 1970). By 1886, Aurora quickly grew as a lucrative mining camp. Many prospectors rapidly moved into the area to make their fortune mining. Housing were not plentiful enough to accommodate the many miners

moving into the area. Therefore, miners and their families were forced to live out of their covered wagons, tents, or any other rudimentary shelter that they were able to quickly put together (Aurora Centennial Committee 1970). Often newly arriving miners would work with a partner to obtain a land lease and proceed to work the prospect together. These early mining operations were excavating shallow ores with a simple pick, shovel, and a windlass and bucket to hoist the ores to the surface (Raffery 1970). Large mining companies were also working mines in the area, and some newly arriving miners, or miners who failed to succeed at mining on their own, could seek employment with these larger mining companies (Aurora Centennial Committee 1970). The first of the mining companies in Aurora was the Aurora Syndicate Mining Company ("History of Newton" 1888). As more miners moved into the area, businesses quickly grew. Businessmen would often use their covered wagons in order to sell their goods because of the lack of buildings available (Aurora Centennial Committee 1970).

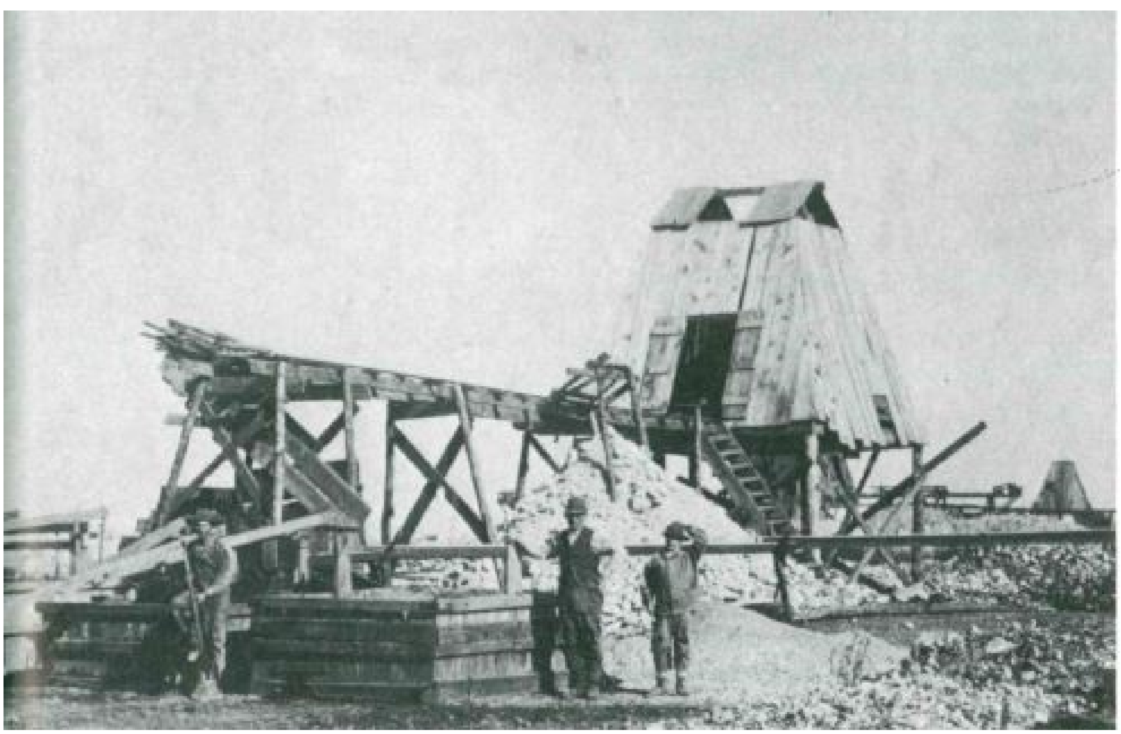

Figure 4.16. One of the early, shallow, mine site in Aurora. This mine was more elaborate than most in the Aurora area at the time. Circa 1886 (Aurora Centennial Committee 1970).

By the 1880s, Aurora had around 300 residents, a train depot, many stores, a school, churches, a bank, a newspaper, hotels, gambling halls, saloons, a theater, and a post office. Also, Aurora's first electrical company was established. The electrical company was established by E.L. Foster who built a powerhouse in Aurora in 1887 (Lawrence County Historical Society 1974; Aurora Centennial Committee 1970). Social events were also on the rise in the 1880s. Fairs, baseball games, bicycle races, and informal buggy races around the square were common place (Aurora Centennial Committee 1970). By 1888, Aurora was considered one of the best lead mining camps in the area and would often ship out as much zinc and lead in one week as the Joplin area mines ("History of Newton" 1888).

The 1890s were another decade of growth in Aurora. The population grew to 3,482 by the end of the 1890s (Aurora Centennial Committee 1970). A public water system was built in 1891 that carried up to 20,000,000 of clean water daily from Marbut Spring in Verona to the residence of Aurora. The first sewage system was established in the later part of the 1890s (Lawrence County Historical Society 1974; Aurora Centennial Committee 1970). Additionally, in 1892, a railroad line was extended that connected Aurora to Mt. Vernon and Greenfield. This line was later incorporated in the Frisco system (Aurora Centennial Committee 1970). In 1897, Aurora Mill Company was the first manufacturing business established. Figure 4.17 shows the growing business district in Aurora around the turn of the century.

Beginning in the 1890s, the mining activities began to shift from the excavation of the shallow lead deposits to the excavation of the deeper zinc deposits. This occurred because the shallow lead deposits had previously been extensively excavated, and the number of successful shallow prospects was becoming fewer each year. Also, the mining operations began to become mechanized with the introduction of steam and electric powered equipment. This contributed to

improved excavation, milling, and smelting process that allowed the success of the zinc being recovered within deeper ore deposit. The excavation of deeper ore deposits required improved technology and methods to be successful. Larger mining companies were able to used improved technologies to excavate the deeper ore deposits (Aurora Centennial Committee 1970). This resulted in many individuals or small partnerships abandoning their individual prospect to begin working for mining companies in the area. Figure 4.18 shows one of the large mining companies in the area. However, there was still some minor success in shallow mining until the 1920s (Aurora Centennial Committee 1970).

Figure 4.17. Aurora's business district. Circa 1900 (MDHR 2011).

In the beginning of the twentieth century, the mining operations in the area began to slowly move to the newly discovered larger ore deposits found in Oklahoma and Kansas. This new market of lead and zinc coming out over-supplied the market causing the price of lead and zinc to drop dramatically. As a result, many mines began to close around Aurora and machinery and mills were often sold to mining operations in the western portion of the TSMD. The miners soon followed the mining equipment, and many moved to the new mining areas in Oklahoma and Kansas (Aurora Centennial Committee 1970).

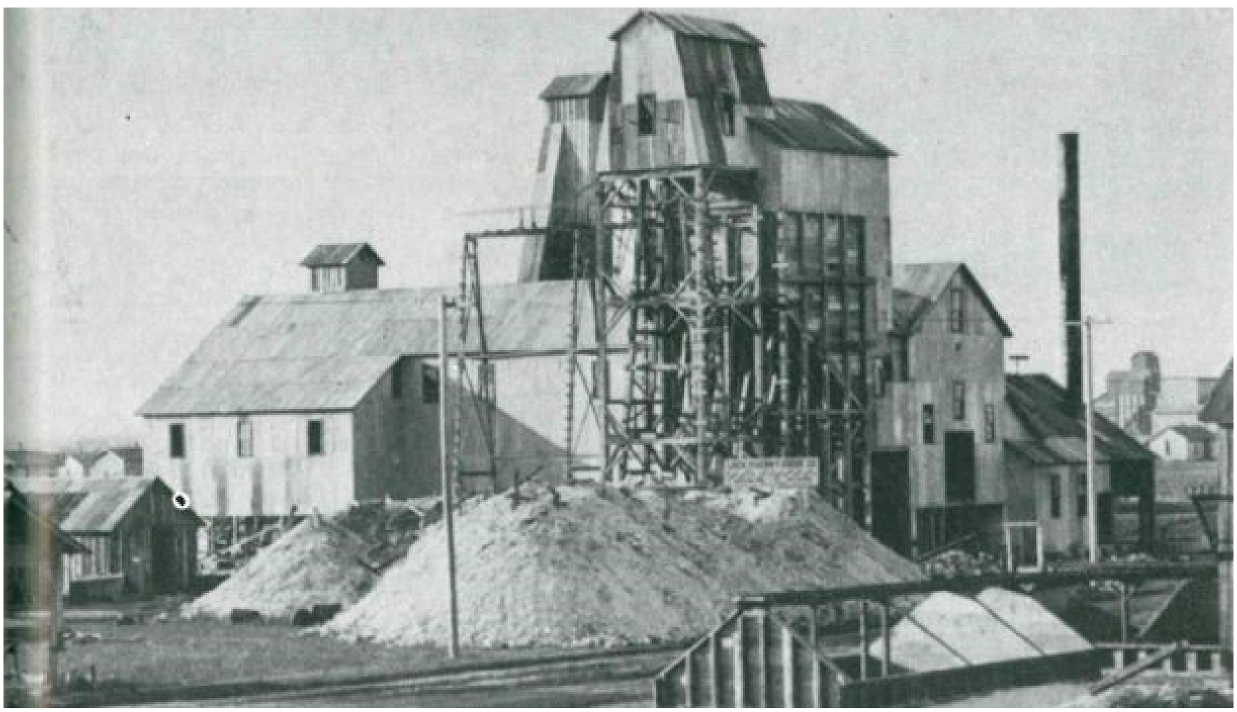

Figure 4.18. Lucky Jennie Mine was a typical steam-powered mine with one smelting stack in the Aurora area. Circa 1900 (Aurora Centennial Committee 1970).

Some of the businessmen of Aurora fought to keep Aurora a prosperous town. They went as far as prospecting in new locations or operating mines at a financial loss for themselves, in order to attempt to return Aurora to its previously flourishing town. However, these attempts

often resulted in businessmen losing large amounts of money with no success at making Aurora prosperous again. Manufacturing businesses were established in the early twentieth century. For example, the Majestic Mill, established in 1907, had the capacity to produce 1,000 barrels of flour a day (Aurora Centennial Committee 1970).

The start of WWI in 1914 caused many of Aurora's citizens to come out and support the United States Armed Forces. Citizens purchased war stamps and bonds, and a number of Aurora's young men were proudly sent overseas to fight in the "wars that would end all wars". Additionally, the start of the war also in caused the price of lead and zinc to rise. Therefore, a few of the mines in the Aurora area reopened and new strikes were developed starting in 1914 to meet the demand for lead and zinc. However, with the conclusion of WWI in 1918, the mines closed again (Aurora Centennial Committee 1970).

With the mines closing at the end of WWI, Aurora turned to manufacturing to supplement its economy. In the early 1920s, Juvenile Shoe Corporation and the Midwest Map Company were both established, boosting its economy (Aurora Centennial Committee 1970). However, this boast was very short lived. The Great Depression of the 1930s, devastated Aurora. In 1931, the Bank of Aurora closed and it did not pay out its first dividends to its depositors for more than five years and then only by eight percent of its deposits (Aurora Centennial Committee 1970). In 1933, the People's Bank closed and this left Aurora without a bank until 1935. By that time the citizens of Aurora had little or no money to deposit in the bank (Aurora Centennial Committee 1970). The dust bowl drought hit Aurora in 1934 through 1936. The local starving cattle were often the only source of food for the residents. The cattle would be slaughtered and canned at the local WPA cannery. The limited economy of Aurora relied heavily on government relief checks and WPA. The Aurora Mill was destroyed in a fire at the beginning

of the 1930s. The Majestic Mill suffered damage from a fire in 1937. Therefore, milling and other manufacturing jobs in the area became an unreliable source of income (Aurora Centennial Committee 1970).

In the mist of the hardship of the Great Depression, Aurora did take advantage of the federal funds allocated by Roosevelt's New Deal money to make improvements in their town. New Deal projects included the development of new parks, including a park on established on an abandoned mining site just two miles east of town, a new baseball grandstand, tennis courts, a municipal swimming pool, a new sewer treatment plant built, and sewer lines extended, and road improvements (Aurora Centennial Committee 1970). These projects provided employment and permanently benefited to the local community.

Even before the United States formally joined WWII, Aurora's National Guard units were among the first National Guard units mobilized in September 1940. The units were sent to Camp Hulen, Texas for training (Aurora Centennial Committee 1970). During WWII, a few mines activities resumed in the area. The American Lead and Zinc Company operated one mill in the Aurora area, but these activities were quickly closed with the conclusion of WWII in 1945. This permanently ended the lead and zinc mining in the Aurora area. Today, Aurora has a population of less than 8,000 residents and its economy is primarily based healthcare and transportation.

4.6 Oronogo

The town of Oronogo was originally called Minersville, Missouri during the pre-Civil War era. The town's name was later changed from Minersville to Oronogo around 1870 due to the already established existence a town named Minersville, Missouri in Christian County

(WCAGS 2007a; North 1883). The earliest accounts of lead mining around the present-day town of Oronogo dates back to 1836. This early mining was carried out by Native Americas and European trappers in order to produce a lead shot for personal use (Gibson 1972; North 1883). These early mining activities were concentrated along Center Creek on the southern edge of Oronogo (Gibson 1972). By 1849, around the same time commercial mining was beginning in Joplin, a small commercial mining operation was established along Center Creek. Along with multiple mining shafts that were used in the small commercial mines, a small smelter was also in use (Renner 1985; Gibson 1972). Commercial mining further expanded in 1851 when Andrew McKee and Thomas Livingston discovered the first lead ores within the city limits of the later established Minersville (Gibson 1972). As a result of the McKee-Livingston discovery, Livingston opened a general store and the mining camp was established within a five-mile radius of the find (VanGilder 1995; Gibson 1972). Despite these early discoveries of lead ore, most of the significant amount of mining occurred in the area during the post-Civil War era. Early settlers in the area still depended heavily on hunting, trapping, farming, and milling as their main source of income (VanGilder 1995). The town of Minersville was plated in 1856 by Stephen O. Paine (VanGilder 1995; North 1883).

Despite the limited mining that occurred throughout the Civil War in 1861 to 1865, mining quickly resumed and grew in Minersville following the war. In 1865, the Granby Mining and Smelting Company started acquiring land around Minersville and updated the Minersville’s smelter to a blast smelter (North 1883). The Granby company began extensive mining in the area and encouraged mining developments in Minersville by leasing small tracts of land to prospectors, providing financial incentives for prospectors to sink a shaft and periodically offering rewards to leaseholders whom excavated the largest amounts of ore within a set time

period (Renner 1985). Figure 4.19 shows a newspaper ad placed in the Carthage Banner placed by the Granby Mining and Smelting Company encouraging miners to develop prospects in the Minersville area. This resulted in prospectors quickly moved into the area. Among these prospectors were Sergeant and Moffett who would later be key in the development of the mining operations in Joplin (North 1883). Minersville's population grew to approximately 1,000 to 2,500 residents at its peak (North 1883). As seen as Figure 4.20, churches, mercantile stores, schools, hotels, a bank, and other businesses were established in Minersville in the late nineteenth century (WCAGS 2007a). In 1869, the first post office was built. However, since Minersville, Missouri was already a name of a town in Christian County, the postal office could not be named Minersville. The town's residents decided to change the town's name from Minersville to Oronogo, Missouri. The name Oronogo was a reference to the mining activities that the town was known for. Therefore, the residents agreed that the town should be "Ore-or-no-go" (WCAGS 2007a; North 1883). In 1903, the Southwest Missouri Railroad Company built a depot for their electric streetcars in Oronogo (WCAGS 2007a). This allowed access to better transportation for the miner to get to the mining sites.

The largest and best-known mines in the Oronogo area is the Oronogo Circle, shown in Figure 4.21. In 1899, Guy Waring opened a circle mine south of Oronogo under the Oronogo Mutual Mining Company. Before the mined closed in 1906, the mining company began stripping and blasting the pillars in the mine at a depth of 180 feet. The company predicted the removing of the pillars would produce a 220 feet cave-in. However, the result was a 20-acre cave-in that was 265 feet in depth (WCAGS 2007). The caved in mine was left abandoned until the 1930s. Starting in the 1930s, the Oronogo Circle Mine was dewatered with large pumps and strip-pit, or open-pit, mining operations began at the mine. The strip-pit mining operation in Oronogo grew

to be the largest in the world for lead and zinc (WCAGS 2007a). It is estimated that the Oronogo Circle produced thirty million dollars of ore (Renner 1985). In 1948, the pumps were shut off at the Oronogo Circle Mine and the site became an unsanctioned swimming hole for the local residents. With the closing of the Oronogo Circle Mine the mining operations in Oronogo closed their close permanently. In 1978, the pit was purchased by Rod McCollum and John Mueller and it became the Blue Water Recreation Park and Scuba School.

MINERS WANTED!

Jasper Lead Mines!

The mines of the Granby Mining and Smelting Company, situated at Minersville, nine miles west of Carthage, in Jasper county, afford at the present time, the greatest inducements to all working men, seeking remunerative employment, and healthy homes.

The Granby company confidently assert that no industrious miner, out of employment, or absolutely engaged in mining, will be disappointed either in the profit of working these mines, or in the health, fertility and beauty of their surroundings.

The company will pay one dollar per foot for sinking shafts to the mineral, and where the miner strikes a lead, or opening, he is allowed to return the amount advanced him for sinking, from the price of the mineral he may raise, thus securing to himself at once, entire control of the shaft he has sunk, with a mining lot so long as he works the same, subject only to the rules regulating the mines, which pay a fair price for his mineral, and a rent of two dollars per thousand to the company.

This offer, it will be seen, guarantees to each miner a support—whether he discovers mineral or not, and in every case where mineral is found, secures him the actual benefit of the profits of mining. The undersigned believes that no Company in the United States can afford the same inducements or the same guarantees.

These mines are now being accurately surveyed and platted. All persons claiming mining lots are notified to come forward immediately, and point out their lines and receive a lease for same from the company. All land not so claimed, located and leased, will be declared forfeited and leased in suitable mining lots to first applicants to work same.

Good laboring men, of steady habits soon learn to mine, and will find it profitable as the mineral is readily found in paying quantities.

A large amount of transportation will be required for Sedalia. Farmers and others engaged in wagoning will find it advantageous to haul our lead to that point for the present.

Cash paid for cord wood, stone coal, lime and Charcoal. Apply to

J. MORRIS YOUNG,
Resident Superintendent, Minersville Jasper Co., Missouri.

Figure 4.19. The Carthage Banner Newspaper on June 11, 1868 advertises mining opportunities in Minersville by the Granby Mining and Smelting Company (MDHP 2011)

Figure 4.20. Oronogo circa 1905. The mine smelter and mill are seen in the background (MDHR 2011).

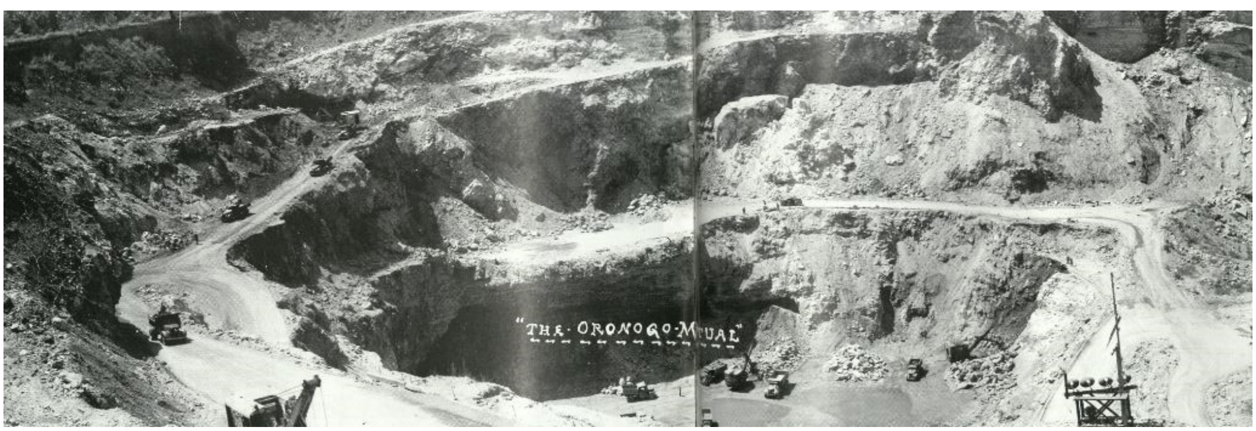

Figure 4.21. Oronogo Circle Mine operated by The Oronogo Mutual Mining Company. Circa 1930 (WCAGS 2007b).

4.7 Springfield

The mining activities on the eastern edge of present-day Springfield, Missouri, around the junction of Pierson Creek and James River predated European settlement in the region and is the first recorded location of lead mining in southwest Missouri. The mining operations at Pierson Creek were very small compared to the later mining operations around Joplin, Missouri. Henry Rowe Schoolcraft first explored the region in 1819 and noted evidence of mining activities along Pierson Creek, which he assumed were conducted by the Delaware Native Americans and early European hunters in the area (Cooley and Fuller 1976; Gibson 1972; Rafferty 1970). The first commercial mining at Pierson Creek occurred as early as 1844 at or near the Phelps Mines (Cooley and Fuller 1976). However, these early commercial mining activities in the 1840s were sporadic and within a few years the mining activities ceased due to low lead prices.

Mining operations at the Phelps Mines were intermittently carried out over the next fifty years by various individuals who held leases on the land. In the late 1850s, commercial mining reappeared at the Phelps mines. By 1875, land was leased by Charles and Henry Sheppard of Springfield, along with Judge Picher of Joplin, and a seventy-seven-foot mine shaft was sunk. Although this shaft was productive initially, mining at this depth quickly became unrewarding and the mining operations once again ceased at the Phelps Mines (Cooley and Fuller 1976). Mining reassumed in 1885 when Joseph O'Donnell leased land at the Phelps mines. Beginning in 1886, Colonel John E. Phelps leased the Phelps mines for the next five years until the Phelps Mines closed permanently in 1891 (Cooley and Fuller 1976).

The Pierson Creek Mines, shown in Figure 4.22, which were located one- quarter mile upstream from the Phelps Mines, began mining operations in 1885. Like the Phelps Mines, the Pierson Creek Mines were intermittently worked by numerous lease holders, including Nathalie

Mining Company, Springfield Jack and Lead Mining Company, and Choteur Mining Company (Cooley and Fuller 1976). The Pierson mining rights were typically leased from land owners for approximately a ten percent royalty and most of the mines had a mill site within close proximity of the excavation sites (Cooley and Fuller 1976). The Pierson Mines permanently closed its mining operations around 1920 due to mining competition around Joplin and the decreasing availability of metal ores (Cooley and Fuller 1976).

Figure 4.22. Pierson Creek District Mine. Circa 1900. Photo used with permission from Bob Pavolwsky.

4.8 Discussion

Lead and zinc mining have contributed to the economic growth and the establishment of many communities and towns in southwest Missouri. Mining operations provided employment in

local mines and in the manufacturing industry which grew the early economy in southwest Missouri. Joplin, Granby, Neosho, Aurora, Oronogo, and Springfield each depended heavily on the mining industry to build their economies. Today each town’s economy has moved away from lead and zinc mining, but the legacy of mining remains a significant part of its histories and sense of heritage.

CHAPTER FIVE: POST MINING ERA

5.1 Methods

5.1.1 Geographic Information System. Maps of the study area were created using data obtained from Google Earth, Environmental Systems Research Institute (ESRI) ArcGIS Online, and Missouri Department of Natural Resources (DNR). Data were placed into ESRI ArcMap 10.6 in order to create a base map of the study area. First, a new Geodatabase was created using ArcCatalog. Additionally, in ArcCatalog, within the newly created Geodatabase, new feature classes were created to document significant state boundaries, county boundaries, town boundaries, streams, major roads, and lakes within the study area. For each feature class created, the North American Datum (NAD) 1983 UTM Zone 15N was chosen as the coordinate system. Next, in ArcMap, a base map that contained each of the features was added from ArcGIS Online and NAD 1983 UTM Zone 15N was chosen for the layer coordinate system. NAD 1983 UTM Zone 15N was chosen in order to assure a uniform coordinate system was used throughout the maps. Once the base map was added, each selected feature was digitized using the editor feature in ArcMap and tracing the features from the base map. After the state, county, and town boundaries were digitized as well as the streams, major roads, and lakes were digitized, the ArcGIS base map was removed from the map layer.

Next, the geographic locations of the mining sites were obtained from the Department of Natural Resources' (DNR) Geosciences Technical Resource Assessment Tool (GeoSTRAT). GeoSTRAT data can be found at the DNR's website and contains geographic and metadata layers about bedrock geology, earthquakes, geothermal, groundwater, karst, mines, surficial geology, and wells throughout Missouri. The Inventory of Mines, Occurrences, and Prospects

database can be found under mines layer. The mines database is based on data obtained from the United States Bureau of Mines' Mineral Industry Location System and is intended to be used as a research tool for mineral exploration and land management (MDNR 2019b). The Inventory of Mines, Occurrences, and Prospects database were downloaded from the layer package, extracted, and added as a layer in ArcMap. Once in ArcMap, the Inventory of Mines, Occurrences, and Prospects was imported into the Geodatabase used for this study in ArcCatalog by importing Feature Class (Multiple). Next, the editor tool was used to remove any mining activities that were not geographically located within the study area and mining activities that were not targeting lead and zinc as the recoverable metals. Once completed, only mining sites that were within the study area boundaries and were known locations of lead and zinc mining were included in the map. From this base map, maps of each of the individual mining towns were obtained by zooming into each of the six mining sites studied.

Finally, the visible chat piles were mapped from satellite images found on Google Earth. Upon close examination of the six chosen mining towns, the locations of remaining, visible chat piles were plotted in ArcMap by creating a new feature class for the chat piles and digitizing the location of the chat piles over the study area maps. These remaining chat piles were also documented by screen photos taken on ground level from Google Earth. These locations of chat piles were mapped only on the maps of the six historic mining towns, because of the small and scatter nature of the remaining chat pile made it hard to see on the larger complete study area map. Additionally, these chat pile locations were not verified in the field, except in Granby, Missouri.

5.1.2 Sediment Metal Content Database. Data of metal contamination levels from previous studies in southwest Missouri were collected and evaluated from published theses,

environmental reports from the United States Geological Survey, and other independent or academic research conducted throughout the Missouri portion of the TSMD. Sediment analysis data were targeted and collected from theses by Peebles (2014), Kothenbeutel (2008), Rodgers (2005), Frederick (2001), Trimble (2001), and Carlson (1999). Only data that were collected from the surface sediment samples and analyzed using ICP (inductive coupled plasma spectrophotometry) were included in this study. Sediment analysis that were repeated in the same spatial location but with varying temporal periods, were averaged and documented for this study. Although XFR analysis of sediment samples gives rapid results that cost significantly less than ICP analysis of sediment, they are considered less precise than ICP. Because of this difference and for consistency purposes ICP data were only selected.

The collected data was compiled in Microsoft© Excel 2016. Once in Microsoft© Excel, geographic coordinate system for all data were converted to NAD 1983 UTM Zone 15N in order to have a uniform coordinate system throughout the study. This created a challenge since data were not reported in a uniform coordinate system. Therefore, all coordinate systems were converted and documented in Excel. Once the ICP sediment analysis were documented into Excel, the file was saved as Microsoft Excel Comma Separated Values File. The chart was then added to ArcMap by the add data button and navigating to the correct location that the chart was saved. Once in ArcMap 10.6, the attribute table was geographically plotted by right clicking the chart, pressing Display XY Data and choosing the X Field and Y Field as the UTM Easting and Northing columns respectively. Next, the layer was imported to the Geodatabase for the study, same as the mine locations.

Next, the lead and zinc concentrations in the sediments were plotted individually on the maps. First, the background concentration of lead and zinc levels were decided using the

probable effect concentration (PEC) determined by MacDonald et al. (2009) as basis. The PEC is the threshold concentration of a chemical in sediment in which below the PEC level there is likely very little or no adverse biological effect and above the PEC level there is likely an adverse biological effect (MacDonald 2009).

For lead, the PEC value was reported as 150 parts per million (ppm) and for zinc 2,083 ppm. Once the PEC values were input for lead and zinc the concentration maps were created using four ranges of heavy metal concentration. First, the lowest concentration range shows lead and zinc levels that fall below the PEC value and therefore has very little or no contamination. Next, the concentration range show sediment that is contaminated with up to two times the PEC value for lead and zinc. The third concentration range shows values that are up to three times the PEC value for lead and zinc. The fourth concentration ranges show sediments values to exceed three times the PEC value for lead and zinc.

The varying range values are displayed in graduated symbol by right clicking the Layer, choosing Properties, and choosing Symbology tab. Within the Symbology tab, Quantities were selected. Under Quantities, Graduated Colors were selected. Next, either the lead or zinc values were chosen to be displayed and the four value ranges from above was added. Finally, the displayed colors were chosen.

5.2 Environmental Consequences of Mining

The unintentional environmental consequences of mining were questioned by some individuals since the early nineteenth century. In 1818, Henry Schoolcraft described the lead mines in eastern Missouri as endless mining prospects scattered across the landscape. He noted that these abandoned and active prospects occurred in every direction and had caused large piles

of gravel and other mining waste that were constantly accumulating near the mining prospects (Smith 1987; Schoolcraft 1972). In locations outside Missouri, environmental activists, such as John Muir, opposed mining practices that caused environmental destruction and left large amounts of mining debris scattered (Smith 1987). The water quality due to mining was also noticed by many individuals during the nineteenth century. Streams that once flowed clear and clean, became murky, muddy, or rust color and contained high amounts of chemical pollutants that had health consequences for the residents that lived near the mining sites (Smith 1987). In some locations, the unintentional consequences of mining had altered the landscape and caused physical hazards and acid mine drainage that persisted long after the mining activities ceased (Smith 1987).

5.2.1 Physical Hazards. Within the TSMD, large disturbed surface areas including open shafts and sinkholes were present. A study conducted by the United States Bureau of Mines found more than 1,500 open mine shafts and 500 surface collapses in the TSMD in the early 1980s (Brosius and Sawin 2001). These physical hazards have caused loss of life, property damage, and the contamination of groundwater and surface water (Brosius and Sawin 2001).

Many of the remaining open mine shafts and surfaces collapses in the district occur in the Oklahoma portion of the TSMD. Discovery of significant quantities of metal ores in the northeast Oklahoma and southeast Kansas portion of the TSMD came later than in southwest Missouri. Specifically, the first commercial mining began in Kansas in 1886 and Oklahoma in 1891 (Gibson 1972; Brockie et al. 1968). Compared to most of the mining in southwest Missouri, the metal mining in Oklahoma and Kansas was much larger in scale and was mined the deeper, underground ore deposits. Mining in Oklahoma, particularly in Picher Field near Commerce, Oklahoma was so extensive that it accounted for over sixty-one percent of the total

district production of lead and zinc ores (Brockie et al. 1968). Production of this quantity produced large, deep mine shafts and many surface collapses, known as subsidence that still scar the surface in many areas in Oklahoma (Nairn et al. 2001).

5.2.2 Acid Mine Drainage. Acid mine drainage is produced by oxidation of sulfide minerals. Sulfide minerals, such as marcasite and pyrite, are present in the rocks of the district. If left undisturbed, sulfide minerals will slowly leach into the surrounding environment and cause little harm to the ecosystem (USEPA 1994). However, mining activities exposed significant quantity of sulfide minerals to oxygen and water which produced acidic water. During the active mining period, many mines were dewatered to keep the mines dry and workable. Once the mining activities creased, water filled the underground cavities. The underground water was then exposed to sulfide from the walls of the mines, as well as from the remaining unexcavated rocks in the mines and became acidic (Jamieson 2011; Brosius and Sawin 2001; USEPA 1994). The acidity in the underground water caused the release of lead, zinc, and cadmium from the rocks. The acidic water, along with the dissolved metals, was then discharged into waterways causing chemical contamination throughout the district (Gutierrez et al. 2019; Pope 2005; Christenson et al. 1990).

The alkaline pH condition of the Missouri portion of the TSMD provided inadequate conditions to produce acid mine drainage due to the buffering capability of the limestone rocks present in the area. However, the Oklahoma portion of the TSMD has developed acid mine drainage due to the acid pH condition of the area (Gutierrez et al 2019).

5.3 Superfund Sites

In 1980, as a consequence of the increased environmental awareness that developed in the mid-late twentieth century, Congress passed the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or Superfund. Superfund provided federal authority to fund cleanup of toxic waste sites that pose a risk to human health or the environment (USEPA 2019b). As a result of the environmental degradation caused from over one hundred years mining activities, the United States Environmental Protection Agency (USEPA 2019b) designated four Superfund Sites within the TSMD and placed them on the National Priority List (NPL). The NPL is the list of hazardous waste sites in the United States eligible for long-term remedial action financed under the federal Superfund program (USEPA 2019b). Within the TSMD, the originally designated NPL Superfund Sites included: Oronogo-Duenweg Mining Belt Superfund Site, Missouri; Newton County Mine Tailings Superfund Site, Missouri; the Cherokee County Superfund Site, Kansas; and Tar Creek Superfund Site, Oklahoma; (USEPA 2019b).

5.4 State of Remediation

There are many complexities in the remediation efforts within the Superfund sites of the TSMD. This includes political challenges, stemming from the Superfund site spreading across three states and social challenges, stemming from the economic resources in the area and tribal lands included as portions of the Tar Creek Superfund Site. Also, as a result of the extensive, widespread contamination of soil, sediments, surface water, and ground water, as well as the high cost of remediation, remediation efforts remain on-going throughout the TSMD and could continue to take decades to complete. Although there are a number of similarities in the four

original Superfund sites within the TSMD, remediation in each of the Superfund sites has occurred with varying levels of success.

5.4.1 Tar Creek Superfund Site, Oklahoma. Although this Superfund site is not in Missouri, it is described here as an important site within the TSMD because of being ranked the nation's number one NPL site (USEPA 2019a; ITRC 2017; Nairn 2001). Tar Creek Superfund Site covers over 40 square miles and includes the towns of Miami, Quapaw, and Commerce, Picher and Cardin Oklahoma. However, Picher and Cardin were dissolved as part of a residential relocation and buyout effort due to the high risk of exposure to toxic waste present (ITRC 2017; Nairn 2001). The site was first given prominence in 1979 when acid mine drainage was detected in Tar Creek and killed most of the downstream biota (USEPA 2019a; Nairn 2001). In response, the site was added to the NPL in 1983 (USEPA 2019a; Nairn 2001). The site was placed on the NPL due to its chemical pollutants that were produced by numerous chat piles, tailing ponds, contaminated soils, contaminated groundwater, contaminated surface water, contaminated fish and other wildlife or plants, and large amount of surface disturbances (USEPA 2019a).

Approximately seventy percent of the site is tribal land (Nairn 2001). Therefore, remediation has been a partnership between the federal, state, and tribal community (USEPA 2019a). To date, finished remedies include: 2,940 residential and high priority properties have been cleaned up, Picher and Cardin where residences had a high risk of exposure to toxics have been relocated and bought out, over 4 million tons of mining waste and affected soils have been remediated, and 83 abandoned wells have been plugged (USEPA 2019a). Abandoned wells that went through the shallow, contaminated Boone Aquifer to the deeper Roubidoux Aquifer was a source of contamination to the Roubidoux Aquifer which serves as the primary drinking water in the area. The Roubidoux Groundwater Monitoring Program has been put into placed to

continuing to monitor the aquifer for contaminants (USEPA 2019a). Figure 5.1 shows an example of a completed remediation site at Tar Creek. However, years of remediation still lay ahead of the site due to the extensive mining that occurred throughout the site. The Tar Creek Superfund Site is significant because it is the first Superfund site where a Native American community is leading the cleanup.

Figure 5.1. Before and after a cleanup on site at Tar Creek. This site is now used for agricultural purposes (USEPA 2019a).

5.4.2 Cherokee County Superfund Site, Kansas. The Cherokee County Superfund Site covered approximately 115 square miles and included Galena, Treece, and Baxter Springs sites (ITRC 2017; USEPA 2015). The site was placed on the NPL in 1983 as result of millions of cubic yards of mine tailing, contaminated soils, surface waters, sediments, ground water, and physical ground disturbance (USEPA 2015). To this date, finished remedies include: removal of residential yard soils, primarily in Galena, due to the historic presence of a former smelter; excavation and removal of millions of cubic yards of mining waste to fill in abandoned mine shafts; sealing abandoned wells to prevent further contamination in the Roubidoux aquifer; improved access to safe public drinking water, and voluntary relocation in Treece (ITRC 2017).

5.4.3 Newton County Mine Tailing Superfund Site. The Newton County Mine Tailing Superfund site covered about 300 square miles in northern Newton County and included the urban area of Granby, Spring City, Wentworth, and Stark City (USEPA 2018). Historic mining activities produced approximately 150 million tons of waste that caused contamination of groundwater in the shallow aquifer, surface water, soils, and sediments adjacent to the waste sites (USEPA 2018). The USEPA's investigation of site began in 1986 when a preliminary assessment of the area revealed elevated levels of cadmium, lead, and zinc in the soil and groundwater. In 1989, the MDNR confirmed the USEPA results of elevated lead levels in the soils and groundwater (USEPA 2018).

Further investigation of the site of the site continued in 1995 when elevated blood-lead levels were discovered in children living adjacent to the historic mining sites. This discovery of the elevated blood-lead levels in children led to further investigation into the heavy metal concentrations in residential yard soils and private drinking water well (USEPA 2018). In response to the elevated heavy metals, in 1998 the EPA began to provide bottled water to homes

within the site and began to install access to safe public water supplies by connecting to clean city water or replace contaminated shallow wells with new deep-aquifer wells (USEPA 2018). Removal of hundreds of contaminated residential yard soils began in 1999 and the site was placed on the NPL in 2003 (USEPA 2018).

The first phase of the remediation was completed in Granby in 2017. The first phase included excavation and removal of 771,000 cubic yards of contaminated waste and cleanup of 100 acres of previously contaminated land (USEPA 2018) Remediation continues throughout the Newton County and includes removal of contaminated mining and milling waste in soils and sediments and disposal of the contaminated wastes, soils, and sediments in central repository on site to be capped with 18-inch soil cover. Once mining waste is capped in central repository, revegetation is introduced to reduce mobilization of contaminants in the soils (USEPA 2018). This process is called phytostabilization.

5.4.4 Oronogo- Duenweg Mining Belt Site. The Oronogo-Duenweg Mining Belt Site covered over 250 square miles and included the urban areas of Joplin, Webb City, Carterville, and Duenweg (USEPA 2017). The site initially contained over 150 million tons of surface mining waste and about 2,600 residential yard soils were contaminated with high levels of heavy metals caused from smelter fallout (USEPA 2017). Preliminary Assessment of the site began in 1986 and the site was placed on the NPL in 1990 (ITRC 2017; USEPA 2017). In 1991, a study conducted by the Missouri Department of Health and Senior Service, formally known as the Missouri Department of Health, revealed that approximately fourteen percent of children, under the age of seven, had elevated blood-lead levels that lived within the site. As a result in 1994, the USEPA began removal of contaminated soils in locations of high priorities including daycare, public playgrounds, and homes with young children (USEPA 2017). Additionally, USEPA began

supplying bottled water in homes with contaminated private wells while a public water supply was constructed to these homes (USEPA 2017).

Remediation is on-going throughout the site. To date, over 1,800 acres of contaminated land have been cleaned up, 4 miles of tributary streams have been restored through removal of sediments, millions of tons of mining waste has been excavated and removed to a central repository were it was capped, 2,600 residential yard soils has been removed and replaced, abandoned mines shafts have been plugged, access to safe public drinking water or new deep-aquifer wells have replaced private wells, and phytostabilization has been introduced to reduce heavy metal mobilization (USEPA 2017). Figure 5.2 shows an example of a completed remediation site within the Oronogo- Duenweg Mining Belt Site.

5.5 Post Mining Maps

5.5.1 Mine Concentration and Remaining Chat Piles. Maps were created to document the geographic location of mining concentrations and the remaining chat piles within the surrounding six study areas. Figures 5.3, 5.4, and 5.5 document the remaining that remains in Joplin, Granby, Oronogo respectively. The remaining chat piles were documented using Google Earth and photographs taken in the field. Figures 5.6, 5.7, and 5.8 document the historic excavation, milling, and smelting sites within the six study areas.

5.5.2 ICP Lead Level Maps. Maps were created to document the lead concentration in the surface sediments. Light yellow dots represent concentration levels that fall below the PEC value. Light orange dots represent concentration levels that are up to two times the PEC value. Dark orange dots represent concentration levels that fall up to three times the PEC value. The red dots represent concentration levels that exceed three times the PEC value. Figure 512, 5.13, and 5.14 document the lead levels in the sediment around Joplin, Aurora, and Springfield.

5.5.3 ICP Zinc Levels Maps. Then, maps were to document the zinc concentration in the surface sediment. Light yellow dots represent concentration levels that fall below the PEC value. Light orange dots represent concentration levels that are up to two times the PEC value. Dark orange dots represent concentration levels that fall up to three times the PEC value. The red dots represent concentration levels that exceed three times the PEC value. Figure 515, 5.16, and 5.17 document the zinc levels in the sediment around Joplin, Aurora, and Springfield.

5.6 Discussion

Completed remedial actions at the Missouri Superfund Sites of the TSMD include the removal and replacement of contaminated soils in daycares, playgrounds, and residential yards, installing access to safe public water supplies or replacing contaminated shallow wells with deep-aquifer wells to replace private wells that were contaminated by mining waste, filling-in sink holes and mine shafts that were caused by historic mining activities with mining waste from chat piles that was abandoned around the district, removal of remaining chat piles and other mining waste that is placed in a central disposal that was capped to prevent further leaching of heavy metals into the ecosystem, and phytostabilization (USEPA 2018; USEPA 2017; ITRC 2017).

Removal of the chat piles throughout the district decreased the amount of heavy metals that can dispersed from the chat piles into the surrounding ecosystem. This dispersion of heavy metal contaminants from chat piles occurs from leaching, wind dispersion, erosion, and migration into the surrounding surface water, ground-water, and soils (ITRC 2017; Lambert et al. 2005). Physical removal of chat piles permits the removal of the source of contamination. Therefore, eliminating further contaminants dispersing into the local environment. Additionally,

some chat piles in the TSMD have been repurposed to fill-in sinkholes and mine shafts that were still exposed and continued to provide physical hazards. The disadvantages of excavation and removal of chat piles is the high cost of completing the remediation and the risk of spreading contaminants further through dust and soil particles that are circulating during the excavation process (Lambert et al. 2005).

Phytostabilization is a common method of remediation used in the Missouri portion of the TSMD (USEPA 2018; USEPA 2017). Phytostabilization is an in-situ method of remediation that uses plants to limit the mobility of the heavy metals. Reduced mobilization of heavy metals, reduces their bioavailability (Bolan et at. 2011). By using carefully chosen vegetation, the plants allow the contaminants to accumulate in their roots, shoots, and rhizosphere region. Therefore, the amount of contaminants leaching into the ecosystem is reduced. According to Bolen et al. (2011) the goal of phytostabilization is to contain the contaminants within the vadose zone of the soil. Additionally, phytostabilization reduces the spread of contaminants by reducing erosion and decreasing wind-blown dust that can further disperse contaminants. Phytostabilization has many advantages as a method of remediation. The initial cost phytostabilization is very small compared to many remediation methods (Bolan et at. 2011; Lambert et al. 2005). However, phytostabilization still has setup cost and on-going monitoring cost. This is because phytostabilization does not remove contaminants from the sites so contaminated sites requires regular monitoring to ensure contaminants are not remobilized. Additionally, with phytostabilization, any future land-use of these contaminated sites are limited because they are unsuitable for development. Although phytostabilization provides an effective, low cost method for remediation of heavy metals, phytostabilization is most effective if used in combination with soil amendments or other remediation methods (Bolan et al. 2011).

Figure 5.2. Before and after excavation and removal of mining waste and introduction of phytostabilization at Oronogo–Duenweg Mining Belt Site. Photos by MDNR (2017).

Figure 5.3 Chat Piles that remain in Joplin, Missouri 2019. Image taken from Google Earth.

Figure 5.4. Chat Piles that remain in Granby, Missouri 2019.

Figure 5.5. Chat Piles that remain in Oronogo, Missouri 2019. Image taken from Google Earth

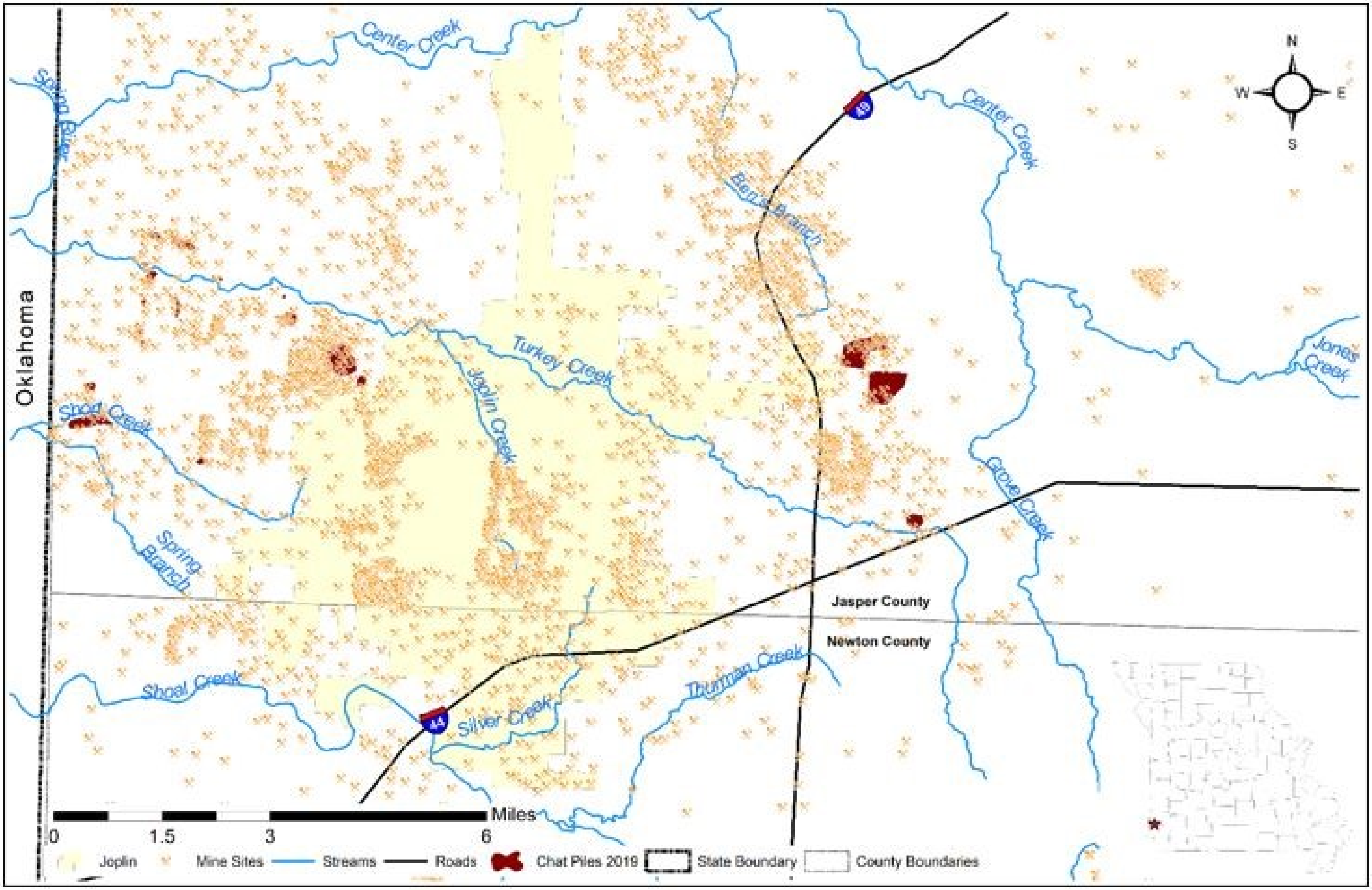

Figure 5.6. Map of Joplin, Missouri and surrounding area with historic lead and zinc mine locations and remaining chat piles.

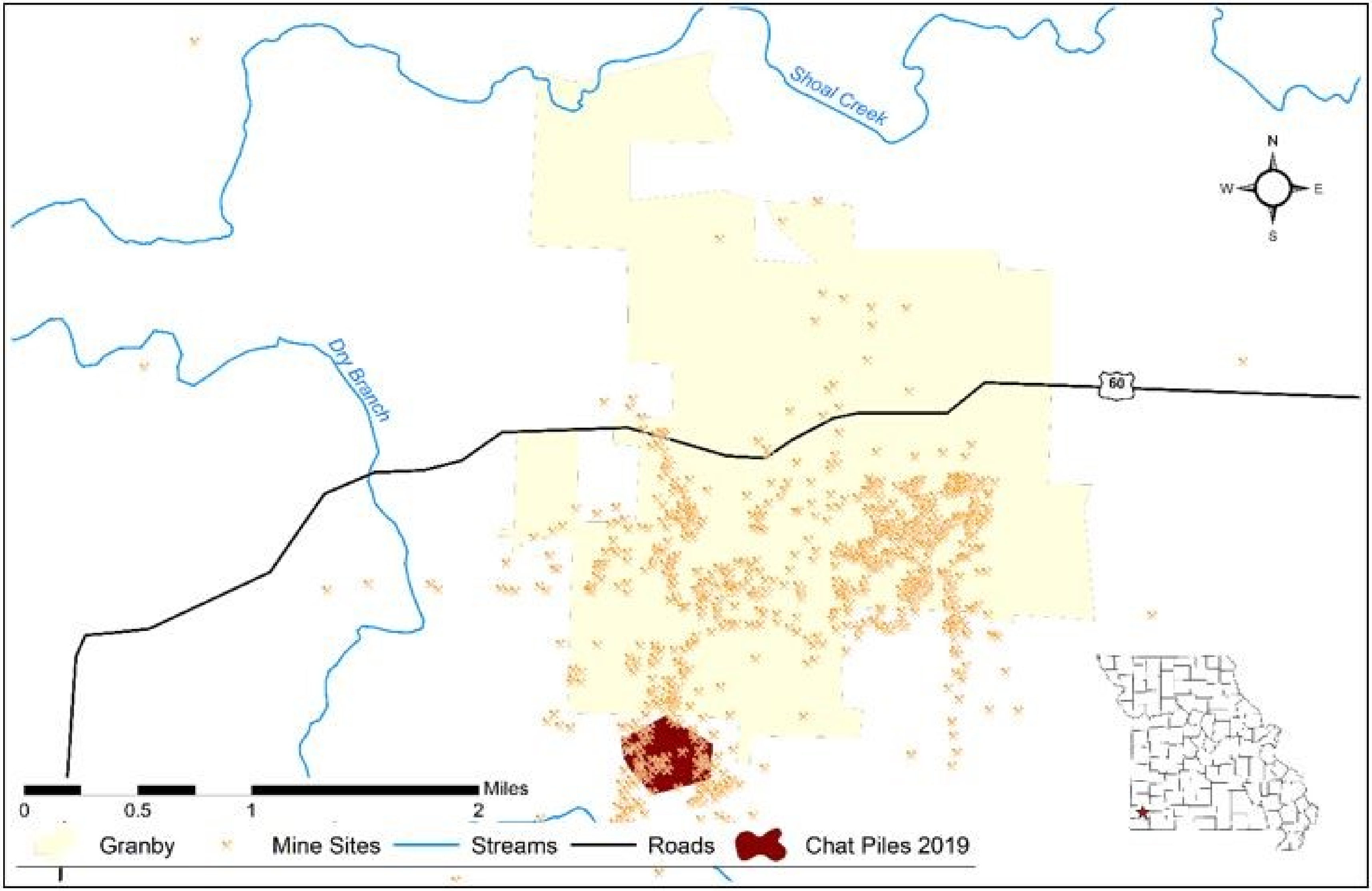

Figure 5.7. Map of Granby, Missouri and surrounding area with historic lead and zinc mine locations.

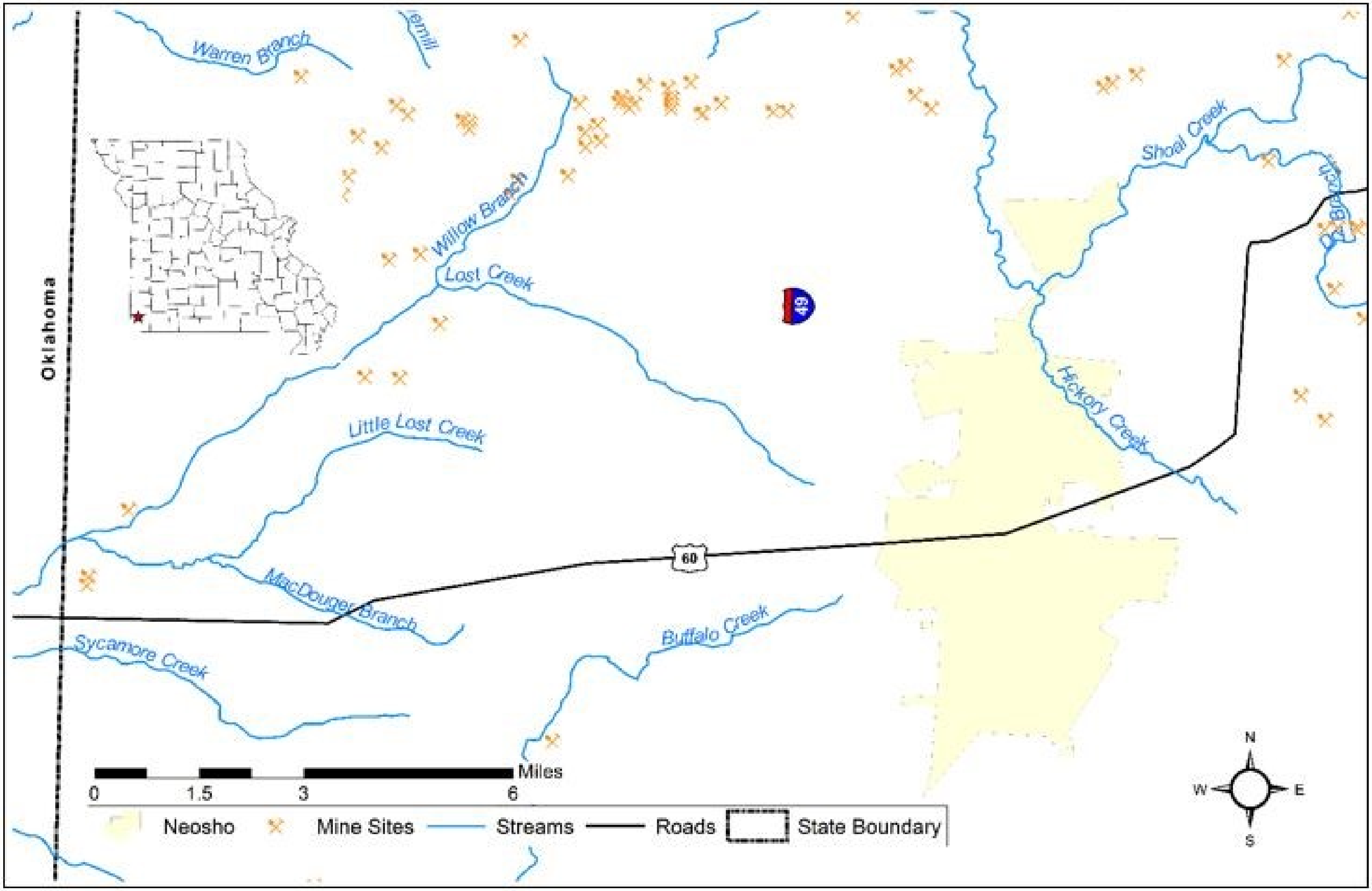

Figure 5.8. Map of Neosho, Missouri and surrounding area with historic lead and zinc mine locations. Note: there are no more chat piles remaining (2019)

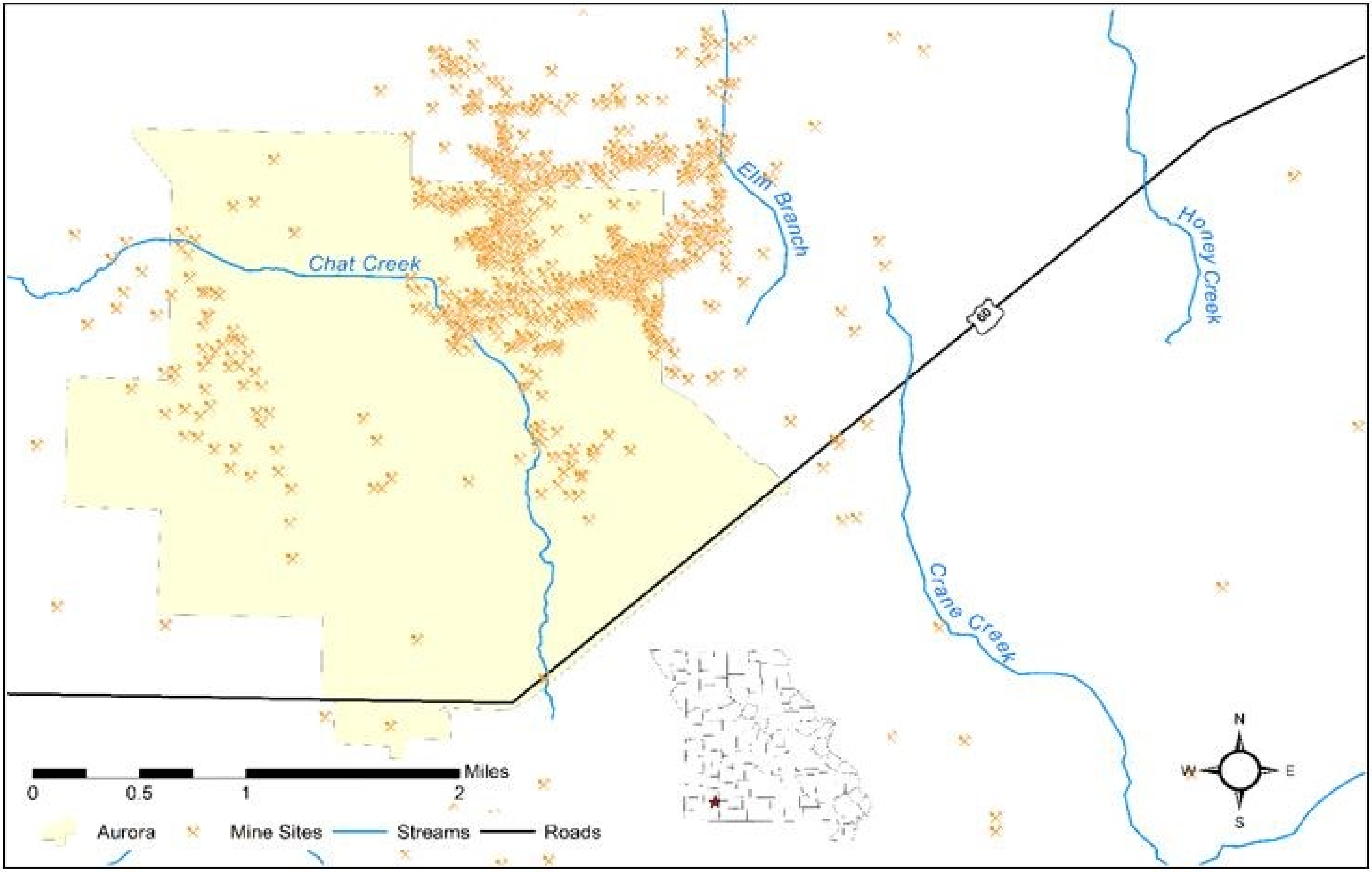

Figure 5.9. Map of Aurora, Missouri and surrounding area with historic lead and zinc mine locations. Note: there are no more chat piles remaining (2019)

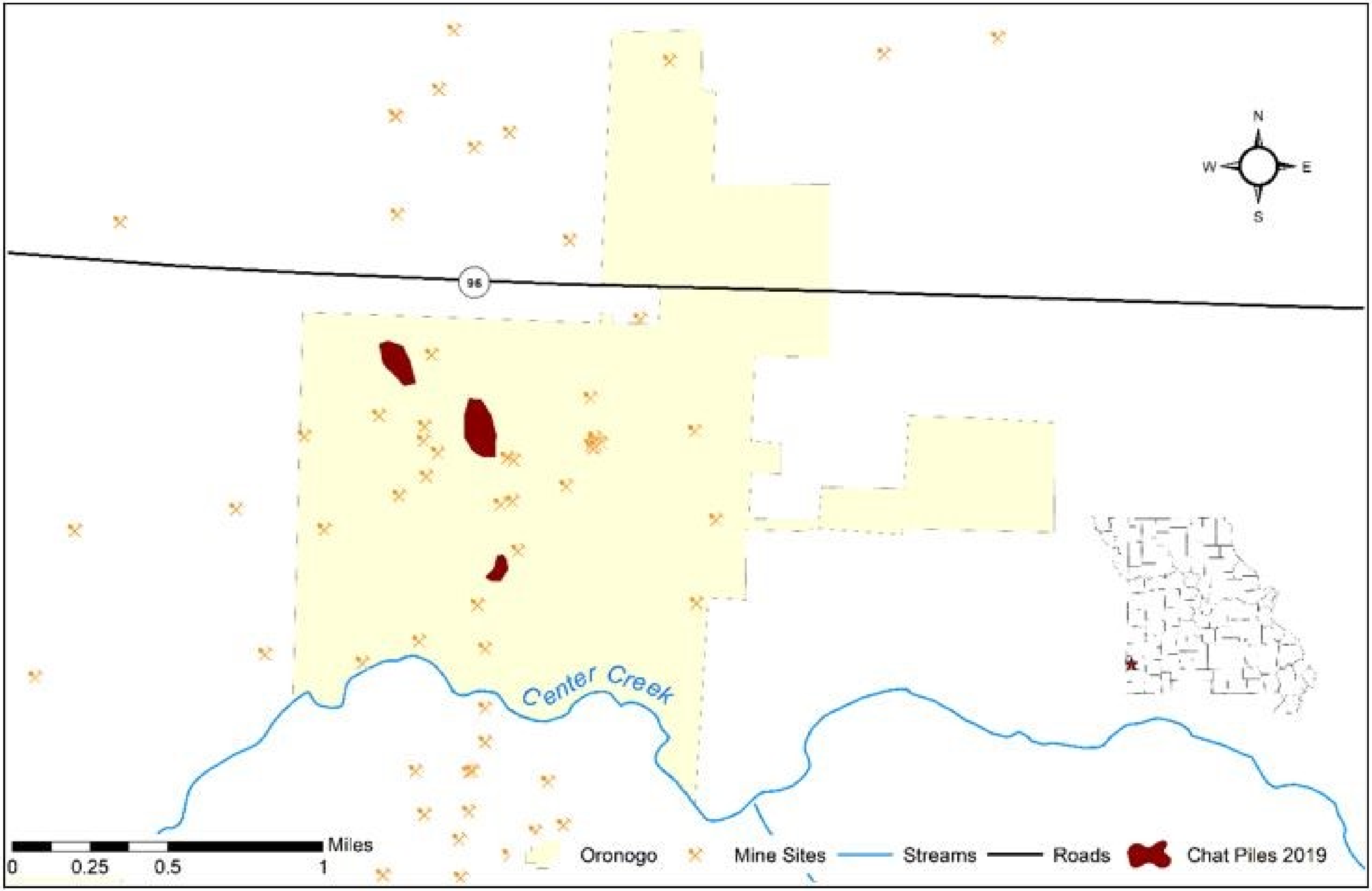

Figure 5.10. Map of Oronogo, Missouri and surrounding area with historic lead and zinc mine locations and remaining hat piles.

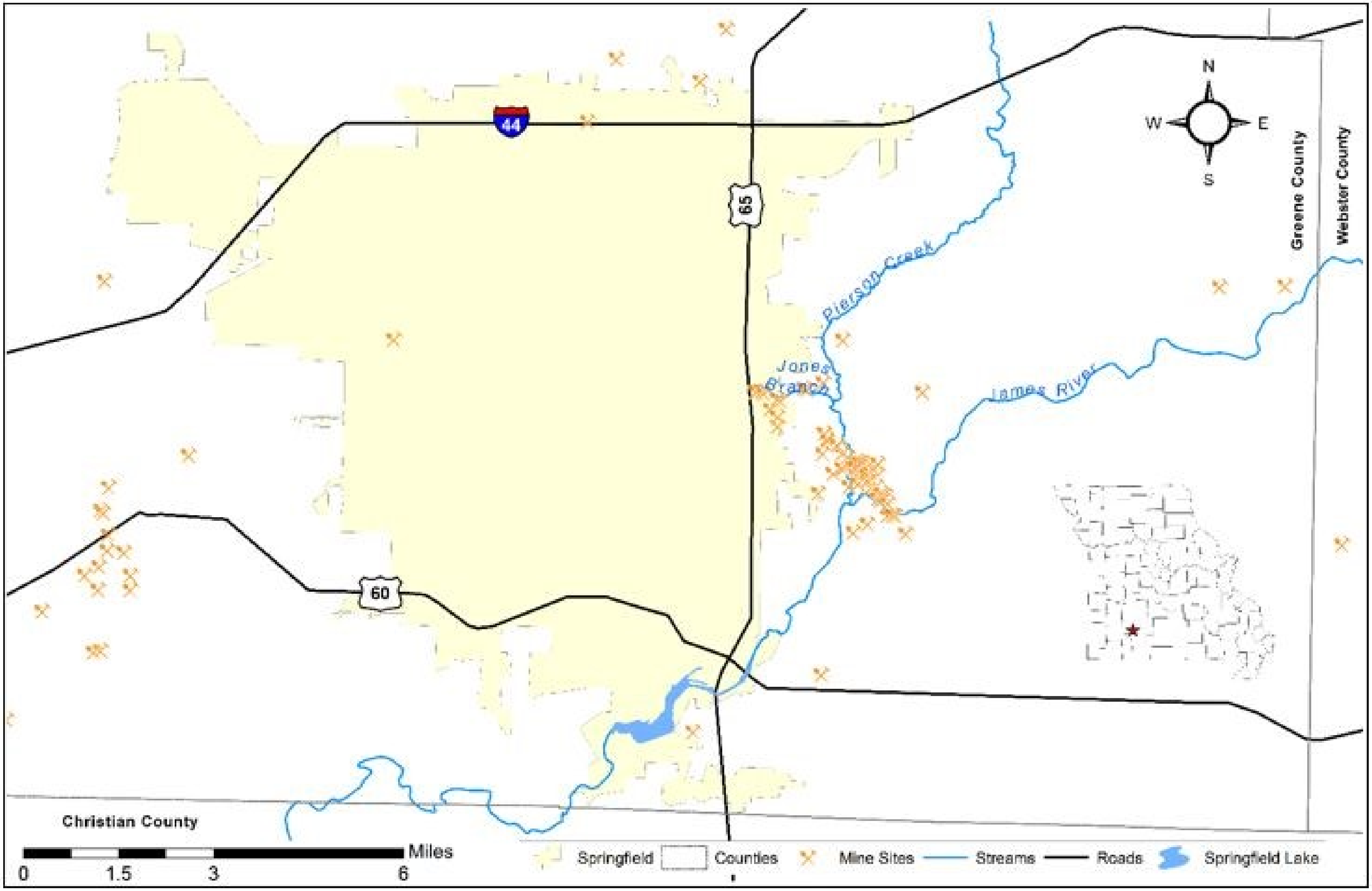

Figure 5.11. Map of Springfield, Missouri and surrounding area with historic lead and zinc mine locations. Note: there are no more chat piles remaining (2019)

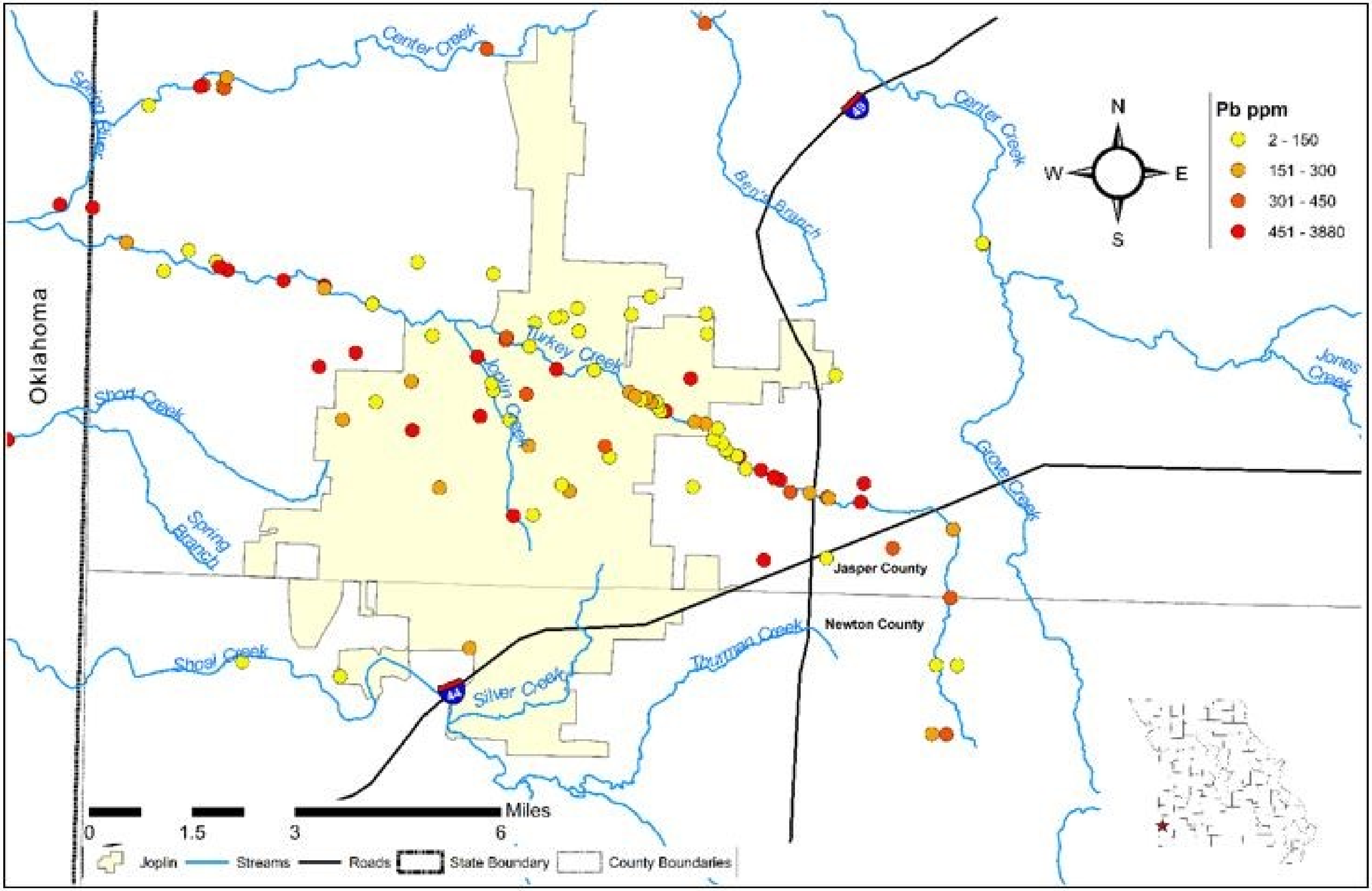

Figure 5.12. Lead levels documented in the Joplin area.

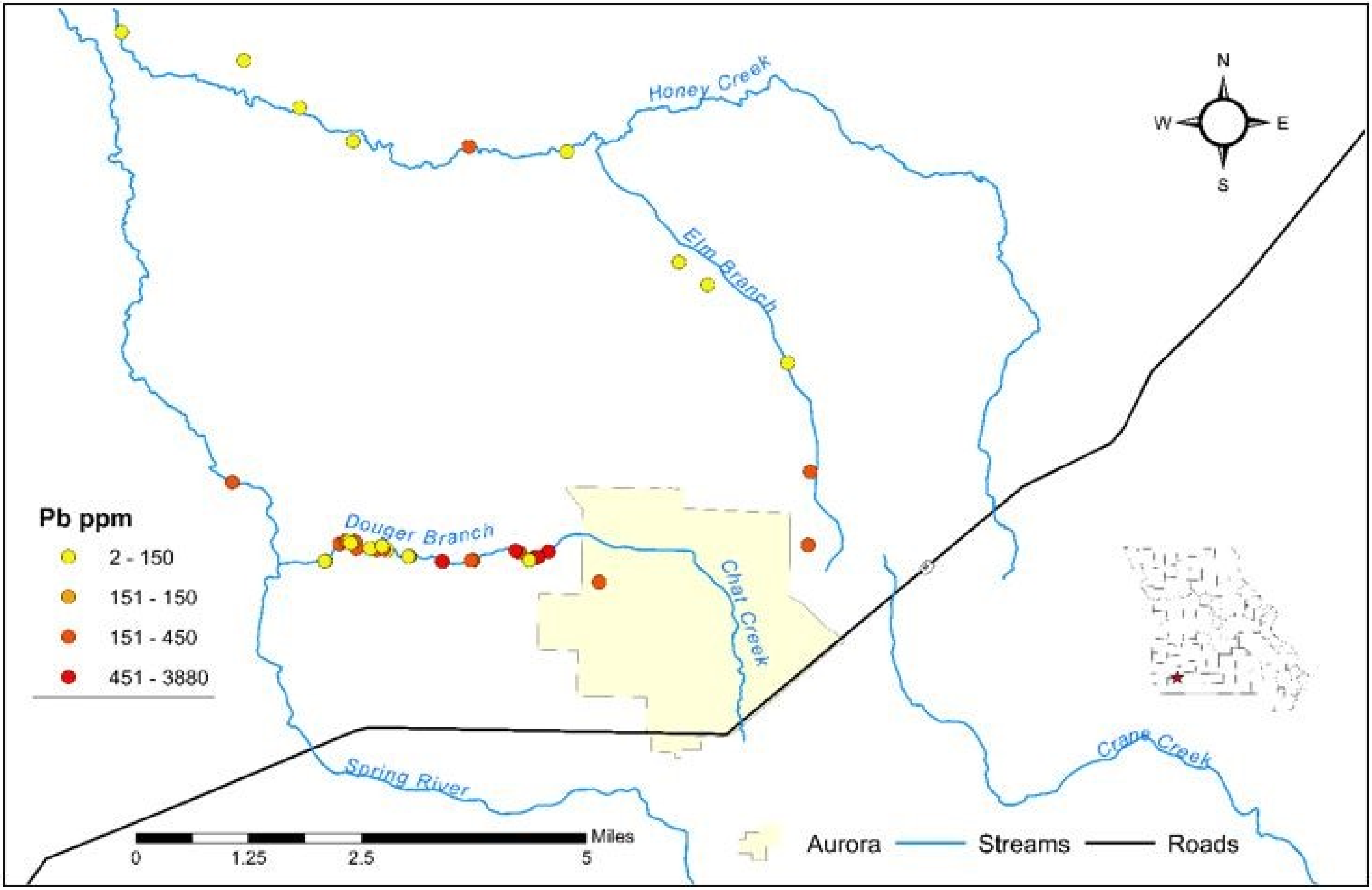

Figure 5.13. Lead levels documented in the Aurora area.

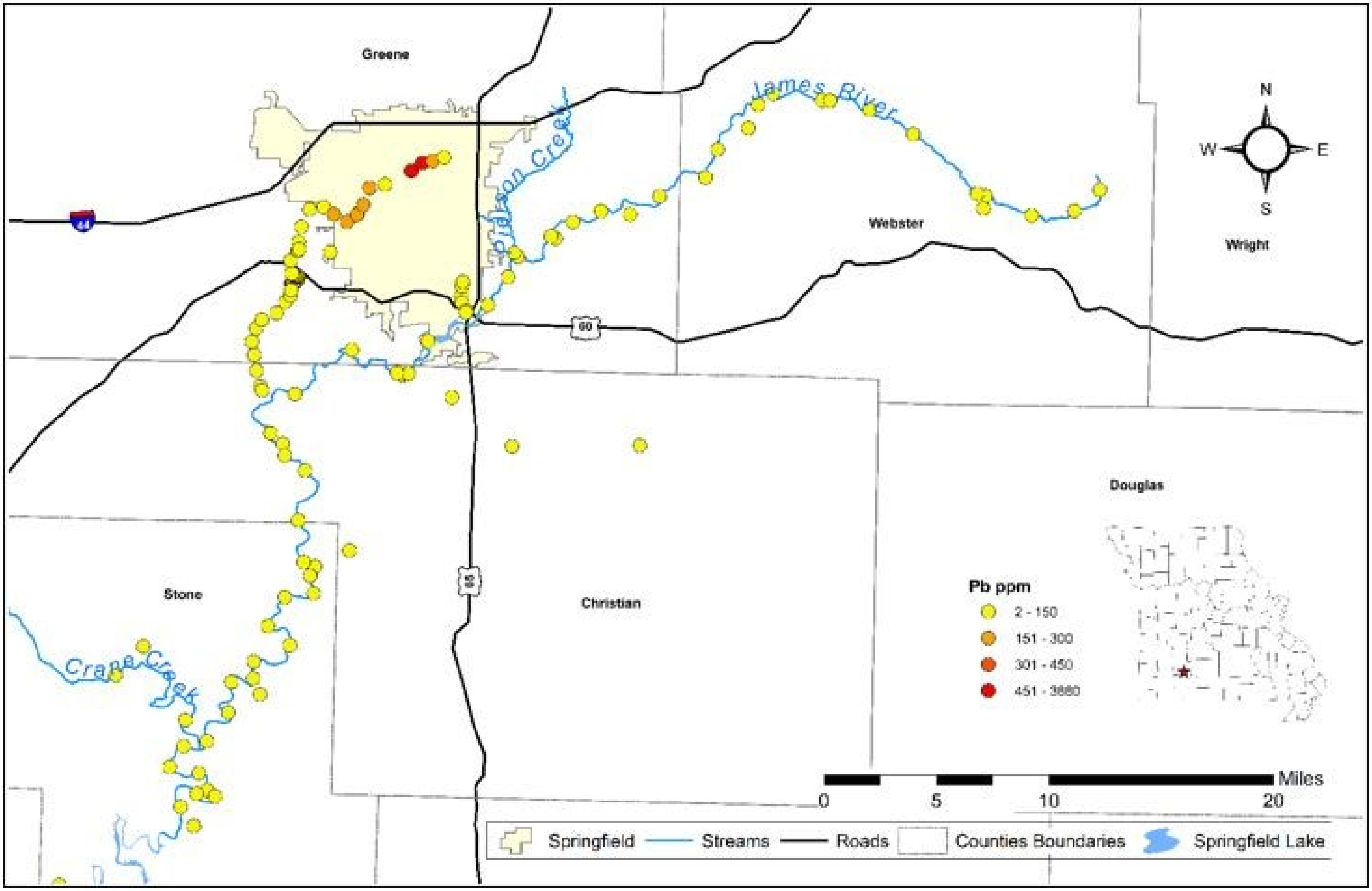

Figure 5.14. Lead levels documented in the Springfield area.

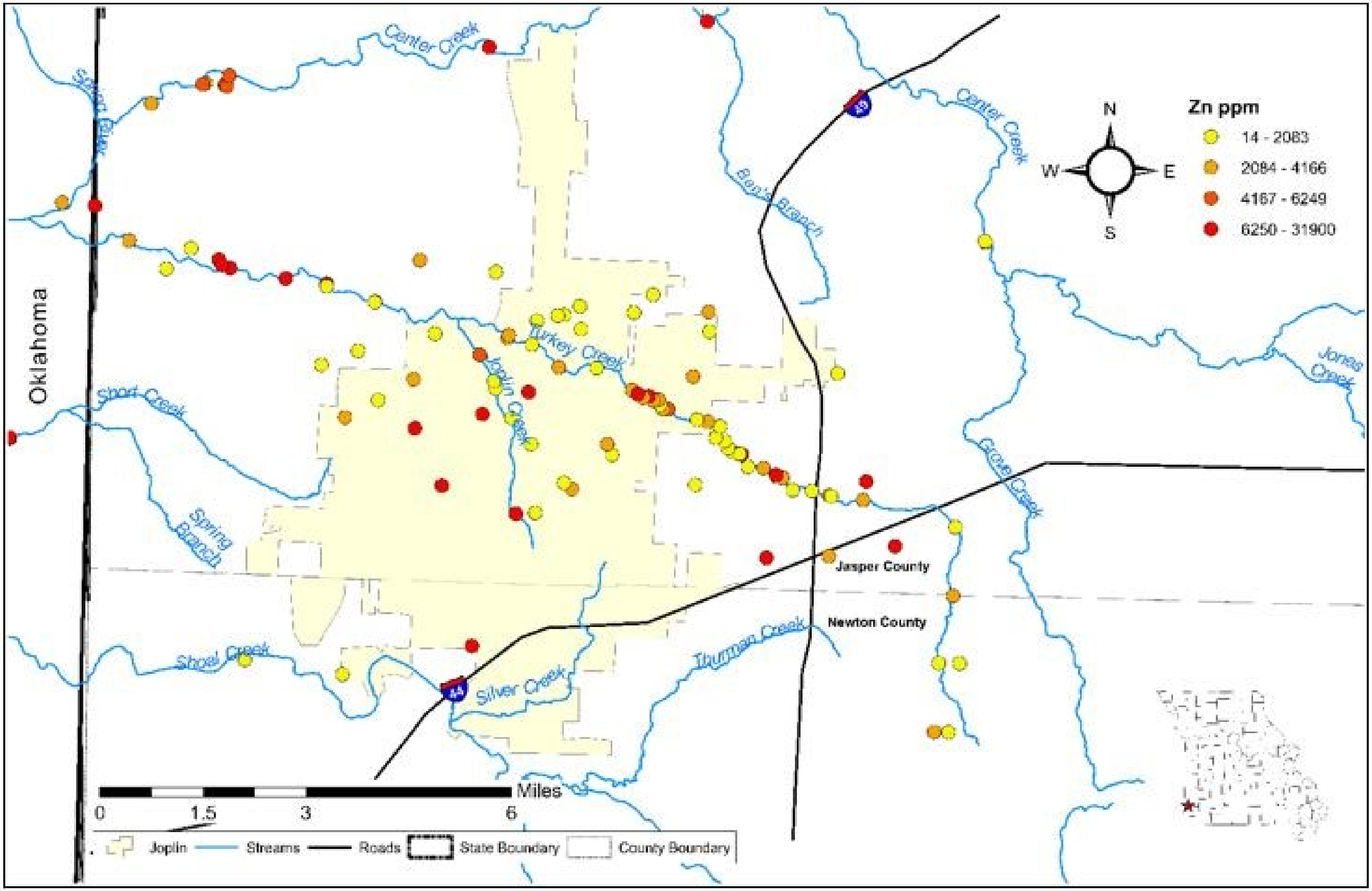

Figure 5.15. Zinc levels documented in the Joplin area.

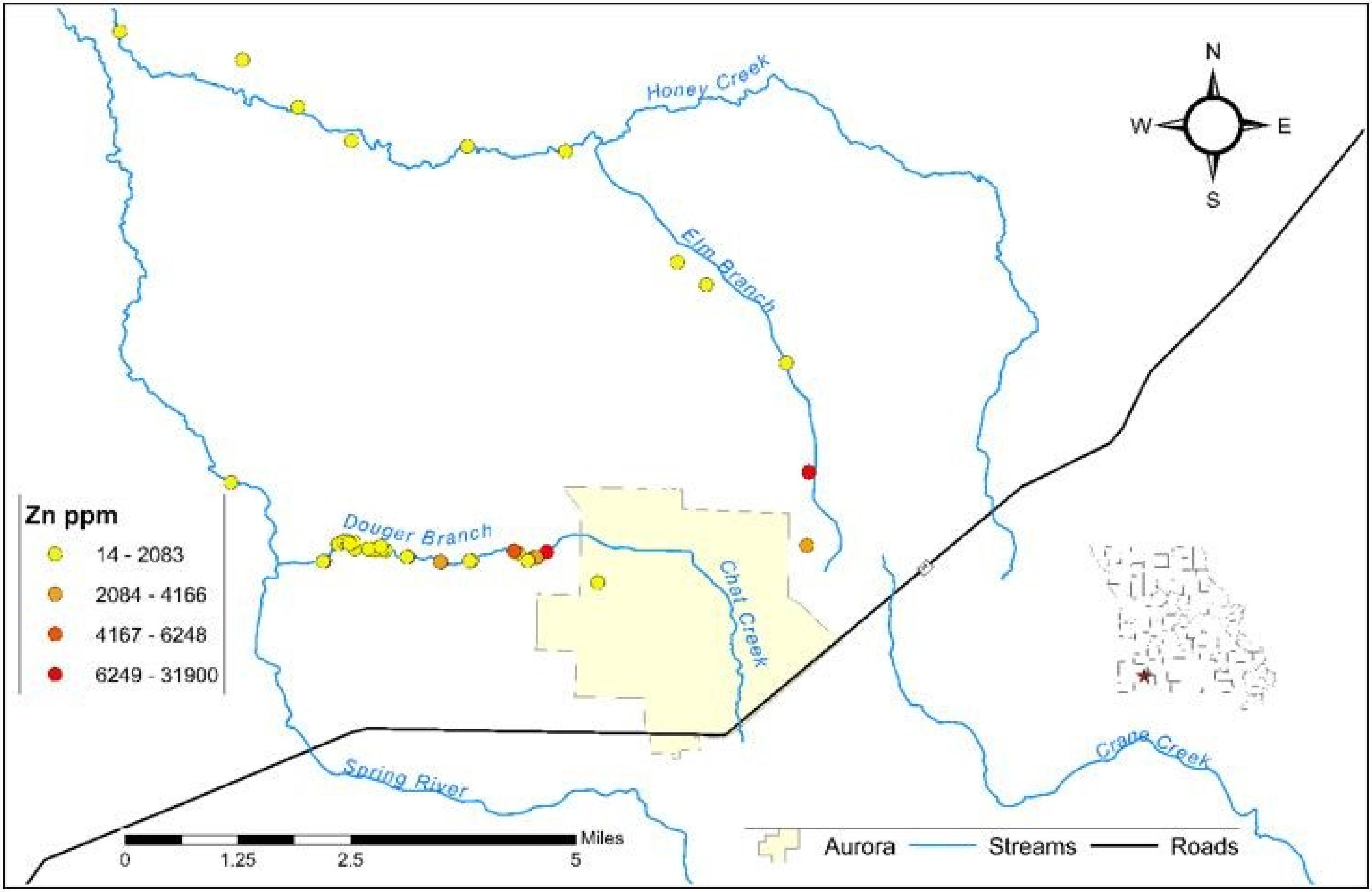

Figure 5.16. Zinc levels documented in the Aurora area.

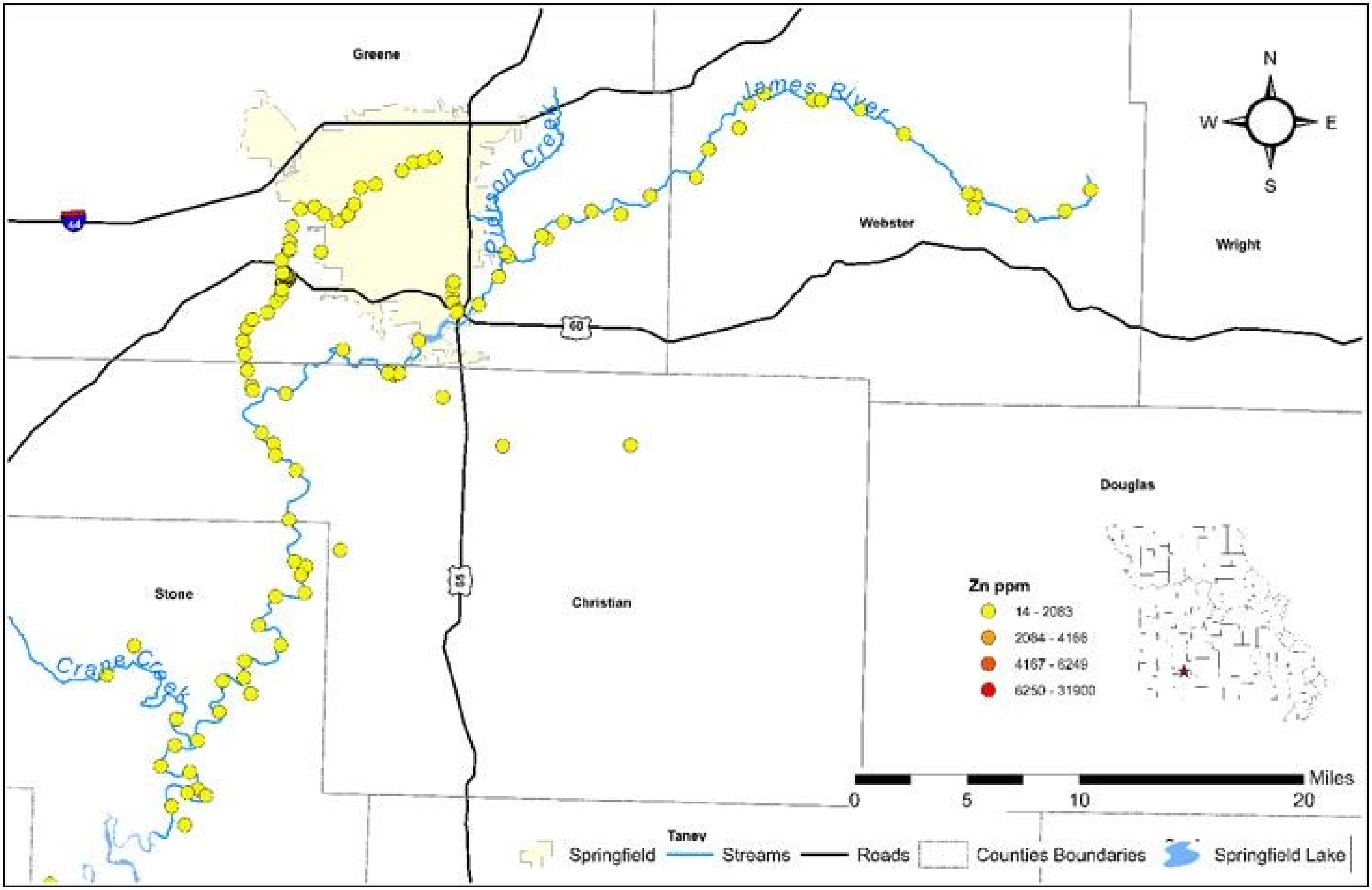

Figure 5.17. Zinc levels documented in the Springfield area.

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Appendix

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
464410.37	4103863.55	63	194	Rodgers, W.E (2005)
464131.76	4104983.75	55	193	Rodgers, W.E (2005)
463979.33	4106125.18	70	212	Rodgers, W.E (2005)
463812.23	4107067.42	79	254	Rodgers, W.E (2005)
464112.67	4108017.66	73	257	Rodgers, W.E (2005)
464512.82	4108630.78	66	195	Rodgers, W.E (2005)
465570.48	4109109.65	73	241	Rodgers, W.E (2005)
466190.01	4109895.02	86	261	Rodgers, W.E (2005)
466556.26	4110375.59	119	368	Rodgers, W.E (2005)
466624.98	4111243.74	182	245	Rodgers, W.E (2005)
466681.94	4111274.36	183	381	Rodgers, W.E (2005)
466782.46	4111272.18	191	342	Rodgers, W.E (2005)
466871.75	4111327.19	108	313	Rodgers, W.E (2005)
466959.17	4111382.76	80	137	Rodgers, W.E (2005)
467051.91	4111458.61	56	118	Rodgers, W.E (2005)
467076.65	4111493.68	73	152	Rodgers, W.E (2005)
467096.53	4111536.98	83	214	Rodgers, W.E (2005)
467139.20	4111615.91	74	209	Rodgers, W.E (2005)
467137.67	4111702.23	68	166	Rodgers, W.E (2005)
467112.17	4111766.01	94	336	Rodgers, W.E (2005)
467059.90	4111797.83	153	338	Rodgers, W.E (2005)
466950.34	4111802.92	88	307	Rodgers, W.E (2005)
466851.00	4111855.78	53	164	Rodgers, W.E (2005)
466759.75	4111910.28	91	315	Rodgers, W.E (2005)
466667.07	4111961.79	104	339	Rodgers, W.E (2005)
466582.05	4112869.05	93	287	Rodgers, W.E (2005)
467104.56	4113570.23	71	252	Rodgers, W.E (2005)
467150.27	4114204.07	85	268	Rodgers, W.E (2005)
467342.28	4115297.84	120	356	Rodgers, W.E (2005)
471388.85	4116219.54	199	367	Rodgers, W.E (2005)
467939.17	4116520.87	122	367	Rodgers, W.E (2005)
468950.46	4116684.48	147	416	Rodgers, W.E (2005)
469676.65	4116180.50	185	351	Rodgers, W.E (2005)
470630.70	4115630.74	152	459	Rodgers, W.E (2005)
471326.23	4116154.19	159	468	Rodgers, W.E (2005)
471793.84	4116858.07	155	309	Rodgers, W.E (2005)
472243.44	4118070.69	196	492	Rodgers, W.E (2005)
473337.36	4118300.12	150	582	Rodgers, W.E (2005)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
475213.91	4119286.17	710	513	Rodgers, W.E (2005)
475992.37	4119855.13	775	329	Rodgers, W.E (2005)
476757.89	4119985.00	195	438	Rodgers, W.E (2005)
477574.39	4120244.26	63	282	Rodgers, W.E (2005)
438403.48	4092718.51	252	3140	Carlson, J.L. (1999)
438444.58	4094027.32	434	31900	Carlson, J.L. (1999)
438037.07	4095971.77	16	178	Carlson, J.L. (1999)
562365.95	4096821.54	40	1265	Carlson, J.L. (1999)
436610.57	4097365.00	30	594	Carlson, J.L. (1999)
436097.67	4097770.46	26	330	Carlson, J.L. (1999)
434098.19	4099742.05	22	200	Carlson, J.L. (1999)
432348.42	4099835.42	300	188	Carlson, J.L. (1999)
430279.97	4099931.76	24	152	Carlson, J.L. (1999)
429326.00	4100531.35	28	122	Carlson, J.L. (1999)
428334.19	4101371.78	20	118	Carlson, J.L. (1999)
426148.16	4101878.76	34	266	Carlson, J.L. (1999)
423976.38	4103763.81	18	66	Carlson, J.L. (1999)
366166.37	4103677.44	846	17900	Peebles, J.P. (2014)
365137.21	4100577.23	274	9260	Peebles, J.P. (2014)
364429.51	4104333.91	243	11100	Peebles, J.P. (2014)
363794.66	4105681.37	1115	28900	Peebles, J.P. (2014)
365382.43	4106011.02	947	13850	Peebles, J.P. (2014)
366068.62	4105924.31	125	221	Peebles, J.P. (2014)
366522.68	4105314.20	239	1890	Peebles, J.P. (2014)
367176.34	4107110.86	596	3450	Peebles, J.P. (2014)
368936.92	4108390.92	97	579	Peebles, J.P. (2014)
366663.11	4108197.29	67	706	Peebles, J.P. (2014)
365694.86	4109346.36	79	629	Peebles, J.P. (2014)
363916.04	4109622.80	145	3120	Peebles, J.P. (2014)
364265.97	4107898.82	82	325	Peebles, J.P. (2014)
363768.69	4106826.72	263	3820	Peebles, J.P. (2014)
362158.49	4105935.43	269	3670	Peebles, J.P. (2014)
361605.28	4107168.99	1715	460	Peebles, J.P. (2014)
360769.10	4109195.09	519	7930	Peebles, J.P. (2014)
359460.80	4109438.75	612	8110	Peebles, J.P. (2014)
357964.56	4109421.31	123	974	Peebles, J.P. (2014)
352692.70	4108216.94	1385	5810	Peebles, J.P. (2014)
356293.84	4110899.69	1185	8450	Peebles, J.P. (2014)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
357091.52	4110083.41	238	2220	Peebles, J.P. (2014)
354295.15	4105447.88	410	4450	Peebles, J.P. (2014)
354283.71	4105470.28	3880	9230	Peebles, J.P. (2014)
355523.45	4110972.12	664	4010	Peebles, J.P. (2014)
357613.84	4113294.86	150	2120	Peebles, J.P. (2014)
358545.80	4109899.85	123	1210	Peebles, J.P. (2014)
367293.40	4108337.16	93	546	Peebles, J.P. (2014)
370691.01	4108413.78	140	3480	Peebles, J.P. (2014)
370712.04	4107947.38	93	857	Peebles, J.P. (2014)
368890.96	4106577.24	288	3570	Peebles, J.P. (2014)
369531.08	4106295.44	168	1225	Peebles, J.P. (2014)
368418.42	4105060.62	73	1755	Peebles, J.P. (2014)
370376.89	4104353.40	51	286	Peebles, J.P. (2014)
371259.93	4105118.57	130	1530	Peebles, J.P. (2014)
372298.75	4104538.63	57	317	Peebles, J.P. (2014)
373720.72	4106969.67	34	342	Peebles, J.P. (2014)
374313.45	4103997.95	936	3810	Peebles, J.P. (2014)
373517.87	4104107.92	336	2170	Peebles, J.P. (2014)
376479.66	4103361.22	242	1230	Peebles, J.P. (2014)
376576.86	4100169.51	61	284	Peebles, J.P. (2014)
376318.92	4098553.16	304	470	Peebles, J.P. (2014)
375979.55	4098563.68	224	2720	Peebles, J.P. (2014)
376087.68	4100174.88	35	324	Peebles, J.P. (2014)
374388.13	4104433.39	685	6520	Peebles, J.P. (2014)
373509.86	4102682.09	114	3770	Peebles, J.P. (2014)
376420.58	4101753.07	312	2690	Peebles, J.P. (2014)
375063.65	4102915.98	367	7140	Peebles, J.P. (2014)
372043.29	4102641.25	1285	7360	Peebles, J.P. (2014)
370324.07	4106893.56	1075	2180	Peebles, J.P. (2014)
369384.84	4108809.44	130	1205	Peebles, J.P. (2014)
362863.50	4108648.39	120	2020	Peebles, J.P. (2014)
362855.85	4108637.42	99	364	Peebles, J.P. (2014)
362464.05	4107500.75	893	307	Peebles, J.P. (2014)
367476.71	4104257.81	208	3840	Peebles, J.P. (2014)
366621.66	4103699.76	69	368	Peebles, J.P. (2014)
367298.16	4104399.33	53	313	Peebles, J.P. (2014)
365689.95	4106620.25	41	225	Peebles, J.P. (2014)
365655.68	4106790.92	96	1990	Peebles, J.P. (2014)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
362934.12	4106342.73	124	1410	Peebles, J.P. (2014)
366466.35	4106530.25	395	9170	Peebles, J.P. (2014)
366543.29	4107646.09	98	710	Peebles, J.P. (2014)
367150.98	4108322.76	69	631	Peebles, J.P. (2014)
367668.39	4108542.12	41	1065	Peebles, J.P. (2014)
367698.42	4108003.43	47	257	Peebles, J.P. (2014)
368061.89	4107091.42	75	382	Peebles, J.P. (2014)
368312.62	4105306.40	311	2600	Peebles, J.P. (2014)
336963.40	4093768.56	172	2850	Peebles, J.P. (2014)
333818.74	4092573.54	14	35	Peebles, J.P. (2014)
365317.32	4107406.67	793	4430	Peebles, J.P. (2014)
524500.38	4117927.11	20	28	Frederick, B.S. (2001)
522680.52	4116412.02	24	48	Frederick, B.S. (2001)
519624.25	4116096.15	24	54	Frederick, B.S. (2001)
516318.00	4117475.81	30	64	Frederick, B.S. (2001)
515726.03	4117659.61	24	78	Frederick, B.S. (2001)
511135.74	4121904.86	24	74	Frederick, B.S. (2001)
508029.83	4123688.64	18	48	Frederick, B.S. (2001)
504630.30	4124333.29	14	28	Frederick, B.S. (2001)
500049.30	4124023.82	12	52	Frederick, B.S. (2001)
492999.53	4117462.890	10	22	Frederick, B.S. (2001)
488783.02	4116388.93	12	26	Frederick, B.S. (2001)
496278.56	4118816.67	10	26	Frederick, B.S. (2001)
497141.82	4120819.42	20	36	Frederick, B.S. (2001)
499334.85	4122328.94	42	74	Frederick, B.S. (2001)
516147.12	4116581.88	16	24	Frederick, B.S. (2001)
505196.80	4124302.78	26	42	Frederick, B.S. (2001)
501132.90	4124825.10	8	14	Frederick, B.S. (2001)
490878.25	4116170.62	16	32	Frederick, B.S. (2001)
486784.94	4115621.37	14	34	Frederick, B.S. (2001)
485550.17	4114452.46	26	150	Frederick, B.S. (2001)
485229.89	4114607.10	20	44	Frederick, B.S. (2001)
482835.10	4113132.41	12	54	Frederick, B.S. (2001)
482589.03	4113410.26	118	1100	Frederick, B.S. (2001)
482141.46	4111685.57	6	264	Frederick, B.S. (2001)
479200.17	4109288.65	42	144	Frederick, B.S. (2001)
480706.23	4109685.67	14	40	Frederick, B.S. (2001)
476430.63	4107108.048740	16	46	Frederick, B.S. (2001)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
478123.12	4103066.64	56	84	Frederick, B.S. (2001)
469395.24	4113478.72	16	78	Frederick, B.S. (2001)
467176.43	4113672.01	66	220	Frederick, B.S. (2001)
466622.30	4110746.63	118	224	Frederick, B.S. (2001)
464519.82	4103575.09	78	236	Frederick, B.S. (2001)
474720.57	4104709.34	22	88	Frederick, B.S. (2001)
474473.68	4104710.08	10	64	Frederick, B.S. (2001)
475016.97	4104770.14	20	94	Frederick, B.S. (2001)
474202.37	4104803.43	10	46	Frederick, B.S. (2001)
470974.11	4106477.96	34	98	Frederick, B.S. (2001)
466889.17	4103318.97	14	48	Frederick, B.S. (2001)
465149.26	4100521.70	42	160	Frederick, B.S. (2001)
467125.75	4094289.06	42	134	Frederick, B.S. (2001)
411769.72	4100602.01	20	48	Frederick, B.S. (2001)
413657.38	4101599.60	18	32	Frederick, B.S. (2001)
415235.94	4103833.35	14	58	Frederick, B.S. (2001)
417569.25	4107601.08	14	88	Frederick, B.S. (2001)
482436.94	4099574.43	12	32	Frederick, B.S. (2001)
470801.16	4092118.47	40	108	Frederick, B.S. (2001)
468324.47	4090956.44	2	38	Frederick, B.S. (2001)
428488.84	4105868.10	22	28	Frederick, B.S. (2001)
491576.73	4099622.07	10	28	Frederick, B.S. (2001)
467975.84	4090310.56	34	56	Frederick, B.S. (2001)
468218.42	4089046.21	20	66	Frederick, B.S. (2001)
466164.44	4088776.82	14	66	Frederick, B.S. (2001)
464379.19	4081820.00	8	34	Frederick, B.S. (2001)
459656.06	4072411.72	14	32	Frederick, B.S. (2001)
464968.74	4086717.06	16	66	Frederick, B.S. (2001)
466521.88	4085324.12	14	39	Frederick, B.S. (2001)
463943.55	4084163.76	14	52	Frederick, B.S. (2001)
463913.68	4082962.03	12	66	Frederick, B.S. (2001)
462353.30	4082722.30	16	52	Frederick, B.S. (2001)
462120.79	4080535.49	12	60	Frederick, B.S. (2001)
460576.27	4078477.91	12	48	Frederick, B.S. (2001)
458940.02	4078115.90	16	60	Frederick, B.S. (2001)
457942.13	4076641.57	16	70	Frederick, B.S. (2001)
460020.78	4076200.15	18	48	Frederick, B.S. (2001)
456054.61	4085248.56	10	52	Frederick, B.S. (2001)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
459072.89	4079994.93	10	44	Frederick, B.S. (2001)
454088.62	4083194.32	2	74	Frederick, B.S. (2001)
429222.15	4075352.54	12	234	Frederick, B.S. (2001)
434209.59	4073124.66	20	132	Frederick, B.S. (2001)
444879.21	4067563.85	10	48	Frederick, B.S. (2001)
450015.75	4068179.45	12	34	Frederick, B.S. (2001)
460609.51	4074964.82	12	50	Frederick, B.S. (2001)
461177.36	4074530.80	12	46	Frederick, B.S. (2001)
459865.16	4074721.80	8	34	Frederick, B.S. (2001)
458720.88	4073772.02	4	32	Frederick, B.S. (2001)
466010.63	4099747.74	24	88	Frederick, B.S. (2001)
466155.45	4098915.14	18	66	Frederick, B.S. (2001)
467608.88	4097830.93	24	94	Frederick, B.S. (2001)
467509.74	4091298.43	12	90	Frederick, B.S. (2001)
478876.09	4111218.43	104	177	Emily, SGF
478786.82	4110328.94	50	501	Emily, SGF
478854.02	4109853.96	26	605	Emily, SGF
479175.94	4109294.04	37	446	Emily, SGF
479127.63	4109155.49	60	252	Emily, SGF
478844.53	4111027.70	59	218	Emily, SGF
478900.39	4111347.06	107	181	Emily, SGF
433764.93	4092605.60	1365	7030	Trimble, J.C. (2001)
433589.40	4092507.58	1065	6910	Trimble, J.C. (2001)
433528.70	4092500.32	822	5560	Trimble, J.C. (2001)
433528.70	4092500.32	788	5220	Trimble, J.C. (2001)
433528.70	4092500.32	774	5360	Trimble, J.C. (2001)
433257.64	4092580.41	206	916	Trimble, J.C. (2001)
433188.22	4092618.45	246	1035	Trimble, J.C. (2001)
433188.22	4092618.45	384	2440	Trimble, J.C. (2001)
433188.22	4092618.45	312	1820	Trimble, J.C. (2001)
432425.26	4092447.15	550	2980	Trimble, J.C. (2001)
432425.26	4092447.15	324	2470	Trimble, J.C. (2001)
432425.26	4092447.15	246	1780	Trimble, J.C. (2001)
431875.48	4092424.77	310	1590	Trimble, J.C. (2001)
431287.48	4092518.19	384	1305	Trimble, J.C. (2001)
430889.70	4092632.72	60	286	Trimble, J.C. (2001)
430822.97	4092646.95	256	994	Trimble, J.C. (2001)
430582.91	4092661.41	160	1095	Trimble, J.C. (2001)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
430337.80	4092661.41	180	1140	Trimble, J.C. (2001)
430337.80	4092661.41	194	784	Trimble, J.C. (2001)
430337.80	4092661.41	396	730	Trimble, J.C. (2001)
430038.26	4092739.09	194	538	Trimble, J.C. (2001)
430146.15	4092794.74	246	786	Trimble, J.C. (2001)
430146.15	4092794.74	192	454	Trimble, J.C. (2001)
430146.15	4092794.74	198	1100	Trimble, J.C. (2001)
429792.27	4092440.57	214	1270	Trimble, J.C. (2001)
429792.27	4092440.57	148	940	Trimble, J.C. (2001)
433575.55	4092507.67	460	3490	Trimble, J.C. (2001)
433182.51	4092620.88	594	4730	Trimble, J.C. (2001)
432386.56	4092444.48	394	620	Trimble, J.C. (2001)
431867.89	4092430.19	622	4150	Trimble, J.C. (2001)
431268.84	4092515.96	112	578	Trimble, J.C. (2001)
430700.22	4092642.59	314	1890	Trimble, J.C. (2001)
430584.82	4092660.80	64	126	Trimble, J.C. (2001)
430314.61	4092783.23	204	1135	Trimble, J.C. (2001)
430217.30	4092795.34	140	946	Trimble, J.C. (2001)
429774.07	4092433.58	146	1160	Trimble, J.C. (2001)
434674.14	4092058.16	208	1260	Trimble, J.C. (2001)
433430.91	4092452.29	62	500	Trimble, J.C. (2001)
433430.91	4092452.29	62	468	Trimble, J.C. (2001)
433430.91	4092452.29	64	276	Trimble, J.C. (2001)
433427.07	4092448.75	28	130	Trimble, J.C. (2001)
433427.07	4092448.75	50	298	Trimble, J.C. (2001)
428125.97	4093845.63	232	844	Trimble, J.C. (2001)
430795.72	4092700.73	78	540	Trimble, J.C. (2001)
430242.74	4092753.47	42	120	Trimble, J.C. (2001)
430242.74	4092753.47	32	116	Trimble, J.C. (2001)
430242.74	4092753.47	84	162	Trimble, J.C. (2001)
373564.41	4104086.70	274	1480	Collette, Z. (2019)
373116.91	4104212.37	212	1210	Collette, Z. (2019)
372662.07	4104233.42	346	1050	Collette, Z. (2019)
372423.31	4104520.55	471	2860	Collette, Z. (2019)
372273.65	4104584.06	1870	7180	Collette, Z. (2019)
371977.93	4104748.23	1000	4130	Collette, Z. (2019)
371613.89	4104775.06	71	585	Collette, Z. (2019)
371466.10	4105065.61	590	7280	Collette, Z. (2019)

UTM Easting	UTM_Northing	Pb ppm	Zn ppm	Source
371412.17	4105079.63	127	1830	Collette, Z. (2019)
371146.56	4105216.40	64	271	Collette, Z. (2019)
371068.33	4105380.50	51	462	Collette, Z. (2019)
370856.75	4105456.76	128	854	Collette, Z. (2019)
370956.78	4105724.77	144	1460	Collette, Z. (2019)
370674.76	4105833.40	291	2420	Collette, Z. (2019)
370414.27	4105878.90	163	1710	Collette, Z. (2019)
369741.84	4106127.61	453	5070	Collette, Z. (2019)
369617.42	4106129.54	149	2256	Collette, Z. (2019)
369556.75	4106230.35	121	1591	Collette, Z. (2019)
369514.20	4106353.07	138	3933	Collette, Z. (2019)
369398.32	4106332.67	162	2885	Collette, Z. (2019)
369284.33	4106434.31	176	19510	Collette, Z. (2019)
369150.50	4106403.09	130	2705	Collette, Z. (2019)
369027.28	4106482.68	189	21995	Collette, Z. (2019)
377194.81	4110034.16	49.3	397	Smith, D.C. (2016)
377170.59	4110065.34	61	356	Smith, D.C. (2016)
370659.76	4115218.11	247	10300	Smith, D.C. (2016)
370659.76	4115218.11	411	8410	Smith, D.C. (2016)
365544.05	4114620.10	411	7090	Smith, D.C. (2016)
358893.57	4113773.30	374	4000	Smith, D.C. (2016)
359337.05	4113735.06	231	4380	Smith, D.C. (2016)
359385.87	4113703.41	360	4540	Smith, D.C. (2016)
358819.06	4113743.73	451	5150	Smith, D.C. (2016)
359439.32	4113949.14	197	4550	Smith, D.C. (2016)
365978.37	4107800.58	428	3060	Smith, D.C. (2016)
366004.03	4107861.83	396	3680	Smith, D.C. (2016)
361727.86	4109071.42	755	8800	Smith, D.C. (2016)
361726.85	4109009.78	211	1310	Smith, D.C. (2016)
359194.57	4109637.40	128	9270	Smith, D.C. (2016)
359266.55	4109512.89	841	9880	Smith, D.C. (2016)
362096.76	4099909.90	82	907	Smith, D.C. (2016)
359804.15	4100255.86	48	233	Smith, D.C. (2016)