Perceptions of Historical Climate Change and Park Policy: The Impact on the Fremont Cottonwood in Zion National Park

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PERCEPTIONS OF HISTORICAL CLIMATE CHANGE AND PARK POLICY:
THE IMPACT ON THE FREMONT COTTONWOOD IN ZION NATIONAL PARK

A Dissertation Presented
by
KATHLEEN ANN KAVARRA CORR

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY

February 2022

Department of Geosciences
PERCEPTIONS OF HISTORICAL CLIMATE CHANGE AND PARK POLICY:
THE IMPACT ON THE FREMONT COTTONWOOD IN ZION NATIONAL PARK

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KATHLEEN ANN KAVARRA CORR

Approved as to style and content by:

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Piper R. Gaubatz, Chair

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Richard W. Wilkie, Member

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Thomas H. Stevens, Member

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Stephen Burns, Department Head
Geosciences
DEDICATION

This dissertation is dedicated to the women in my life whose actions and love kept me alive in times of extreme difficulty, walked with me through meadows and hilltops pointing out to me new horizons thereby; creating opportunities for me I had not imagined for myself. What they shared with me from their own struggles to obtain educations, to heal their own trauma, maintain and grow their own joy and health, find and create happy relationships, and to be creative has been monumental in my own healing and allowing my innate joy and talents to move beyond survival into manifestation. As my mother, Jackie Perry Corr, wrote to me of Rilke’s thoughts in his Letters to a Young Poet, on the matter of well-being, “Always the wish that you may find patience in yourself to endure, and simplicity enough to believe and that you may acquire more and more confidence in that which is difficult.”

To Jaqueline Perry Corr, my mother, best-friend, spiritual teacher and soul-mate who has always believed in me and with whom I had so much fun and meaningful conversations! We danced, attended plays, operas & delighted in fine dining! We made many happy memories together!

To Kathleen Maron Corr, my Nana, whose loving arms I still feel around me & who introduced me subways, Macy’s and NYC!

To Josephine Perry, Grandmother, who went West, was a role model in business and adventure!

To Aunt Maureen Corr, whose life in China as professor and missionary inspired me!

To Aunt Julia Pendrak, we had the happy side of life together in Philadelphia!
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To Dr. Luelle Hamilton, Mentor, whose wholistic patient care inspired the functional medicine movement. She taught me about native plants, fasting, detoxification & healing on every level.

To Linda Cope, Mentor and best-friend who led me to The Work, the Ramcharitmanas, to a home on the Cope Farm, an ashram with all its adventure, healing and personal growth!

To Sylvia Rubin, my remarkable therapist with whom I have had the exceptional good fortune to collaborate in a mutually creative relationship of healing, research and support.

To the magnificent Fremont cottonwood forest in Zion Canyon, what a relaxing delight to hear them whispering above as the Canyon winds blow by…!
I wish to thank all the teachers, family, friends, librarians and curators that have helped me on this awesome journey of completing my Ph.D.

I most wholeheartedly want to thank Dr. Piper Gaubatz, an outstanding advisor and Chair of my dissertation committee. Her exquisite poise, brilliance, and competence provided the perfect style of guidance for me! Dr. Richard Wilkie and Dr. Tom Stevens my committee members, whose courses inspired my studies of present and past resource management. Richard Kohler, whose own historical research led me to John Wesley Powell’s graph of the rise of the Great Salt Lake 1850-1869 that was my first Eureka moment on this dissertation journey validating my hunch that significant wet periods could occur in the arid lands of Utah.

I want to thank the University of Massachusetts Graduate School for their patience and generous support in awarding me a Dissertation Field Research Grant and their Summer Dissertation Writing workshops. The UMass Graduate Record Office has been so kind and patient with me over the years offering important institutional information and help. Tina Spano has been exceptional in guiding me through the last institutional steps to cross the finish line! I also want to thank all at the UMass Geosciences Department over the years for their belief in my project and for allowing me the time to complete my research. In particular I want to thank the Geography Department for awarding me in 2021 the Geography Department Fellowship I was so honored!! I want to especially thank Michele Cooke and Eve Vogel who with Piper Gaubatz, and others stood with me through thick and thin. I also want to thank all those
in the department that have looked out for me and have supported my dissertation endeavors.

I want to thank the gracious and excellent help I have received from the friendly and competent UMass librarians at the W.E Dubois Library who have helped: with research, carrels, sending documents and books to me, RefWorks, and more.

I especially want to thank everyone at Zion National Park (ZNP) especially Dave Sharrow, former hydrologist, Jeff Bradybaugh, Superintendent, (who as Head of Resource Management hired me as a ranger) Miriam Watson, Archives and Museum Curator, Amanda Peters curator assistant. I am so grateful to Superintendents Scoyen, Patraw, and Allen for their descriptive notes of the early management of ZNP. And especially to Horace Albright who left his memoirs.

I want to thank the Union Pacific Railroad Museum, Council Bluffs, IA and museum’s curator, Patricia LaBounty for the beautiful historic photos and documents of Zion National Park before 1930s. Curator La Bounty offered me access to a cornucopia of essential data.

I owe much to Springdale, UT Librarian Karen Crawford who diligently located historical books and who stashed back-up copies at all stages of my dissertation at her home. She epitomizes the best of the versatile all round excellent small-town librarian! She is the best!

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I want to lovingly thank my family. My father James who taught me how to do complete a task thoroughly and with excellence. My Mother, Jacqueline, who brilliance shown intellectual light, awareness and peace into my being.

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And to the Golden Hearts my 15 nieces and nephews who show their love to me often and to whom I say when Nature speaks to you listen. For me it has been the trees and Zion Canyon!

And finally, many thanks to John Wesley Powell, Captain Stansbury, Ralf Woolley, Clarence King and others. You were consummate researchers and scientists and you left with the trees and their historic rings, great stories of the environments of the past. I fell in love with you all!
Describing the Virgin River as it flows through Zion National Park’s Zion Canyon was transformed through massive flood control re-engineering projects in the 1930s. The armoring of the river has had significant impacts on riparian vegetation, particularly on the stands of native Fremont Cottonwood trees that once filled the narrow valley. What was the motivation for this massive flood control project carried out in an arid region with less than 15 inches of rain per year?

This dissertation explores the motivations which contributed to the decision to armor the river in the 1930s, and the ongoing consequences of that decision on the ecology of Zion Canyon. This exploration is carried out with a mixed-methods research
approach which combines analysis of historical documents, such as reports of flooding by early Mormon pioneers and correspondence between key actors in the management of ZNP, and scientific data (drawn from scientific publications, USGS databases, and National Park and Union Pacific Railroad archives), interviews with ZNP staff, and the author’s personal observations and analysis which began in 2000 while she was a Zion National Park ranger.

Key findings include the discovery that (1) an unusually wet period (pluvial) in the early 20th Century led to misperceptions of the local climate and (2) armoring the river was a result not only of those perceptions, but also of a concern with preserving and adding to the flatlands at the base of Zion Canyon to facilitate construction of visitor infrastructure in the new Zion National Park. The impacts of the armoring of the river remain severe and threaten the future of the native Fremont Cottonwood riparian forest.

The dissertation also finds that restoration of the river’s natural course would be consistent with the 1916 Organic Act preservation mandate and is necessary to restore Zion Canyon’s ecosystem. Such restoration might well be key to preserving Zion National Park’s riparian environment for the 21st Century.
WHAT SPARKED THE RESEARCH JOURNEY?

Curiosity and a concern for the preservation of the majestic Fremont Cottonwood shade trees in Zion Canyon in Zion National Park (ZNP) motivated my search to understand the historical National Park Service management of Zion Canyon. What had happened to the riparian ecosystem in Zion Canyon such that young Fremont cottonwood trees in Zion Canyon were missing? The essential provider of habitat as well as shade and beauty in Zion Canyon, the Fremont cottonwood trees were disappearing, yet why had no one noticed until 1997? Almost 70 years had elapsed since river management decisions in Zion National Park in the late 1920s and the early 1930s had inadvertently conspired to interrupt the “natural state” of the riparian ecosystem in Zion Canyon. But wasn’t the “natural state” of a National Park meant to be preserved by the Organic Act of 1916? The Virgin River riparian zone is at the heart of Zion Canyon. Once dominated by the Fremont Cottonwood Forest the riparian ecosystem had been in a “natural state” when Zion Canyon came under the protection of the Federal government as Zion National Park in 1919. Was not Zion Canyon meant to be protected and preserved for future generations?

A Back Country National Park ranger patrols the designated wild lands and harder to reach areas of a National Park. A Front Country ranger patrols the lands most used by the public and offers interpretive, vegetation, and visitor services. One hot July afternoon in 2001, while hiking the Zion Canyon floor as a Front Country Ranger, checking on secondary trails, answering questions for visitors, and picking up litter, I happened upon a rusted length of wire embedded in a dirt trail next to the Virgin River. I mused
“Certainly, this piece of wire shouldn’t be on the trail and poses a safety concern.” When I bent over to pick it up, it wouldn’t budge. I nudged the wire with the toe of my boot and even used a stick to prod the dirt out from under it. The wire did not give an inch. With a pondering hesitancy and a furrowed brow, I looked down at the wire crossing the trail and continued my patrol. Looking back over my shoulder at the exposed wire I wondered, “What the heck was under the trail”?

This question arose from the belief that a National Park was for the most part natural. Yet something big and solid sat in place under the ground between the Lodge and the Grotto in Zion Canyon. The Organic Act of 1916 mandated protection of the “natural state” of the lands brought into the National Parks system. A wire embedded in soil adjacent to the bank was certainly not “natural.” Finding the answer to this question led over time to a different view of Zion Canyon. Suddenly riverbanks were covered with cement thrown over giant boulders. Wire was not only embedded in trails but twisted and torn from sagging wire cages and found dangling over the Virgin River’s streamflow. Sections of the riverbank were walls of stone so expertly constructed of wire and rock that Italian masons noted for their expertise, might have constructed them. Eventually I found that these stone and wire constructions had a name: revetments, wire cages filled with rock. Historical photos confirmed that even more cages were buried under the Zion Canyon floor (see Figures 5-30 and 5-31).

Questions arose for which answers were vague or unknown. What were these revetments for? Why were they found close to the Virgin River banks? When I attempted to find answers to these questions from my colleagues in the National Park Service, who had worked for Zion National Park longer than I had, the answer was limited to one
phrase “to protect the Lodge from flash floods.” This made sense initially, but as the extent of the river channeling revealed itself unsettling questions arose. Why were the original and “natural state” sandy riverbanks of the Virgin River removed and replaced with steel cagers filled with tons of rock? Why was the entire river as it flows through Zion Canyon moved out of its traditional S shaped course, straightened, and pushed to the west side of the Canyon? This make-over project had been massive in scale.

The years 1999-2005 were drought years in southwestern Utah. The slender Virgin River streamflow was running at 50 cubic feet per second (cfs). Visitors to Zion Canyon would ask, “What is the name of that creek”? The fact that rain in southwestern Utah averaged fifteen inches per year fueled a persistent puzzlement. This isn’t much rain when compared to the average 40-53 inches per year in southern New Jersey, the reference point for regional precipitation without flooding that this author knew well.

In the regional historical literature of southwestern Utah stories of floods and rockslides affecting the Virgin River streamflow existed. The 1966 high water event of 10,000 cfs was legendary as was the 1996 massive rock slump that pushed the river and road towards the southeast and center of Zion Canyon. Due to the spontaneity and at times, deadliness of these events, rockslides and flash floods had gathered a legendary mystique. Whenever one of these unique geologic incidents occurred, residents in Zion Canyon and ZNP employees were excited and talked about the event for days.

Although powerful and deadly, flash floods were often limited in area, not always associated with a river and passed quickly. National Park visitors had been in the wrong place at the wrong time, had misread the weather, or the force of debris in high river flow and had died. Structures adjacent to any river or at the base of Zion Canyon Mesas were
always vulnerable to precipitation. Farmland had been washed away. Nevertheless, the solution to protect the Zion Lodge by scouring and redesigning the entire geomorphology of the Virgin River for the 6 miles of Zion Canyon, looked to be extreme. Unless unknown conditions or factors were at play. A persistent curiosity within me quietly kept turning the wheels of inquiry. There must be a first cause, hidden somewhere in the story of these revetments? Did this have anything to do with why the younger generations of Fremont cottonwood trees were missing in Zion Canyon?

One question lingered, why would the National Park administrators change the entire course of the Virgin River in a desert region? A hunch arose from the chorus of unanswered questions. There must have been a significant climate change, heretofore, unknown. This climate or weather change in the arid lands must have made a strong impression on the administrators of Zion Canyon so much so that they believed and worried that significant amounts of river volume would be flowing through Zion Canyon, well into the future. I was keeping my eyes out for data but left the Canyon for seven years to recover from a severe bicycle accident, to care for my disabled father, and to complete a Master of Science degree in Geography. Intermittently returning to Zion Canyon whenever possible, my thoughts were never far from the sanctuary of Zion Canyon and the mystery surrounding the demise of the Fremont Cottonwood trees.

On one occasion back in Zion, an architectural historian and friend was giving a talk. One of his slides showed a graph indicating a nine to eleven-foot rise in the level of the Great Salt Lake attributed to John Wesley Powell’s 1879 treatise, *The report on the lands of the arid region of the United States, with a more detailed account of the lands of Utah*. Eureka! Even though this increase in lake level was during 1860-69 at least it
showed that a significant wet period was possible and had occurred in the desert Southwest. Furthermore, it had been noticed and chronicled. But the Zion National Park administrators were digging-up the Virgin River banks in the early 1930s sixty-five years after this wet period. Could the impression of high water in arid Utah or in the Virgin River have persisted that long? Or had another wet period influenced early Zion National Park management?
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CHAPTER 1
INTRODUCTION

The perennial Virgin River, the ecological and visitor focus of Zion National Park (ZNP), creates a lush green riparian zone amid an arid Southwestern canyon landscape. The principal native forest species in the riparian zone of Zion Canyon Fremont cottonwood (*Populus fremontii*) is declining. A historical review reveals that the floodplain forest ecology in ZNP has changed composition. While Fremont cottonwood dominated the forest in the early years of Zion National Park administration, at present three species co-dominate the riparian forest: the Fremont cottonwood, the velvet ash (*Fraxinus velutina*), and the box elder (*Acer negundo*) (Hereford et al., 1995; Steen, 1999).

In the 1930s, to stabilize the movement of Virgin River, the National Park Service armored and straightened the river channel by placing large rock-filled revetments (iron cages filled with rock) on banks of the Virgin River. These massive impediments constructed first by the Emergency Conservation Work (ECW) program and later by the Civilian Conservation Corps (CCC) blocked the natural channel movement of the North Fork of the Virgin River (known as the Virgin River in Zion National Park) and removed the sandy riverbank substrate necessary for Fremont cottonwood propagation. The 1930s containment of the river channel has limited cottonwood recruitment, and in many places along the Virgin River separated the floodplain from the river (McMahon & Moody, 2001; Steen, 1999). To preserve and revitalize the Fremont cottonwood and the riparian ecosystem in Zion Canyon, restoration of the river to a more natural channel is necessary. If given back their native habitat along the Virgin River in Zion Canyon, Fremont
cottonwood trees known to grow fast will take root in Zion Canyon. My research suggests that returning areas of the Virgin River banks to their natural state will help ensure a healthy, dynamic, productive and beautiful riparian ecosystem for visitors during the next one hundred years.

Southern Utah is an arid area with less than 15 inches of rain a year. In the desert environment of the Southwest United States, rivers run shallow, meander in a braided channel pattern and can seasonally disappear depending on annual precipitation and aquifer recharge. The Virgin River is a perennial river therefore a constant source of water for Zion Canyon. Due to the rapid change of altitude between the source of the Virgin River in Navaho Lake, north of Zion Canyon, and Zion Canyon, a change of 5500 feet in less than 50 miles, the river has substantial erosive power especially in times of storm runoff and flooding.

The armoring of the Virgin River substantially changed the morphology of the Virgin River consequently, narrowing and deepening the river basin. This disturbance to the Virgin River channel has resulted in significant variations in the riparian ecosystem. The Fremont cottonwood forest is disappearing. These native trees provide essential resources to the Zion Canyon ecosystem. For example, the trees provide a canopy for shade above the desert floor which cools air and water temperatures for fish, birds, fauna, and people. The Fremont cottonwoods improve both surface and underground water quality and provide habitat for many species of wildlife: snakes, lizards, small mammals, mule deer, cougar, and birds such as the Canyon Wren and the endangered Southwestern Willow Flycatcher.
What was the motivation for this massive Civilian Conservation Corps project of 1930-34 that changed the river morphology of the Virgin River and unintentionally the precious and fragile riparian flora and fauna of Zion Canyon? Many people conclude that the armoring of the Virgin River was simply a federal program of employment. During the desperate times of the Depression despondent men needed work. For others motivation was an obvious need to protect the recent infrastructure investments made to the new Zion National Park. I propose that a factor not well documented, human perception of environmental conditions, contributed to the decision to armor the Virgin River in Zion Canyon.

This dissertation contributes scholarship in historical ecology by illustrating the relationship of human perceptions via firsthand narratives and historical accounts as valid forms of climate documentation. During my term working as a Natural Resource and an Interpretive National Park Ranger at Zion National Park in 2000 and 2001, I came across historical accounts from pioneering European Americans migrating to Southern Utah. These narratives stood out as an anomaly in the backdrop of the desert environment of Southern Utah. These commentaries hinted at another heretofore unrecognized factor that may have played a significant role in the decision to armor and channel the Virgin River in Zion Canyon. Using these commentaries and other historical data, I link the chronicling of weather as documented in the narratives of pioneering Mormon settlers in Utah, with scientific evidence that indicate two significant climate changes in the desert environment of Utah and the American Southwest occurred during the Mormon settlement period 1847-1929 in Southwest Utah. I explain the relationship between these unrecognized environmental climatic events which occurred simultaneous to the
European American settlement of Southern Utah and Zion Canyon, with the motivation to armor and channel the Virgin River in Zion Canyon.

Just as hegemony silently influences the social, cultural, ideological, or economic activities of a culture, climate exerts a preponderant systemic influence over human activity and perception. From my research climate change in southern Utah came in the form of a five-year increase in precipitation in the 1860s and another seventeen-year period of significant increase in regional precipitation 1905-1922 in an historically desert ecosystem. These previously undocumented climate change events have been historically unrecognized players in the human inter-relationship with the environment of Zion Canyon (Salzer & Kipfmueller, 2005; Sauer, 1963). I propose that the climate unconsciously influences human perception of the local environment, and it follows that it affects decision-making concerning the future of that environment. This reciprocal albeit unconscious relationship contributed to the armoring and straightening of the Virgin River.

The single large disturbance of channeling and armoring the riverbanks of the Virgin River in Zion Canyon generated long term effects on the riparian ecosystem in Zion Canyon (Auble & Scott, 1998; Scott et al., 1997). Additionally, through this dissertation research I show how the Organic Act of 1916 supports the need for restoration of the Virgin River in order to preserve the Fremont Cottonwood trees in Zion Canyon and consequently revitalize the depleted riparian ecosystem.

Building on my research and drawing on theoretical and methodological frameworks from the geographic sub-disciplines of historical geography, historical ecology, river hydrology, riparian ecology, climatology and dendrochronology I address
key research questions regarding the motivation for the armoring of the Virgin River by the National Park Service in the 1930s as well as the long-term status of the Fremont cottonwood trees as a result of the armoring and channeling of the Virgin River 1930-34. These research questions include:

1. What do the historical accounts of Mormon pioneers indicate about the climate in southern Utah from the 1860s through the 1930s?
2. What scientific evidence concurs with these historical narratives about climate in southern Utah from 1860s through the 1930s?
3. Why did Zion National Park administrators decide to armor the Virgin River in Zion Canyon?
4. What unknown factors influenced the decision to armor and channel the Virgin River?
5. How has the Zion Canyon riparian ecosystem changed since the armoring and channeling of the Virgin River 1930-1934?
6. What explains the lack of juvenile cottonwood trees in the riparian ecosystem in Zion Canyon in Zion National Park?
7. How does the Preservation Mandate in the Organic Act of 1916 influence Zion National Park policy towards restoration of the riparian ecosystem in Zion Canyon?
8. What are the restoration options for the Virgin River in Zion Canyon?

Through this research I hope to contribute to the scholarship that explores the multiple venues in which environmental management and environmental history are constructed thereby serving as indicators of past environmental conditions (Cole, 2001; Pesch & Garber, 2001; Steen, 2002). My dissertation research on historical accounts of the Mormon pioneers contributes to both historical ecology and environmental history in two avenues. First, these historical accounts can be used as indicators of short but significant micro-climate variations within the larger more static regional desert climates.
of Utah and the American Southwest (Ladurie, 1972). Secondly, landscape is a reciprocal history of relationships between the culture of its inhabitants and the physical geography of the area and environment (Cronon, 1983; Crumley, 1994; White, 1980). The accounts of the pioneers become important indicators of the past intersection of the prevailing historical cultural and social attitudes as well as the human perceptions that characterized past interactions and relationships with the surrounding geography and ecology of Zion Canyon. Analyzing these historical relationships can provide insights to scientists and National Park Service managers. Elucidating and understanding the background of past decision-making processes can guide present and future management and restoration options and processes (Dunwiddie, 2001; Moore & Witham, 1996; Steen, 2002).

Past ecological disturbances, especially large-scale disturbances leave their signature on the ecology of an environment. Large scale disturbances can shape the ecosystem composition and ecological processes of an ecosystem for decades and well into the present-day environment (Auble & Scott, 1998; Foster et al., 1998; Harding et al., 1998; Motzkin et al., 1996; Turner & Dale, 1998). Initially land managers and owners have changed landscapes with the goal of progress in mind, nonetheless; over time they unwittingly become partners in sweeping ecological changes that can tarnish the envisioned progress.

This dissertation contributes to the knowledge base on ecological restoration. There is a body of research that supports the process of probing the environmental conditions of the past in order to gain valuable guidance for future restoration goals (Christensen, 1989; D. Egan & Howell, 2001; Steen, 2002; Swetnam et al., 1999). Including the broad array of complex biological, ecological, climatic, physical as well as
cultural factors at play in a landscape improve environmental stewardship. Understanding how decisions were made concerning land management in the past and what factors were at play in the past influencing decisions, can elucidate patterns of anthropogenic cultural constraints active in present ecosystem management. Comparing past parameters with present parameters offers a systems analysis application to present management strategies which ideally will lead to more successful restoration planning and policy.

Chapter Organization

Chapter 1 – Introduction

Chapter 2 – Was the Early 20th Century Unusually Wet in Southern Utah? Evidence from the levels of the Great Salt Lake, Dendrochronology, and River Streamflow Levels. This chapter conveys the evidence for the pluvials of 1865-1869 and 1905-1922. This scientific data includes comparison of levels of the Great Salt Lake, dendrochronology studies throughout the Southwest, and streamflow levels from the Virgin River, Colorado River and the Weber River.

Chapter 3 – Preservation of Valuable Flatlands: A heretofore unrecognized reason for channeling the Virgin River. This chapter reveals the root causes of the armoring and channeling of the Virgin River in Zion Canyon.

Chapter 4 – Early National Park Management and the Environmental Perception of Zion Canyon. This chapter describes early National Park Service management policies as well as the formation of local and long-standing perceptions of the Virgin River. How have these perceptions played a role in the armoring and channeling of the Virgin River?

Chapter 5 – Cottonwood Propagation. This chapter discusses Fremont cottonwood propagation and recruitment. How has the armoring of the Virgin River prevented the
Fremont cottonwood from reproducing? This chapter also looks at the role microburst/cloudburst precipitation in Utah has on the creation of flash floods.

Chapter 6 – Channeling the Virgin River. This chapter analyzes the processes and consequences of channeling the Virgin River in Zion National Park, addresses flood control issues, and discusses recent unrealized plans to restore the natural geomorphology of the Virgin River in Zion Canyon.

Chapter 7 – Conclusion, Discussion and Recommendations

**Background Information: The Geographic Character of the Region**

Zion National Park located in Southwest Utah is situated on the southwestern rim of the Colorado Plateau and preserves an area of 146,597 acres (229 square miles). The North Fork of the Virgin River originates on the Markagunt Plateau 50 miles north of Zion National Park in the spring-fed Navaho Lake and flows 162 miles southwest into Lake Mead southeast of Las Vegas, Nevada. In less than 50 miles the Virgin River drops from an elevation of 9000 feet to 3500 feet above sea level, making the slender Virgin River a strong erosive force in the landscape. Southern Utah is an arid area with less than 15 inches of rain a year. In the desert environment of the Southwest United States, rivers meander around sand bars creating a shallow of sandy braided channel pattern. Many rivers seasonally run dry or run underground disappearing for part of the year depending on seasonal precipitation.

The North Fork of the Virgin River flows through the famous Zion Canyon, which is in the southeast quadrant of Zion National Park. The Virgin River canyon runs from northeast to Southwest for 23 miles. The upper backcountry portion of this canyon, called the Narrows, is 14 miles in length and accessible only on foot walking in the river.
channel. This upper region of the canyon is extremely narrow, only 25 feet wide in some sections and contains little or no flood plain. It is clearly distinct from the lower and wider area known as Zion Canyon. This lower part of the canyon begins at the Temple of Sinawava and ends nine miles downstream outside of the National Park in the town of Springdale, Utah. Seven of these nine miles are within Zion National Park, encompassing the geographic area of Fremont Cottonwood decline. Known as the front country of Zion Canyon, the riparian zone here is .25-.50 miles in width at its widest point, accessible by a road, and well-traveled by visitors to Zion National Park.

The East Fork of the Virgin River, whose headwaters are east of Zion National Park, runs through an adjacent less known, less accessible yet ecologically similar canyon called Parunuweap. The North and East Forks of the Virgin River join outside the southern border of Zion National Park just southeast of the town of Springdale, UT. In the last four to ten million years each fork of the Virgin River has carved through uplifted sedimentary strata exposing a geologic panorama of Navajo sandstone, Kayenta mudstone, Moenave, Chinle, and other sedimentary formations as well as lacustrine and fluvial deposits.

**Environmental History of Zion Canyon 1860-1934: Influence on Armoring and Channeling of the Virgin River**

The original known inhabitants of Zion Canyon, the Ancestral Puebloans, left signature stone and mortar structures, in both the North Fork and East Fork canyons of the Virgin River. These people inhabited the region now known as the American Southwest from about 700AD until circa 1140 AD. After this time, it is thought that a twenty-to-thirty-year drought came upon the region causing the Ancestral Puebloan culture to disperse due to this climate change.
According to an ethnographic and anthropological survey of Paiute Tribe members undertaken by the National Park Service (1997), the ancestral Paiute people of Southern Utah intermittently spent time in Zion Canyon. The Paiute people deemed portions of the canyon as sacred places. One such area known as the Temple of Sinawava was dedicated to one of the major deities in the Paiute culture known as the Wolf God. Sinawava means Wolf God in the Paiute language (Zion National Park, 1997). Presently this area of Zion Canyon serves as the northernmost stop on the Zion National Park shuttle system and is the jumping off point for exploring on foot the upper reaches of Zion Canyon known as the “Narrows.” The ancestral Paiute people also farmed the flat irrigable riverside land and river sandbars in Zion Canyon (Hebner & Plyer, 2010). Many Native American tribes seasonally migrated between summer and winter homelands. It is likely that during the hot summer months native Paiute people would have summered in the cooler canyon.

The more recent permanent settlement of Zion Canyon began in 1863 with the European American Mormon settlers, Isaac and Elmina Behunin. Two other Mormon families the Giffords and the Heaps joined the Behunin family, settling permanently in Zion Canyon. Along the banks of Virgin River, they farmed, planted orchards, and dug irrigation ditches that can still be seen and continue to operate in Zion Canyon (Woodbury, 1950).

United States President Theodore Roosevelt, one of the founders of the National Park system, served as President from 1901-1909. He traveled to the West on a regular basis finding solace as well as physical and emotional restoration in the vast geographic beauty and solitude of these less populated regions (Goodwin, 2013). Roosevelt wanted
to share opportunities for these same exhilarating and healing experiences with his fellow Americans, the great population of them in the East. Many were immigrants living in dense urban environments. William Howard Taft following in the footsteps of his friend Theodore Roosevelt and the Conservation Movement designated Mukuntuweap, the Paiute name meaning “straight arrow: for Zion Canyon, as a National Monument in 1909 (Goodwin, 2013). The United States Congress proclaimed Mukuntuweap National Monument, Zion National Park in 1919. United States Federal Government officials were intent on working with the railroads to showcase the new western National Parks to the American public most residing east of the Mississippi River.

From 1924-26 the Union Pacific Railroad built the only road into Zion Canyon as well as the first permanent lodging known as “The Zion Lodge” for visitors to overnight in Zion National Park. Armoring the Virgin River would address the need to protect this investment from the meandering Virgin River. The answer for many to the question of why hundreds of men would be brought into Zion Canyon to armor and straighten the river channel of a river that has an average flow of less than 100 cubic feet per second flowing thru a desert climate, simply rests in the Depression era politics and infrastructure protection. These motivations, although important and appear to be rational deductions, do not get at the prime influence for this expenditure of money and mission.

Historical geographers, Swetnam et al., researching the factors necessary for successful restoration and informed management wrote, “Historical perspectives increase our understanding of the dynamic nature of landscapes and provide a frame of reference for assessing modern patterns and processes” (1999, p. 1189). Land-use, settlement history, precipitation patterns, and National Park Service culture have influenced the
Virgin River’s management history and in particular the rationale for constraining the channel of the Virgin River in Zion Canyon.

Seasonal climatic variation dramatically affects Virgin River hydrology, and river hydrology has in turn affected settlement and river management in Zion Canyon. Records for the last 80 years show volume baseline for the Virgin River in Zion Canyon average between 40-100 cubic feet per second (cfs) (Zion National Park, 2014). Snowmelt generated flows in late spring contribute to most of the runoff volume above the baseline flow. There is an additional contribution to river flow from the rains that come in the monsoon season July through September. Because the hillsides of the watershed are predominantly bare rock surfaces, runoff drains quickly, floods can occur in any season. A notable example of this situation occurred in the winter of 1966. From December 3-6, 1966 an unusual winter storm dropped nearly 14 inches of rain onto 6 inches of snow throughout the southern Colorado River watershed. The snow promptly melted resulting in extreme high streamflow and debris flows throughout the southern Colorado River watershed including in the Virgin River watershed (Fedarko, 2013). The highest recorded volume of 10,000 cfs for the Virgin River since the pluvial years of 1905-1922 occurred after this storm. And as recently as January 2005 the volume of Virgin River streamflow exceeded 4000 cfs (Sharrow, 2018). Except for a large bend in the canyon and two places where the river has broken through the revetments, the present river channel runs straight through the canyon. The surrounding floodplain is removed from the river, dry and in some places over 15 feet higher than the river channel.

Historical accounts record a river geomorphology and hydrology as much different than today. Jessie Smith, who explored the canyon prior to the Mormon
settlement of the 1860s, reported that the river swung widely across the canyon floor, and he saw signs of “great freshets” causing over bank flooding (Steen, 1999, p. 40). Another 1860s era explorer Samuel Witwer reported that the “channel was not entrenched when he visited the canyon” (p. 42). J. L. Crawford, who was born in 1914, and grew up in Zion Canyon, commented in 1998 that, “the park was a swamp for many years” (p. 42). Another elderly local resident, P. Hepworth, interviewed in 1998 noted that “there used to be quite a few wetlands and swamps all along the river” (p. 42; Hereford et al., 1995).

Regional histories, church records, diaries, and newspaper accounts from the 1860s onward contain detailed records of numerous destructive floods caused by the Virgin River. Flood-related loss of farmland and damage to irrigation structures, dams, and dwellings were continuing problems for early American and European/Mormon settlers of the region (Larson, 1961). Before the Department of the Interior began to administer Zion Canyon in 1909, intensive grazing took place in the upper Virgin watershed, causing widespread hillside denudation, which contributed to flooding (Bailey, 1935; Woodbury, 1933). Unusually large floods characterized the 1880s and early 1900s (Hereford et al., 1995).

In 1919 Zion Canyon came under the authority of the National Park Service. In 1925-26 the Union Pacific Railroad constructed Zion Lodge about halfway up the canyon on the site of original Mormon homesteads (Crawford, personal communication, July, 2001). The flooding and natural channel migration, that had been contentious for settlers in the recent historic hydrologic framework, threatened the new facilities (Steen, 1999). Several factors influenced National Park Service Virgin River management decisions that led to the armoring of the Virgin River channel in the 1930s. First, there was a need to
reduce watershed erosion thought at the time to have been brought about by intensive grazing. Secondly, the building of the new lodge and upgrading the road created a desire to protect infrastructure. Thirdly, decisions were made as a climatic response to the high river flows and the historic record of flooding from the late 1860s, 1880s and early 1900s. These high flows and flooding have been interpreted as a result of intensive grazing and cyclical precipitation. However, the effect of grazing may not have contributed as much to high stream flows as previously thought, while steep topography and cloudbursts may have had more impact on streamflow (Woolley, 1946). Finally, because of the Great Depression a surplus of labor needed work, and a federal project, such as the channeling of the Virgin River, would utilize this workforce (McMahon & Moody, 2001; Nielson, 2006). Nonetheless, my research indicates that two other factors previously not recognized contributed to high river flows and flooding.

**Virgin River Riparian Zone**

The importance of riparian zones has been well established scientifically. Of Zion National Park’s six habitat zones, the riparian zone consists of less than five percent of the land area yet contains over 87% percent of the plant and wildlife diversity (Utah State Water Plan, 1993). “Riparian habitats are among the most ecologically productive and diverse terrestrial environments, by virtue of an extensive land-water ecotone, the diversity of physical environments resulting from moisture gradients, and a mosaic of habitats created by dynamic river changes” (Naiman 1993, cited in Steen, 1999, p. 19). The annual precipitation in the region of ZNP is less than 15 inches per year and the temperatures in summer consistently reach over 100 degrees Fahrenheit. It is not
surprising that the Virgin River is the lifeblood of the surrounding arid Southwestern landscape.

Typical riparian vegetation in the American Southwest consists of cottonwood trees, willows, salt cedar, arrowhead and seep-willow, rushes, sedges, watercress, and cattails (Utah State Water Plan, 1993). Riparian vegetation creates habitat, moderates the thermal input of the sun, and dictates species composition of fish and birds, their population size, and available nutrients for the ecosystem (Utah State Water Plan, 1993). The Virgin River riparian zone in Zion Canyon influences habitat quality of several federally listed endangered species including the Southwest Willow Flycatcher, the woundfin minnow, the Virgin River chub, and the Virgin spinedace (Fridell, 2003; Utah State Water Plan, 1993; Zion National Park, 2001).

The typical southwestern river geomorphology consists of a main channel and shallower rivulets of water winding back and forth in a braided pattern. This flow pattern leaves changing areas of bare substrate, one of the mosaic habitats in the land-water ecotone. Herein rests the essence of the need for restoration of the Virgin River. Without the constantly changing geomorphology the bare yet periodically moistened substrate needed for cottonwood propagation is not created. The revetments that line the Virgin River deny the river its historic dynamic change and therefore the opportunity to create micro-habitats (ecotones), without which cottonwood seeds cannot grow and mature.

**Cottonwoods Forest Ecology and Historical Decline**

Historically cottonwoods have stood out as an important floodplain forest species (Taylor, 1989; Woodbury, 1933). Historical naturalist accounts describe the floodplain tree community in Zion Canyon as a “deciduous forest dominated by Fremont
cottonwoods and willows” (Woodbury, 1933). Woodbury made a list of the canyon’s obligate riparian species putting Fremont cottonwood first followed by four species of willow. He lists box elder and velvet ash after the willows, indicating their lesser prevalence. Another naturalist in 1932 describes the omnipresence of cottonwoods in Zion Canyon: “cottonwoods dot the shore, surround the dwellings…cover the roadways and grace the campgrounds” (J. Grey, 1932, quoted in Steen, 1999, p. 44) (see Figure 1-1).

**Figure 1-1**

*Opening Day of ZNP May 15, 1920*

Note: This photograph shows abundant Fremont Cottonwood trees in mid Zion Canyon before armoring the Virgin River 1930-1934. Source: Union Pacific Railroad Museum.

More recent surveys in the late 1980s and early 1990s indicate a change in this status. Taylor (1989) shows co-dominance with velvet ash, box elder and Fremont cottonwood. Harper (1992) found box elder most prominent followed by velvet ash and
then Fremont cottonwood. Steen (1999) found that there were significantly fewer cottonwood trees in areas of the river where revetments existed and more cottonwood trees along the floodplain where no revetments were present.

Cottonwoods live to be between 75 and 130 years old. In recent years employees from the Resource Management and Research Division at Zion National Park have observed a lack of young members of the species on the riparian forest floor. An internal Zion National Park (1996) project proposal states that, “since the elimination of the flooding, due to channel-bank alteration in the 1930s, the cottonwood trees have not reproduced successfully with the consequence that the younger trees are about 60-70 years old” (ZNP (1996) proposal quoted in Steen, 1999, p. 1).

Cottonwoods are a primary succession species of the floodplain forest in the Southwest; therefore, impacts to riparian ecosystems affect this species. Fremont cottonwood reproduction requires bare moist soils, elevated and distant enough from the channel to be safe from channel scour (Auble & Scott, 1998; Friedman et al., 1995; Scott et al., 1999).

Manipulation of water resources stands out as a major cause of decline for cottonwood populations (Cooper et al., 1999; Scott et al., 1999). Alterations to surface flow or to ground water, in addition to natural causes such as drought stress and flooding, affect all the early stages of cottonwood recruitment. The channel edge movement that occurs naturally as a result of variable flow rate in shallow, braided channel southwestern rivers provide one important mechanism for creating the combination of protected and moist site conditions necessary for cottonwood reproduction. If both channel movement and variable flow rate were restricted by straightening of the channel as has happened on
the North Fork of the Virgin River, it is likely that Fremont cottonwood reproduction would be adversely affected.

Young Fremont cottonwoods depend on relatively shallow water tables. Cooper found that in a seedling’s third or fourth year, the plant’s taproot draws from the water table. If the flood plain were elevated well above the river, as it is in the areas of the revetments in Zion Canyon, seedling survival rate would be considerably lowered (Cooper et al., 1999).

**Restoration Attempt Rationale**

Changing riparian ecology reflected by a loss of native Fremont cottonwood trees may affect Zion National Park’s ability to carry out its mission as directed by the National Park Service Organic Act of 1916. This Act of Congress mandates the duties of the National Park Service in conserving scenery, wildlife, and the natural and historic objects found within the National Parks. If cottonwoods are not reproducing, this species may constitute a much smaller portion of the riparian forest in the future and thereby ecological function and diversity may change as well as historic scenery.

Zion National Park undertook a small-scale, manual, riparian tree restoration project in 1998. Within 42 enclosures seedlings of ash, cottonwood, willow and box elder were planted and drip irrigation projects installed. By 2005 only a handful of trees had survived. The project was labor intensive and according to Denise Louie, Zion National Park botanist, the project failed, underscoring the need for more systemic river restoration in order to maintain large tree species (D. Louie, personal communication, November 2005).
According to McMahon and Moody, who evaluated the potential for restoration of the Virgin River in 2001, “without active intervention the magnificent canopy of cottonwood trees, part of the historic landscape within Zion National Park, will vanish in the next few decades” (2001, p. iii). They also conclude that, “there is significant potential for increasing cottonwood reproduction and riparian function by removing rock and wire revetments and restoring channel dimension, pattern and profile” (p. vi). After 90 years the revetments are crumbling and have become a safety hazard in many areas. Yet these revetments continue to constrain the Virgin River channel.

The Bureau of Land Management (Prichard et al., 1993) defines a healthy riparian area as existing: “in dynamic equilibrium with the stream-flow forces and channel aggradation/degradation processes producing change with vegetative, geomorphic, and structural resistance.” In a healthy situation, the channel network adjusts in form and slope to handle increases in stormflow/snowmelt runoff with limited perturbation of channel and associated riparian-wetland communities (Hindley, 1996, p. 11). It is not certain whether this objective will be achieved by Zion National Park River management. However, the Bureau of Land Management has successfully restored and monitored western riparian areas (Prichard et al., 1993).

Zion National Park’s (2001) most recent General Management Plan states that maintaining resources including plant communities at healthy and viable levels is one of its primary missions. The 2001 General Management Plan also calls for the restoration of the North Fork of the Virgin River as a means of revitalizing the floodplain, but the General Management Plan does not make a commitment as to how or when the restoration program will occur. Additionally, any restoration is expensive and economic
costs are measured against competing federal objectives. In the present economic climate of federal deficits and foreign war spending, restoration projects remain under-funded.

**Mormon Pioneer Accounts of Life in Southern Utah: The Anomaly**

The motivation for the large-scale Civilian Conservation Corps (CCC) project at first seemingly obvious as protection of the National Park Service Zion Lodge infrastructure begs the question of why armor the Virgin River in a desert environment, an ecosystem with average rainfall of less than 15 inches per year. I worked as a Resource Management and Interpretative Zion National Park Ranger in 2000 and 2001. There had been a drought several years underway when I arrived in June 2000 which lasted another four years. In 2000 my first summer as a Park Ranger in Zion National Park rain fell only once. I remember thinking it dramatic that people danced in the parking lots with palms upturned to the sky when 10 minutes of light rain fell. Considering the desert environment, I was experiencing I began to wonder what prompted the armoring of the river.

In addition to being part of an Interpretive Ranger’s job, studying the environmental and cultural history of Zion National Park fascinated me. Several of the original inhabitants of the canyon, born in areas once homesteaded and now within the National Park Service lands, were still alive though approaching 90 years of age. Additionally, the human history of the canyon remains populated with romantic and industrious portraiture of people not yet lost to time or obfuscated with overpopulation and the layering of the built environment. As I began to read the accounts of the European settlers’ first coming into Southern Utah and Zion Canyon, also known as Dixie, I noticed some odd and out of place commentary in the journals and narratives that
I was reading and researching. Repeatedly these immigrants into the desert terrain mentioned the term “flooding.”

Surveying my surroundings, I noticed the scarcity of trees, felt the dryness of the air leathering my skin, and the sand working its way into my boots. I saw the narrow ribbon of water that is the Virgin River, a sight that causes many Easterners visiting Zion National Park, to ask, “What’s the name of that creek”? I asked myself, “Why were pioneers reporting on flooding”?

The frequent description of flooding in the settler accounts in Southern Utah struck me as an anomaly and a contradiction to the climatic experience I was having in 2000 and 2001. The experience of those in the same terrain 137 years earlier appeared to be distinctly different to the desert heat and scant precipitation at the turn of the Millennium. I asked myself two important questions: “What was all this flooding about that the European American settlers often chronicled in their diaries”? And “Could the climate have been different in the 1860s when the first Mormon settlers first appeared in Southern Utah and in the first twenty years of the 20th Century when Zion Canyon came under the auspices of the United States Department of the Interior”?

Zion Canyon narrows from its mouth in the town of Springdale to where it is about a mile wide to less than a quarter mile wide in the interior of the canyon, where the Zion Lodge stands. The only area in Zion Canyon that could serve as a base for visitors coming into the narrow high walled canyon were two small pieces of flatland about halfway up the 9-mile canyon. At the birth of Zion National Park, the original campground and administrative building rested on less than an acre of flat ground at the base of steep two thousand five hundred feet high canyon walls in the area known as the
“Grotto.” The Park headquartered its administration in a tiny three-room stone building. This historic structure now serves as an apartment for artists in the Visiting Artist program of Zion National Park. An adjacent flat piece of ground about a mile down river consisting of about two acres became the site for the Zion Lodge. These only flat areas in Zion Canyon served as a base camp for exploration of Zion Canyon and the upper elevations and regions of the early Zion National Park. Was it plausible that concern existed by National Park officials for the long-term viability and stability of these small plots of flatland?

**Academic Context**

This dissertation first serves as a cautionary tale for anyone involved with ecosystem management. The environmental history of Zion Canyon shows the long-term results of faulty decision-making and anthropocentric focused priorities. These practices disregarded the community of life forms which shared and depended on Zion Canyon’s riparian ecosystem for life and well-being. As a result, a large-scale biological disturbance was created which presently is in the process of fundamentally changing Zion Canyon’s riparian ecosystem.

Secondly, this research contributes to the scholarship of human-environment geography, illustrating how cultural and physical geography become influences one upon the other. The nature of the scholarship in this dissertation is diverse and can be applied to the geographic subfield of historical geography and the closely related fields of environmental history, historical ecology, and the relationship between these three concentrations and environmental restoration (Balee & Erickson, 2006; Crumley, 1994; D. Egan & Howell, 2001; Sauer, 1963; Steen, 2002; Swetnam et al., 1999).
Carl Sauer, in his essay, “The Morphology of Landscape,” describes geography as one of the first sciences. He bases this primary position of geography as a way people have understood themselves and their relationship to the land through ancient tales that chronicle the relationship between humans and place (Leighly, 1969). Sauer (1930) writes, “The literature of geography in the sense of chorology begins with parts of the earliest sagas and myths, vivid as they are with the sense of place and of man’s contest with nature.” (p. 317). It is within this relational context of a long abiding “contest with nature” that the first European American pioneers to Zion Canyon and then the Superintendents of the National Park decided to alter the landscape of Zion Canyon (Patraw, 1932a).

The Virgin River was seen as an unpredictable force that threatened the people and their plans for Zion Canyon and the regional area. The prevailing environmental relationship between humans and nature at this time was one of nature being seen as a single separate element, some “thing” to contend with: a wild animal, a mountain in the way, a desert to cross, a river to control and so on. In the period of 1866-1912 many individual Europeans and Americans set out to “conquer” the last unexplored regions of the globe only this time more as explorers, settlers, and naturalists rather than colonizers. For these adventurers and scientists, nature was still seen as a formidable force -a twisting tornado, a blowing hurricane, a freezing sea, a forest fire, a cascading river — that had to be tamed, constrained, re-routed, traversed, etc. Surviving these contests with nature became associated with character, leadership, and heroic abilities. The complex community interactions that form an ecosystem were, but for a few visionaries, not yet
the prevailing scientific or colloquial understanding of nature. Without even a vague understanding of the connectedness of flood plains to river forests, and forests to small mammals and birds, decisions concerning the environment were made with one framework in mind that of human desires, needs and goals. This was deemed progress. It took the form of control.

The Virgin River would flood, but not necessarily in a seasonal fashion or in a predictable place. Also, floods were not just from the rivers in Utah but from the type of precipitation common in Utah (see Chapter 5). Most of the information pertaining to flooding and the Virgin River, accessible to persons in the 1920s, may have come from a few published sources, or from saved stories from local newspapers, but most information about the behavior of the Virgin River likely came from memories shared orally among regional residents.

Sauer establishes a rationale for the science of geography, he notes that all science is a collection of bits and pieces of information. He writes, “Every field of knowledge is characterized by its declared preoccupation with a certain group of phenomena, which it undertakes to identify and order according to their relations” (Sauer, 1930, p. 326). Geography, Sauer asserts, is not just a collection of observations, facts, or descriptions of a land or a place, but a study containing linkages, relationships, connections that form the contextual experience of place. Sauer suggests in order to understand the truth of a place or an event the geographic researcher as well as the public must find and understand the unseen qualities among the bits and pieces of experience or research. “These facts,” Sauer ascertains, “are assembled with increasing knowledge of their connection; the attention to their connection denotes the scientific approach” (p. 327). A fact standing
alone offers less information to a scientist or observer than a fact standing in relationship to other phenomena. Sauer drew inspiration for the idea of including relationship among facts from the German philosopher, Hermann Graf Keyserling, who Sauer quotes from Keyserling’s 1910 book *Prolegomena Zur Naturphilosophia:*

A fact is first determined when it is recognized as to limits and qualities, and it is understood when it is viewed in its relations. Out of this follows the necessity of predetermined modes of inquiry and the creation of a system that makes clear the relation of the phenomena...Every individual science is I as a special discipline in so far as it accepts the section of reality that is its field tel 25uell and does not question its position in the general scene of nature, within these limits however, it proceeds critically, since it undertakes to determine the connection of the phenomena and their order. (Keyserling quoted in Sauer, 1930, p. 316)

I propose that one of the essential unseen facts in the channeling of the Virgin River is that the regional climate of the American Southwest had changed significantly during 1905-1922. This climate change occurred in the early lives of most of the people making decisions about the relationship between the Virgin River morphology and Zion Canyon, especially if these decision-makers grew up in the American Southwest. Additionally, I assert that the regional climate had also changed significantly from 1861-69 when the Mormon settlers first arrived in southern Utah. The traumatic memories of increased Virgin River streamflow that greeted the vulnerable Mormon settlers arriving in southern Utah in 1861 left emotional scars of Virgin River destruction. These personal weather-related traumas evolved into cultural traumatic memories of the Virgin River. These past experiences were reinforced by high streamflow again during the 1905-1922
pluvial. The stories of these dramatic climatic change events have remained for
generations in the collective cultural memory of regional residents and river management
decision makers. These memories and their accompanying oral lore have created a
persistence of perception that has framed the expectations of the behavior of the Virgin
River, accurate or not.

Obviously, residents experienced increased precipitation. But it is unlikely that
they understood the scale of the changing weather nor the regional context of this change
in climate to past or future weather patterns or to long-term established regional climate
trends. Human beings resist ambiguity. Yet ambiguity is what we all live with. The
uncertainty of the duration of a period of increased precipitation even if there was an
expectation of cyclic weather patterns, instinctively would have added apprehension to
the perception of increased Virgin River streamflow.

Sauer, like Keyserling, underscores that geography, as well as being an areal
knowledge, is also a science of relationships. Geography strives to understand and reveal
the significance of chorologic relations, which is the study of diverse phenomena existing
together in a place. Sauer observes, “According to such definition of the grounds of
knowledge, the first concern is with the phenomena that constitute the section of reality
which is occupied by geography, the next with the method of determining their
connection” (Sauer, 1930, p. 316). Causal relationships over time form the basis of
geographic and ecological inquiry.

The “section of reality” occupied by geography is an area or place, also known as
the knowledge of the lands or landscape. The relationships between facts, observations
and bits of knowledge are not haphazard or accidental. In geography there is the idea that
inter-dependence occurs among these facts, observations, and bits of knowledge, forged through long term evolutionary coexistence. Discovering this areal interdependence of phenomena includes the human interactions and cultural expression of landscape as well as synthesis of multiple biological and physical layers and players in an area also known as a place and more complexly an ecosystem. Both physical and cultural forces shape the land creating a particular association of forms. Sauer stresses the inclusion of multivariate understanding and ultimately of layered analysis of the constituents of a landscape. He elegantly declares:

The objects that exist together in a landscape exist in interrelation. We assert that they constitute a reality as a whole that is not expressed by a consideration of the constituent parts separately, that area has form, structure, and function, and hence position in a system, and that it is subject to development, change, and completion. Without this view of areal reality and relation, there exists only special disciplines not geography as generally understood. The situation is analogous to that of history, which may be divided among economics, government, sociology, and so on; but when this is done the result is not history. The facts of history are time facts, and they give rise to the concept of a period. The facts of geography are place facts, and their associations give rise to the concept of landscape. (Sauer, 1930, p. 321)

Sauer’s insights of relationship and interdependence are not only fundamental to geography but also at the heart of ecosystem ecology. Chorology as used in geography means to encompass the causal relations between geographical phenomena occurring within a particular region. Chorology used by environmental science adds to this meaning the spatial distribution of organisms over an area. Both meanings, as used by historical
geography and environmental science respectively, apply to the area of Zion Canyon. The reduction in the number of young cottonwood trees in Zion Canyon since the armoring of the river has become an ecological issue as well as a historical one.

The biological relationships among the organisms in the Zion Canyon riparian ecosystem were ignored because the National Park Service did not yet have a sense of the scientific necessity or approach needed to manage the unique and precious vast natural areas in the new National Park System. In Zion Canyon biological relationships between the river and trees, birds and trees, trees and trees have been affected by the armoring of the Virgin River. I suggest all the biological relationships in Zion Canyon have been affected by the armoring and channeling of the Virgin River. There are a decreasing number of Fremont Cottonwood trees offering shade, habitat, water processing, beauty, and much more presently in the canyon. This decrease in habitat or water processing would naturally lead to changes in the amounts of other organisms in the Zion Canyon riparian zone. Why is this?

Chapter 5 will explain this dearth of Fremont Cottonwood trees as well as explain what conditions in a riparian ecosystem foster cottonwood propagation and what conditions hinder rejuvenation? Chapter 5 will also address the conditions in Zion Canyon created after the channeling and armoring of the Virgin River and how these biological changes have affected Fremont cottonwood propagation and recruitment. There are also an increasing number of beavers gnawing on aging magnificent cottonwood trees felling them before their time. Thereby slowly eliminating the seed source for future cottonwood trees in Zion Canyon. The relationship between beavers and cottonwood trees is not well understood and not the topic of this dissertation.
Nevertheless, their growing numbers represent an example of Sauer’s inclusion of the chorology of the riparian ecosystem, necessary to include and understand when researching the issue of the decline or rejuvenation of the Fremont Cottonwood forest in Zion Canyon.

The scarcity of cottonwood saplings composing what would be the future generation(s) of cottonwood habitat is not only a biological issue but becomes also a narrative which over time enters the realms of restoration ecology, historical ecology, and environmental history. A discrete change over time due to human disturbance is occurring within Zion Canyon that will have long term effects on the riparian ecosystem in Zion Canyon. This process of change over time also falls within the framework of chorology residing within the subject matter of historical geography. The armoring of the river was set in motion by the accumulation of bits of ideas, facts, and perceptions by human beings who made decisions under the influence of a variety of relationships, some conscious, some seen, and others outside of the realm of human understanding, unconscious and unseen at that historic moment. However almost all the ideas, facts and perceptions they gathered focused on human needs and concerns leaving out the entirety of biological relationships in Zion Canyon.

**Academic Context: Historical Ecology**

Historical ecology provides a multi-dimensional view of an environment, a view that includes interactions among living beings as well as facts about them and the landscape. Sadly, most of the living beings in an environment have become facts, items to count and not participants in the health and vitality of the landscape nor in the decision-making process concerning the ecosystem in which they live. This long-standing
process of disregarding the interrelatedness of organisms and the inherent rights of organisms themselves to exist in their unique evolutionary path have hardly been realized. Even though I completed a master’s degree in Social Justice Education, when I brought up the topic of speciesism and the injustice towards living systems in nature, one of my professors discounted my perspective on creating social justice and inclusive behavior towards nature. It was another example of anthropomorphic centrism and the fact that I have always been 10-15 years ahead of my time! Nonetheless, the idea that species have rights is slowly moving through international legal systems. Inherent rights of protection for ecosystems and all species represent a necessary validation of the right to an authentic life for all life species and of the enormous natural processes and economic value these species, systems, and relationships in nature contribute to the health and welfare of all living beings.

Numerous computer models with the means to view environmental change over time have been generated from plentiful data documenting environmental change in the form of remote sensing data, spatial distribution and the ability to meld layers of discrete classes of data within software programs such as Graphic Information Systems (GIS). Carole Crumley identifies what historical ecology adds to the study of ecology, environment, and, I would add, historical geography. She aptly writes that historical ecology aims to “incorporate information about how humans have altered the environment or about how environmental change revised human activity.” She importantly observes, “Changes in subsistence strategies, demography, or perception have through time resulted in both intentional and unintentional modification of the
“global environment” (Crumley, 1994, p. 1). William Cronon, author of *Changes in the Land* underscored the inter-relatedness sought after by historical ecology. He wrote:

An ecological history begins by assuming a dynamic and changing relationship between environment and culture... Moreover, it assumes that the interactions of the two are dialectical. Environment may initially shape the range of choices available to a people at a given moment, but then culture reshapes environment in responding to those choices. (Cronon, 1983, p. 13)

This dissertation contributes to the scholarship in the field of historical ecology by specifically addressing the category of “perceptions” that have created unintended modifications to an environment. Decisions concerning Zion Canyon were influenced by the perception of considerable precipitation experienced in the American Southwest during the pluvials of 1865-69 and 1905-1922. However, this precipitation was a significant increase in the normal amount of moisture in the desert community. The actuality of these changes which were occurring on a global and regional scale was outside of the perception of the persons making decisions on the geomorphology of the Virgin River in Zion Canyon. A remarkable example of myopic perception applied to environmental conditions in Zion Canyon resides in the fact that ZNP Superintendents were using precipitation data that had begun to be gathered in 1904 one year before the 1905-1922 pluvial began and applying this data from 1904 to their year of ZNP Management as if this weather data represented the entire range of weather that had ever existed in Zion National Park territory (Patraw, 1932a, 1934; Scoyen, 1930a,b, 1931). Acting as if this short-term temperature and precipitation data represented long-term climate reality illustrates an element of hubris residing in the early managers of Zion
National Park. It may also indicate the excitement of having any records at all to consult. The allure of data overrode as it often does now, the inherent biases contained in numbers disconnected to the qualitative context. Although likely unintentional, this example indicates the extremely narrow frame of reference operating within ZNP early management with regards to understanding weather. This narrow framework likely extended to many decision-making processes in early Zion National Park management. This example sheds light on the framework of perceptions operating at the time of the armoring and channeling of the Virgin River and resides within the scholarship of historical ecology.

The lack of propagation of cottonwood saplings escaped notice for over 67 years even though Zion Canyon is the centerpiece of the front country visitation in Zion National Park. It is true that the changes were subtle and complex and not immediately discernable to human perception. Yet how could this lack of young Fremont Cottonwoods trees have escaped notice if preservation of natural lands, one of the mandates of the Organic Act 1916 had been a part of the environmental management goals? The local scale of this dissertation falls clearly into the category of historical ecology. My research describes the interrelatedness between human perception and decision-making on the fate of the riparian ecosystem by federal officials within Zion National Park. Crumley (1994) noted, “The discipline’s (historical ecology) historic focus on the dynamics of change render, an anthropological perspective particularly appropriate to unraveling complex chains of mutual causation in human-environment relations” (p. 2). The contexts of my case study of Zion Canyon fall within the scope of historical ecology as described by both Crumley (1994) and Cronon (1983).
This dissertation includes “an anthropological perspective” in the form of historical research attempting to understand the motivation for the extensive CCC channel entrenchment of the Virgin River in a desert environment. Furthermore, this research addresses Crumley’s concept of “unraveling of the complex chains of mutual causation” preceding and following the armoring of the Virgin River by the CCC which resulted in imperceptible and complicated changes to the riparian ecosystem in Zion Canyon. From one simplified perception of ZNP management at that time, the CCC were performing a much-needed task. From the viewpoint of preserving the natural ecosystem for future generations the CCC was doing harm to the beloved native and magnificent Fremont Cottonwood Forest.

This dissertation also encourages National Park officials to take another look at restoring the Virgin River to a more natural channel resembling its original sandy and braided geomorphology. Although it appears to casual observers that the remaining cottonwoods are abundant, these are what is left of what was once a multi-age forest with numerous members across generations. According to Turner et al. (1998) when a disturbance is large resulting in few or sparse residuals the spatial effects of the disturbance become increasingly important. Almost all the cottonwoods remaining within Zion Canyon are in the last quarter of their life span which is 85-130 years. Becoming fewer and fewer this last generation of Fremont cottonwoods are the residuals of the disturbance caused by the channeling of the Virgin River. Presently the trees can supply native seed for propagation in the disturbed area. If Zion National Park continues to follow the “do-nothing” course it presently has decided upon, (D. Sharrow, personal communication, April 2006) most of the Fremont cottonwood trees will be dead before
the geomorphology of the river returns if ever, to a form conducive for Fremont Cottonwood propagation.

Researchers are increasingly recognizing that the lack of understanding of historical conditions causes conservation strategies and restoration plans to be misguided or unsuccessful (Kondolf, 2001; Motzkin & Foster, 2002; Walter & Merritts, 2008). Historical ecologists synthesize data from many sources and from diverse fields: geography, climatology, biology, ecology, history, sociology, and anthropology. The diversity of data assists in creating a clearer vision of the past ecology as well as the cultural environment interacting with that ecology. There is hope that this understanding contributes to significantly clarifying goals in the restoration of an ecosystem. In the case of the restoration of Zion Canyon economic, cultural, and ecological concerns must be considered in a restoration plan. A restoration project would need to consider many contexts and conditions, for example: establishing soils suitable for the propagation of the cottonwood trees, the nesting regimes of the Southwestern Willow Flycatcher, beavers, fish, protection of the National Park infrastructure, and the means by which park visitors can continue to access trail heads and the Lodge, both with vehicles and on foot, while moving protection from high streamflow from the Virgin River riverbanks to the Canyon Valley road.

The dissertation contributes to the scholarship in historical ecology by using firsthand historical accounts as veritable sources of climate data. I use historical accounts from pioneers in southern Utah to illustrate anomalous climate periods. These accounts assist in understanding the environmental conditions in which the pioneers lived and how their perceptions of the environment were being influenced by the change in climate. The
data about the weather arising day to day, month to month, year to year found in Zion National Park Superintendent reports as well as in pioneer accounts establishes a record of climate conditions. These weather conditions in turn affected the idea of what long term climatic conditions would be. These ideas about climate affected planning and management not only of regional infrastructure such as irrigation ditches, dams, placement of fields, and roads but also in Zion National Park recently coming under federal management.

Federal and regional agencies have commenced applying the tools of historical ecology to aid in the management and restoration of damaged ecosystems and environments. The National Oceanic and Atmospheric Association (NOAA) (2015) collects historical data in the form of journal entries and historic photographs for management and restoration of National Marine Sanctuaries. They are using records of cod catches to estimate fish populations and fishing patterns. Historic fishing charts and historic photographs are being consulted to understand in what ways humans were interacting with the sea in the Massachusetts Bay and Maine Fisheries in the New England Region (NOAA National Marine Sanctuaries, 2015)

The San Francisco Estuary Institute, a regional agency whose mission is science-based estuary ecosystem management also uses historical ecology to guide the research and restorative mission of the organization. They note that in the diverse climate and cultural framework of California, historical ecology has been very useful:

In California, where our cultural memory is short, and we have tended to impose concepts appropriate to more humid regions to our Mediterranean and semiarid landscapes. Historical ecology reveals a landscape well-designed for extreme seasonal and inter-annual climatic variability and controlled by fundamental geologic controls that remain intact — the “dry side of the ecological palette” that
has been largely overlooked in conservation planning. (San Francisco Estuary Institute, 2015)

Thus, this dissertation contributes another piece to the heretofore unrecognized factors influencing National Park ecosystem management policies. In its entirety the narrative presented here suggests that much wider, long-term, and more inclusive studies addressing species viability, long-term climate variations, human cultural paradigms about nature, as well as human use goals and interactions between humans and the ecosystem must be undertaken before large infrastructure projects are embarked upon. The same can be said for restoration projects.

**Methodology**

Research for this dissertation included qualitative research methods such as interviews, review of original and secondary written sources, and field observations. I link historic documents and pioneer accounts to recent climate research establishing these pioneer accounts as indicators of two anomalous and significant climate changes during the period 1865-1869 and 1905-1922. These climate changes have previously been unaccounted-for factors in the motivations for channeling the Virgin River.

This research is supported through construction of a case study using primary and secondary sources. It examines the event in which the Civilian Conservation Corps armored and channeled the course of the Virgin River resulting in a large-scale ecological disturbance within Zion Canyon. In order to gain a sharpened understanding of why this event happened as it did, I include materials from archival records of the National Park Service, particularly those preserved at the Zion National Park archives. These documents include superintendent reports, historic meteorological, biological and geographic data, species surveys, ethnographic reports, historic plans, and photographs. It
should also be noted that in the archives of Zion National Park, there are significant gaps in the years 1909-1927 and 1934-50 and my requests to the Department of Interior for information during these gaps have come back stating “no information found”.

Additionally, I have consulted the archives at the Union Pacific Railroad in Council Bluffs, Iowa for historic photographs and commentary pertaining to Zion Canyon. Michael Edmond, a contributor to “The Handbook of Historical Ecology” suggests the importance of finding textual documents in as many local sources as possible. He writes, “Think geographically, whenever possible. Structure your research around a specific location or finite region.” He encourages researchers to “consult local historic organizations” (2001, p. 74). Making use of this guidance, I also consulted the Washington Historical Society, the Utah State Historical Society, and the Utah Rangelands database as well as regional histories, church records, diaries and newspaper accounts. These organizations hold many documents which offer additional local and regional perspectives to the federal government archives.

**Connected Research**

I have established research contacts and groundwork in Zion National Park since 2000. Through my work as a park ranger, I made contacts with the park hydrologist, botanist, local historians, state climatologists, and original settlers in Zion National Park. Making use of this network of personal connections, I carried out informal and semi-structured interviews with government officials and staff. These interviews began in 2006 and focused on park policy, internal research, approaches to park management and restoration. As a Resource Management Park Ranger, I worked daily in the riparian zone of Zion Canyon becoming familiar with the flora and fauna of this ecosystem. I have
walked the riverbanks of the Virgin River and noted the soil covered gabions lining these banks. I have gathered stories and information from other rangers and scientists familiar with the history of Zion National Park. As an Interpretation Park Ranger, I read many internal documents as well as many firsthand pioneer and employee commentaries describing conditions in the riparian ecosystem and the cultural history of the indigenous Paiute peoples and the Mormon European American settlers.

Dendrochronology is the science of dating events and climatic variations in the environment during the past by the comparative study of growth rings in trees and aged wood. In order to ascertain the changes in climate I propose, I contacted the University of Arizona Dendrochronology Research Center and the Utah Climatology Center in order to find new climate data concerning the region of the Southwestern United States and more locally in Southern Utah and Northern Arizona. USGS historic water gauge streamflow databases as well as historic water level data of the Great Salt Lake provide resources for corroborating regional precipitation changes.

Historical photographs, which portray the character of landscapes as they were in the latter 1800s and early 1900s, can be used as a reference for ecological health (Hindley, 1996). Visual comparisons of photos taken from the same location can provide information on vegetation and river channel changes. ZNP as well as the Union Pacific Railroad and Utah State University have extensive archives of historic photographs, which have provided material for photographic comparisons.

**Conclusion**

The story of early Zion National Park management of the North Fork of the Virgin River using Emergency Conservation Work Act and Civilian Conservation Corps
to armor and channel the Virgin River in Zion Canyon clearly shows that undertaking large projects within National Parks particularly projects that add infrastructure to areas with previous limited human incursion, can dramatically change the long-standing nature of flora and fauna within the ecosystem. Human migration into natural environments has been occurring for millennia. Yet there are several aspects of the armoring of the Virgin River that draw closer attention. The first are the long-term effects of the channeling of the Virgin River in Zion Canyon on one, major riparian species, the Fremont Cottonwood and the as yet unresearched effects of this channeling and armoring on native endangered fish and bird populations in Zion Canyon in particular the Southwestern Willow Flycatcher, the woundfin minnow and Virgin River spinedace. Another poignant aspect is the slowness of the Zion National Park management to notice the decline of the Fremont Cottonwood Forest resulting from the major disturbance that the CCC’s straightening and armoring of the river channel caused in Zion Canyon. The river was armored in 1930-34 yet the results of this armoring in terms of change in the composition of the riparian ecosystem went unnoticed until 1997. Why did this occur? There appeared from archival records that no follow-up riparian zone studies were included in the original planning for the revetments nor in the construction of the revetments.

I hope that my research can encourage a revaluation of restoration options for the Zion Canyon riparian ecosystem. Bringing the analytical tools of historical geography and historical ecology to bear on the situation, promises to yield insights into polyvalent and nested social, cultural, political, biophysical and climatic forces that historically influenced and may continue to influence the environmental management of riparian ecosystem in Zion Canyon within Zion National Park.
Species and biological communities have inherent limits. “Human generated changes must be constrained because nature has functional, historical and evolutionary limits. Nature has a range of ways to be, but there is a limit to those ways and therefore, human induced changes must be within those limits” (Christensen, 1996 quoted in Swetnam et al., 1999, p. 1202). The revetments constraining the natural channel of the Virgin River are an example of human generated changes that have created functional limits on the propagation of Fremont Cottonwoods in Zion National Park. Constraining the river channel with revetments limits the historic movement of the Virgin River channel resulting in the separation of the river from its floodplain. This in turn prevents the formation of dynamic micro-habitats necessary for the propagation of cottonwood trees.

The 2001 publication of the General Management Plan for Zion National Park presented several promising signs for the cottonwood trees of Zion Canyon. The first was the mandated obligation to review, research, and respond to the results of human intervention on riparian ecology in Zion National Park. The second opportunity rested in the public acknowledgement of the cottonwood propagation problem. The third opportunity made public the goal of river restoration. However, the 2014 Virgin River Comprehensive Management Plan focuses more on visitor use management than restoration of the Virgin River. This Plan proceeds with the option of “benign neglect” rather than removal of the armoring along the Virgin River as the best option for dealing with the loss of the Fremont Cottonwood native forest in Zion Canyon. This dissertation states that “benign neglect” is not the best option to preserve for future generations the natural state of the riparian ecosystem in Zion Canyon.
Restoration of the river will be another in a series of human interventions along
the North Fork of the Virgin River. Each intervention is a part of the succession of land
utilization that Carl Sauer (1930) noted defines function, perception, and the historical
geography of place (p. 45). Zion Canyon is a place where Fremont Cottonwoods have
historically and ecologically dominated the riparian forest. The luscious cottonwood
canopy cherished over the decades by those seeking social and biological shelter and
restoration of soul and body, in Zion Canyon, will be no more without freedom for the
Virgin River’s channel edge. The removal of revetments will be a responsible step
forward in recreating ecological integrity and function for the riparian ecosystem in Zion
Canyon. Giving the riverbanks back to the Virgin River is a necessary step towards
restoring and maintaining what research tells us was a healthy native Fremont
Cottonwood Forest in Zion Canyon. The Organic Act of 1916 tells us that the mission of
Zion National Park must include preservation of the natural state of the riparian
ecosystem in Zion Canyon for future generations. Rebuilding a healthy riparian
ecosystem now in 2022 that reunites the Virgin River with young Fremont cottonwoods
is an investment akin to supporting youth sports teams. The future returns far outweigh
the initial investments.
CHAPTER 2

WAS THE EARLY 20TH CENTURY UNUSUALLY WET IN SOUTHERN UTAH?
EVIDENCE FROM: THE LEVELS OF THE GREAT SALT LAKE,
DENDROCHRONOLOGY, AND RIVER STREAMFLOW LEVELS

I have spoken of the rich years when rainfall was plentiful. But there were dry
years too, and they put a terror over the valley. The water came in a thirty-year
cycle. There would be five or six wet and wonderful years where there might be
nineteen to twenty-five inches of rain, and the land would shout with grass. Then
would come six or seven pretty good years of twelve to sixteen inches of rain.
And then the dry years would come, and sometimes there would be only seven or
eight inches of rain. The land dried up and the grasses headed out miserably a few
inches high and great bare scabby places appeared in the valley. The live oaks got
a crusty look, and the sagebrush was gray. The land cracked and the springs dried
up and the cattle listlessly nibbled dry twigs. Then the farmers and the ranchers
would be filled with disgust for the Salinas Valley. The cows would grow thin
and sometimes starve to death. People would have to haul water in barrels to their
farms just for drinking. Some families would sell out for nearly nothing and move
away. And it never failed that during the dry years the people forgot about the rich
years, and during the wet years they lost all memory of the dry years. It was
always that way (Steinbeck, 1952, p. 5-6).

Rise of the Great Salt Lake 1860-1877 and 1905-1922

Although the consensus of the Zion National Park hydrologist (1998-2019) Dave
Sharrow, and other Zion National Park Administrators has been that the main reason for
armoring the Virgin River was to protect the Zion Canyon Lodge from Virgin River
flooding (Sharrow, personal communication, April, 2019) I will argue that this is not the
prime cause for the extensive flood control hastened upon the Virgin River commencing
in 1930. Consider that weather, according to the United States Geological Survey, refers
to regional short term atmospheric conditions while climate is the weather of a specific
region averaged over a long period of time (United States Geological Survey, 2021).
Consider again that precipitation for southern Utah averages fifteen inches or less a year.
Where then did the rain come from that created the “floods” that early Superintendents of
Zion National Park in the mid to late 1920s feared?
This dissertation asserts that the decisions to armor the Virgin River in Zion Canyon by early National Park Service Superintendents were made under the influence of a singular, extraordinary, and wet climatic condition in the Southwest region of the United States lasting from 1905-1922 with significant wet years into the late 1920s. I propose that this 17-year anomalous climatic condition of considerable increased precipitation known as a pluvial, significantly altered the environmental perception of the weather and therefore the regional climate for many of the inhabitants of southwestern Utah. Newcomers to southern Utah, including the nascent management decision makers in the new Zion National Park, who had not known arid years, would be more susceptible to misinterpreting this discrete pluvial phenomenon as indicative of typical and long-term Southwestern United States wet weather and climate.

This doctoral research proposes that before unease about the safety of the Zion Lodge from Virgin River flooding emerged concerns were well established about the instability of the few acres of flat land in Zion Canyon. In a 1918 telegram from Stephen Mather, Director of the National Park Service to Horace Albright, Assistant Director, found in the Union Pacific Railroad Museum Archives, Mather expressed his concerns about the flat lands in Zion Canyon washing away (Mather, 1918). Additionally, in a telegram from a National Park Service Engineer Robinson to the Chief Engineer Hunlly dated October 6, 1923. Robinson stated: “The site chosen for the Zion Park Hotel should be on high ground” (Robinson, 1923). The flatland where infrastructure to support visitation for the new National Park could be built was limited. The nine-mile-long Zion Canyon progressively tapers from its mouth in the south to an area in northern section of canyon called the Narrows. Here steep sandstone walls stand leaving only 25 -50 feet of
access between them. Zion Canyon is less than .25-.50 mile wide in most places. The available flatland for proposed visitor infrastructure was under 5 acres total. In other words, the limited flatland necessary to establish a National Park in Zion Canyon was in short supply and National Park Service Administrators feared it would wash away from the increased streamflow of the Virgin River.

In the blossoming era of governmental water control that was moving through the West in the 1920s little or no long-term consequences to the riparian areas or for that matter, the sources of water themselves, were included within the parameters of water control decision-making. The rationale for control of the Virgin River followed this pattern of exclusion of consequences to the riparian areas of Zion Canyon. However, long term consequences did occur for Zion Canyon’s riparian areas. Decisions made to straighten the river channel, move the channel to the western edge of the Canyon, and armor its riverbanks have affected the long-term relationship of the Virgin River with its riparian zone, resulting in the demise of the magnificent native Fremont cottonwood forest throughout Zion Canyon.

Periods of significant increase in rainfall occurred in the American Southwest during the years 1833-1840, 1865-69, 1887-89, and from 1905-1922 (Salzer & Kipfmueller, 2005). Climatologists call such a period of significant increase in precipitation a pluvial. It must be noted that pluvial or for that matter, a drought period, is not solely confined to the years designated by the research parameter calculated as “significant” for increases or decreases in moisture. Increased rain often occurred before and after the years, designated within statistical research parameters considered “officially” as a pluvial. This research scenario is also the same for periods of drought.
Interestingly a period of significant decreased precipitation among the pluvial’s rainy years was noted within the seventeen years of the official 1905-1922 pluvial and has become a signature for this pluvial. An example of this phenomenon occurred in 1910, a third of the way through the 1905-1922 pluvial, when a dry spell occurred. Precipitation in 1910 measured against the previous five years of increased precipitation appeared significantly less to Superintendent Scoyen in his 1929 Annual report. He was comparing precipitation in 1929 to his records which were from only 1904 onward noting that the dry period he was going through could only be compared to that of 1910. Yet compared to years before the pluvial, the 1910 levels would be considered closer to normal precipitation for southwestern Utah.

In the latter half of the 1920s increased rain was common but did not meet the pluvial parameters for the research by Salzer and Kipfmueller (2005). However, in the historic framework of this dissertation these years were considered wet enough to illicit substantial flood concern from the early Zion National Park Superintendents. Moreover, the mid and late 1920s followed the wettest longest period in the American Southwest in 1425 years (Salzer & Kipfmueller, 2005). Low levels of rain would appear to be normal only when compared to the two previous decades between 1880-1900 for which there was no available data.

The increase in precipitation during the first years of the 20th Century created a notable change in the typical arid climate of the American Southwest. Amidst the arid Southwest even one year of moisture more than the normal 15 inches is noteworthy but consider contending with seventeen years of more rain than anyone can remember! These circumstances would likely etch a deep impression of wet weather for the region into the
memories of the locals and cloud the perception of what would be considered the normal weather in that arid region. This climate anomaly may not have been recognized as atypical by the recent European immigrants to the Southwest or by the novel administrators of the new Zion National Park in 1919. Even if the pluvial had been recognized as unusual, as it was by some observers, the Zion Park administrators had no way of knowing the scale of the increased precipitation nor how long the moister climate and ensuing rise in the Mukuntuweap streamflow would last. It would be what is frequently called a “new normal” in present day parlance. As the present day, ZNP Superintendent, Jeff Bradybaugh, remarked (personal communication, 2018), “They did the best they could with what they knew at the time.”

Regardless of human environmental perception, the pluvial of 1905-1922 created unique and atypical environmental conditions for the Mukuntuweap River in Zion Canyon. Furthermore, this situation changed environmental conditions for Zion National Park administrators and local inhabitants. The pluvial increased the amount and resulting force of the Mukuntuweap River streamflow, widened the river and increased the number of adjacent and intersecting channels of the Mukuntuweap River (Hereford et al., 1995, 1996). The perception of the Mukuntuweap River as a source of frequent flooding, and therefore a powerful threat to the establishment of visitor-use operations, made sense to park administrators within the context of the pluvial. But this environmental perception was inaccurate as a forecaster of the long-term natural behavior of the Mukuntuweap River later renamed the Virgin River.

This environmental perception would also prove inaccurate for the expectations of long-term patterns of precipitation occurring in the desert Southwest. The experience of
increased river flow created by the seventeen-year pluvial led these early administrators to believe that the Virgin River would be a considerable long term and perennial threat to the establishment of the new Zion National Park. To create a “park” environment, infrastructure would be needed to accommodate visitors into the upper reaches of the canyon. However, Zion Canyon was a narrow sandy, swampy environment with little flat land upon which to build accommodations for tourists (Crawford & Hepworth quoted in Steen, 1999, p.42). Research in the archival Superintendent Reports of Zion National showed that visitor use was a key statistic gathered by the early National Park Service. Visitor use of the National Parks served as the prime rationale for convincing the United States Congress to appropriate funds for buying the lands comprising the National Parks (Albright & Cahn, 1985). Visitor use numbers continue to this day to be a prime factor in evaluation of National Park use and needs by the Department of the Interior. However, these numbers do not tell the full story of the impact of visitor use on these unique and spectacular National Park environments. Nor do they activate the federal resources needed for the 50-50 balanced relationship between use and preservation within National Parks mandated by the Organic Act of 1916.

This chapter will present the evidence for the significant climate change in which uncommon increases in moisture occurred in the vernacular region known as the Southwest of the United States of America, and more particularly in the state of Utah during the periods 1865-69 and 1905-1922. Three sources of data have been researched and compared to support the premise that the periods afore mentioned experienced an unusually significant amount of moisture for the region resulting in a skewed perception of the long-term environmental conditions within Zion Canyon. The sources for the data
are the rise of the level of the Great Salt Lake, dendrochronology studies of the Southwest region, and the streamflow levels of the Virgin River, the Colorado River, and the Weber River.

**The Rise of The Great Salt Lake 1850-1869**

*The Scientific Climatic Insight of John Wesley Powell*

In 1877 John Wesley Powell, the leader of the first expedition down the Colorado River, published a portrait of the American Southwest for the Department of the Interior and Congress in Washington, D.C. entitled *The Report on the Lands of the Arid Region of the United States, with a More Detailed Account of the Lands of Utah*. Without any benefit from modern scientific technology, or a century of precipitation records, or computer modeling, Powell understood the arid nature at the heart of the desert Southwest. It is likely that the Native American inhabitants, the Paiutes and Ute peoples, equipped with longstanding intergenerational knowledge of the lands of the Southwest and a strong oral history, understood the inherent aridness of the Southwest and its cyclic short-term rainy periods. It is possible, too, that the early trappers and frontiersmen, the first whites to visit the arid American desert of the Southwest and initially dependent on the vast regional Native American knowledge, also understood the essential dryness of the region known to Easterners and United States government officials as “The Great American Desert.” But the regional Caucasian immigrants to the Southwest, particularly to the lands now known as the state of Utah, Mormon devotees, seeking refuge from previous religious persecutions, may not have understood the essential arid nature of the region.
These pioneers arrived from the deciduous forest biomes of Europe and the humid forests of the eastern and mid-western United States. They dreamed of new opportunities primarily agricultural, envisioned irrigated farms blooming in the desert from the challenging work of putting their shoulder to the plow. Brigham Young, head of the Mormon religion and the pioneer settlement in Salt Lake City, sent 300 tradesmen of every sort, south to the lands watered by the Mukuntuweap River. This area in southern Utah became known as “Dixie” by the pioneers. Many of these Mormon settlers had emigrated from the South where they had raised cotton. The hot climate and longer growing season of southern Utah had produced a quality of cotton sufficient for markets in the East. The Civil War years created a dearth of cotton in the northern states and coincided with the initial settlement period of southern Utah. Cotton was seen as a way for the new mission to be self-sufficient. Also, it was economically prudent to have a crop to trade with other Mormon missions and to sell to the cotton hungry markets in the East (Larson, 1961). This area is now known as Washington City and St. George, Utah.

The journey to southern Utah from the small Salt Lake City Mormon community tested the faith and physical endurance of these families. Reid (1964) depicts Brigham Young’s expectations for what the settlers had to be able to do to survive:

The very isolation of Brigham Young and his people also demanded economic and industrial independence. Agriculture, including its allied branches must be made the foundation stone upon which these Mormon settlers must build if permanency were to be obtained. They must be prepared to raise their own food supplies, their own wool, their own cotton, and to manufacture their own clothing. They must locate their own iron and coal mines, establish their own foundries, their own tanneries, in short, they must be an
entirely self-supporting society. In order to obtain this independence, they must acquaint themselves with and to a great extent unitize the resources of the West. (p. 55)

Unbeknownst to them, these refugees from religious persecution in the East and Mid-West came into the Southwest when two extreme periods of increased precipitation softened and nourished the arid desert 1865-1869 and 1905-1922 (Salzer & Kipfmueller, 2005). Considering that agriculture had to be the “foundation stone” of the Mormon immigrants’ survival, the two periods of increased precipitation added enormously to their chances of survival and success. The extra rain created an opportunity that the Mormons, aware of their precarious isolation, could meld with the preparation inherent within everyone’s skill base. “With religious and necessary devotion, the individual and the environmental conditions would be harnessed, and all accomplishment subsumed into the communal needs for survival” (Reid, 1964, p. 56).

Few Mormon pioneers were scientists on the order of John Wesley Powell. Nor had many ever seen a desert. Yet some noticed the rain. These settlers often in need of spiritual validation for their persistence concluded that the increased rain was the answer to their prayers and the entitled rewards for their religious righteousness and perseverance (Fite, 1966; Powell, 1879).

Powell, a keen observer of his environment and a geoscientist of his time, understood the religious attributions the Mormon settlers applied to the wetter climate. Many of these settlers had left their ancestral homes in the moist British Isles to follow first, Joseph Smith, and then, Brigham Young, into the unknown and wild regions of the West. They also submitted large tracts of their free will to the hierarchy of the Mormon faith, which relied on obedience and a collective culture of adherence. John Wesley
Powell (1879) noted that some of the Mormon pioneers from 1847 and onward had noticed the first documented pluvial period 1865-69 through their observations of the increase in the levels of The Great Salt Lake. Powell described the varied rationales attributed to this increase in precipitation between 1850-1869 (p. 66). He also exhibited his keen scientific and observational faculties when he wrote:

> It is frequently asserted that the cultivated lands of Utah “draw the rain”; or that the prayers of the religious community inhabiting the territory have brought water to their growing crops; or that the telegraph wires and iron rails which gird the country have in some way caused electricity to induce precipitation but none of these agencies seem to be competent. The weather of the globe is a complex whole, each part of which reacts to every other, and each part of which depends on every other. The weather of Utah is an interdependent part of the whole and cannot be referred to its causes until the entire subject is mastered. (Powell, 1879, p. 70-71)

The Homestead Act of 1862 that deeded 160 acres to pioneers who resided five continuous years on surveyed public land manifested the American Dream of free land in return for cultivating it and simply living on it! Gilbert Fite (1966) noted that Powell thought that these immigrants arriving in droves should be warned as to what to expect from the geographic conditions of the West and to understand the precarious chances for agricultural success west of the 100th meridian. Powell thought that the 160 acres farm was too small for long term settlement in the arid conditions of less than 15-20 inches of rain a year. Powell thought that grazing not farming would offer the best economic outcome for settlers (Fite, 1966, p. 95).
Figure 2-1

Map of 100th Meridian Where John Wesley Powell Marked the Geographic Line Where Eastern Humidity Drops and the Arid Lands Began

Note: Annual average precipitation dropped from 61 centimeters on the eastern edge to 46 centimeters at the western edge. Presently the sharp aridity gradient still exists, but it's moved closer to the 98th meridian. Climate models predict that this line of aridity will move further eastward in coming decades. Source: Earthmagazine, (2021).

Fite (1996) underscored Powell’s observations of the laymen and religious attempts to understand the observed increase in precipitation during the early 1860s in the lands west of the 100th meridian (see Figure 2-1). Fite (1996) commented, “Most scientists scoffed at the idea, but many laymen argued that plowing and loosening the soil permitted it to absorb more moisture, thereby giving greater evaporation and in turn producing more rain” (p. 96). Fite goes on to illustrate another common explanation for the increased rainfall. He quotes an emigrant to the arid lands, “The Lord just knewed we
needed more land, an’ He’s gone and changed the climate. It’s raining more out here than
it used to” (p. 96).

Powell cared enough about the welfare of his fellow Americans heding west
seeking a new life that he made his concerns about the climate and the Homestead Act of
1862 public. He observed that a “different type of agricultural organization was required
beyond the policy of giving 160 acres homesteads for farmers in arid regions to succeed”
(Fite, 1966). Fite cites a New York Tribune correspondent who wrote in response:
“Powell had raised a matter of grave and general concerns. If it is true that there is
scarcely any good land left fit for a poor man’s farm the sooner the fact is announced the
better” (Fite, 1966, p. 95).

Powell (1879) had seen that the Native American people survived through
seasonal migration following the grazing buffalo. He understood that the five-year
residency requirement for ownership of the land imposed by the Homestead Act of 1862
could be a dangerous venture with unpredictable year by year swings between rain and
drought. For immigrants tied fast to the land, searching for the dream of agricultural
security, success was risky and dependent on the weather. But the weather was complex,
its origins unknown and reliability suspect.

Marc Reisner (1986) portrayed John Wesley Powell as a “genuine Renaissance
man the likes of Mark Twain, John Muir, Abraham Lincoln, Dean Howells and Hamlin
Garland” and “a member of a subspecies of men that flourished during the 19th Century
and went extinct with the end of the frontier” (p. 25). Reisner depicted their innate genius
and yearning to outfit this authentic intelligence with reason, skill, and a connection to
their wise forefathers:
They lived on subsistence farms at the edge of the frontier. They lacked formal education, breeding or refinement. Schooled by teachers who barely knew more than they did, chained to the rigors of farm life, they got their education from borrowed books devoured by the embers of a fireplace or surreptitiously smuggled into the fields. What they lacked in worldliness and schooling, however, they more than made up in vitality, originality, and circumambient intelligence (Reisner, 1986).

It may be the encompassing intelligence and an all surrounding environmental awareness that Reisner ascribes to Powell, that gave Powell a clear understanding of the climate of the Southwest. Powell’s scientific perception developed in years spent outside in farm fields, on Civil War battlefields, and exploring unknown geography. These powerful life experiences afforded him the confidence to ascertain and assert the innate persistence of the extremes of dryness in the land of the Southwest known at this time as “the Great American Desert.”

It is not clearly known how John Wesley Powell understood the cyclical nature of the climate in the Southwest. He laid out the truth of the basic dry nature of the lands west of the 100th meridian in his monumental study for the United States Congress Report on the Lands of the Arid Region of the United States with a More Detailed Account of the Lands of Utah (Powell, 1879). He researched and wrote to accurately present the geographic and long-term agricultural obstacles facing the onslaught of migrating settlers coming from the eastern United States and Europe. Allowing for brief cyclical interludes of moisture, Powell understood and conveyed the basic aridity of this region in his report:
But if it be true that increase of the water supply is due to increase in precipitation, as many have supposed, the fact is not cheering to the agriculturalist of the Arid Region. The permanent changes of nature are secular; any great sudden change [in climate] is ephemeral, and usually such changes go in cycles, and the opposite or compensating conditions may reasonably be anticipated. For the reasons so briefly stated, the question of the origin and permanence of the increase of water supply is one of prime importance to the people of the country. If it is due to a temporary increase of rainfall, or any briefly cyclic cause, we shall have to expect a speedy return to extreme aridity, in which case a large portion of the agricultural industries of the country now growing up would be destroyed. (Powell, 1879)

How did Powell understand that the increased precipitation was not the new norm for the Southwest? Why was it that his environmental perception was sound not short-sighted? Was it his keen observation skills or that he had been in the region for over ten years by the time he crafted *Report on the Lands of the Arid Region of the United States with a More Detailed Account of the Lands of Utah*? Or was it that he was not out for a quick buck and cared about what happened to the men, women and children leaving everything behind for the risky opportunity of a fresh start? Did he garner the ability to see long term patterns from fighting in the Civil War? That he allowed for complexity in his thinking never ceases to amaze.

In general, when people seek to understand and create stories around natural phenomena the stories often arise from a simple subjective observation, whether true or not, that fits into a hegemonic framework, often influenced, and reinforced by the status of a hierarchy or by structures of power. Subjective experience does not need fact to
support it. It simply is declared and repeated, establishing a false sense of knowing. This kind of knowing often reinforces self-esteem and status in a community yet may not be true in any way shape or form. Stories simply become beliefs because they have been passed around, are simple in structure, and assimilated into the status quo narrative. Stories also attempt to rationalize the sequences of cause and effect that occur in phenomena. These rationales serve to allay the fear of the unknown or to increase a sense of security in the face of vast inherent unknown and changing variables. In Chapter 4 I will explain how this process influenced the environmental perception of the Virgin River in Zion Canyon.

This kind of meaning-making could be equated with the forming of a perception of the environment. Meaning-making occurs within the context of the effect of weather on crops and livestock, and therefore survival. At points in the past, weather was seen as sign of evil or of a God’s beneficence or wrath. Creating rationales also feels good to an individual because they are creating an intelligent explanation, a rational cause and effect relationship within the bounds of their frame of reference. A person may observe, for example, “See it is raining and I have recently plowed, so rain must follow the plow.” This observation explains immediacy and participation of the observer in the process of discovery. Although explaining a sequence, a conclusion drawn solely from the subjective observation avoids complexity, objectivity, and the interconnectedness of natural systems. Although valuable, subjective observations are only a part of the variables creating a situation. What about the corollary situation that occurs when one plows, and rain does not fall? The fallacy of rain following the plow not only influenced many farmers in the late 1800s but also influenced many farmers as well as policy
makers in the Dust Bowl era of the 1930s, so much so that the dust from the Mid-West blew all the way to Washington DC (T. Egan, 2006). This simplified environmental perception was also attributed to the behavior of the Virgin River by locals and would have a hand in determining the long-term fate of the riparian ecosystem of Zion Canyon.

**Evidence for the First Pluvial 1865-1869 in the Recorded History of the American Southwest: The Rise of the Great Salt Lake**

The first pluvial in the American Southwest that was noted and recorded then statistically verified occurred between 1865-1869. But reports of increased rain began in the late 1850s and lasted into the early 1870s (Salzer & Kipfmueller, 2005). The evidence for this increase in precipitation comes from the rise in water level in The Great Salt Lake (Powell, 1879). After his service in the Civil War, Powell went west and led the United States Geographical and Geological Survey of the Rocky Mountain Region and was the first person to document the Colorado River in the Grand Canyon by leading a rafting expedition through the Grand Canyon. Not only did he raft the Colorado River on two explorations, but he also published two descriptive memoirs of these voyages. Well-known as a competent explorer and scientist, he was later appointed the second Director of the United States Geological Survey by the famed geologist and first Director, Clarence King.

Powell (1879) substantiated the rise in The Great Salt Lake first by describing how the level of The Great Salt Lake rises. Powell explained:

It rarely happens that the annual evaporation is precisely equal to the annual inflow, and each year the lake gains or loses an amount, which depends upon the climate of the year. If the air which crosses the drainage basin of the lake in any year is unusually moist, there is a twofold tendency to raise the mean level. On one hand there is greater precipitation, whereby the inflow is increased, and on the other hand there is less evaporation. So, too, if the air is unusually dry, and the inflow is correspondingly small, the loss by evaporation is correspondingly great,
and the contents of the lake diminish. This annual gain or loss is an expression, and a very delicate expression, of the mean annual humidity of a large district of country, and as such is more trustworthy than any result which might be derived from local observations with psychrometer (An instrument used for measuring the amount of moisture in the atmosphere.) and rain gauge. A succession of relatively dry years causes a progressive fall of the lake, and a succession of moist years a progressive rise. (p. 58)

Powell was helped immensely in his documentation of the rise of The Great Salt Lake by two surveyors, each working for the Federal government nineteen years apart. The first was Howard Stansbury, a major in the US Army Corps of Topographical Engineers (Powell, 1879, p. 66.) Major Stansbury led an expedition in 1849 to map the Great Salt Lake and to look for alternative routes for western bound settlers. In his expedition to map The Great Salt Lake, Stansbury used the new survey technique of triangulation resulting for the first time in significant accuracy. His expedition was part of a federal project by United States Corps of Topological Engineers to map the large lakes in the northwestern and northern United States (Stansbury et al., 1852). It is of interest to note that not only did Stansbury successfully leave a wonderful record of the level, shape, and boundaries of The Great Salt Lake, moreover; several of his routes were so accurate and of superb elevation and straightness that they became the path of the transcontinental railroad and eventually present transcontinental US Highway Route 80 (Stansbury et al., 1852). It is also of interest to note that the US Corps of Topographic engineers accepted only officers, graduates from West Point and men who were trained in engineering. The US Corps of Topographic Engineers visionary mission left a wealth of reliable data for use by many future researchers. This author being one of those most grateful researchers! Truly the Corps of Topographic Engineers highlights a magnificent mission of foresight and imagination initiated by the United States Federal government!
Powell’s second source of invaluable data was from Yale educated geologist, Clarence King, an American mountain climber, scientist, and author. King created the United States Geological Survey and served as its first director from 1879 to 1881 (USGS, 2021). He was noted for his exploration of the Sierra Nevada and in 1867 was named U.S. Geologist on the United States Geological Exploration of the Fortieth Parallel 1867-1888 (USGS, 2021; King, 1870). On this assignment King surveyed The Great Salt Lake, 19 years after Stansbury’s benchmarking survey. King’s later survey clearly demonstrated a considerable increase in the size and the level of The Great Salt Lake over a 19-year period 1850-1869 (see Figure 2-2) (King et al., 1870; Powell, 1879). Figure 2-2 is an overlay comparison of the survey maps of The Great Salt Lake from the two surveys created by Stansbury et al., 1852 and King et al., 1870. The dotted area was the earlier survey completed by Major Howard Stansbury in 1850. The horizontal lined area is the survey completed by Mr. Clarence King in 1869. Comparing these surveys illustrates the significant increase in the area of The Great Salt Lake between the years 1850 and 1869 (Powell, 1879, p. 66-67).

As a scientist Powell looked for many ways to corroborate his findings, indicating that a considerable increase in the level of the Great Salt Lake since 1850 had occurred. He used his knowledge in various disciplines to collect data for his assessments. He gathered observations of flora and salt saturated lakeside soils as well as consulting the anthropological aspects of the human use of the lake, such as irrigation and livestock use among neighborhoods ringing the lake. He also noted the effects that storms contributed to marking the level of the Great Salt Lake over time. (Powell, 1879, p. 66).
Figure 2-2

Increase in Area of the Great Salt Lake

Note: Comparison Survey Map of the Great Salt Lake 1850 compared with 1869 showing a 17% increase in water levels of the Great Salt Lake over this 19-year period. The dotted area indicates the survey completed by Major Howard Stansbury in 1850. The horizontally lined area indicates the survey completed by Mr. Clarence King in 1869. Source: Powell, 1879, p. 66-67.
Powell’s scientific strategy adds considerable veracity to his assessments concerning the arid regions of the West and the rise of the Great Salt Lake. His data clearly points to a pluvial in the Southwest region from the late 1850s to the early 1870s. This moister environment presented a distinct change in the human experience of the arid lands in Utah. There was much more water flowing in the rivers and washes, sitting as snow on the mountain slopes and mesa tops and in the lakes of the Southwest Region of the United States. Powell noted in his commentary about the rise of the Great Salt Lake that lines of salt and boundaries of sage and other flora gave clues as to the stable or changing level of the Great Salt Lake. He noted that along the lake shores no stumps or signs of growth could be found below the top boundary of Stansbury’s survey. Powell’s own visual assessment of the lake’s shoreline in several locations confirms the lack of plant life below the top 1850 boundary of the lake. Additionally, Powell saw well-established sage brush growing slightly above the Stansbury’s 1850 top edge of the Great Salt Lake. Since sage is a slow growing plant Powell uses the sage plant as evidence to extrapolate that the level seen in Stansbury’s 1850 survey was the long-standing level of the Great Salt Lake. He noted, “It is a familiar fact that the sage (Artemisia sempervirens) never grows in Utah upon soil so saline as to be unfavorable for grain” (Powell, 1879, p. 65). This botanical information served to aid Powell in his assessment of the distance at which the salt spray of the lake would influence plant life around the lake’s edges. Additionally, Powell wondered how long it would take for salt from the lake spray to accumulate in lakeshore soils? Powell also assessed the contrary situation which would be how long it might take for rain to cleanse lake shore soils of salt making them
consistently available for plant growth. The long-term level of The Great Salt Lake would then be intimately linked and indicated by sage brush habitat (Powell, 1879, p. 65-66).

Powell surmised that the lake level must have been relatively stable for a long period before it began to rise between 1850-1869. He continued to note in his report that, as the lake level had been rising many plant stumps “are now seen just below the rising lake level,” Powell offered his assessment of the Great Salt Lake’s hydrology during this nineteen-year period. He asserted:

Thus, it appears that in recent times the lake has overstepped an old boundary to which it had long been subject. Previous to the year 1865, and for a period of indefinite duration, it rose and fell with limited oscillation and with the annual tide but was never carried above a certain limiting line. In that year, or the one following, it passed the line, and it has not yet returned. The annual tide and the limited oscillation are continued as before, but the lowest stage of the new regime is higher than the highest stage of the old. The mean stage of the new regime is 7 or 8 feet higher than the mean stage of the old. The mean area of the water surface is a sixth part greater under the new regime than under the old. (Powell, 1879, p. 66)

This last statement is based on the surveys of Captain Stansbury and Mr. King completed for the United States Geological Survey. The former gathered the material for his map in 1850, when the water level was at its lowest stage, and the latter in the spring of 1869, when the water was near its highest stage. “The one map shows an area of 1,750 and the other of 2,166 square miles. From these I estimate the old mean area at 1,820 miles, the new at 2,125 miles, and the increase at 305 miles, or 17 percent” (Powell, 1879, p. 66-67).
Figure 2-3 includes further documentation within Powell’s *The report on the lands of the arid region of the United States, with a more detailed account of the lands of Utah* for evidence of a short term but significant climate change in the form of a pluvial that appears to occur between 1850-1869 with years of additional moisture until 1877 to contribute to the Great Salt Lake’s rising level. Salzer and Kipfmueller (2005) found the years 1865-69 were the fifth wettest period in the American Southwest in 1,425 years.

**Figure 2-3**

*Rise of the Great Salt Lake Including Storm Levels 1847-1877*

Source: Powell, 1879. p. 64.
Powell’s graph depicts the rise in the Great Salt Lake surface levels and includes storm levels. The storm levels signify a direct association to the high salinity levels of the Great Salt Lake, its basic and defining characteristic. The lake maintains a high concentration of salts for three reasons. The first being that the lake has no outlet. The second being that the lands surrounding the Great Salt Lake contain high concentrations of minerals and the water draining through these lands into the lake, carry high concentrations of these minerals dissolved in the water and snow run off. The third reason is that the temperature and lack of humidity in the arid region surrounding the lake increases the rate of evaporation which further concentrates the minerals in the lake by removing fresh water via the evaporative process.

The storm levels on the graph indicate where waves and spray intermittently yet with seasonal regularity invade the land constituting the lakesides. Because these waves and spray contain so much salt, they heave brine upon the lakeshore and invariably the land becomes soaked through with salt and minerals. This results in a marked zone around the lake in which few if any species of plants can survive thereby becoming a marker of long-term lake levels. Powell explained this phenomenon and his graph (Figure 2-3) further:

The horizontal spaces represent years, and the vertical spaces, feet. The irregular curve shows the height of the lake in different years. Where it is drawn as a full line the data are definite; the dotted portions are interpolated. Upon the same diagram are indicated the levels of two storm lines. The upper is the limit of wave action at the present time and is 3 feet above the winter stage (October 1877). It is everywhere marked by drift wood, and in many places by a ridge of sand. Above it there is a growth, on all
steep shores, of sage and other bushes, but those in immediate proximity are dead, having evidently been killed by the salt spray. Below the line are still standing the stumps of similar bushes, and the same can be found 2 or 3 feet below the surface of the water.

The lower storm line was observed by Captain Stansbury in 1850 and has been described to me by a number of citizens of Utah to whom it was familiar at that time and subsequently. Like the line now visible, it was marked by drift wood, and a growth of bushes, including the sage, extended down to it; but below it there were seen no stumps. Its position is now several feet under water, and it is probable that the advancing waves destroyed most of its features, but the vestiges of the bushy growth above it remain (Powell, 1879, p. 65). Powell continues assessing the evidence for the fact that the Great Salt Lake had been at a lower stable level for a long period. Interestingly this observation corresponds with those Geologist H.E. Gregory who noticed a long period of undisturbed alluvial aggregation for the Virgin River in the area of Zion Canyon occurring in a similar timeframe as Powell’s observation of the Great Salt Lake’s stable level (Gregory, 1950). Powell clarified his graph on the Rise of the Great Salt Lake. He wrote:

The peculiarities of the two storm lines have an important bearing on the history of the lake. The fact that the belt of land between them supported sage bushes shows that previous to its present submergence the lake had not covered it for many years. Lands washed by the brine of the lake become saturated with salt to such extent that even salt-loving plants cannot live upon them…. The rain of many years, and perhaps even of centuries, would be needed to dense (sic.) land abandoned by the lake so that it could sustain the salt-hating bushes, and we cannot avoid the conclusion that the ancient storm line had been for a long period the superior limit of the fluctuations of the lake surface. (Powell, 1879, p. 65)

Powell also used anecdotal data, he termed ‘traditional knowledge’ to gather evidence. This information about the lived experience of the settlers with the levels of the Great Salt Lake is presently called qualitative data. Powell interviewed people living near the water’s edge for their observations in support of the surveys of Stansbury and King. The Mormon settlers to Utah coming with Brigham Young in 1847 had to be ingenious and to use the regional geography to their advantage in any way they could imagine. One
of these novel ideas suggested grazing cattle on the islands of the Great Salt Lake. Powell described the geographic relationship of the Great Salt Lake to pioneer ranching:

Ever since the settlement of Salt Lake City in 1847 the islands of the lake have been used as herd grounds. Fremont and Carrington Islands have been reached by boat and Antelope and Stansbury Islands partly by boat, partly by fording and partly by land communication. A large share of the navigation has been performed by the citizens of Farmington and the shore is in that neighborhood so flat that the changes of water level have necessitated frequent changes in landing place. The pursuits of the boatmen have been so greatly affected that all of the more important fluctuations were impressed upon their memories, and most of the changes were so associated with features of the topography that some estimate of their quantitative values could be made (Powell, 1879, p. 62-63).

Due to the need to feed and water the cattle on these islands on a regular basis, the locals noticed any rise or fall of lake level over the spits of sand they used as walkways to reach their cattle. This anecdotal evidence gives the present-day reader a graphic portrayal of how the increase of precipitation occurring in this region of the Southwest would affect daily life. Powell simply described the change in access to the islands over a thirty-year period 1847-1877. He described:

From 1847 to 1850 the bar was dry during the low stage of each winter, and in summer covered by not more than 20 inches of water. Then began a rise which continued until 1855 or 1856. At that time a horseman could with difficulty ford in the winter, but all communication was by boat in summer. Then the water fell for a series of years until in 1860 and 1861 the bar was again dry in winter. The spring of 1862 was marked by an unusual fall of rain and snow, whereby the streams were greatly flooded, and the lake surface was raised several feet. In subsequent years the rise continued, until in 1865 the ford became impassable. According to Mr. Miller the present height was attained in about 1868, and there have since occurred only minor fluctuations. I visited the bar in company with Mr. Miller on the 19th of October 1877 and made careful soundings. The features of the ford had been minutely described, and there was no uncertainty as to the identification of the locality. We found 9 feet of water on the sand flat, and 9 feet 6 inches in the little channel at its edge. (Powell, 1879, p. 63)

Imagine the huge quantity of water encompassing a nine-foot rise of water over the entire basin of The Great Salt Lake! This water indicates a considerable increase in
precipitation to the normally arid desert landscape. In 1862 in southern Utah this increase in precipitation was also experienced and will be discussed in Chapter 4.

It is important to connect the traditional knowledge as seen in the personal recounting of pioneering Mormon settlers to the actual measurement data that Powell made. Mormon Church history focuses upon the importance of remembering and keeping records. Joseph Smith, the founder of The Latter-Day Saints (LDS), noted in his journal on the day the Church was organized, April 6, 1830, that “The Lord commanded “Behold, there shall be a record kept among you (LDS, 2007). Present day Church Historian, Elder Marlin K. Jensen, explained on the LDS website the importance of journaling and record keeping for LDS members. Jensen offered this insight:

Scriptures especially The Book of Mormon, make clear that “remembering” is a fundamental and saving principle of the gospel. We keep records to help us remember. Remembering the past gives us needed perspective as God’s children to have faith in our future destiny and thus to live more faithfully in the present (LDS, 2007).

Remembering for the pioneering settlers of Utah was a serious undertaking in the form of journaling. Packed with observations, these journals provided additional sources for this dissertation. Observations taken from pioneering Mormon settlers’ journals and shared in historical accounts used in this dissertation appear to confirm or corroborate climatic conditions from the period 1847 onward. In fact, it was reading descriptions of Mormon pioneer reflections such as: Brigham Young’s Dixie of the Desert Exploration and Settlement by H. Lorenzo Reid that supported this author’s hunches that an undocumented climate change had occurred and might have influenced the channeling of the Virgin River.
Powell’s documentation by graph and his narrative description of the rise of the Great Salt Lake also illustrated drought years. When Powell wrote, “Then the water fell for a series of years until in 1860 and 1861 the bar was again dry in summer” he was using traditional knowledge to also note drought years although this was not his primary intention. It is important to note that in Mormon accounts of the Dixie settlement state that when they arrived in late 1861 considerable rain began to fall, adding unexpected adversity and harsh struggle to their arrival at the Cotton Mission (Reid, 1964). Powell’s observations about the bar being dry again, coincide with the years 1857-61, the 16th driest period on the southern Colorado Plateau, as documented in Salzer and Kipfmueller (2005) research. Yet in southern Utah late in 1861 there is Mormon journal evidence (Reid, 1964) that the pluvial years were beginning. Salzer and Kipfmueller (2005) research includes southern Utah because much of this area is on the southern and western edge of the large regional geologic structure called the Colorado Plateau where Salzer and Kipfmueller (2005) researched historical climate change using dendrochronology.

The USGS Water Resources website offers access to historical digitized data and if desired USGS will create a graph for researchers. I took them up on this option and the graph (Figure 2-4) is the data I used to display the levels of the Great Salt Lake over the last 150 years. In this graph the pluvial of 1865-69 is represented in the thin rectangular box moving from left to right and by the second and highest and widest peak on the graph. This peak represents the five years of a considerably wet period in northern Utah that actually lasted into the early 1870s. Moreover, this increased moisture was also seen in southern Utah. The new Mormon settlers arriving to the Southwest region of the United States and to southern Utah were the first permanent group of Caucasians to meet
the “Great American Desert” and to make it their homes. Their environmental perception based on living within the pluvial of 1865-69 gave them a distinctly different climatic experience than that of the Native Americans already well established in the region. These indigenous communities who had subsistence farmed and hunted in the region for centuries knew much longer dryer and harsher conditions compared to the new 1847 Mormon settlers to northern Utah and the 1861 Mormon settlers to southern Utah. In Figure 2-4 one can also see the pluvial of 1905-1922 in the wider red box highlighting the third and wider peak with the rise in precipitation beginning in 1905 and levels of high-water marks in the Great Salt Lake being sustained from about 1910 through the late 1920s. Graphs of similar shape will be seen again in the next two sections of this chapter with data from dendrochronology and streamflow as evidence for the pluvial of 1905-1922. This increase in precipitation shaped the perception of the regional environment for all those living in the Southwest, and consequently resource management in the early years of Zion National Park.

**Dendrochronology: The Study of Tree Rings as a Climate Change Indicator**

Tree ring studies further support my premise that the climate and the responding environment of the Southwest were atypically wet during the periods of Mormon settlement 1847-1877 in northern Utah and 1861-1891 in southern Utah, as well as during the initial administration of Zion National Park 1909-1934. This chapter additionally offers data derived from dendrochronology and streamflow as evidence for climate change in the first decades of the 20th Century in southern Utah 1905-1922.
In this section the evidence from Dendrochronology will be presented. The set of data derived from tree ring studies augments the evidence already presented in the beginning section of Chapter 2: The Rise of the Great Salt Lake. Several of the dendrochronology studies presented herein reach back over a millennium; therefore, they address both the period of initial Mormon settlement of southern Utah 1861-1891 and the timeframe of the initial active administration of Zion National Park 1918-1934. These studies also present a comparison of long term typical arid climate with the atypical wet periods occurring during the European American Mormon settlement of Utah.

Dendrochronology, the study of tree rings, offers the modern-day scientific sleuth, a tool with which to peer into the past. Dendrochronology is the science of dating events and climatic variations in past environments by using the comparative study of growth rings in trees and aged wood. The lifetime of a tree is marked by growth rings, one for
every year of life. However, in some regions with two seasonal wet periods such as in the American Southwest, there can be a second annual growth ring. The width of the ring added to the outside of the tree is in part dependent on the amount of moisture available to the tree. Thus, trees in the same area add thin rings during dry years and thick rings during wet years. In a geographical area if a string of tree samples can be found that overlap in time, a precise sequence of tree rings creating a timeline can be derived. This tree ring timeline is called a chronology. By using living and dead trees of different but overlapping ages, a chronology can be linked and catalogued. A chronology then becomes part of a library of tree rings of different calendar ages in a region.

Dendrochronology researchers have completed such chronologies for Bristlecone Pines in the U.S.A., waterlogged Oaks in Ireland and Germany, and Kauri in New Zealand thereby creating records extending back over the last 14,000 years. In order to understand and plan for climate change the need for regional climate histories has become essential. This need has spurred tree ring study research on a regional level resulting in an increase of regional tree ring chronologies since the year 2000. Trees daily offer essential environmental services to human beings. In addition, trees offer a climatic service that extends well beyond the present. They act as a bellwether of climatic conditions over historic timeframes.

**The Origins and Development of Tree Ring Research**

Leonardo de Vinci first suggested that tree rings mirrored the climatic conditions in which they grew. In the first half of the 20th Century A. E. Douglas founded the Laboratory of Tree Ring Research at the University of Arizona. Tree ring studies began to be used scientifically in the United States during World War II when a scientist named
Edmund Schulman used tree rings to access drought conditions and the dependability of water-power generation at Hoover Dam. Schulman sampled a single core from a single tree and made a climatic assessment for that locality. Schulman more remarkably found and sampled many of the oldest known trees on Earth, the Bristlecone Pine. He died unexpectedly but his work initiated a tree ring chronology now going back about 14,000 years (Stockton & Jacoby, 1976; Straka, 2008).

Since Shulman’s initial introduction of tree rings into scientific research and vernacular, substantial improvements in the area of dendrochronology have been contributed by H.C. Fritts at the Laboratory of Tree Ring Research at the University of Arizona in Tucson. Fritts created a standard procedure that included the protocol of sampling ten trees in each site and then averaged the results of two core samples per tree to determine a mean-value function. Fritts also calculated multi-variate statistical techniques to respond to varying temporal climatic trends (Stockton & Jacoby, 1976, p. 3-4).

The validity of using tree rings as stable reference points for comparison of attributes such as precipitation, derives from the presence of radiocarbon ubiquitous in the environment. Radiocarbon dating was invented in the late 1940s. The timescale and dates retrieved from measuring radioactive carbon in objects provide repeatable and reliable progressions. These time progressions do not necessarily follow calendar years but are measured back from the year 1950 and noted with the term BP indicating “Before Present” with present being the year 1950.

Radiocarbon dating can be used to measure the amount of radiocarbon in individual tree rings. The amount of radiocarbon in the atmosphere is the same at any
given time. However, levels of radiocarbon do fluctuate and can be affected by solar flares. Also, individual samples can be affected by local industrial pollution.

Tree rings that grow in the same year should have the same amount of radiocarbon. Additionally, different tree ring assays can be compared not only for the same amount of radiocarbon in a tree ring but also by matching erratic fluctuations that are common in radiocarbon atmospheric levels. These fluctuating levels can be seen in different trees that were alive during the same years resulting in valid comparisons among different tree species across varied geographic regions of the world (Beta Analytic Testing Laboratory, 2017).

Linick et al. compared the radiocarbon among Bristlecone Pines across the United States in their 1986 dendrological research. The purpose of this research was two-fold:

1. to provide a calibration of the carbon 14 timescale for the conversion of ages in carbon 14 years BP to ranges of true calendar years; 2. To study the variations of atmospheric Carbon 14 levels with time as a matter of geophysical interest to examine the causes of these secular variations and changes in the strength of the earth’s magnetic field and changes in the flux of solar and cosmic rays. (p. 943)

Not only did Linick et al. (1986) correlate the geographical consistencies of radiocarbon by species and age but they created the only chronology of a tree species, Bristlecone pine, that continues unbroken to 6554 BC (p. 945).

Local climate factors such as precipitation and temperature influence the width of a yearly tree ring growth. Oak trees, Bristlecone pine, cedar, and silver pine from New Zealand all grow at different yearly rates. For example, the Bristlecone pine, an evergreen, grows at a slow rate and the deciduous oak much more rapidly. However, the amount of radiocarbon should be the same for the same year tree ring.
As a means of independent verification of the amount of radiocarbon in tree ring samples across geographic regions and species, scientists compared chronologies from three different regions of the world (Hogg et al., 2002). Hogg and his associates performed a series of high-precision measurements on decadal samples of tree ring dated oak (*Quercus petraea*) from Great Britain and cedar (*Libocedrus bidwillii*) and silver pine (*Lagarostrobos colensoi*) from New Zealand. These measurements showed consistency of radiocarbon levels between the samples from both the chronologies of the Northern and Southern Hemispheres (see Figure 2-5).
Stuiver et al. (1986) compared the levels of radiocarbon in the dendrochronology chronology of the Bristlecone Pine in North America with the Western European chronology of oak trees in three locations Heidelberg, La Jolla, and Seattle (see Figure 2-6). The results showed similar levels of radiocarbon among samples from similar time-frame periods of 14C ages with tree rings 1. German Oak series. The two Bristlecone Pine data points assume an age of 7190 yr. BC for ring number 1. On the right of the

Source: Hogg et al. (2002)
The results of both studies that compared levels of radiocarbon among tree rings on a global scale illustrated the close correlation between the amounts of radiocarbon in groups of trees all living at significant geographical distances but at the same periods of time. If random error was a characteristic of dendrochronology, then these tree ring chronologies separated by oceans would have considerable displacement, yet the results showed significant reliability and concurrence of the same radiocarbon amounts in the same year tree ring. These and other studies validate the data contained in tree rings as well as the stability for using tree rings as a reliable data source of climatic data over long periods on local as well as regional and global scales.
Applications of Dendrochronology

Tree ring studies perform well as indicators of climatic conditions and offer clear indicators of climate change over time. Dendrochronology also offers versatility in its applications. Tree ring studies have pointed to decade-long droughts in the Southwest (Meko et al., 2007). Tree ring studies aided anthropologists in the search for explanations regarding the mysterious and sudden disappearance of the great Ancestral Puebloan civilization of the Southwest 700-1300AD. These droughts are considered one of, if not the main reason, why the complex Ancestral Puebloan civilization abruptly disappeared from its population centers in the American Southwest such as Chaco Canyon in present day New Mexico and Mesa Verde in western Colorado. Gray et al. (2004) acknowledged that the long-term drought regimes in this region would have created stringent limitations for the Ancestral Puebloan people formerly known as the Anasazi. Grey et al. (2004) research, derived from tree ring studies, indicated multi-decadal drought at the end of the 13th Century. Gray et al. (2004) explain:

The Anasazi could not have relied on crop surpluses from adjoining regions during the Great Drought. Starvation and disease associated with nutrient deficiencies must have claimed large portions of the Anasazi population. As an example, a drought in the 1660s decimated the Pueblo of Tabira in the Estancia Valley of central New Mexico. By 1669 no crops had been harvested for three years, and more than 450 of Tabira’s inhabitants (half of the pueblo) starved to death. (p. 957)

Salzer and Kipfmuller (2005) (see Table 2-1) report the years 1090 -1101AD as the eleventh driest set of years in 1425 years (p. 475). Using tree ring chronologies E. Cook et al. (2004) found the four driest epochs in their study to be the years 936 A.D., 1034 A.D., 1150 A.D. and 1253 A.D. (p. 1017). The 1150 A.D. drought as well as the
1250 -1288 A.D. drought reported by Gray et al. (2004) correspond to the widespread abandonment of Ancestral Puebloan dwellings in the Southwest.

Over the last 15 years, as a means of updating strategic planning and water policy, water resource managers have used dendrochronology data matched with streamflow records to determine historic stream flows for rivers in the arid American Southwest. An example of an effort to construct a more accurate water policy based on underlying long-term climate conditions available from dendrochronology research is the recent review of the historic Colorado River Compact of 1922. This agreement was based only on streamflow records during the pluvial years of 1905-1922 not on any long-term research or dendrochronology research that would have indicated longer term and dryer climatic patterns with far less annual streamflow. Therefore, there was a perception by the administrators of the 1922 Colorado River Compact that high streamflow levels of the early 20th Century were going to continue well into the future.

The present-day allocations of Colorado River water to Mexico and the seven US states within the river’s basin were based on unusually elevated levels of the Colorado River. This high streamflow resulted from the increased precipitation that occurred during the 1905-1922 pluvial (Woodhouse et al., 1976). Dendrochronology helped to confirm that the 1922 stream levels were not hydraulically accurate over the long term. As a result, the 1922 Colorado River Compact water allocations would not be available over the long term.

The Compact was based on Colorado River flows of 16,400,000-acre feet (20.2 km³) per year (641 m³/s) whereas Woodhouse et al. (2006) estimated 14,300,000-acre feet (17.6 km³) per year (559 m³/s) as a more historically accurate Colorado River flow.
Stockton and Jacoby (1976) estimated stream flow for the Colorado River at an even lower average of 13,500,000-acre feet (16.7 km³) per year (528 m³/s) (p. 3). If the administrators of the Colorado Compact of 1922 were under the environmental perception of high streamflow in the Southwest well into the future might the new administrators for Zion National Park also been under this same regional environmental perception due to the pluvial of 1905-1922?

Ciancarelli et al. (2014) researched the connection between the North American Monsoon (NAM) and late tree ring growth. In the Southwest region of the United States a rainy summer Monsoon period commences in late June and ends in late August. This summer precipitation period can contribute substantial precipitation to yearly totals and can be an indicator of overall moist or drought conditions. The November through April period of moisture in the Southwest causes a first layer of tree ring growth and the NAM gives rise to a second layer that together determines yearly tree ring growth.

Ciancarelli and her associates (2014) sought to link NAM precipitation with second layer tree ring growth width in the Southwest. This linkage would add validity to the use of tree ring data for understanding long term climate variation and patterns throughout the Southwest. Their research found:

Tree-rings stand as substantial primary data essential for verifying and documenting changes in climate over the long periods of time especially in water sensitive desert environments such as, the Southwest region of the United States. This preliminary analysis strongly supports the hypothesis that latewood tree-ring data are a reliable paleoclimate proxy to capture monsoon precipitation interannual variability and extends the earlier work of Stahle et al. (2009) to now consider the associated spatial patterns. (Ciancarelli et al., 2014, p. 703)
Dendrochronology of Southern Utah

The climatic conditions during the initial Mormon settlement 1847-1877 of northern Utah, the early Mormon settlement of southern Utah 1861-1891, and during the initial period of transfer of land containing Mukuntuweap Canyon and surrounding environs from private holdings to the U.S. Department of Interior in 1909-1919 were unusual for the desert conditions of the Southwest region of the United States. In this dissertation, research by various scientists using dendrochronology establishes these settlement periods as having exceptionally wet climatic periods.

The environmental conditions influencing the pioneer migration to the American Southwest in the periods 1847-1877 and 1905-1922 were unique and transformative to the arid lands of the Great American Desert. These were wet years for the Great American Desert (Powell, 1879). Powell saw firsthand that the level of The Great Salt Lake had risen. He was not the only living being to witness this increase in moisture. The trees on the Colorado Plateau also took note.

Zion National Park lies on the southwestern quadrant of the Colorado Plateau. As a result of both plate tectonics and volcanic activity over the last ten million years this geomorphic formation rose from sea level to heights over 10,000 feet above sea level. Matthew Salzer and Kurt Kipfmueller (2005) dendrochronology research supply compelling evidence to support my claims that the initial periods of Caucasian settlement on the Colorado Plateau in southern Utah, occurred under wet climate regimes and periods of significant climate anomaly.

Through their tree ring study Salzer and Kipfmueller (2005) paint a remarkable picture of climate patterns over the last 1,425 years across the southern Colorado Plateau.
Their research identifies thirty-five extreme-wet periods and 30 extreme-dry periods in the American Southwest since the end of the 10th Century CE (see Table 2-1). Wet and dry periods range from five to twenty-six years in length. The period 1865-69 is listed as the fifth wettest period during Salzer and Kipfmueller’s millennial research timeframe. 1865-1869 coincides with the initial Mormon settlement of St. George, Utah in 1861-1870 and other small towns in southern Utah as well as the settlement of Zion Canyon in 1863 by the Mormon pioneers Isaac and Elmina Behunin.

Adding additional evidence to support my research premise, Salzer and Kipfmueller (2005) found that the longest wet interval in their precipitation reconstruction of 1425 years was the seventeen-year period 1905-1922. These same years are also listed as the 14th wettest period in the 1,425-year research period (see Table 2-1'). 1905-1922 are precisely the years leading up to and including the creation of the Mukuntuweap National Monument in 1909 by President Taft and the formal designation of this National Monument as Zion National Park in 1919 by President Woodrow Wilson.

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1The wettest time frame in their study was the 5-year period from 985 to 989 AD. In terms of dry periods Salzer and Kipfmueller (2005) note that the driest interval in their precipitation reconstruction was the six-year period from 1818 to 1823 and the longest drought was twenty-six years, from 699 to 724 AD.
### Table 2-1

*Reconstructed Precipitation Record for the Southern Colorado Plateau over the Last 1,425 Years*

<table>
<thead>
<tr>
<th>Wet periods</th>
<th>Anomaly</th>
<th>Rank</th>
<th>Dry periods</th>
<th>Anomaly</th>
</tr>
</thead>
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<tr>
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<td>1</td>
<td>1818–1823</td>
<td>−1.25</td>
</tr>
<tr>
<td>1325–1334</td>
<td>+1.79</td>
<td>2</td>
<td>920–924</td>
<td>−1.13</td>
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<tr>
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<td>+1.61</td>
<td>3</td>
<td>1751–1757</td>
<td>−1.06</td>
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<tr>
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<td>+1.53</td>
<td>4</td>
<td>1666–1672</td>
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<tr>
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<td>+1.44</td>
<td>5</td>
<td>660–664</td>
<td>−1.04</td>
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<td>7</td>
<td>1893–1904</td>
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<td>8</td>
<td>1292–1300</td>
<td>−0.93</td>
</tr>
<tr>
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<td>9</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>31</td>
<td>1728–1742</td>
<td>−0.64</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32</td>
<td>909–910</td>
<td>−0.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33</td>
<td>1182–1191</td>
<td>−0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34</td>
<td>1033–1046</td>
<td>−0.46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35</td>
<td>1144–1154</td>
<td>−0.35</td>
</tr>
</tbody>
</table>

Source: Salzer and Kipfmueller (2005, p. 475)
In Salzer and Kipfmueller’s data the beginning and end years listed in each time frame entry on the list are included fully in the sample, for example 1865-69 is a five-year period. The study does not record increments of time smaller than five years in the precipitation calculations. Therefore, years before and after the 5-year designations may share significant wetness or dryness with an adjacent wet or dry year sequence listed in the table. Additionally, a single year or two at any time may show significant levels of wetness or dryness but these are not noted by Salzer and Kipfmueller (2005).

Salzer and Kipfmueller’s data has significance to the Mormon settlement for both northern Utah, which began in 1847 and southern Utah, which began in 1861 because increased moisture in a desert ecosystem would help assure agricultural success which in turn would equate to survival for the pioneer community. Using Salzer and Kipfmuellers’s (2005) table the period from 1833-1840, 7 years before the Mormons arrived in Utah, was the 8th wettest period. The seven years’ time frame before the first Mormon settlers arrived in 1847 is a long time for evidence of this moisture to remain and be noticed by the initial settlers of northern Utah. Nonetheless. This amount of moisture in an arid environment would be significant. Young trees may have sprouted or survived because of this moisture. The assessment of the long-term effects of a pluvial on the desert ecosystem is outside of the scope of this dissertation but important to note. Because before this pluvial there was a significant drought 1818-1823 in the region, in fact the driest five-year interval in the 1425-year study. Significance does occur in the pluvial of 1865-69 because this timeframe was during the initial five-year period when Mormons were settling in southern Utah. 1865-1869 was the 5th wettest pluvial in Salzer and Kipfmueller’s research. The years1905-1922, when the beauty of Mukuntuweap
Canyon was being discovered and preserved, was the 14th wettest period and the longest wettest period in over 1425 years! Weather affected the success or failure of these early pioneer communities (Larson, 1961; Reid, 1964; Woolley, 1946). It is important to note that this settlement range of time 1847-1922 also had three of the driest periods according to Salzer and Kipfmuller with 1857-1861 being the 16th driest, 1870-1883 the 14th driest and 1893-1904 the 7th driest period.

Such significant dry periods raise the question, would the Mormon settlements have survived without the pluvials? Both the drought from dry years and the floods from wet years left their mark on the nascent Mormon settlements. With some towns in southern Utah failing due to drought, Paria, and some from flooding, Grafton. Both the wet and dry periods are noted in the historic literature about the Mormon settlement of Utah. Information from Mormon diaries add a year-by-year ground view of the local weather that the broad time frame dendrochronology research cannot capture. These intimate experiences indicate that years 1861-62 were also extremely wet years in the St, George region of Southern Utah, and that several years in the 1870s were unusually dry (Reid, 1964; Larson, 1961; Woolley, 1946).

Salzer and Kipfmuller (2005) used tree ring chronologies to ascertain precipitation patterns. Recall from earlier in this chapter that each tree in the research group may not have a 1,425-year tree ring history, but each tree carries a record of part of the timeframe studied. Some trees overlap in time, which creates a link in a tree ring timeline. These chronologies form a series of time frames that illustrate climatic conditions and connections among trees in a region. In Salzer and Kipfmuller’s study some deadwood was used for periods before 700 AD. Salzer and Kipfmuller found
Ponderosa pine, Douglas fir and Bristlecone Pine trees spread out over Arizona and southern Utah as sources for tree ring data in their study (see Figure 2-7).

**Figure 2-7**

*Map of Arizona and Adjoining States Showing Location of the Tree Ring Site (S) Used in the Temperature (Diamond) and Precipitation (Circle) Reconstructions*

Source: Salzer and Kipfmueller (2005, p. 467)

Their results show strong validity because in addition to tree ring data Salzer and Kipfmueller (2005) took known temperature data and correlated it with historic temperature records. Then they statistically correlated this temperature data to the tree ring data thereby using two independent strings of data over long periods of time. These were first independently correlated with recorded historical data, then the temperature data set and tree ring data sets were statistically correlated with each other.
The pluvial period 1865-69 does not coincide with temperature table (Table 2-2) in the Salzer and Kipfmueller (2005) research. However, the wet period 1905-1922 does coincide with the temperature table in the Salzer and Kipfmueller’s report. The years 1911-1930 appear as the third coolest period in Salzer and Kipfmueller’s 1,425 -year temperature study! The years 1911-1930 coincide with 11 years of the seventeen years of the 1905-1922 pluvial. The considerable coolness would limit evaporation thereby increasing moisture in the soil, in lakes, and in rivers. This cooler period could also explain the increased precipitation that continued into the last years of the 1920s and was noted in the Zion National Park Superintendent Reports of the late 1920s. As a result of the longest wettest period 1905-1922 coinciding with the third coolest period 1911-1930, in the first years of the 20th Century, the fertility of the land, the streamflow, and force of Virgin River would have increased. The climate would have been noticeably different with both temperature decreasing and precipitation increasing in a normally hot and dry desert ecosystem. This change would surely have been noticed creating a new perception of the climate for the inhabitants of southern Utah. Furthermore, the early 20th Century perception of a wet climate may have been amplified due to following directly after the seventh driest period in 1425 years 1893-1904 (Salzer & Kipfmueller 2005)!

Salzer and Kipfmueller (2005) also noted “Temperature and precipitation are usually out-of-phase in the American Southwest. Due to cloud cover and sensible heat effects, when it is dry it is usually warm and when it is wet it is usually cool” (2005, p. 478). Presently, I reside in Zion Canyon and have experienced this cool wet pattern firsthand albeit for shorter intervals. From November of 2015-2018 the canyon weather resembled this pattern with cool temperatures accompanying wet weather. Since first
residing in Zion Canyon in 2000 the months of November, December 2015 January and February 2016 have been the wettest and coolest I have known. 2015 was an El Nino year. 2

The out-of-phase pattern of dry with warm and wet with cool does not hold true all the year since the Southwest has a summer monsoon period from late June through August. When this pattern occurs, the temperatures rise, and the air becomes very warm while the climate is wet.

The wet 17-year period from 1905-1922 no doubt influenced the environmental perception of those living in Zion Canyon and in southern Utah. Scientists suggest that the pluvial in the Southwest was widespread geographically occurring also in the Northwest and in the Central Plains regions of the United States (Fite, 1966; Salzer & Kipfmueller, 2005). In terms of human perception, seventeen years is certainly a long enough period to think one knows something about the neighborhood or region in which one lives. The environmental perception of pioneer settlers and administrators of Zion National Park would have been affected by this regional climate anomaly and will be discussed further in Chapters 3 and 4.

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2 As a relevant source of present-day climate change data, I encourage the reader to also take note of the first entry in the right-hand column of the Salzer's and Kipfmueller's Temperature Table for the years of warmest temperatures. The years 1946-1996 are listed as the warmest years and longest length of warm temperatures in the 1,425-year study. The entry 1946-1996 documents fifty years of regional warming and serves as an indicator within the 1,425-yr period of a significant temperature increase over this long period of time. Salzer's and Kipfmueller's research on climate up to this period 1946-1996 illustrate that the duration of any of the wet, dry, cold, or warm periods to be cyclical in periods of less than three decades. This fifty-year period of increase in temperature found in Salzer and Kipfmueller's research identified the presence of factors such as the greenhouse gas effect that may be tipping climate temperatures into a new "normal," This 50-year period is a notable change and may indicate a change in the underlying factors controlling rate and duration of oscillation of climate. Ultimately a change in the oscillation rate would likely affect the ability for species of all life forms to be able to change fast enough to endure long term non-cyclical changes in the environment.
B. I. Cook et al. (2011) supply further evidence that the early years of the 20th Century were extremely and persistently wet for the Southwest region of the United States and that the perception of regional climate had changed. They coined the years 1905-1917 as “the Early 20th Century North American Pluvial” and attributed this period as containing the most increased moisture in the region over the previous 500 years. They surmised that this pluvial was responsible for the perception that legislators and other water managers held that the amounts of water in rivers and streams during this period would continue well into the future. This belief allowed for “overly generous water allotments in the water-limited American west” (p. 5043). Cook et al. then hedge their conclusions and assert that the infrequency of such a pluvial is likely double their 500-year time frame when data from tree ring chronologies reconstructing drought years is aligned with their data. They conclude the Early 20th Century pluvial “may have been the wettest period in the west anytime in the last 1000 yr.” (p. 5044).

B. I. Cook et al. (2011) used tree ring chronologies, temperature records, as well as the Palmer Drought Severity Index (PDSI) as sources for their analysis of precipitation trends. Particularly in the Southwest, evaporation also termed “evaporative demand as a function of temperature” and precipitation also termed “moisture supply” play significant roles in determining climatic conditions (p. 5044). The Palmer Drought Severity Index, initially created in 1965, records the duration, spatial extent, and intensity of drought. The index statistically incorporates evaporative demand and moisture supply over North America and reflects winter and spring moisture as well as summer moisture into its statistical range which makes it useful for understanding the effect of the two periods of moisture in the American Southwest, winter rains and summer monsoons.
Table 2-2

Reconstructed Temperature Record for the Southern Colorado Plateau over the Last 1,425 Years

<table>
<thead>
<tr>
<th>Short-term (≥ 5 years and ≤ 50 years) anomalous cool and warm periods in the reconstructed temperature record</th>
<th>Cool periods</th>
<th>Anomaly</th>
<th>Rank</th>
<th>Warm periods</th>
<th>Anomaly</th>
</tr>
</thead>
<tbody>
<tr>
<td>683–700</td>
<td>−1.96</td>
<td>1</td>
<td>1946–1994</td>
<td>+1.99</td>
<td></td>
</tr>
<tr>
<td>1636–1653</td>
<td>−1.83</td>
<td>2</td>
<td>402–410</td>
<td>+1.91</td>
<td></td>
</tr>
<tr>
<td>1911–1930</td>
<td>−1.46</td>
<td>3</td>
<td>1529–1534</td>
<td>+1.65</td>
<td></td>
</tr>
<tr>
<td>43–22 BC</td>
<td>−1.44</td>
<td>4</td>
<td>1708–1721</td>
<td>+1.49</td>
<td></td>
</tr>
<tr>
<td>1195–1219</td>
<td>−1.38</td>
<td>5</td>
<td>1736–1744</td>
<td>+1.48</td>
<td></td>
</tr>
<tr>
<td>534–553</td>
<td>−1.34</td>
<td>6</td>
<td>266–228 BC</td>
<td>+1.46</td>
<td></td>
</tr>
<tr>
<td>268–279</td>
<td>−1.34</td>
<td>7</td>
<td>1753–1761</td>
<td>+1.34</td>
<td></td>
</tr>
<tr>
<td>1330–1364</td>
<td>−1.27</td>
<td>8</td>
<td>238–252</td>
<td>+1.34</td>
<td></td>
</tr>
<tr>
<td>122–108 BC</td>
<td>−1.25</td>
<td>9</td>
<td>299–311</td>
<td>+1.29</td>
<td></td>
</tr>
<tr>
<td>897–902</td>
<td>−1.25</td>
<td>10</td>
<td>1777–1801</td>
<td>+1.24</td>
<td></td>
</tr>
<tr>
<td>1512–1527</td>
<td>−1.22</td>
<td>11</td>
<td>201–194 BC</td>
<td>+1.24</td>
<td></td>
</tr>
<tr>
<td>846–859</td>
<td>−1.15</td>
<td>12</td>
<td>89–73 BC</td>
<td>+1.21</td>
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</tr>
<tr>
<td>1810–1825</td>
<td>−1.13</td>
<td>13</td>
<td>1688–1698</td>
<td>+1.16</td>
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<tr>
<td>1763–1771</td>
<td>−1.12</td>
<td>14</td>
<td>840–845</td>
<td>+1.05</td>
<td></td>
</tr>
<tr>
<td>987–991</td>
<td>−1.00</td>
<td>15</td>
<td>673–682</td>
<td>+1.01</td>
<td></td>
</tr>
<tr>
<td>1835–1854</td>
<td>−1.00</td>
<td>16</td>
<td>1586–1593</td>
<td>+1.00</td>
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</tr>
<tr>
<td>1094–1120</td>
<td>−0.98</td>
<td>17</td>
<td>347–352</td>
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<tr>
<td>1661–1683</td>
<td>−0.98</td>
<td>18</td>
<td>591–609</td>
<td>+0.98</td>
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<tr>
<td>804–824</td>
<td>−0.96</td>
<td>19</td>
<td>878–893</td>
<td>+0.86</td>
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<tr>
<td>144–134 BC</td>
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<td>20</td>
<td>190–163 BC</td>
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<tr>
<td>663–669</td>
<td>−0.93</td>
<td>21</td>
<td>1146–1155</td>
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<td></td>
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<tr>
<td>1599–1612</td>
<td>−0.90</td>
<td>22</td>
<td>706–717</td>
<td>+0.82</td>
<td></td>
</tr>
<tr>
<td>94–103</td>
<td>−0.88</td>
<td>23</td>
<td>1067–1091</td>
<td>+0.81</td>
<td></td>
</tr>
<tr>
<td>230–235</td>
<td>−0.88</td>
<td>24</td>
<td>1390–1443</td>
<td>+0.80</td>
<td></td>
</tr>
<tr>
<td>177–194</td>
<td>−0.87</td>
<td>25</td>
<td>16–2 BC</td>
<td>+0.77</td>
<td></td>
</tr>
<tr>
<td>729–736</td>
<td>−0.85</td>
<td>26</td>
<td>1367–1380</td>
<td>+0.72</td>
<td></td>
</tr>
<tr>
<td>1258–1271</td>
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<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1225–1245</td>
<td>−0.75</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>470–486</td>
<td>−0.75</td>
<td>29</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>368–381</td>
<td>−0.66</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PDSI values are determined yearly, incorporating local soil moisture, air temperature and precipitation. Positive values indicate wetter than normal conditions (pluvials) and negative values indicate drier conditions (droughts) (Cook et al, 2011, p. 5044).

B. I. Cook et al. (2011) describe the PDSI as having “persistence,” an analytical characteristic described as “values over one summer will often partially reflect moisture conditions and climate anomalies from previous months and seasons...therefore PDSI will contain information regarding temperature and precipitation anomalies during the antecedent winter and spring as well as the contemporaneous summer” (p. 5044). However, there are some weaknesses with the PDSI. The PDSI index treats all precipitation as rain. Therefore, the PDSI is not as accurate at higher elevations where precipitation falls as snow such as in parts of the Western United States.

B. I. Cook et al. (2011) determined after analyzing precipitation and temperature records that the 20th Century pluvial that they define as from 1905-1917 was a combination of unusual increased winter moisture combined with reduced evaporation from cooler summer season temperatures (p. 5045). They compared this data to tree ring chronologies spanning north to south from southern Canada to Mexico and east to west from the Great Plains to the Pacific Coast. The tree ring data over this broad geographic area also indicated that significantly increased precipitation extended throughout Western North America during the pluvial years 1905-17 (p. 5046).

In this map of North America (see Figure 2-8) higher numbers — the darker green regions- indicate increased moisture and the minus numbers-darker brown regions- indicate decrease in moisture. The scale is derived from the North American Drought
Atlas (NADA) version 2a. This NADA is constructed from 1821 tree ringed based chronologies and provides well validated data used to examine the spatial range of the pluvial as well as the intensity of the increased precipitation during the pluvial. The NADA also “places the pluvial anomalies within the context of the moisture variability over the last 500 years” (B. I. Cook et al., 2011, p. 5045). The data is similarly localized around a mean of zero as in the PDSI, where again positive values indicate wetter than normal conditions (pluvial) and negative values indicate drier conditions (drought) (B. I. Cook et al., 2011).

**Figure 2-8**

*Summer Season (June July August) Tree Ring Constructed PDSI Anomalies from the North American Drought Atlas Averaged Across All Pluvial Years*

Source: Cook et al. (2011, p. 5046)
B. I. Cook et al. (2011) also noted the pluvial occurred in two phases with a one-year hiatus in the increase of precipitation around 1910. In this year more normal and drier conditions were found. Cook et al. suggest that this temporary stop in the pluvial was likely due to La Nina activity in the tropical Pacific. This weather pattern tends to suppress precipitation in the Southwest and in the Southern Great Plains of North America (p. 5046). This hiatus of precipitation has become a signature of the Early 20th Century North American pluvial and was commented upon by Zion National Park Superintendent Scoyen in his May 1928 Monthly Report.

After evaluating several factors and long-established global weather patterns and relationships such as: Arctic Oscillation (AO), El Nino Southern Oscillation (ENSO), Sea Surface Temperature (SST), Evaporative Demand (ED), and the General Circulation Model (GCM) B. I. Cook et al. (2011) could not find a definitive cause for the distinctive increase in precipitation during 1905-1917 pluvial. Their results indicated definite winter periods during the pluvial years correlating with Arctic Oscillations but not with enough certainty. Pacific Sea Surface temperatures also pointed to a relationship but again without certainty. El Nino illustrated only a weak relationship. In the end B. I. Cook et al. stated that “unresolved discrepancies exist between General Circulation Modeling of North American hydro-climate variability and empirical studies of climate data” (p. 5056). This conclusion leaves scientists with evidence but not assurance. B. I. Cook et al. listed in their conclusion that the prime cause of the pluvial was simply as observed fact. These facts represent what those on the ground at the time would likely have seen and plainly described. Yes, it rained and snowed more over the Southwest with regional
variations and the temperatures were cooler, so evaporation was less and that the cause of these conditions remains a mystery (p. 5056).

However, B. I. Cook et al. (2010), used computer modeling to locate global climate factors that would correlate and predict past pluvials and droughts. They looked at factors such as El Nino Southern Oscillation (ENSO), Sea surface temperature (SST) in two regions of the Pacific Ocean and one region in the North Atlantic Ocean. With regards to the pluvial of 1905-1917, the years in which they define the early 20th Century pluvial Cook et al. (2010) found strong correlation with Sea Surface Temperature. In the following quotation “PC” represents a physical characteristic variable, and in this case represents particular ocean basins. B. I. Cook et al. (2010) wrote:

The first three PCs show significant correlations over the period 1900–2005 with SSTs (Sea Surface Temperature) in various ocean basins and are used to represent the potential SST forced variability in the PDSI (Palmer Drought Severity Index) data: PC 1 (Tropical Pacific), PC 2 (North Pacific), and PC 3 (Atlantic). Using Pacific forcing only (PCs 1–2), we are able to reproduce the 1948–1957 drought and 1905–1917 pluvial above a 95% random noise threshold in over 90% of the ensemble members; the addition of Atlantic forcing (PCs 1–2–3) provides only marginal improvement. (B. I. Cook et al., 2010, p. 1097)

They concluded:

For the pluvial event (1905-1917), the tropical North Pacific forcing case reproduces the spatial pattern and intensity of the PDSI pattern from the NADA (North American Drought Atlas). Almost the entire western region is wetter than normal in both the simulated and observed pattern, with the major wet anomaly extending along an axis from the southwest forcing in the Pacific. The Atlantic case does little to change the actual median pluvial pattern, suggesting strongly that the Atlantic played little role in forcing the early 20th Century pluvial. (B. I. Cook et al., 2010, p. 1106)

**Utah Dendrochronology Studies Undertaken by Utah Climate Center**

The first dendrochronology studies in northern Utah undertaken by The Utah Climate Center based in Salt Lake City, Utah were completed in 2013. The results
offered additional documentation of unusually wet conditions in the Southwest in the early years of the 20th Century. Researchers Allen et al. (2013) used dendrochronology as the methodology to compare Logan River streamflow with tree rings from northern Utah. Allen et al. developed six tree ring chronologies to research hydro-climate variability in northern Utah. This study sought to understand long term regional climate as it might guide water resource management for the increasing needs of the burgeoning population in the urban area of Salt Lake City.

Salt Lake City lies within the arid lands of John Wesley Powell’s report. Although the geology of northern Utah composed of metamorphic rock differs from the sedimentary sandstone layering of the rock in the deserts of southern Utah, arid climatic conditions prevail in both regions. The dry climatic conditions in northern Utah are not as severe as in southern Utah, but this northern Utah region is climatically considered desert. In the United States, Utah with yearly precipitation averaging 12.26 inches is the second driest state after Nevada. The Salt Lake City area is slightly less dry, with an average of 16.5 inches of precipitation at the airport and about 20 inches on the benches-the transition area between basin area and the base of the mountains surrounding Salt Lake City.

Allen et al. (2013) was concerned with projected water availability in order to improve regional water management. They sought long term climate patterns by researching patterns of drought common in the arid lands of the Southwest. Their research aimed to use tree ring studies to indicate a lack of moisture over time, but in so doing the tree rings also indicated periods of wetness. Their research covered the period 1605-1921. They statically correlated tree ring growth with Logan River streamflow. The
Logan River is the largest tributary to the regionally important Bear River. Both rivers have their drainages to the northeast of Salt Lake City. Allen et al. (2013) drew their results by combining their six new tree ring chronologies with twenty-eight established regional tree ring chronologies. The researchers had historic streamflow records and contemporary streamflow records for the Logan River. These streamflow levels were then statistically correlated with the tree ring chronologies.

Allen et al. (2013) results indicated a dearth of moisture in the years 1846 and 1847 when the Mormons first arrived in Utah. Short term drought periods occurred during the years 1888, 1889, 1890 when Mormon settlements had existed in southern Utah for about two decades. These were not long tenures of dryness and therefore settlers could contend with them and survive. Although some Mormon settlements such as those on the Paria River east of Kanab, Utah, an area east of Zion Canyon did not survive these years of drought in the late 1880’s (Highway Monument US TR 89 Mile Marker 29 towards Page, Arizona). It is now known that extended periods of drought lasting for three decades or more have occurred several times in the last 1000 years (Woodhouse et al., 2010).

Allen et al. (2013) results once again validate my hypothesis that there was a significant increase in precipitation during the early 1900s, when private and public interest was developing towards the goal of preserving Zion Canyon as a national wonder. Allen et al. (2013) report, “Individual high flow years were reconstructed in 1986, 1984, 1983, 1907, 1793, and 1726–1727.” All high flow years occurred in extended periods of above-average flow, putative pluvials. Lower-frequency variability indicated by the 5-year running average revealed the early 1980s was the most extreme
pluvial in their record, followed by the early 1900s. Historic pluvials, approaching the 20th Century magnitude, include years within the: 1790s, 1720s, and 1640s” (Allen et al., 2013, p. 5).

Comparing Allen et al. (2013) outcomes with Salzer and Kipfmueller (2005) it is useful to note that the data of Allen et al. covered a shorter time frame 1605-2000 while the Salzer and Kipfmueller extended back another 1,000 years. It is important to notice that the periods labeled as pluvials in Allen et al. match closely with the periods of increase precipitation found by Salzer and Kipfmueller. Once again, the years 1905-1922 are the fourteenth wettest, but the longest period of a significant increased precipitation in Salzer and Kipfmueller’s 1,425-year study. In the diagrams that Allen et al. furnish describing Logan River streamflow, the periods 1860s show above average streamflow for the Logan River as well as the period of early 1900s. (Allen et al., 2013) (see Figure 2-9).

The conclusions drawn by Allen et al. (2013) indicate greater variations in streamflow and precipitation are likely to have occurred during their research period, and that their reconstructions may not accurately portray the magnitude of the extreme wet or dry events. This disclaimer proposed that water availability was far more volatile in the past; and that future water availability for the Salt Lake City region can be subject to great inconsistency. The perception of water availability in Utah tends to be one of dependable supply. According to the 2010 US Geological Survey of Water Use in the United States Utah uses the most water per capita in the United States (Maupin et al., 2014). Most of this water use has been through agriculture. However, with the population of Utah increasing rapidly and new residential suburbs spreading out around the major
towns of Salt Lake, Moab and St. George residential use of water has significantly increased.

The value of moisture-sensitive tree ring chronologies continues to be acknowledged by scientists. Over 600 chronologies have been developed in North America ranging from the boreal forests of Canada to the tropics of southern Mexico. Tree rings supply scientists with a rich source of data that can reproduce decade scale droughts and pluvials with accuracy. These chronologies represent an outstanding array

**Figure 2-9**

*Locations of 426 Tree-Ring Chronologies Used by Cook et al. (1996) to Reconstruct Summer PDSI*

Note: Locations of 426 tree-ring chronologies used by Cook et al. (1996) to reconstruct summer PDSI. Some symbols represent multiple chronologies. All chronologies end in 1979 or later. Chronologies dating back to 1676 (green triangles), 1600 (blue triangles), and 1500 (or earlier) (red triangles) Source: Fye et al., 2003. p. 902.
of “exactly dated, annually resolved paleoclimatic proxies used to improve and expand the geographical coverage of Palmer Drought Severity Index (PDSI) reconstructions over North America” (Fye et al., 2003, p. 908) (see Figure 2-9).

Fye et al. (2003) dendrochronological analysis also points to the significance of the early 20th Century pluvial 1905-1917. They conclude that this pluvial was “[o]ne of four intense, long lasting, and widespread wet episodes over the Great Plains and western United States in the past 500 yr. In fact, the 20th Century pluvial appears to have been the

**Figure 2-10**

*The Early 20th Century Pluvial and its Analogs*

Note: Maps (a) and (b). Mean instrumental and reconstructed summer PDSI for the period 1905–17; (c)–(e) Mean reconstructed summer PDSI averaged and mapped over the United States for the time periods indicated. Source: Fye et al. 2003
most extreme wet episode in the past 500 yr.” (Fye et al., 2003, p.908). Their
dendrochronological research reveals a new cyclic analysis indicating the wet periods
that last over a decade are rare with 200 years separating these decadal pluvials in the
seventeenth and nineteenth centuries (Figure 2-10) (Fye et al., 2003).

The accuracy of tree ring data sources has been underscored by Fye et al. (2003).
They indicated that tree ring chronologies reproduce “much of the fine scale structure of
the instrumental drought and wetness regimes” more so than the statistical analysis would
acknowledge. They emphasize that “tree ring reconstructions of summer PDSI faithfully
reproduced the relative severity of the Great 20th Century pluvial, Dust Bowl, and 1950s
droughts” (p. 908).

According to Fye et al. (2003) the Early 20th Century North American Pluvial
stands out over the other pluvials of the preceding 500 years in area, intensity, and
duration. This pluvial spatially extended across the Central Plains to the West Coast and
covered the southwest of North America. A mid-period break in precipitation stands as a
signature of this pluvial. Midway through the pluvial span, dry or near normal conditions
returned for the year 1910. This distinctive change is associated with La Nina conditions
in the tropical Pacific. In this environmental condition radiative heating increases over
the tropical Pacific heating up the tropical Pacific Ocean. This event has been shown to
enhance the development of La Niña-like conditions, which in turn suppress precipitation
in the southwest United States (Woodhouse et al., 2010, p. 21283).

In the May 1928 Monthly Report from Zion National Park Superintendent Scoyen
indirectly referred to the dryness of the year 1910. His weather observations in southern
Utah display the mid-break signature of the pluvial of 1905-1922. He wrote:
Weather: With the exception of 1910 the past month was the hottest May in this section in 24 years of records. Precipitation was about normal for this month but the lack of rainfall throughout the late spring has resulted in drought conditions at this time. Based on normal conditions of weather we may expect little relief until July. (Scoyen, 1928a, 1156 01-05, p. 1)

Superintendent Scoyen in August 1928 again makes note of the weather in the mid-break years of the 1905-1922 pluvial. He noted: “The hot dry weather which was prevalent in the park during June and July continued throughout the month of August. The mean temperature for the month was three degrees above normal and precipitation only one fifth the usual amount.”

Going back over weather records of the Springdale Station dating back to 1904, I have found that the three summer months of June, July and August have had the highest mean temperature on record with but two exceptions 1909 and 1910. However, the total precipitation for these months [1928] of 0.49 inches is the lowest summer total record. The two years on which average temperature for these three months exceeded that of this year had heavy rains. It is therefore evident that we have just passed through the most severe and trying summer in this section in the past 24 years. (Scoyen, 1928c).

Superintendent Scoyen considered the dryness of June, July, and August 1928 and that of 1910 as unusual! It appears that he did not consider that these dry months might be the real norm. Scoyen comments indicate how much the pluvial years with their moisture had become the experienced and expected norm for folks in and around Zion National Park. Wet years immediately followed the mid-break of 1910 and continued until the end of 1920s.

Fye et al. (2003) exhibit enthusiasm for the accuracy that tree rings offer for the future study of wet and dry decadal events in the climatic past. These 500 yr. old tree ring reconstructions provide a benchmark to which 20th and 21st Century moisture anomalies
can be compared. Furthermore, the tree ring chronologies document climate variability on the late-Holocene era throughout the United States. The exact dating that tree ring chronologies provide to researchers, aides in reconstructing paleo-climate data and can be used to “improve and expand the geographical coverage of PDSI reconstructions over North America” (Fry et al., 2003, p. 908).

Streamflow as a Climate Change Indicator

In addition to tree ring studies, streamflow is a clear measure both visually and statistically of the amount of water falling into a drainage area. In this section I offer streamflow data as another independent source for evidence of climate change in the early 20th Century in the American Southwest and particularly in southern Utah.

As an example of immediate local expression of the pluvial, I found streamflow gauge data at Virgin, Utah since 1909 for the Virgin River in southern Utah that reveals the presence of the pluvial within 12 miles of Zion Canyon. For regional expression of the pluvial in streamflow records, I will look at research done on the northern Utah Weber River and for the widescale Southwestern streamflow expression of the pluvial I will look at streamflow records for the Colorado River.

What is Streamflow and What are Watersheds?

When considering the streamflow of a river it is essential to understand what streamflow represents and how it is affected. The amount of water in a river that is being measured has derived from that river’s watershed. A watershed is the geographic area, the topography or varying land surfaces upon which all the water within it eventually drains to a single outlet. This includes all surface water: streams, lakes, reservoirs, wetlands and all the underlying ground water. The outlet can be the mouth of a bay, the
outflow of a reservoir, or any point along a stream channel (Allen et al., 2013; Hedman and Osterkamp, 1982; Thomas and Benson, 1975). In this research streamflow is being measured from points along a river channel.

Watersheds also go by the names: drainages, basins, or catchments and are distinct and often separated by highpoints in terrain. Large watersheds such as those for the Colorado River contain many smaller watersheds. The water quality and volume of streamflow are affected by many constituents within a watershed: flora, fauna, soil and geological types, slope, human created catchments, pollution, as well as human and animal water use upon the land area above the river outflow point. The streamflow of a river can indicate conditions over a large area of land upriver (McMahon and Mein, 1986; Thomas and Benson, 1975).

Kahya and Kalayci (2004) substantiate the reliability of a watersheds as indicators of climate change. They argue that “under certain geomorphic conditions, the nature of a river reflects the integrated watershed response to climatic forcing. This critical point was previously noted by Cayan and Peterson (1989); (Kahya and Dracup (1993) in searching teleconnections between surface hydroclimatic variables and the large-scale atmospheric circulation” (2004, p. 129). Climate forcing is the physical process of changing climate by large scale factors which are varied in form. Some examples are solar radiation levels, volcanic eruptions, changing albedo, and changing levels of greenhouse gases in the atmosphere or as in the research of Kahya and Kalayci (2004) large-scale atmospheric circulation. It is important to note that the geomorphology of a watershed is stable over long periods of time, especially compared to climate change. Therefore, changes in the hydrologic parameters such as streamflow of unregulated watersheds may indicate
changes in climate. “Consequently, hydrologic variables might be used as indicators to
detect and monitor climate change” (Kahya & Kalayci, 2004, p. 129).

Kahya and Kalayci (2004) research links large atmospheric circulation to
streamflow and therefore climate and weather. To understand the paragraph above one
must understand that teleconnections are “pronounced features of time-average
atmospheric circulation.” Time-average atmospheric circulation is the name given to
organized spatial patterns of atmospheric flow (Cayan & Peterson, 1989, p. 376). The
“features” are characterized by wavy atmospheric flows of several hundred to thousands
of kilometers of planetary atmospheric waves that correspond to somewhat stationary
troughs of atmospheric pressure. These troughs give rise to remote correlations of
patterns over long distances. These patterns are called teleconnections (p. 377). Cayan
and Peterson (1989) have linked large atmospheric patterns sometimes called “climate
forcing” to streamflow. Large scale atmospheric patterns are sometimes linked to long
term cyclical patterns of climate change. Currently much research and climate computer
modeling seek to understand climate patterns as the result of largescale atmospheric
interfaces and interactions across the globe.

Streamflow levels are variable and seasonable. But streamflow is often the most
accessible source of water for human and agricultural consumption therefore streamflow
levels will directly affect the survival of the human, flora, and fauna community in a
region. Streamflow will be experienced as a force of nature and thereby influence the
environmental perception of the force of a river in relation to landscape and infrastructure
nearby. In acknowledging the effects of streamflow on communities over time, Cayan
and Peterson (1989) recognized how “stream flows have fluctuated considerably over the
instrumental record [Roden, 1967; Langbein and Slack, 1982; Bartlein, 1982; Meko and Stockton, 1984]” (p. 377). Cayan and Peterson (1989) noted, “The socio-economic, physical and biological significance of this year-to-year variability is great. The impact of this variability is particularly strong in the western United States where water resources are limited” (p. 377). This variability can leave a strong impression upon a community, especially one highly dependent for its survival upon the quality and quantity of streamflow. How a community responds to this variability can often be extemporaneously reactive as was the case of the armoring of the Virgin River. This will be discussed in Chapters 4, 5 and 6.

**Figure 2-11**

*Streamflow of the Virgin River in Zion Canyon, Virgin River Watershed*

Records of streamflow of the Virgin River have been recorded since 1909. This data has been obtained by a gauge on the Virgin River, near the town of Virgin, UT, 12 miles west and down-river of Zion Canyon. It is likely that levels of the Virgin River in Zion Canyon were higher than those recorded in Virgin, UT because the canyon walls are much further apart in the town of Virgin than in Zion Canyon. Additionally, there is a wide sandy floodplain for the Virgin River beginning about 7 miles south from the town of Springdale, UT and streamflow would be absorbed into ground water and spread out over the riparian zone (see Figure 2-11). Streamflow records were obtained from the USGS website. These streamflow records from 1909-1936 are depicted in Figure 2-12.

Thirteen years of consistent high streamflow are clearly seen in the streamflow data from 1909-1923. The presence of consistent increased streamflow on the Virgin River at the Virgin town gauge during the early years of the 20th Century coincides with the timing of the Early 20th Century pluvial. The increased Virgin River streamflow matches similar timeframe patterns for increased streamflow on the Colorado River and the Weber River as will be discussed. This data for the Virgin River is the most fundamental and significant data since it represents the streamflow for Virgin River closest to Zion Canyon during the second half of the pluvial period. The graph also indicates spikes of wet weather during the late 1920s when consistent records started being kept by the Zion National Park Superintendents.
In the graph of Virgin River (see Figure 2-12) streamflow was consistently
elevated above 100 FT3/SEC reaching 1000 FT3/SEC and on several occasion 10,000
FT3/SEC from 1909 until 1920. There was a decrease in streamflow in 1920 and 1921
with an increase in streamflow returning in 1922 and 1923. Streamflow levels decreased
and remained lower during the 1930s and beyond. The pattern of consistent increased
streamflow is clearly indicative of the effect of the Early 20th Century pluvial within the
Virgin River drainage in southern Utah.

**Figure 2-12**

*Virgin River Streamflow FT3/sec 1909-1935*

![Graph showing streamflow values from 1909 to 1935 for the Virgin River.](image)

Note: Date within Red Box notes streamflow mostly above the 100FT3/SEC level 1909-

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**Streamflow of the Weber River in Northern Utah**

The Weber River has been an important source of water for the inhabitants of the
Salt Lake City region since before the days of Mormon settlement beginning in 1847. A
125-mile-long river originating in the 11,000 ft. peaks of the Uinta Mountains in northern
Utah, the Weber River flows into the Great Salt Lake. This river would have contributed to the rise of the Great Salt Lake as explained earlier in the chapter. Cayan and Peterson (1989) used historic Weber River streamflow records beginning in 1904 to link streamflow levels with North Pacific Atmospheric Circulation. This period coincides with the beginning of the Early 20th Century pluvial. Weber River streamflow records indicate a significant and unusual increase in precipitation (see F) that is indicated by the

Figure 2-13


Figure 2-14

*Time Series of Monthly Streamflow Anomalies for Selected Stations*

Note: Anomalies are standardized by dividing by standard deviation for each month. Long-term annual streamflow (m³ s⁻¹) is noted for each series. Red box noted high streamflow for Weber River during pluvial years. Source: Cayan and Peterson, 1989, p. 381
streamflow levels during the early part of the 20th Century. Cayan and Peterson’s (1989) chart (see Figure 2-14), graphically highest peaks and therefore streamflow levels occurred between 1905 and the early 1920s. This data indicates that extent of the pluvial reached northern Utah as well as extending into the southern basin of the Colorado River and into the Virgin River in Zion Canyon.

Cayan and Peterson (1989) graph of monthly streamflow (see Figure 2-14). Figure 2-14 supports the existence of the pluvial by illustrating the weather patterns over a wide range of the west over most of the 20th Century. They were looking at Northern Pacific Ocean climate forcing and so looked at streamflow over a range of rivers surrounding that region of the ocean. It is clear from looking at the Weber River data that there was a significant increase in streamflow and therefore precipitation in the time frame of the pluvial. Cayan and Peterson (1989) confirmed the climate change of 1905-1922 when they wrote:

Perhaps the greatest social and economic impacts of these fluctuations result from periods of prolonged high or low streamflow, and it is important to view modern day variations in the context of the fluctuations over the entire available record. During the earlier part of the record can be seen a persistent episode of the unusually high streamflow throughout the Southwest during the early 1900s (e.g., see Weber River anomaly plot), while prolonged low flows show up in all streams in the northwestern United States during the mid-1920s throughout the early 1940s. (p. 395)

**Colorado River Streamflow**

Streamflow data from the last four centuries clearly tell the story of the widespread nature and frequency of severe droughts lasting from several years to a decade or more in the Upper Colorado River Basin (E. Cook et al., 2004; B. I. Cook et al., 2010) Although less frequent, this same data also points to increases in streamflow over the same time period (E. Cook et al., 2004; B. I. Cook et al., 2010; Woodhouse et
al., 2006). The Colorado River has a watershed that extends through several western states and is the most important source of surface water supply in the western United States. Because of the wide geographic reach of the Colorado River watershed, its streamflow rate would logically indicate increased or decreased regional precipitation.

The streamflow rate of the generous and nurturing Colorado River can be measured in two ways. First, streamflow can be tabulated and labeled as “virgin” indicating flow before any diversion of water leaves the river for any reason. Or secondly, the streamflow can be labeled as “runoff” and “measured streamflow” which are flow levels taken from gauges along tributaries and on the Colorado River itself at specific points with diversions added back in when it is possible to do so. Two notable Colorado River gauge points are located at Cisco, Utah and Lees Ferry, Arizona (McMahon & Mein, 1986).

Stockton and Jacoby (1976) conducted the first effort to reconstruct Colorado River streamflow records using tree ring studies, river gauges, and historical data. Water records are available beginning in 1914 for the three main tributaries to the Colorado River: The Green River, the Main Stem of the Colorado Headwaters, and the San Juan River. Gauges at Lees Ferry have been in place since 1921.

The Colorado River watershed covers an area of about 246,000 square miles and includes all of Arizona, and parts of California, Colorado, New Mexico, Nevada, Utah, and Wyoming (see Figure 2-15

*Colorado River System*). Stockton and Jacoby (1976) surveyed the historic river gauge data from the three major basins and sub-basins of the Colorado River (see Table 2-3).
Table 2-3

River Basins and Sub-Basins in the Colorado River Watershed

<table>
<thead>
<tr>
<th>Basin</th>
<th>Sub-Basins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green River</td>
<td>Wind River – Uinta River</td>
</tr>
<tr>
<td></td>
<td>Yampa River – White River</td>
</tr>
<tr>
<td>Main Stem of Colorado Headwaters</td>
<td>Frasier River</td>
</tr>
<tr>
<td></td>
<td>Gunnison River</td>
</tr>
<tr>
<td></td>
<td>Taylor River</td>
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<tr>
<td></td>
<td>Dolores River</td>
</tr>
<tr>
<td>San Juan River</td>
<td>Navajo River</td>
</tr>
<tr>
<td></td>
<td>Florida River</td>
</tr>
<tr>
<td></td>
<td>Animus River</td>
</tr>
</tbody>
</table>

Stockton and Jacoby (1976) noted that the Green River and Main Stem of the Colorado basins and sub-basins displayed higher gauge levels associated with wet climate conditions and higher flows during the second decade “the teens” of the 20th Century onward. For the same two basins, lower gauge levels indicating lower flow levels and dry conditions began to appear in the 1930s. The San Juan River sub-basins were less affected by both the Great Pluvial of the 20th Century and the Great Dust Bowl droughts of the 1930s (Stockton & Jacoby, 1976).
Stockton and Jacoby’s (1976) research strove to reconstruct long term run-off records for the major basins within the Colorado River watershed. To validate streamflow data Stockton and Jacoby correlated both tree ring and the streamflow data from the river.
Gauges. They tapped several existing tree ring chronologies for their correlations and furthermore created more tree ring chronologies on the major tributaries. Such chronologies were originally non-existent and were needed to compare gauge data with tree ring data. Their work resulted in historic streamflow records for the three rivers within the Upper Colorado River Basin (UCRB) the Green, the Colorado and the San Juan Rivers.

Constructing streamflow records for the major basins and subbasins of the Upper Colorado River Basin would indicate areas where the foremost amount of precipitation occurred that contributed to the streamflow gauges at Cisco and Lees Ferry, thereby indicating the boundaries of regional climatic change. Mapping streamflow levels to another land-based but stationary indicator of precipitation, the tree ring chronologies, also situated in the various watershed basins and sub-basins, added validity to the claim that streamflow on the Upper Colorado River Basin is an indicator of change in precipitation, which is an indicator of climate change. Together the tree ring chronologies and the streamflow gauge records mapped the areas that were the sources of increased or decreased streamflow indicating historic regional climate change.

Stockton and Jacoby constructed hydrographs from 1512-1961 depicting the total annual flow for the Colorado River at the Colorado River Compact Point. This point was assigned to Lees Ferry, Arizona, which is located at the boundary between the Upper and Lower Colorado River Basins. Based on their research the “virgin” mean streamflow of the Colorado River is estimated to be 13.5 million-acre feet. The Colorado River Compact used the level of 16.2 million-acre feet as their benchmark for water distribution to the seven states in the Compact. This calculation illustrated several problems facing
water management: the tendency for an inflated view of regional water supplies, short-term misunderstanding of climate, as well as water policy reactivity to streamflow variability. The inflated view of long-term water availability surrounding the Colorado Compact indicated how the forecast and perception of the future climate was affected by the Early 20th Century pluvial.

Stockton and Jacoby (1976) also found that based on their hydrographs “the early part of the 20th Century 1906-1930 was one of anomalously persistent high run-off from the Colorado River Basin… it was greatest and longest high flow period of the Colorado River in the last 450 years” (Stockton & Jacoby, 1976, p. 1).

The correlated streamflow and tree ring studies also showed that this wet pluvial was preceded by a long persistent low-flow period lasting from 1870-1894. Only one other low flow period of comparable length and duration occurred from 1566-1595. There have been no similar low flow periods since gaging began on the Colorado River between 1921-23” (Stockton & Jacoby, 1976, p. VII). But neither have there been high flows suggesting that the drainage basin of the Colorado River is generally an arid land.

The graph in Figure 2-16 displays flow levels for the Colorado River from 1500 through the 1960s. In the period shortly after 1900 there is a considerable rise in the Colorado River streamflow over an extended period. This increase in streamflow correlates with the other data presented in this dissertation that underscores that there was a long and significant increase in precipitation during the early part of the 20th Century in the American Southwest and in southern Utah. After the 17-year pluvial technically ended in 1922, wet years occurred through the late 1920s. This length of time, about 23 years, amounts to a period of increased precipitation for nearly a generation in a
landscape and region that is normally an arid desert environment. Also evident in the graph for the years 1860-1870 are indications of the earlier shorter pluvial 1865-1869 as was noted in Salzer and Kipfmueller (2005).

Figure 2-17 shows the streamflow on the Colorado River Main Headwaters at Cisco, Utah. Cisco is 340 miles from Zion Canyon by highway. However, it is much closer as the crow flies and located north and slightly east of Zion National Park. Its proximity to Zion National Park is mentioned to underscore that streamflow in this region would reflect regional events also experienced by the drainages of the Virgin River which

**Figure 2-16**

*Best Estimate of the Long-Term Hydrograph of Colorado River Annual Runoff at the Compact Point Lee Ferry, Arizona*

Notes: The upper graph shows the actual year-by-year values; the lower graph is the same data but with high frequency components—those with a period less than ten years—removed. Red Box shows early 1900s pluvial years increases in run off. Blue box shows 1865-69 pluvial increase in run-off Source: Stockton and Jacoby, 1976
flows south through Zion Canyon and ultimately into the Colorado River. It is interesting to note that it appears that streamflow at Cisco, Utah was higher and lasted longer than those at Less Ferry.

The increase in streamflow evident in Figure 2-16 and Figure 2-17 correlate in time with the other data presented in this dissertation indicating that there was a long and significant increase in precipitation during the early part of the 20th Century as well as in 1865-69.

**Figure 2-17**

*Reconstructed Hydrograph for the Total Annual Runoff or Virgin Flow of the Colorado River near Cisco, Utah*

Note: The upper graph shows the unfiltered data; the lower graph is the same data but with the high frequency components-those with a period of less than ten years removed. Red Box notes 1905-1922 pluvial Blue box notes 1865-69 pluvial. Source: Stockman and Jacoby, 1976, p. 32
Connie A. Woodhouse, Stephen T. Gray, and David M. Meko (2006) chose to revisit Stockton and Jacoby’s (1976) study for several reasons: technological innovation in computer modeling, forty more years of streamflow data since 1961, the limits of Stockton and Jacoby’s data set, and technical breakthroughs in tree ring chronologies.

Woodhouse et al. (2006) updated research and confirmed the high streamflow levels of the early 20th Century that Stockton and Jacoby reported in their 1976 study. They once again found the highest sustained stream flows in the entire record, 1520 to 1961, occurred in the early decades of the 20th Century. Thus, pointing to the fact that the state water allocations agreed to in the 1922 Colorado River Compact were not going to be realized with Colorado River water on any consistent basis in the future (Woodhouse, Mckim, Ray, 2006) Additionally, the most persistent severe drought occurred in the late 16th Century, with flows during this period much lower than for any event in the 20th Century (Woodhouse et al., 2006, p. 1). Lucky for those having lived in the Southwest in the 20th Century. However, for future generations the availability of water in this arid region remains uncertain.

Various constituent needs for water raise water management concerns for the future in the Southwest of the United States. A drought such as the one that occurred in the 16th Century would substantially lessen the streamflow of the Colorado River to the effect that the streamflow and the water sharing obligation devised in the Colorado Compact could not be fulfilled. But it doesn’t take a drought of the 16th Century magnitude to cause concern for water availability. Presently in the summer of 2021 drought regulations have gone into effect in Utah.
Additional to the streamflow allocations from the Colorado Compact, other essential water concerns exist. Human population in the Southwest and within all regions served by the Colorado River Compact, continue to grow at a rapid pace. Covid has sent thousands of Californians inland to Utah which offers cheaper home costs. Significant water use for the protection of wildlife and endangered species and their habitats are seldom included in drought concerns and must be included in future water management calculations.

Woodhouse et al. (2006) used four gauges in the Upper Colorado River basin for their update on the reconstruction of streamflow on the Colorado River. They included gauges at: Green River at Green River, Utah; Colorado River near Cisco, Utah; San Juan River near Bluff, Utah; and Colorado River at Lees Ferry, Arizona. The selected gauges represent flows in the three major sub-basins, as well as the total flow of the Upper Colorado Basin (p. 1). This data includes the eastern half of Utah from the north to the south and is within the regional and climatic scope of Zion Canyon within Zion National Park located in the southwestern corner of the state of Utah.

Woodhouse et al. (2006) found some variation between their analysis and Stockton and Jacoby’s (1976) outcomes. Nonetheless, Woodhouse et al. (2006) also found that multiyear droughts in Upper Colorado over the past four centuries have been widespread. The gauges monitoring the three sub-basins for drought were always consistent in time and duration with Stockton and Jacoby’s results, however; the magnitude tended to vary slightly (Figure 2-18).
Woodhouse et al. (2006) found coherence among the streamflow samples at the sub-basin research gauges as seen in the extreme 5, 10, and 20-year droughts documented at Lees Ferry. Low flows in one sub-basin coincided with low flows in other subbasins. One notable exception occurred. When the flow in the Green River was low, the San Juan flow was sometimes high. Woodhouse et al. commented: “In most of these periods of contrasting drought conditions, Lees Ferry flows are average, but a few cases (e.g., the 1930s) suggest that drought in the Green River can have an overriding influence on flows at Lees Ferry, even when high flows prevail on the San Juan” (p. 14). The reverse relationship is interesting because it may indicate the ecological and geographical
boundaries between the upper and lower Colorado River basins. The researchers found a few examples of when the magnitude of droughts and wet regimes did vary among the sub-basins, but the timing and duration of high and low flows were consistent among the research reconstructions (p. 14).

The benefits and usefulness of streamflow reconstructions are numerous. Reconstruction provides essential hydrology data for ecological and municipal management groups. Streamflow reconstructions indicate that unpredictable catastrophic drought can occur as well as unpredictable pluvials. These reconstructions of river flow also validate and complement other types of seasonal climate variability studies particularly dendrochronology. Streamflow data also illustrate clearly that “over the past four centuries severe multiyear and decadal-scale droughts in the Upper Colorado River basin have tended to be widespread events (Woodhouse et al., 2006, p. 14).

**The Character of the 1905-1922 Pluvial**

When assessed in the context of long-term time periods, the Early 20th Century Pluvial is considered rare. Woodhouse, Kunkel, Easterling, and Cook (2005) explained that even in the context of an 1186-year reconstruction of precipitation, the Early 20th Century Pluvial stood out as exceptional (p. 1).

What was the nature of the Great Pluvial of the Early 20th Century? Was the rain constant or sporadic, arriving in winter or with the cyclical summer monsoons common in the Southwest? Were the amounts of rain consistent over the 17-year period or heavier in certain years or seasons?

The intensity and duration of the increased precipitation would affect human perception and response to the climate conditions across the Southwest. The collection
and measurement of rain in rain gauges across Utah and the Southwest offer an avenue for validating and understanding the nature of the Early 20th Century Pluvial. Woodhouse et al. (2005) analyzed both tree ring chronologies and rain gauges searching for characteristics of this momentous climatic event. They used “annual standardized precipitation anomalies averaged for the period 1905–1917 for stations with at least 50 years of precipitation data and at least 10 years during 1905-1917. This includes 1284 U.S stations with 136 stations in the nine-state pluvial region” (p. 2) which includes the states of: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.

Woodhouse et al. (2005) took 20th Century weather records and analyzed precipitation for seasonality, intensity and frequency. Their result characterized the pluvial precipitation as moderate to heavy occurring primarily in winter with a handful of extremely wet winters. Coinciding temperatures were unusually cool. “The combination of duration, intensity, and spatial extent make this an unusual event, not only in the 20th Century, but in the past 12 centuries” (p. 1).

They also found that during the pluvial, intense wet years fell into a consecutive group. When sums of precipitation of 10-year periods were ranked, “the four highest ten-year sums in the 1186-year record ended in 1915, 1916, 1914, and 1917. The three highest running 20-year sums are also included in the 20th Century pluvial, ending in 1924, 1923, and 1922” (p. 2). This pluvial also had a unique signature in that five-years into it, in 1910, there was an abeyance of precipitation, a return to more normal regional precipitation, that Zion National Park Superintendent Scoyen (1928a) saw as an anomaly, compared the previous five years of increased precipitation (May, ZION:1156/01-05).
Discussion

Stockton and Jacoby (1976) appear to be one of the first or the first researchers to recognize that something had happened to the climate in the Southwest in the not-so-distant past. Woodhouse et al. (2006) in reevaluating Stockton and Jacoby’s (1976) research revalidated a dawning awareness that a significant climate change had occurred in the early 20th Century and it had been forgotten and not documented. Nonetheless, this climate change had profound effects on water policy decision making on many levels, more specifically for the Virgin River in Zion National Park as well as for the Colorado River. This climate change gave the impression that there was going to be plenty of water around to support the development of the Southwest. This impression persists in the minds of many decision makers, especially in Utah, to this day. The pluvial also gave Zion National Park administrators the fear that there would be high streamflow that could wash away the flatland in the narrow Zion Canyon.

My own curiosity which led to this dissertation arose from a rational and simultaneous intuitive point of view that the actions of the early Superintendents of Zion National Park to extensively armor and channelize the course of the Virgin River didn’t make sense in the context of a desert environment. Why would the National Park Service spend thousands of dollars on redesigning the Virgin River course in a desert? And why when I was reading up on the human and environmental history of southern Utah and Zion National Park did the word “flood” come up more times that I have ever seen in any environmental or geographic reading?

Other researchers happened upon unusual tree ring specimens that made them think twice about recent historical climate. Water managers who allocated Colorado
River water noticed that there was less and less water in the Colorado River than in 1922 (Woodhouse et al., 2006). Anthropologists wondering why there appeared to be an abrupt end to the Ancestral Puebloan culture searched for a reason and started looking at drought data to figure out what had happened to that civilization and in so doing found pluvial data.

For those who lived through the pluvial of 1905-1922, these years were ones of “singing in the rain” throughout the Southwest as many pioneer settlements benefitted from the increase in moisture in the desert environment. Grain and grass grew in abundance. Grain gave settlers the sustenance to make bread and to feed hogs and to supplement their vegetable gardens. It also gave them a notion of security. They could stay if they could sustain themselves. This ability to endure was predicated upon agricultural fecundity which was dependent on precipitation.

Those that had settled in southern Utah were an isolated lot. Bartering with food and tithing with food were tools of survival for the Latter-Day Saints. Grass provided hay with which to feed their cattle and horses. A fifth-generation Utah Mormon woman told me that her grandfather was a teenager during the pluvial years. She related how he often described the land during his youth and early adulthood. She recalled that her grandfather regularly stated that “The grass grew so high that it touched the belly of the horses.” Tall grass in the desert was astounding and something to remember for her grandfather. Such high grass blowing in the desert of southern Utah evinced an awe that comes from being present at a phenomenon. Another possible indicator of the fecundity of this period in southern Utah are the extensive Juniper trees all the same age growing in many forests along the Interstate 15 corridor. More research is necessary to confirm this and again this
is not the focus of this dissertation. Yet it is hard not to notice that these trees all look about 115 years old!

Unfortunately, the pluvial also wrecked lives and communities. For many settlers living close by or on the riparian flood plain, the chronic flooding dismantled their pioneer settlements, destroyed their irrigation ditches, swamped their fields, and muddied their only source of drinking water. This 17-year pluvial which lasted longer with considerable wet years occurring through the 1920s amounts to a climate change that lasted almost generation. The moisture was in total contrast to the normally dry desert environment. A generation is long enough to affect the perception of the climate, especially for those young enough to know only the pluvial years and to not know the true aridness of the desert lands. This change in environmental perception from one of aridness to moisture doubtlessly affected decision making in all facets of society.

It is clear from the data provided in this chapter that a prolonged period of moisture dominated the weather in southern Utah during the initial period of Mormon settlement in southern Utah 1861-1891. This period was then followed by another unusually wet period in southern Utah 1905-1922 during the establishment of Zion National Park. The contrast of these wet periods to the normal arid desert conditions of southern Utah constituted a notable change in the climate, not only experienced by the environment but by the people living in that environment. The duration of these wet periods also created and intensified a false environmental perception of what local climate was and would be in the future. These relatively isolated newcomers, imbued with a compulsory need for self-reliance, had to understand the region in which they found themselves, as it was then, wet and cool. They likely started to form a revised or
new environmental perception of the region, albeit an inaccurate understanding of the
geography in which they found themselves. But what more could they do but be thankful
for the good years! Not many read Powell’s *Report on The Arid Regions of the United
States with a More Detailed Account of the Lands of Utah.*
CHAPTER 3

PRESERVATION OF VALUABLE FLATLANDS:
A HERETOFORE UNRECOGNIZED REASON FOR CHANNELING THE
Virgin River

East of the canyon are many spectacular scenes which make this region famous. Illustrations of some of its unique landscapes have been admired ever since the first photographs of them were taken nearly 45 years ago. And yet so little was known of the canyon, and of the nature of the rocks, that probably the full significance of the illustrations was never realized. At that time the bottom-lands had not fallen prey to the ravages of floods and the cultivated fields have a hospitable aspect [see Figure 31] that relieves the mental tension created by the galaxy of monumental scenes around them. Most of the fields have been washed away, since the photograph reproduced as figure 31 was taken, but the verdure covered slopes endure with little change. (Lee, 1917, p. 51)³

By 1917 the 12th year of the 1905-1922 pluvial Geologist Willis Lee had seen that floods had removed the flatlands from the landscape in and around Zion Canyon. By comparing an older photograph to his firsthand observations and research in and around Zion Canyon he noted that circa 1872 the bottomlands were intact yet gone by 1917. What would have caused this extensive change of landscape? Lee was gazing at the power of the pluvial’s increased precipitation to scour the Canyon’s floor via the increased streamflow of the Virgin River and cloudbursts. The main premise of this dissertation is that the climate change that occurred in the form of a pluvial in the early part of the 20th Century affected the geomorphology of the Virgin River and its streamflow. Concomitantly the pluvial affected the environmental perception of the Virgin River’s force consequently affecting the decision making of those administering

³ Lee’s Report was sent to Zion National Park from Rocky Mountain National Park in 2002. The figures and photos within the report did not accompany the report to ZNP. The figures and photos mentioned in the above quote are not at Rocky Mountain National Park nor at Zion National Park. Their whereabouts are unknown as per Amanda Peters, ZNP Museum Tech September 15, 2021.
the new Zion National Park. But why would an increase in precipitation affect decision making?

**The Environmental Narrative of the Pluvial**

In 1847 the American and European immigrants known religiously as Mormons arrived in the arid lands of what is now northern Utah with perfect climatic timing. Most of the settlers were members of The Church of Jesus Christ of Latter-Day Saints. Within fourteen years of their arrival the first signs of the sixth wettest period in 1425 years would bring fertility to the arid lands they occupied and supplanted from the native Ute and Paiute tribes (Salzer & Kipfmueller, 2005). The Mormon newcomers to the region noticed that it was raining more, because the Great Salt Lake was rising, and the mountainsides of the Wasatch and Unita ranges were white with snow adding additional spring moisture from snow melt.

John Wesley Powell (1879) in his 200 pages: *The report on the lands of the arid region of the United States, with a more detailed account of the lands of Utah* commented on some of the ideas that the new Mormon residents developed to explain the beneficial change in the weather from desert dry to agriculturally enabled moist beginning in 1861. To Powell’s credit he documented a few of these ideas that attempted to explain the increased precipitation in the 1860s due to human presence or actions. In his report to the US Congress Powell labeled these attempts at understanding the increase in moisture from 1861-69 “The Agency of Man.” He considered such concepts devoid of scientific analysis.

The Mormons were a tight knit persecuted religious group as a result, they applied a religious framework to most aspects if not to everything in their lives. According to
John Wesley Powell (1879), the Mormon settlers interpreted their perceptions and environmental phenomena surrounding them to the pleasure or displeasure of their God with their religious devotion. Weather came from God and many of the pioneers deemed that they must be favored by God with increased moisture. Despite much persecution these settlers had shown trust in the Lord and steadfast commitment in the search for their Promised Land, the valley upon which they had recently settled. The rain was one of the rewards for their faith and perseverance.

Powell also commented upon the prevailing attempt at a scientific explanation for the increased rain and snow. The hypothesis reasoned by many was that since they had arrived in the valley, they had been plowing the land, and so they figured that rain must follow the plow (Powell, 1879, p. 70). It is interesting to note that this theory held sway for another seventy years and was used during the Great Depression, as a means, albeit unsuccessful, of generating rain during the parched years of the Dust Bowl era in the 1930s (Duncan & Burns, 2012). Another scientific attempt at an explanation for increased precipitation pointed to the increase in telegraph wires across the region and the static power in these wires was thought to affect the atmosphere (Powell, 1879, p.70).

Powell also acknowledged the unsupported claims of a popular Dr. Hayden who believed that an increase in human population due to settlement in an area prompted the increase in moisture. Powell quoted a report composed of testimony by notable academics of the region:

Similar testimony was gathered by Prof. Cyrus Thomas in 1869 in regard to the increase of water supply at the western edge of the plains, and the following conclusion appears in his report to Dr. Hayden (page 237 of the reprint of Dr. Hayden’s reports for 1867, 1868, and 1869): All this, it seems to me, must lead to the conclusion that since the territory [Colorado] has begun to be settled, towns and cities built up, farms cultivated, mines opened, and roads made and travelled,
there has been a gradual increase of moisture. Be the cause what it may, unless it is assumed that there is a cycle of years through which there is an increase, and that there will be a corresponding decrease, the fact must be admitted upon this accumulated testimony. I therefore give it as my firm conviction that this increase is of a permanent nature, and not periodical, and that it has commenced within eight years past, and that it is in some way connected with the settlement of the country, and that as the population increases the moisture will increase. (Powell, 1879, p. 71)

Powell was an astute observer and synthesizer of observed data. He did not buy Thomas’s analysis and added: “Notwithstanding the confidence of Professor Thomas’s conclusions, he appears to have reached them by a leap, for he makes no attempt to analyze the influence of civilized man on nature to which he appeals” (Powell, 1879, p. 71). Powell looked upon all these explanations as misguided or more colloquially put as “hooey.” He understood that the long-term nature of the region was arid.

The increased rain from 1861-69 influenced the environmental perception of the European immigrant settlers, as can be seen by Powell’s documentation of the proposed explanations for the increased moisture. It is interesting to note that in the first sixty years of Mormon settlement in the American Southwest, two pluvials occurred. The first officially occurring between 1865-69, the fifth wettest period in 1425 years. The second 1905-1922 considered the longest and wettest period in 1425 years (Salzer & Kipfmueller, 2005). Moister years lingered until the early 1870s, but then a drought period ensued interrupted briefly in 1888 with rain, but then another dry period arrived lasting into the 1890s and early 1900s. This longer arid period caused a contraction of Mormon settlements in southern Utah especially those that were outliers. A plaque along Utah Route 89 about 50 miles east of Kanab commemorates one such casualty, the Paria Settlement, which could not grow any food during this drought period causing the site to be abandoned. This contraction of Mormon settlements in southern Utah would have
continued because many of the settlements barely hung on in the desert environment, but then the pluvial of 1905 arrived and the grass began to grow again. In the first pluvial period, wetter years commenced before the official pluvial timeframe and lingered for several years after. In the second pluvial period wetter years continued almost nine years past the statistically official pluvial period. In the records of dry periods wet years would be interspersed and so it was the same in wet periods that a dry year or two would occur. During the pluvial of 1905-1922, 1910 was one such dry year (Salzer & Kipfmueller, 2005). Those children born upon the arrival of the Mormons in 1847 to Utah, their children and their grandchildren, three generations would have come to maturity during two remarkable wet periods allowing for these newcomers to the arid lands of the Southwest, to apprehend albeit mistakenly that their regional climate was wetter than it really was in the long term.

**Concern for the Instability of Small Plots of Land in Zion Canyon**

Research in the archives of the Union Pacific Railroad located in Council Bluffs, Iowa and the archives of Zion National Park in Springdale, Utah yielded an alternative first cause for the channeling of the Virgin River. In these archives I found evidence that substantiated a deep concern by National Park Service officials for the long-term stability of the small plots of land laying mid-way up Zion Canyon. This fundamental concern arose from the realization that only a few acres of flat land existed in Zion Canyon upon which to build a National Park. Moreover, they feared that the Virgin River would wash away these small pieces of flatland as Lee had noted in the epigram at the beginning of this chapter.
These small patches of flatland were composed of thick yellow and pink sands that continually shifted in response to the Virgin River flow. The stability of any flatland in Zion Canyon rested with the seasonal currents and volume of the Virgin River waters. Before 1931 the holdings of this new Zion National Park contained only the narrow, yet strikingly scenic canyon. These few acres of shifting sands had to provide the base for visitation and exploration of the Canyon and the upper elevations and regions of the nascent Zion National Park.

The data found in the archives of Zion National Park support the premise presented in this dissertation, that conservation of the limited flatland in Zion Canyon was the first cause and the implicit rationale for the extensive channeling of the Virgin River. Linking the data presented in Chapter 2 that confirmed a significant increase in regional precipitation from 1905-1922, and thru the end of that decade, coupled with data of the concomitant increase in Virgin River streamflow with the Superintendent narratives found in the ZNP archives indicate that the mobility of sandy flatlands was a prime concern for early Zion National Park management. This geographic factor was one of the main reasons, if not the main reason heretofore not being linked, to the channeling of the Virgin River.

My research found that the fear of losing these small plots of flatland in the heart of the Zion Canyon to changing river volume and river course was the original rationale for armoring and channeling the Virgin River. The spectacular orange and red colored canyon walls stood as the main draw for establishing a national park within the Virgin River canyon. The amount of flatland within the canyon was so precious and precarious that a loss of any amount of the land would undermine the feasibility of hosting visitors
to Zion National Park on any significant scale. The instability of flatland would also severely limit the scale of marketing Zion National Park as part of the new National Parks American dream that Mather and Albright had proposed and advertised to the US Congress (Albright & Cahn, 1985).

**The Geomorphology of the Zion Canyon Flatlands**

For millennia, the waters of the Virgin River and rockslides have determined the fate of the flatlands in Zion Canyon. And for millennia precipitation has controlled the volume and impact of the river flow on the Zion Canyon floor. The natural geomorphic sedimentation and erosion cycles of Virgin River came to a halt with the channeling of the Virgin River commencing in earnest on a large scale in 1930. This end to periodic flooding and to the natural movement of the river came with unsuspecting damage to the biological health of the riparian ecosystem encompassing the ground on both sides of the Virgin River in Zion Canyon.

In 1909 the US government adopted Mukuntuweap Canyon into the protected circle of special lands of great beauty and resources with the intention of bringing people to recreate in the Zion Canyon. However, the only area in Mukuntuweap (now Zion) Canyon that could serve as a base for visitors coming into the narrow high walled canyon were two small pieces of flatland about halfway up the 9-mile canyon. One piece measured about an acre or two and the other, a mile south measured about two-three acres. At the inauguration of Zion National Park in 1919, the planned campground and administrative building rested on less than two acres of flat ground at the base of steep 2500 feet high canyon walls in the area that became known as the “Auto Camp” and now as the “Grotto.” The National Park headquartered its administration in a tiny three-room
stone building adjacent to the Auto Camp. This historic structure was renovated for the 2009 one hundredth year anniversary of Zion National Park becoming a National Monument. This original stone building now serves as a small residence for artists in the Visiting Artist Program of Zion National Park. An adjacent flat piece of ground about a mile south and down river consisting of about two-three acres became the site for the Zion Lodge built in 1926.

Before the settlement of the canyon by Isaac and Elmina Behunin, the first European Americans to make a home in the canyon, the Paiutes intermittently farmed these flat areas but did not inhabit them (Hebner & Plyler, 2010). These small but essential flat areas originated from the accumulation of various types of sediment deposits. Hereford et al. (1995) in their geological survey of *The Geomorphic History of the Virgin River in Zion National Park Area, Southwest Utah* determined that deposits resulted primarily from “mainstem deposits of yellowish grey very fine to medium grained sand and minor sub-rounded to rounded gravel as well as tributary contributions consisting of debris flow, landslide and rockfall deposits (p. 9).

Additionally, Hereford et al. (1995) noted:

> These alluvial deposits are underlain by lacustrine deposits that predate the upper Holocene alluvium. These deposits accumulated in a lake that formed upstream of a large landslide that originated on the west side of Zion Canyon about 5km (3.1mi) upstream of Springdale…The landslide blocked the entire width of the canyon near river level, and the resulting lake was up to 115 m (377 ft) deep and extended up the canyon at least 4.3 km (2.6 mi). (p. 9)

Hamilton (1992) using radiocarbon dating estimated that the minimum age of the lake was about 4000 years old.

This vast prehistoric rockslide was known as the “Sentential Slide.” It is thought that an earthquake precipitated the release of half of the Sentinel Mesa blocking the river
and forming the lake. The mesa tops near the mouth of Zion Canyon are considered guardians of the Canyon. These monumental stone ridges have names that connote protection for the Canyon and those living in it. The Sentinel, a West Rim Mesa-top is diagonally opposite the famous East Rim-mesa top guardian called The Watchman. Both stand near the entrance of Zion Canyon, which was considered a refuge and a sanctuary by the first Mormons settlers, who had fled persecution throughout the Midwest before arriving at safety and settlement in Utah.

The deep layers of fine dark red sediment, the remnants of this earthquake slide can be seen at the intersection of Rt. 9 and Zion Canyon at the present-day Canyon Junction shuttle stop. It is thought that the Virgin River broke through this deep sediment about 4000 years ago, releasing the waters of the lake and leaving the only flat bits of habitable land in the canyon at the present sites of the Grotto and the Zion Lodge locations. These flat habitable stretches are the sandy tabletop of about 370 feet of lacustrine sedimentation laid down in the lake that occupied Zion Canyon for those 4000 years (Hamilton, 1992). Shifting alluvial sands and gravel rest above these lacustrine sediments and together they form the limited usable flatlands in Zion Canyon.

**Aggradation and Erosion Cycles of the Virgin River**

Since the breakthrough of the Virgin River there have been periods of build-up of the river channel and canyon alluvial valley known as aggradation intermingled with periods of erosion called entrenchment (see Figure 3-2). During an episode of erosion, the river channel is lowered and often widened. Hereford et al. (1995) found four terraces above the active river channel and floodplain in Zion Canyon. The oldest terrace known as the “prehistoric” includes a period of deposition ending about A.D.1100-1200 and a
period of erosion from A.D. 1200-1400. Another period of deposition known as the “settlement” period, lasted from about A.D. 1400-1880. This long era of aggradation was followed by a highly erosive period lasting from the early 1880s-1926 known as the “historic” era. However, this erosional period also called the historic arroyo cutting period extended until 1940 when the river started depositing again. This period of sedimentation from 1940-1980 is called the modern alluvium. Following the modern alluvium is the present development of the active river channel and floodplain that commenced about 1980 (Hereford et al., 1995).

Another eminent geologist Herbert E. Gregory (1950) in “Geology and Geography of Zion Park Region, Utah and Arizona” described the aggradation and erosion of the Southwest region similarly. However, Gregory observed a longer aggradation period from 1300-1700 A.D. with fewer erosion episodes than Hereford et al. (1995) surmised. Gregory also suggested that this aggradation period may have commenced much earlier than 1300 A.D. and lasted perhaps 1000 years (1950, p. 172). This longer range of aggradation may be the cause of the deep 15-25 feet sandy banks that line intermittent stretches of the Virgin River, where the revetments have fallen away, and can also be found along other Southwestern riverbanks for example in Hop Valley in the Kolob region of Zion National Park (personal observation, 2020). Gregory (1950) adds that after 1700 A.D. for “150 years thereafter streams in shallow meandering channels did little but transport the products of weathering and rain wash and thus gave form to the remarkably even surface of the latest valley fill” (p. 172). Gregory’s observations explained the geomorphologic pattern of smooth sandy riverbanks contiguous with streamflow as described in historic photos of the Virgin River taken
since the late 1870s. He noted: “In the middle Virgin, and the middle Parunuweap, the streams were flowing on alluvium in fairly well-defined channels and flood plains. Likewise, in many deep canyons, alluvium formed the floor to considerable depths, smoothing out the irregularities in profile on the bedrock beneath” (p. 173) (see Figure 3-1).

Hereford et al. (1995) and Gregory (1950) both agree that since the latter half of the 19th Century erosive cycles have dominated in the Southwest of the United States until the late 1920s. These erosive cycles produced enormous changes in short amounts.

**Figure 3-1**

*Historic Photo Showing Sand Aggregation at the Forefront, as well as Abundant Fremont Cottonwood Photo from 1920s*

Source: Crawford (1986)
of time in the geomorphology of rivers in the Southwest including the Virgin River.

Gregory (1950) underscored this process that occurred in this geologically short span of years 1880-1929 when he wrote:

Since about 1880 stream work in the Zion Park region might be termed catastrophic, comparable to earthquakes and volcanic eruptions rather than to the slow production and removal of waste characteristic of most streams elsewhere. In a day or even a few hours the streams perform work that under other conditions might require tens or hundreds of years, even if it could be done at all. Obviously, the present rapid erosion in the Zion Park region is caused by the floods that repeatedly add speed and volume to perennial streams and fill the channels of normally dry water courses with mud clogged torrents; each flood deepens and widens many channels, rearranges meanders, eats headward, and develops innumerable lateral branches (p. 174).

Gregory (1950) recognized that this historic stream entrenchment, also called arroyo cutting, throughout the Zion National Park region and throughout the Southwest would affect the nascent pioneer settlements dotting the region. The undercutting of riverbanks as swollen rivers widened their channels would result in the relocation of roads and settlements and the abandonment of other towns. The agricultural patterns of the region would be affected by the flooding that causes the arroyo cutting, resulting in the destruction of dams, reservoirs, and the filling-in of irrigation ditches with sediment (p. 174-176). These kinds of disasters due to flooding would be remembered and create center of Zion Canyon. The floods from these two pluvials would become legendary and their memory would affect environmental perception of Zion Canyon into the 21st century. This topic will be discussed in Chapter 4.

Gregory (1950) does not mention the extensive flooding of the early 1860s in southern Utah but in Salzer and Kipfmueller (2005) 1865-1869 is the fifth wettest period in 1425 years! The floods of this 1861-1870 period are documented in Larson (1961); Reid (1964); Ingram and Malamud-Roam (2013). These erosive events along with the
Figure 3-2

Virgin River: River Protection Map with Original S Curve Channel

Note: Dark lines show planned revetment building & channel straightening. Red arrow shows loop channel adjacent to Lodge where 1929 high streamflow initiated revetement building (see Figure 6-6). Source: ZNP, 1929; Box 15450. Zion National Park Archives.
brief wet years in the late 1880s, and the longest pluvial to occur in 1425 years from 1905-1922, constituted a considerable “climate anomaly,” and represented unusual and significant wet years during the Mormon settlement period of Utah.

**Historical Virgin River Geomorphology**

Historical accounts record a Virgin River geomorphology and hydrology and riparian ecosystem substantially different from today (see Figure 3-3). Jessie N. Smith, who explored the canyon prior to the Mormon settlement of the 1860s, reported that the

**Figure 3-3**

*The Virgin River Channel Throughout the 20th Century*

Notes: Note the river occupies the bottomlands of Zion Canyon in 1903, 2 yrs. before the pluvial of 1905-1922 begins. Source: Lee, W.T. # 2713, Box 15450, Zion National Park Archives.
river meandered across a narrow valley, showed signs of large freshets, and that a minor flood would cover the bottomland extensively (Crampton, 1965, p. 84-90). Another 1860s era explorer, Samuel Witwer, reported in Hereford et al. (1995) that the channel was not entrenched when he visited the canyon. Larson (1961) in his book, *I Was Called to Dixie*, noted the Mukuntuweap River was evidently shallow because a dam constructed in 1859 consisted of a cottonwood log laid across the river anchored by two slots cut into each bank (Larson, 1961, p. 681). Samuel Witwer in his memoir published in 1927 and quoted by Hereford et al. (1995) describes reminiscences of settlers from 1865-66 as stating that “the North Fork in Zion Canyon was flowing through a narrow meandering channel with abundant brush, grass, and timber that made cultivation difficult” (Hereford
et al., 1995, p. 24). J. L. Crawford, who was born in 1914, and grew up in the Oak Creek section of Zion Canyon, commented in 1998 that, “the park was a swamp for many years” (Steen, 1999, p. 42). Another elderly local resident, P. Hepworth, interviewed in 1998 noted that “there used to be quite a few wetlands and swamps all along the river” (Hereford et al., 1995).

In the archives of Zion Natural Park, descriptions of the canyon indicate an unstable canyon floor morphology composed of sand and riverbanks contiguous with the river level. As seen from the original “River Protection” map (see Figure 3-2) drawn in January 1929 of Virgin River channel for by the Department of the Interior located in the Zion National Park archives, the original river channel would have been shallow, braided,
and swinging from side to side in an S curve pattern throughout the length of the canyon (see Figure 3-4).

Historical photos show that the river was level with its banks and that these riverbanks were sandy (see Figure 3-4). The Virgin River, banks presently are in many places steep, composed of large rocks that have fallen out of the revetments, or the banks contain the intact trapezoidal iron cages filled with rocks and covered with soil (see Figure 3-5). In some places the river has broken through and eroded away the revetments and this has broadened the river’s channel.

Source: Corr (2020)
The Canyon Floor When the Park Service Arrived: Sand

Those who first hiked the Mukuntuweap Canyon, whether they were a Native American, Mormon explorer, “Plein air” artist eyeing to render in oil the Canyon’s wonderous beauty, Horace Albright in pursuit of the Canyon’s designation as a National Park or as an early park visitor pursuing invigoration from the Canyon’s grandeur, all needed to trudge through deep Sulphur colored sand to their destinations. This sand originated in the Navajo sandstone composing the upper Canyon walls and it was deep. As wind, rain, ice, and gravity continue to erode the solid sedimentary sandstone sentinels of Zion Canyon the sandstone breaks-up into grains of sand that fall and cover the canyon floor and the riverbed.

The Navajo sandstone walls were once the tallest sand dunes the world has ever known, called the Navajo Desert. When formerly at sea level, sea water and then fresh water inundated these dunes and over time the calcium, iron and other minerals with pressure petrified the sand into rock. More recently about ten million years ago, this region known as the Colorado Plateau, was uplifted through a combination of plate tectonics and volcanic activity. Wind and water erosion have been at work returning the adhered quartz crystals to their free-flowing state of sand that covers most of the Zion Canyon floor.

As all beach goers know, each step taken in the sand slows the next step down. Shoes and socks fill with sand weighing down and significantly slowing a sightseer’s gait. Early administrators made note of this sand and considered it to be unstable and a problem that would hinder visitor use. The soft sand composing most of the floor of Zion Canyon moved with the river and nourished the riparian plants that grew there, especially
the Fremont cottonwood trees. The sand created a constant impediment to convenient and swift movement whether by foot, horse hooves or wagon wheels for all early explorers, inhabitants and visitors to Zion Canyon. When Zion Canyon came under the control of the National Park Service one of the first issues the Superintendents decided to contend with was the soft, deep, and shifting sands.

As stated above the riparian area in Zion Canyon was once moist, sandy, and movable. However, presently it has become hardened, static, and controlled. The first hardening of the canyon floor began with changing the soft sandy trails into hardened footpaths by mixing the sand with clay or asphalt to make the trails more accommodating to hiking in Zion Canyon. In 1924-26 further hardening of the Canyon’s sandy bottom came with the transformation of the dirt wagon trail into the main macadam road through Zion Canyon. Since 1862, this rough trail had guided the three European-American homesteading families, the Heaps, the Giffords, and the Behunins with their goods to and from church and markets in Springdale about 12 miles away. The next move to harden the sparse flatland arose from the need for visitor accommodation in the form of campsites. In the location now known as “The Grotto,” close to the canyon walls, an area big enough for 60 cars was hardened and extended by laying clay over the sand (Allen, 1931a, b). The need to prevent reoccurring flooding stemming from the pluvial of 1905-1922 generated the most extensive hardening of the canyon floor channeling the Virgin River. Massive lengths of the sandy S curved riverbanks were shoveled away and new riverbanks built-up using iron trapezoidal cages filled with rock.

Workers blasted nearby canyon walls to obtain the tons of rock needed to create new straight and higher riverbanks (see Figure 3-6). These abutments took the braided
river geomorphology and forced it into a single straight-line geomorphology, in as many places along the 9 miles stretch of river in Zion Canyon, as was possible (see Figure 3-7). This construction forced the Virgin River’s waters into predictable avenues of flow down canyon. Sand and dirt concealed these artificial riverbanks, the revetments, from the public’s view (see Figure 3-7). If one didn’t know anything about southwestern river geomorphology no one would know that they were standing within a canyon whose river and riparian ecosystem had been remade.

When the National Park Service took over management of Zion Canyon this thick sand was the substrate for the swampy areas and the riparian forest of Fremont Cottonwood trees of mixed generational age that covered the canyon floor and flood plain. This sandy canyon bottom provided one of the essential elements necessary for the Fremont Cottonwood to propagate and thrive in the Zion Canyon riparian ecosystem (See Chapter 5).
Figure 3-6

Rock Blasted from the Top of the Zion Canyon Walls to Fill Revetments

Notes: Watchman Mesa seen in background. Source: Box 15450 ZNP Archives, 1930-34.
Figure 3-7

Construction of Revetments on the Virgin River in ZNP

Source: Box 15450. ZNP Archives, 1930-34.
Figure 3-8

Virgin River Original Sandy Riverbanks Before Armoring in 1930

Notes: Note braided channel, multi-aged trees. Source: Box 15450, ZNP

Figure 3-9

Zion Canyon with Cottonwoods and Sandy Floodplain

Source: Union Pacific Railroad Museum (1910-1928).
Historical pictures and descriptions of the Zion Canyon ecosystem can be used to plan for the restoration of this fundamental and prime natural feature of Zion National Park (see Figures 3-1, 3, 4, 8, 9). But nothing beats an example of the original riparian area still intact. In searching an example of undisturbed stretches of the Virgin River that resemble early descriptions of the Zion Canyon floor and riverbanks, I found a section of the Virgin River just outside the National Park boundary between Rockville, UT and the town of Virgin, UT. which I label Site 3. This stretch maintains the natural S curve geomorphology, sandy riverbanks, river level contiguous with the riverbanks as well as young Fremont Cottonwood trees in spatial patterns typical of cottonwood forests. (see Figure 3-10). Additionally, the sand at this stretch of the Virgin River extends about 100 feet into the flood plain and is so deep that it resembles the beaches at the Jersey Shore, where I have spent many happy summer days! Sinking into the yellow pigmented sand of the riverbanks in this stretch of the Virgin River, brought up childhood memories of my father and I trudging through the deep beach sand in our pursuit of a water’s edge far enough away from other lone fishermen to be able to cast a wide and whipping line and sinker far beyond the breaking wave fronts.

This stretch of the Virgin River matches early environmental descriptions of Zion Canyon (see Figure 3-10). Surprisingly this stretch of the Virgin River’s sandy riverbanks and floodplain were laden with young cottonwoods, a sight one does not presently observe in Zion Canyon. This short stretch of the Virgin River contains a living portrait of what administrators and early residents likely found in the upper areas of Mukuntuweap Canyon at the time when the riparian ecosystem became Zion National Park. This portion of the Virgin River between Rockville and Virgin resembles all the
descriptions that I have read over the past few years describing Zion Canyon from the eyes of the original inhabitants, visitors, and administrators. To find this stretch of the river thrilled me! This is a living example of what a healthy riparian ecosystem in Zion Canyon could resemble with restoration! Another clue as to what a restored Virgin River floodplain in Zion Canyon might contain, more sand, comes from the Zion National Park archives.

Comments from early Zion NP Superintendents provide a link to the original sandy riverbanks and flood plain of the Virgin River. Consider what Superintendent E.T. Scoyen said about the top of Zion Canyon where a trail to the Narrows had just been finished in 1928. Originally visitors trudged over a mile through sand to see the spectacular views formed as the Zion Canyon walls narrowed. To alleviate the struggle through the sand, a trail was built, and an artificial surface laid down. E. T Scoyen, the second Superintendent of Zion National Park in his Administrative Annual Report for 1929 filed August 27, 1929, described this deep sand stretching from the Temple of Sinawava north along the riverbanks. Superintendent Scoyen remarked:
This trail leads for a distance of one mile from the Temple of Sinawava to the Narrows, a place where the canyon walls come very close together. Due to the fact that a very large proportion of the park visitors walk over it, we consider it as being a very important part of the park trial system, and something entirely different from the usual foot trail.

During the year, the entire trail was reconstructed. A surface five feet wide of oil-bound macadam was placed. The work was done in such a way that there is no evidence of the artificial surface, but it has the appearance of a gravel path. If anyone, who had previously struggled up through the deep sand to see the Narrows, could return and walk over the new trail I am sure that they would appreciate the improvement (p. 8).

The sandy surfaces of the small flat areas in the canyon were also mentioned in relation to the Public Auto Camp. This plot of land, now called the Grotto, supplied the
original place for overnight camping in the canyon. In August 1931, Administrative Monthly Report written by Superintendent Thomas Allen, he commented on the sand at the Public Auto Camp. Under the heading, Miscellaneous Construction, Allen commented:

Several small items of construction were completed in 1931, These include extensions of the water and sewer systems at park headquarters, (which is now the Grotto), further improvement of the grounds in the administration area, and extension and improvement of the public campground by topping a large sandy area with clay (p. 6).

The process of hardening sandy areas in Zion Canyon stabilized the shifting sandy areas and retained them as stable flat areas in Zion Canyon. However, the cottonwood trees that were already growing there or planted before the clay was laid down are now nearly 100 years old or more. In 2009 sapling cottonwood trees were planted at the Grotto as part of Commemorative Century celebration of Zion Canyon becoming a National Monument. Sadly, during the last twelve years, unlike most cottonwood trees that grow rapidly, many of planted trees still resemble saplings. This author has informed the Park Service about the clay layer at the Grotto with hopes that further plantings will have holes dug through the clay giving the tender tree roots an opportunity to reach the sandy sublayer and water table.

The process of hardening the Canyon floor continued as early Park administrators created more accessible pathways and trails to points of interest in Zion Canyon. By making scenic views accessible, more visitors would be attracted to the National Park. Members of Congress required a reason to appropriate funds for the marvelous experiment of creating a National Parks System. The long-term Federal government investment in these Public Commons also required yearly justification for appropriations
for each of the Parks in the National Park System. Detailed visitor records in the Zion
National Park Monthly Superintendent reports met the need for visitor use verification
required by the Department of the Interior, the governmental branch that oversaw the
National Park Service. Trails on the valley floor of Zion National Park had to be made
appealing and usable for the public. Hardening the sandy trails with clay met this goal
(Albright & Cahn 1985, p. 3).

Look to what P. P. Patraw, Superintendent of Zion National Park, remarked about
the sand in Zion Canyon in the 1934 Annual Report under the heading, Public Works
Roads and Trails, Minor Projects section FP-172 Refrigerator Trail Reconstruction,
Superintendent Patraw confirmed:

With the allotment of $18,000.00 for this project the reconstruction was
completed, and the oil mixed surfacing carried from the foot to and nearly through
Refrigerator Canyon, a total distance of .96 mile. The surfacing consists of the
application of emulsified asphalt to the native sand and thorough mixing of this
application for an average depth of four inches. This surfacing has proved
extremely beneficial, not only in eliminating dust and difficult treading through
deep sand, but also in practically eliminating damage from storm runoff. (p. 5).

The shifting sand beneath the intrepid soles of those traipsing through Zion
Canyon makes another appearance in section FP-173 Valley Trails Light Clay Surfacing
under the same general heading in the 1934 Superintendent Annual Report.
Superintendent Patraw described the payments for the hardening of trails atop the sand in
Zion Canyon. He noted:

Most of the work on this project was completed in October, consisting of
application of light clay binder on top of native sand on the Weeping Rock,
Grotto and Emerald Pool Trails. The allotment of $900.00 is practically spent at
the close of this report period (p. 5).

The Public Auto Camp laid out originally upon a sandy flat adjacent to the Virgin
River on the east side of the Canyon floor originally held spaces for 60 cars. But as
tourism increased in 1931 the Auto Camp began an expansion. ZNP Superintendent Thomas Allen, Jr. wrote in his June 1931 Monthly Report:

Sixty new camp tables have been purchased and assembled in the public camp grounds at both Zion and Bryce Canyon and at Zion Canyon Camp work is in progress mixing the sandy ground in here-to-fore unusable land with clay in order to extend the area of that camp ground. (p. 4)

It is evident that the shifting deep sands that composed the canyon floor and flood plain of the Virgin River in Zion Canyon posed an impediment to the development of visitor use at the young Zion National Park. Yet the sandy substrate provided ideal conditions for the generation of cottonwood seeds. The comments about the hardening of the sandy surfaces in Zion Canyon with clay can aid the reader in imaging the breadth and depth of the original soft sandy conditions of the Zion Canyon valley floor. The deep sandy canyon floor could easily be moved by high water. Therefore, this sandy flood plain could not initially be relied upon to provide a stable foundation for trails, campsites, and buildings for the new Zion National Park unless it was hardened and protected.

**Valuable Zion Canyon Flat Lands and the Effects of the Pluvial:**

**Inconsistent Weather Data and Human Perception of the Environment**

The environmental perceptions of early Zion National Park administrators can be seen in the comments left by them in the Annual and Monthly Superintendent reports of Zion National Park. These perceptions give an immediate person-in-the-canyon feel to the Annual and Monthly reports. However, several problems exist with this data. The first problem stems from the fact some of the Superintendent comments do not always match the few statistics of precipitation and temperature that remain from the pluvial period 1905-1922. The precipitation reports from 1904-1926 have considerable missing data yet show some pluvial trends where data was collected. Dave Sharrow ZNP hydrologist, who
pointed me in the direction of the incomplete data determined that 1927 was the first year with reliable data. A second problem is that from 1909 when the park came under US government control until 1918 as far as I can find, there are only two terse Superintendent reports from Zion National Park. The Superintendents refer to these 1904 records but what is not clear is who is keeping them and exactly where the weather readings are being recorded. Nonetheless, trends can be observed and conditions in the Zion Canyon can be inferred from the regional data in the form of streamflow records and dendrochronology that I have gathered and presented in Chapter 2.

From this record it can be inferred that there was increased precipitation during the pluvial years. Nonetheless, from the 1904 temperature records it can be observed that cooler temperatures were observed during the 1905-1922 pluvial in Springdale and Zion Canyon (see Figure 3-11).

Cooler temperatures were associated with the 1905-1922 pluvial (Salzer & Kipfmueller, 2005). They list the period 1911-1930 as the third coolest period in their 1425-year study (see Table 2-2). These years match the last 11 years of the 1905-1922 pluvial of high water in southern Utah. However, lower temperatures do not always accompany a pluvial. Lower temperatures did not accompany the 1865-1869 pluvial. This period did not even make it into Salzer and Kipfmueller’s (2005) temperature table (see Table 2-1). However, temperatures for July underscore the cooler temperatures for the 1905-1922 pluvial. July presently is often the hottest month in southern Utah with temperatures often over 100 degrees daily! Temperatures for July during the 1905-1922 pluvial were at 80 degrees or below between 1914-1918, middle years of the 1905-1922 pluvial. Furthermore, since 1924 temperatures for July have not gone below 80 degrees!
Below is a graph of July temperatures on record from July 1904 to 1950 (see Figure 3-11). It is of interest to note that the elevated temperatures in July 1910 were thought to be an anomaly by ZNP Superintendent Scoyen in 1928 and 1929 when he was reviewing temperature records since 1904. Yet 1910 is considered a signature of the 1905-1922 pluvial because temperature and precipitation records returned to more normal arid levels.

**Figure 3-11**

*July Average Temperature in Zion National Park, 1904-1950*

Note: Red line indicates 80° F. Source: Zion National Park.
Linkages between environmental conditions and environmental perceptions prompted actions taken upon the environment within Zion Canyon, which in turn indicate that the climate influenced by the pluvial of 1905-1922 affected the decisions to channel the Virgin River. This armoring of the Virgin River dramatically removed the Virgin River from its flood plain resulting in the unexpected demise of the Fremont cottonwood forest that had been a key feature of the riparian ecosystem in Zion Canyon.

Although there were Superintendents managing Zion National Park since 1918, only two short records for the years 1918 and 1919 exist for Walter Ruesch, Acting Superintendent from August 12, 1918, until May 15, 1925. Records do not exist in the archives of Zion NP for the Superintendent Richard T. Evans, Acting Superintendent from May 16, 1925 – 10/33/1925 and 5/29/1926 – 11/30/1926. Requests were made at the National Archives in Washington, DC for any records by these two Acting Superintendents and none were found.

Consistent records began in the Zion NP archive with Superintendent Evind T. Scoyen, who served from 9/11/27 – 1/15/31. It was at this time that Monthly and Annual reports on expenditure, activities, and observations by the Superintendents of Zion National Park were required by the Department of the Interior and the National Park Service. Superintendent Thomas J. Allen managed ZNP from 1/16/31 – 1/15/32 followed by Preston P. Patraw, who guided ZNP from 1/6/32 — 12/31/38. Paul Franke directed the ZNP from 1/1/39- 7/31/39. C. Marshall Finnian followed Franke’s first term 8/01/39- 6/22/40. John Davis had a short term from 7/05/40- 8/15/40, then Franke returned from 8/16/40 – 6/30/43. On 7/01/43 Charles. J. Smith took hold of the reins at Zion NP until 4/30/52. Franke returned 6/01/52 and held the Superintendent position until 12/31/59. My
research focuses upon the administrations of Superintendents Scoyen, Allen, Patraw, Davis, and Franke the period 9/11/27 – 6/30/43.

As a result, the archival files in the Zion NP archives do not align with the years of the 20th Century Pluvial 1905-1922. In reviewing all the Annual reports and all the Monthly Reports from 1927-1940 there were at times references by the Superintendents to weather during the official years of the pluvial. From streamflow records and weather records the effect of the pluvial could be seen beyond 1922. I have had to extrapolate from the statements and reactions of the Superintendents that kept records after the “official” pluvial years how the increased rains occurring in those years influenced their management goals. Precipitation and streamflow records after 1930 indicate less precipitation and lower streamflow patterns continuing through to the present time in the Southwest region of the United States.

From the comments of Zion National Park administrators describing specific environmental conditions in Zion Canyon, it can be extrapolated that the increased levels of precipitation were noticed by administrators whose aim it was to make Zion Canyon visitor friendly. Records of weather including temperature and precipitation levels began in Zion Canyon in 1904. Superintendents of the National Park had only these short-term records gathered within the pluvial years, that could be used as benchmarks of “normal” climatic conditions within Zion Canyon. As a result, these benchmarks would err on the side of increased moisture and Virgin River streamflow. Thus, management decisions based on these short-term statistics would construct a skewed picture of the climate. The picture Zion National Park Superintendents constructed from their data commencing in 1904 the year before the 1905-1922 pluvial included significant moisture and cool
temperatures. None of the Superintendents refer to the drought period through the 1890s until 1904 in their reports.

**Why Was the Virgin River Channeled?**

From my research in the archives the initial reason for channeling the Virgin River was the fear that the small amount of flatland in Zion Canyon would be washed away by the Virgin River (Allen, 1931c; Kittredge, 1928; Patraw, 1932a, b; Robinson, 1923; Scoyen, 1929b). If this were so, there would be insufficient flatland at the base of Zion Canyon upon which to build a National Park. Other reasons developed alongside this prime concern becoming intertwined with the concern for saving valuable flatland in Zion Canyon. In 1926 a slender ribbon of roadway lay upon the canyon floor and a lodge had been built halfway up the 9-mile canyon on the two to three-acre piece of flatland. Considering the narrowness of Zion Canyon, and the increased precipitation that had been occurring in the Southwest, these infrastructure advancements needed to be protected. Nonetheless, the initial concerns by National Park administrators were for preserving any flatland in Zion Canyon (Allen, 1931a; Kittredge, 1928; Mather, 1918; Patraw, 1932a, b; Robinson, 1923; Scoyen, 1929b).

Some might answer the question of why the Virgin River was channeled with another practicality that in this remote area of Utah men needed jobs. The new National Park could supply locals with employment, which would create a better relationship with the Springdale and Rockville communities, especially since the Federal government was taking over land that heretofore, had been theirs free to own and use as they wished. When the Great Depression hastened a dearth of employment opportunities a response was demanded. Some would say that the answer to this need came from the construction
of public utilities and Federal infrastructure projects such as National Park improvements. My research suggests that the increased precipitation, from the early 20th Century pluvial, was a prime and on-going factor that had been working behind the scenes to influence the channeling of the Virgin River in Zion Canyon before the needs of the Great Depression arose (Mather, 1918; Robinson, 1923; Kittredge, 1928; Scoyen, 1929a, b; Patraw, 1932a).

A substantial weather change had occurred that was recognized by locals as something different than before. This climate change eluded modern researchers for over a Century. It was only recently statistically measured and verified (see Chapter 2). Officially lasting for 17 years, however wet years continued through the end of the second decade of the 20th Century. As a result, people had seen the waters of Virgin River swell and spill over its banks so often that the term “flood” had become a common term in a desert environment. The pluvial created an impression that high water was the “new normal.” Thus, engendering a justified fear that the small amount of flatland in Zion Canyon would be washed away by the unpredictable streamflow levels of Virgin River. However, this flatland was needed to build and safely maintain infrastructure in Zion National Park. What were Zion National Park administrators to do?

The Valuable Flat Lands

The focus point of the new Zion National Park was Zion Canyon. However, within this narrow high sandstone canyon, composed of steep 2500 ft. towering walls, the flat and usable land at the bottom of the canyon walls extended to only a few scant acres. Since 1863 the families of Isaac and Elmina Behunin, the Gifford’s, and Willian Heap and their descendants had sought sanctuary from religious persecution in Zion Canyon and had intermittently farmed these same lands adjacent to the Virgin River and at the
base of the canyon’s walls. Previously the Southern Paiutes grew squash, beans and corn on these moving Virgin River sandbars but according to historical accounts, the Paiutes did not favor permanently settling in the canyon (Lee, 1917, p. 31; Hebner and Plyler, 2010). But when the United States government planned on settling in Zion Canyon one of the main obstacles to this settlement was a lack of flatland in Zion Canyon. Stephen Mather mentioned to Horace Albright in 1918 that he was concerned that the flatlands in Zion Canyon would wash away (Mather, 1918). The following comments taken from the Annual and Monthly Reports of the Superintendents of Zion National Park clearly establish that the concern for the loss of the flatlands in Zion Canyon was uppermost in their minds and affected their perception of the Virgin River.

In a March 30, 1928, letter to the Director of the National Park Service, Horace Albright, Chief Engineer, F. A. Kittredge, described construction activities in Zion National Park. His comments illustrate the deep concern about the amount of flatland within the canyon upon which Zion National Park could be established for visitor use. He wrote:

This report, with photographs and maps covers in quite detailed manner the construction activities in which this office cooperated with the Superintendent. This report also covers plans for construction of various projects, especially the narrows trail which is proposed for construction this coming season.

The matter of river protection is urgent in order to save the valley land from erosion during the unusual seasons. It should be undertaken as soon as funds can be made available” (p. 1).

In the ZNP Superintendent Monthly Report for September 1929 in the section report on Operations and Conditions in Zion and Bryce Canyons to The Director of National Park Service Washington, D.C. from E. T. Scoyen, the Superintendent of ZNP dated October
With the exception of the afternoon of the 2nd and the early morning of the 3rd, when the worst storm in years broke over Zion Canyon, bringing 3.56 inches of precipitation, the past month has been nearly ideal from the weather standpoint, and there has been very little interruption of tourist travel.

The storm mentioned above caused the worst floods in 10 years in the Mukuntuweap and Parunuweap Rivers⁴, our gage on the former showing a rise of 7 feet. At Rockville, below the junction of these rivers, which forms the Virgin, the flood went three feet over the diversion dam we built last spring to protect the Rockville Bridge, and as this stands 8 feet above low water a flood with a head of 11 feet was indicated. However, the dam was entirely adequate and kept the water from undermining the bridge approaches.

In Zion, two rock cribs protecting the road were carried away, level ground of utmost value to future developments at both the auto camp and the lodge sites was carried away, and the channel has moved over so close to these developments that it is urgently necessary that the river be put back in the old channel as a matter of protection of life and property. It is estimated that this will cost about $10,000.

However, it is impossible to place an estimate on the level ground which was washed out as it can never be replaced and is badly needed. A flood rushing down Refrigerator Canyon was blocked by a log jam, and this turned the water down the West Rim trail across a series of switchbacks carrying away the trail completely and causing about $1,000 Damage. Damage to the park road was estimated at $1,000, and considerable damage was also done to unfinished sections of the Zion Mt. Carmel Highway. (p. 1)

In the August 29, 1931, letter from Superintendent Thomas J. Allen. Jr. to the Director of the Nation Park Service, Stephen Mather, Superintendent Allen clearly indicated the exceptional worth of the land within Zion Canyon. In the section entitled “River Control” Superintendent Allen explained:

Work of controlling the Mukuntuweap River in order to prevent its breaking channels and laying waste to valuable canyon lands has been continued, and results at this time indicate very valuable returns from all funds so far extended in the last two years. Zion Lodge is now well protected and the most dangerous

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⁴ There is a sister canyon to the east and adjacent to Zion Canyon called Parunuweap Canyon, which is not opened to the public. The river running through it was once called Parunuweap River and now is called the East Fork of the Virgin River.
points on the road locations have been taken care of. The work, however, will not be completed without considerable additional funds. (p. 1)

In the 1931 Annual Report Zion Superintendent Thomas J. Allen, Jr. described how changing the Mukuntuweap River channel has extracted much needed flatland from the river’s flood plain. He reported:

Two additional rock dykes, 1,500 feet in length, were built in the vicinity of the Zion Lodge at a total cost of $11,800. The protection which these and previously built dykes afford has enabled construction of the new road past the lodge on a new alignment, allowing it to follow the river to a point near the public campground, thus making available for parking and construction purpose a large area which formerly was a part of the river channel. (p. 5)

Each ZNP superintendent in the early years faced the reality of limited flatlands and the washing away of unstable flatland as well as the unpredictable force of the Mukuntuweap River later renamed the Virgin River. These scarce, loose, and lightly held sandy flatlands represented the only intermittent bits of land upon which to build Zion National Park infrastructure. In the Annual Report for 1932 for Zion National Park Superintendent P. P. Patraw detailed the situation facing the creation of a National Park in a canyon, where the river removes and rearranges the few areas of flat sandy lands as part of the river’s natural relationship with the riparian ecosystem. Superintendent Patraw, an eloquent chronicler of the events during his term of stewardship, depicted the perennial situation facing the construction of the National Park in a narrow canyon originally named straight arrow Mukuntuweap. Under the section deemed “River Control for Road Protection” Patraw set forth the dilemma:

An allotment of $13,000. From Roads and Trails funds was granted in October for performing additional protection work. With these funds 5000 feet of channel change were excavated and 1800 feet of basket dams constructed. High water in the river was experienced from the spring run-off in May and from storms in July and August. The highest stage was reached on August 29 when the river rose 12 feet above the mean, the highest in several years. At this time the value of the
basket dams which had been constructed was well demonstrated, the main force of the current being retained inside the channel with no damage outside, whereas in unprotected places the current rapidly ate into banks and took out alluvial land which cannot be replaced. Each stage of highwater results in widening the channel and if uncontrolled it would take out all of the flat land in the upper area of the canyon. (p. 4)

These descriptions of the rapidly changing geomorphology of the Virgin River support the deep concern and fear of losing the flatlands within Zion Canyon that the Superintendents of Zion National Park portrayed in their comments in the Zion National Park Administrative Reports. Losing the flatlands would leave these administrators with no land on which to build a National Park. Zion National Park came into the National Park Service only three years after the Organic Act of 1916, riding on the wave of enthusiasm and momentum for the National Park Service idea that both Mather and Albright had worked hard for a decade to create. Having no place to host and house visitors would be an economic loss for Zion National Park and for southwestern Utah. These losses could translate into the perception that new National Park would not be able to substantiate the investment that the United States government had made towards the preservation of the outstanding landscape of Zion Canyon.

Hereford et al. (1995), also confirm that this type of notable geomorphic changes in the Virgin River mimicked similar changes in other rivers throughout the Southwest confirming the presence of a larger weather phenomenon on the scale of regional climate. They conclude:

The question of how natural variation of discharge and sediment load alter the alluvial valley was the research topic. This information is necessary to understand the role of climate in the recent geomorphic development of the alluvial valley. Results of this study suggest that valley morphology has changed rapidly in response to natural discharge variations. Moreover, the geomorphic history of the Virgin River is similar to several other streams in the southern Colorado Plateau, suggesting that geomorphic change is linked to climate of the region. (p. 21)
In the local hamlets adjacent to the Virgin River immediately downstream of Zion Canyon, Springdale, Adventure, Shunesburg, Grafton, and Rockville settlers were experiencing the Virgin River as an unpredictable arbitrator of success or failure. The Superintendents of Zion National Park did not want to be at the mercy of this same arbiter. Hereford et al. (1995) clearly understood from their geomorphic studies of the Virgin River that a pluvial would affect the livelihoods and environmental perception of those early Anglo European primarily Mormon settlers. The Mormon response to the desert was an intricate set of engineered irrigation ditches and dams that continue to be used to this day throughout Utah and particularly in Rockville, Utah, the community of 250 residents south and adjacent to Springdale. Hereford et al. (1995) claimed: that the historic arroyo cutting that resulted primarily from increased precipitation “caused major economic losses of property and economic hardship among Anglo settlers” (p. 1). Economic and property loss due to the Virgin River floods of the 1860s and late 1880s was well known by Utahans by the time the Federal government took over Zion Canyon in 1909 (Larson, 1961). But the National Park Service had not yet been created and so Zion Canyon had been sequestered by the United States government, which was not yet ready to administer and manage the lands. As a result, whatever geomorphic conditions and changes that went on in Zion Canyon from 1909 -1928 are not well recorded nor documented by the Federal government, therefore for the most part remain unknown. Yet historical commentary by residents a few miles downstream of ZNP boundaries and observations from geological surveys offer evidence of the status of riparian zone in Zion Canyon during these federally undocumented years.
Nonetheless, the documentation offered by Gregory (1950) and Hereford et al. (1995) describe the change in Virgin River geomorphology due to increased precipitation in the period of the 1905-1922 pluvial. In the prevailing context of the early 20th Century Progressive Era with its bourgeoning can-do optimism emulated by National Park Service, leaders, Mather and Albright, a response to the pluvial with its effect on the increased force of Virgin River upon the flatlands of the sanctuary canyon, Zion, would eventually be undertaken (see Figure 3-12).

**Figure 3-12**

*Flatland Around the Zion Lodge Recovered by Channeling the Virgin River and Pushing it to the Western Edge of Canyon Floor*

Note: The Virgin River appears in brown on this map. The red circle highlights the area of flatland. Source: Google Earth, 2021
CHAPTER 4

EARLY NATIONAL PARK MANAGEMENT AND THE ENVIRONMENTAL PERCEPTION OF ZION CANYON

Zion Canyon is no place for a resort. It is too exhilarating too overpowering one would scarcely think of going there to rest. In a sense, it resembles a museum where so many unusual objects are crowded together that the mind is bewildered and the eye tires. It is rather a goal for the athlete who exults in his strength; for those of alert mind and vigorous body; for the artist who wishes to gain new and grand conceptions of landscape architecture; for any and all who employ unusual and spectacular scenes. (Lee, 1917, p. 12-13)

The towering and inspirational sandstone cliffs of Zion Canyon remain a constant landscape; however, the canyon floor has suffered unexpected changes. The early National Park Service administrators, pioneering inhabitants of Zion Canyon, the native Paiute people and Willis Lee gazed at the same stunning and awe-inspiring canyon walls that visitors to Zion National Park admire today. Wonderstruck by these monumental expanses of orange and rusted red jagged sandstone, human beings in the past and present have sensed and been inspired by the power and majesty inherent in these soaring sentinels. In the last 100 years since Zion National Park entered the National Park System in 1919, people continue to find in Zion Canyon the challenge and refreshment for the body and soul that greeted Willis Lee when he surveyed Zion Canyon in 1917. Why then has the most visited portion of Zion National Park, the riparian land adjoining the Virgin River banks at the base of the canyon walls, lost its inherent vigor?

The riparian ecosystem of Zion Canyon creates a moist nurturing oasis amidst the vast arid lands of southwest Utah. But unlike the sandstone walls where change is measured in geologic time, the ecosystem of the canyon floor has transformed within modern time. It no longer resembles the sandy, swampy, and densely foliated canyon that the Mormon missionary and explorer, Nephi Johnson, would have trekked through
in his 1858 explorations of the upper canyon. Nor does the present Zion Canyon flatland resemble the mythic landscape that the Paiute peoples farmed, but chose to avoid, especially at night due to “fearing injury or death from the evil and capricious gods who dwelt there” (Hebner & Plyler, p. 73). The present Zion Canyon riparian ecosystem and canyon floor is far more static, hardened, degraded, and controlled. However, this unhealthy ecological condition is seldom recognized by the untrained eye or to those coming for pleasure and recreation in Zion Canyon or for a quick “been there done that” hike up Angels Landing.

Observations from the eyes of the early National Park Service administrators, noted in monthly Superintendent Reports and the testimony of Mormon immigrants and explorers of Zion Canyon provide first-hand observations of the environmental conditions within the canyon over time. In addition to the Superintendent Reports, accounts from various other sources, such as residents who grew up in Zion Canyon and historical commentary add to the portrait of how people experienced the geomorphology and biology of the Virgin River and its flood plain within Zion Canyon, before the National Park Service took control of the canyon in 1909. More recent observations made by residents in Springdale and Rockville, the two small towns at the mouth of Zion Canyon, as well as my own exploration of the river within Zion Canyon assist in interpreting the original ecosystem and its contrast to the present environmental status of the canyon’s riparian zone.

This chapter portrays environmental perceptions that influenced the founding of the National Park Service. These include the European and American Parks movements, and philosophies of Theodore Roosevelt, John Muir and Frederic Law Olmsted. Also
addressed are founding management concepts of the National Park Service as well widespread perceptions of the Virgin River held by settlers and Zion National Park administrators. Furthermore, this chapter will explain how these perceptions were linked to early resource management of Zion Canyon by the National Park Service. Examples of Zion National Park management policies towards animal and plant populations will also be discussed to create a portfolio of early management perception and policy. Most importantly, the main premise of this dissertation, that exceptional and unusual climatic conditions in the Southwest region of the United States in the early 20th Century influenced Virgin River management policy, will be explained. Additionally, the long-term and unexpected outcomes of this Virgin River management policy will be elucidated.

The Superintendents of Zion National Park tend to be spare in their written commentary. Nonetheless, their comments in the archives of Zion National Park point to environmental perceptions that indicate specific biological, geographic, and climatic conditions as well as time-stamped human reactions towards these conditions. These reactions helped to create National Park management actions, which were often influenced by local habits and accepted practices of the times, rather than comprehensive long-term policy. These early management reactions created unexpected consequences for the Zion Canyon riparian ecosystem. More specifically the Freemont cottonwood trees, the native forest species, in the riparian ecosystem of Zion Canyon, have suffered from the Virgin River management policy. The riverbanks and flood plain of the Virgin River have been modified such that the flood plain has become separated from the river and for the last ninety years the annual dispersal of cottonwood seeds has not had the
traditional bare moist surfaces upon which to land, take root, and grow the next
generation of Fremont Cottonwood trees. In 2006 Dave Sharrow, the Zion National Park
hydrologist, shocked me when he commented that as a result of the aging cottonwood
forest dying, “soon there will be no shade in the canyon for several generations”
(Sharrow, personal communication, April 2006).

The Parks Movement of the 1850s Out of Which Grew the Foundational Philosophy
of the National Park Service

Each landscape preserved and welcomed into the National Parks system
encompassed flora and fauna of inestimable biological and geological worth often
situated within exquisite natural beauty. These National Park landscapes offered awe and
inspiration to human beings as well as an opportunity for physical exertion and
restoration for the body, mind, and soul. The adoption of the European Parks Movement
in America in the 1850s elevated these attributes to the status of essential to the process
of uplifting the emotional and physical health of Americans. The recognized need by
American society for the restoration of sound mind and body raised the public value of
National Park environments for members of the US Congress (Albright & Cahn, 1985).
The public officials, who appropriated the funds to purchase and administer the National
Parks, were keen to find justifications for the expenditures required to acquire these
treasured landscapes (Albright & Cahn, 1985; Swain, 1970).

The Parks Movement arose as a concerned social reaction to the highly
industrialized and densely populated urban centers in Europe and in America. The
movement began first in England and France in the late 1850s and moved into the United
States soon after. The axiom of the Parks Movement premised the profound notion that
governments could and should consider in appropriations and plans, the physical and
emotional well-being of its citizens (Albright & Cahn, 1985). The 19th Century Victorian writer, John Ruskin, made the observation, “The measure of any great civilization is its cities; and the measure of a city’s greatness is to be found in the quality of its public spaces — its parkland and squares” (as quoted in Hind, 1979, p. ii).

In the second half of the 19th Century, immigrants and those raised in rural agricultural regions migrated to the increasingly industrialized cities in the American east. This industrialization required, from these emigrants, that their precious time be devoured by long hours operating machines in dangerous and soul numbing conditions. Philanthropists thought that these stressed workers needed a means to restore their well-being and inner calm ravaged by daily long hours and grinding 60-hour or more work weeks being paid low wages. Additionally, most lived in densely populated urban neighborhoods with impoverished living conditions. The idea of using nature and physical exertion as a means for rebuilding and maintaining physical and emotional health derived from varied sources including the European Parks Movement but were made popular in the United States by three Americans: Theodore Roosevelt, Frederick Law Olmsted, and John Muir (Swain, 1970).

Each of these men recognized the powerful healing relationship between nature and human beings. Each man devoted a part of his life to protecting and preserving this sacred relationship. Each man understood the healing relationship in a unique way. For Roosevelt, it was his body that was rejuvenated by his years in South Dakota. Doris Kearns Goodwin in her book, The Bully Pulpit points out:

He was often on his horse sixteen hours a day, riding after stray horses, hunting game, joining his men in the hardest work, that of, the spring and fall round ups…these long swift rides in the glorious spring mornings are not soon to be
forgotten…Relentless physical activity served him well. (Goodwin, 2013, p. 110-111).

In addition to reviving the body Teddy Roosevelt well understood how nature healed grief and revived hope. Roosevelt mentioned his deep melancholy, known in the 1800s as “Black Care,” being dispersed by physical exertion, when he wrote, “Black Care rarely sits behind a rider whose pace is fast enough” (p. 110-111). After two years at his South Dakota ranch, recovering from the loss of his mother and his beloved first wife, Alice, on the same day, Roosevelt understood that if he could heal from such depression and loss, his healing transformation could be the same for others. The experience of immersing himself in physical exertion outdoors enabled him to regain his life and find his second wonderful wife, Edith.

As a result of his two-year experience in the west Roosevelt joined Frederick Law Olmsted, in championing nature as a healing balm with the restorative power to rekindle hope and calm to the human spirit. Olmstead considered the Father of Landscape Architecture and one of the founders of the European Park Movement of the 1850s, with Roosevelt believed that government had a social responsibility to assist all citizens in having access to this healing property of nature. Roosevelt declared, “An arable, enticing West could alleviate some of the social evils caused by overcrowding in the East,” Roosevelt would not hesitate “to throw the full force of his influence behind legislation that would halt ‘the ruinous waste of the great national forests” places that held the important natural healing qualities that engendered restoration of body, mind and soul (Goodwin, 2013, p. 353).

For Frederick Law Olmsted, nature cleared the mind of the stress resulting from work and daily living. He recognized the power of open space to restore clarity and
tranquility to the mind. Olmsted spoke often about the role of government to aid its citizens in the pursuit of happiness via the preservation of nature and scenic beauty. Olmsted laid out these fundamental pillars of the conservation movement in his 1865 report: *Yosemite and the Mariposa Grove: A Preliminary Report, 1865*. He supported the conservation of scenic lands such as Yosemite as part of the essential purpose of the American government. Olmsted also believed in the value of large planned urban parks to serve as a panacea for the stress of life found in the high concentrations of people living in urban areas. Like a Politian on the American stage Olmsted (1865) declared:

> These are considerations of a political duty of grave importance to which seldom if ever before has proper respect been paid by any Government in the world but the grounds of which rest on the same eternal base, of equity and benevolence with all other duties of a republican government. It is the main duty of government, if it is not the sole duty of government, to provide means of protection for all citizens in the pursuit of happiness against the obstacles, otherwise insurmountable, which the selfishness of individuals or combinations of individuals is liable to interpose to that pursuit. (para. 25)

Olmsted (1865) was clear and direct in supporting the creation of Yosemite as a place to be preserved by the government for the health and well-being of its citizens. He pronounced “The establishment by government of great public grounds for the free enjoyment of the people under certain circumstances, is thus justified and enforced as a political duty” (para. 34).

Olmsted’s ideas, about the effect nature has upon human emotions and mental clarity, were well respected. He gained fame as one of the designers of New York City’s Central Park in 1858 and the Chicago World’s Fair of 1893. His recitation on the responsibility of government to facilitate good health and well-being for its citizens in his 1865 Yosemite preliminary report provided a solid foundation upon which to create a National Park Service and to build future National Park management guidelines. He also
clearly understood the economic benefits of National Parks to regional businesses that would provide accommodation and transport to visitors to these special protected places. But Olmsted singles out the personal benefits to body and soul for the individual as the primary rationale for preserving large landscapes. Olmsted speaks for the multitudes when he outlines their everyday conditions and how nature can balance these stresses and enervate and renew the human mind and emotions. Olmsted (1865) eloquently described:

It therefore results that the enjoyment of scenery employs the mind without fatigue and yet exercises it; tranquilizes it and yet enlivens it; and thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system. (para. 33-35)

Further Olmsted with Roosevelt and Muir believed that each of their own individual experiences of being healed and held spiritually by nature was possible for all people and that all people deserved this opportunity. Olmsted (1865) observed:

But there is a special reason why the reinvigoration of those parts which are stirred into conscious activity by natural scenery is more effective upon the general development and health than that of any other, which is this: the severe and excessive exercise of the mind, which leads to the greatest fatigue and is the most wearing upon the whole constitution, is almost entirely caused by application to the removal of something to be apprehended in the future, or to interests beyond those of the moment, or of the individual; to the laying up of wealth, to the preparation of something, to accomplishing something in the mind of another, and especially to small and petty details which are uninteresting in themselves and which engage the attention at all only because of the bearing they have on some general end of more importance which is seen ahead.

In the interest which natural scenery inspires there is the strongest contrast to this. It is for itself and at the moment it is enjoyed. The attention is aroused, and the mind occupied without purpose, without a continuation of the common process of relating the present action, thought or perception to some future end. There is little else that has this quality so purely. There are few enjoyments with which regard for something outside and beyond the enjoyment of the moment can ordinarily be so little mixed. (para. 30-31)

One hundred and twenty years before the New Age movement of the 1980s when concepts of Eastern religious practices popularized as “Mindfulness” or “Be Here Now”
began to enter the American experience, Olmsted clearly understood and elucidated these same ideas of the importance of being in the moment, as part of the rationale for the creation of National Parks.

For Muir nature reached deep into the heart and soul of a person. Nature offered unconditional inclusion and acceptance, an intimate and nurturing relationship, that from ancient times has always been regarded as a transcendent experience. Muir in his book, *Our National Parks*, described how nature can provide the enduring sustenance of an intimate relationship for each person. He exclaimed:

> Walk away quietly in any direction and taste the freedom of the mountaineer. Camp out among the grasses and gentians of glacial meadows, in craggy garden nooks full of nature’s darlings. Climb the mountains and get their good tidings. Nature’s peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you and the storms their energy, while cares will drop off like autumn leaves. As age comes on, one source of enjoyment after another is closed, but nature’s sources never fail. (Muir, 1901, p. 56)

The rationale for “use” that Albright and others sought as the hook needed to convince the United States Congress to appropriate funds to preserve large tracts of American wilderness, and to create a National Park Service to oversee these lands, stemmed from the philosophical and political observations of Olmsted. Yet Roosevelt, Muir, and Olmsted each contributed to the creation of the philosophical tenets at the heart of the great endeavor of the American National Parks System (Swain, 1970). Olmsted specifically championed the idea of public parks in both urban and wilderness settings, for the public good. Yet each of these men were committed to championing the benefits of being in nature and scenic beauty to the American public each in their own realm of influence Roosevelt, politically and on the national level, Muir on the personal and
philosophical realm, and Olmsted bridging these two realms with the practical application of open space in the societal realm of the Common Good.

Tying the health and happiness of citizens to the responsible acts of government created the foundational philosophy for the “public use” rationale for the National Park System. Stephen Mather, Twenty Mule Team Borax millionaire, philanthropist, and first Director of the National Park Service, as well as Horace Albright, lawyer, and second Director of the National Park Service, found this philosophy a worthy justification for the acquisition of National Parks and creation of the National Park Service, (Albright & Cahn, 1985). The idea that government had the responsibility to look out for the happiness of its citizens was not a new idea. It had served as a fundamental rationale for another big idea in 1776: the American Revolution. From the electronic archives of the United States government the first paragraphs of Declaration of Independence stated that the pursuit of happiness is a worthy “raison d’être” for the founding of the government of the United States. The document states:

The unanimous Declaration of the thirteen United States of America, when in the Course of human events, it becomes necessary for one people to dissolve the political bands which have connected them with another, and to assume among the powers of the earth, the separate and equal station to which the Laws of Nature and of Nature’s God entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.

We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness.—That to secure these rights, Governments are instituted among Men, deriving their just powers from the consent of the governed, --That whenever any Form of Government becomes destructive of these ends, it is the Right of the People to alter or to abolish it, and to institute new Government, laying its foundation on such principles and organizing its powers in such form, as to them shall seem most likely to effect their Safety and Happiness. (United States Archives, 1776, para 1-2)
The linking of government and happiness to the purpose and function of government helped create the National Park System! At times this fact may seem odd to the 21st Century American citizen. The prevailing rationale states: your poverty, your misery, your poor health, your unhappiness is your own fault. Do not expect the government, often equated with other taxpayers’ money, to ease your woes. The mandate supported by Olmsted, Roosevelt, and Muir and the writers of the Declaration of Independence that the happiness and well-being of citizens is an essential task of the United States government appears today to fly in the face of the present-day corporate America work ethic, which presently means to be personally responsible for every aspect of oneself by oneself. But it important to remember that the happiness directive is at the heart of the government of these United States! Currently 245 years since the Declaration of Independence, contemporary society may be too distant from this fundamental commitment of government to its citizens, to acknowledge the intimacy of government with a citizen’s personal well-being. This interpretation of the purpose of government held so high by Olmsted, Roosevelt, and Muir that inspired Mather, and Albright, appears forgotten today. The notion that the present U.S. Congress or recent former President would consider the happiness and well-being of American citizens as an incentive for Federal policy. Substitute the word “corporations” for “citizens” then the present-day focus of US Congress might be revealed. Nevertheless, this idea that the duty of government lies in making life better for its citizens provides a foundational rationale for the modern-day expansion of National Monuments and National Parks, not the contraction that has been in vogue over the last four years 2016-2020.
The 4.5 million visitors to Zion National Park in 2017, 3.59 million in 2020 down due to covid 2019 pandemic and the almost 5 million visitors already in 2021 attest to the fact that people continue to need nature to restore their inner calm and well-being. Olmsted clearly provided a strong rationale for the benefits of protected natural environments and the benefits of these special environments on both economic, health, and well-being principles. Olmsted’s insight that the toils of economic necessity and the tiring effects that arise from maintaining daily life, no matter the goals, have an uncannily familiar ring to them today. Aspects of the human brain and the human condition remain imminently the same as in 1865. People continue to need to get away from their densely populated cities, daily toils, and stress of all kinds including fear of pandemics such as: the coronavirus. What Olmsted pointed out in 1865 and deemed was a necessary component to the pursuit of happiness persists, and with it the rationale not only for the continued creation of National Parks, but also for establishing capacity limits to the “use” of National Parks in order to preserve and protect the solitude and restorative qualities of nature so well recognized by those that inspired and founded the National Park System.

The Political Context of President Wilson’s First Term Surrounding the Passage of the Organic Act of 1916

Early in 1916, Mather launched an all-out drive for legislation to establish a national parks bureau, and of course Albright joined him…The Sixty-fourth Congress was better informed about the national parks than any previous Congress, thanks to his publicity work and Mather’s unstinting public relations efforts. (Swain, 1970, p. 56)

It is important to note that there was a father and a son each named Frederick Law Olmsted, both of whom contributed enormously to the rationale and codification of the National Parks idea. Frederick Law Olmsted (1822-1903), who promoted the European and American Parks Movements and his son, (1870-1957), of the same name, also a
landscape architect, who joined Mather and Albright in composing the Organic Act of 1916, which codified the National Park Service.

The following enthusiasts of conservation endeavored to forward a US Congressional bill that would create a Bureau of National Parks. Working together: Stephen Mather, Horace Albright, and Fredrick Law Olmsted, Jr., all ardent supporters of National Parks convinced United States Senator Reed Smoot of Utah, an LDS church leader, and Congressman John Raker of California, to annually propose legislation to create a Bureau of National Parks from 1911-1915 (Albright & Cahn, 1985, p. 34). Although unsuccessful during these years, the proposed bills worked to influence and acquaint the US Congress with the need for a centralized department to oversee and manage the preserved land holdings.

The United States Congress was the agency that appropriated the money to acquire the lands that would become National Parks as a result there arose a sense from Congress that there needed to be a show of public use of these lands. Olmsted better than anyone could articulate the dual purpose of preservation, as to be equal in importance to public use. His words were used in the bill of 1916 that became the Organic Act, introduced by Congressman Kent of California to the House of Representatives in late 1915. Olmsted wrote:

The purpose of the National Parks Service is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same and in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. (Swain, 1970, p. 57).

To comprehend the urgency of Mather and Albright in 1916 for the U.S. Congress to establish the National Park Service, it is useful to review the political context in which this foundational act to preserve the beauty and power inherent in the spectacular
environments of the United States, was passed. The significance of this Act in the political environment of President Wilson’s first term 1912-16, when the Organic Act was signed, comes into focus when several of the competing issues vying for Wilson’s attention are illuminated.

The first years of the 20th Century became known as the Progressive Era. However, these years were also called “Dark Days” not only for women, but for African Americans by author Tina Cassidy (2019), a writer of women’s history and culture. Shortly into Wilson’s first term, Cabinet member, Albert Burleson, Postmaster General, and a Texas southerner, complained that “White and Black employees of the Railroad Mail Service had to share washrooms, drinking glasses, and towels and that to improve working conditions… It would be to the advantage of both races to be separated in their work,” Wilson, a Virginian, agreed but added there would be no public announcement about segregation, no executive order, and no notification to any federal employees (Cassidy, 2019). This new institutionalized racism, via the process of segregation, slowly moved through the entire Federal government. As soon as 1914 photographs were necessary to apply for a Civil Service position. Complaints by both White and Black leaders were belittled and dismissed by Wilson (Cassidy, 2019).

Also, during this same historical period, a new Suffragette leader, Alice Paul, masterfully created lobbying efforts both in the U.S. Congress in Washington, DC and in the West, where many states had granted the right to vote to women. Paul and others were meeting with Wilson and members of Congress explaining that Wilson’s notion of Democracy for nations abroad was hypocritical in the context of twenty million women in the United States being denied their Democratic participation of the vote. These
lobbying efforts intensified with protests throughout Washington, DC, especially in front of the White House from 1914-1920. This human rights activism resulted in numerous incarcerations for the women protestors, accompanied by hunger strikes, and the forced feedings of these jailed women. In 1920 Wilson finally supported women’s right to vote and an amendment to give women the right to vote passed in 36 states on August 18 and was signed into law on August 26, 1920 (Cassidy, 2019).

To further add pressure on Wilson he was running for re-election in 1916 and the assassination of Archduke Franz Ferdinand and his wife, Sophie, in June 1914 had sparked WWI, and Wilson’s first wife, Ellen, had died in August of 1914. To this sad litany add the sinking of the Lusitania in 1915 and other vessels with Americans on board, pushing Wilson to declare the United States at war with Germany in 1917. Mather and Albright were savvy policy makers. They had invited many Congressmen, as well as members of the press, on memorable field trips through Yellowstone and other western lands planned for annexation into a National Park System. Mather and Albright sensed the time was right in early 1916 to build on the momentum of Albright’s consistent efforts since 1911, and Mathers’s endeavors since 1914, to lobby Congress strongly for the passing of the Organic Act (Swain, 1970).

All the competing innovative ideas of the Progressive Era carry with them the promise of new opportunities for 20th Century Americans. Except of course the further institutionalization of racism by President Wilson. His segregation policy stands in stark contrast to his historic plea for self-determination via his 14 points and the League of Nations, which he introduced at the Treaty of Versailles. It was within these monumental contexts of women’s suffrage, secretly reimposing segregation, environmental
preservation, and World War I that Horace Albright’s, Stephen Mather’s and Frederick Law Olmsted’s strategy and political mastery shone brilliantly in navigating the Organic Act thru Congress and onto Wilson’s desk for signature during this period of activism 1911-1916.

The Organic Act signed August 25, 1916, by President Woodrow Wilson began a new era for the United States. This Act birthed the National Park Service, also established and enshrined the” use” relationship as a 50-50 partnership equally shared between preservation and recreation in managing the National Parks. The Organic Act established and formalized a relationship of stewardship with nature as it was contained within unique environments and landscapes providing the qualities such as: grandeur, beauty, public use, public health all within an official department of the United States Federal government, The National Park Service. This bureau would operate within the Department of the Interior established in 1849 to manage the nation’s internal affairs.

The Organic Act of 1916 reads:

Sec. 1. Service created; director; other employees There is created in the Department of the Interior a service to be called the National Park Service, which shall be under the charge of a director. The Secretary of the Interior shall appoint the director, and there shall also be in said service such subordinate officers, clerks, and employees as may be appropriated for by Congress. The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified, except such as are under the jurisdiction of the Secretary of the Army, as provided by law, by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. (NPS, U.S.C., title 16, sec. 1)
Early National Park Service Management Policy

In the period between 1872 and 1931 National Park management policy varied from park to park. Superintendents appointed by the Department of the Interior to manage these parks often had no requisite experience (Swain, 1970, p.44). Horace Albright, one of the founders of the National Park Service, was keenly aware of the problems for management that this inconsistency would prove to the long-term vitality of the National Park lands. In his book *The Birth of the National Park Service the Founding Years, 1913-33* he revealed that, “Interior had superintendents in charge of each national park, with a minimum of help. Many of the superintendents owed their jobs to patronage from a senator or congressperson, and none had had any experience in natural area management” (Albright & Cahn, 1985, p. 6, 24).

Even though the first conference addressing National Park management and other problems, had been held in 1911 the issue of the relationship between man and nature, visitor use, and preservation remained undefined. However, as a result of this conference the need for a centralized National Park administration and policy became clear. Horace Albright reported:

That these men were well aware of the inherent conflicts between use and preservation, but the political reality was that the issue could not be settled in an ‘Organic Act’ because Congress would never agree to close off enormous chunks of land and exclude them from public use. So, we had to find a way to provide for use. (Albright & Cahn, 1985, p. 35)

Olmsted crafted the lines that elegantly explained the purpose of the National Parks Service. He wrote:

[The purpose was] to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same and in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. (Albright & Cahn, 1985, p. 36)
This purpose covered “use” but not management of the National Parks. The original wording of the Organic Act contained a provision for an independent commission or board of overseers to address management policy for the National Parks. However, this was omitted from the final bill. Albright in his memoir explained:

We wanted to make it (the Organic Act) short and uncluttered as possible, while at the same time giving the National Park Service enough general power to establish regulations so it would not be necessary for its director to go back to Congress for new authority every year or so. (Albright & Cahn 1985, p. 36)

Some management concerns such as grazing were debated by the working group as the Organic Act was crafted. Stephen Mather argued strongly against grazing of any kind within park boundaries, while several western congressmen proposed that grazing would benefit the National Parks (Albright & Cahn 1985; Swain, 1970). But with eyes on the prize, the pressing goal for all was to get the Act passed and management details would follow.

It took time for National Park Service to understand, create and implement systemwide policy and practices. Franklin Lane, Secretary of the Interior in 1918 wrote a letter to Stephen Mather that contributed to the initial effort to clarify management practices for the nascent National Park Service. In his letter of 1918 Secretary Lane strongly clarified the need for preservation of the natural integrity and beauty of the parks. Lane advocated:

For the information of the public, an outline of the administrative policy to which the new Service will adhere may be announced. This policy is based on three broad principles: First that the national parks must be maintained in absolutely unimpaired form for the use of Future generations as well as those of our own time; second, that they are set apart for the use, observation, health, and pleasure of the people; and third, that the national interest must dictate all decisions affecting public or private enterprise in the parks.
Every activity of the Service is subordinate to the duties imposed upon it to faithfully preserve the parks for posterity in essentially their natural state. The commercial use of these reservations, except is specially authorized by law, or such as may be incidental to the accommodation and entertainment of visitors, will not be permitted under any circumstances. (Lane, 1918 in Dilsaver, 1994, para 2-3)

Secretary Lane authorized clear limits on the commercial use of the National Park lands. In the letter he also outlined issues such as: grazing, outdoor sports, building of roads, educational use of parks, limited cutting of trees, and the need for visitor use accommodation. He did a fine job of contributing to the meaning of conservation and clarified what elements are included within the purview of preservation within the National Parks. However, Lane left out several essential elements such as: animals, birds, rivers and streams, all endemic to the National Parks environments. Nonetheless, Lane realized the importance of establishing a unified management policy. His concerns and advocacy were joined by another visionary Superintendent Roger Toll. Even though the lands included as National Parks in 1919, Grand Canyon NP, Acadia NP and Zion National Park were distant from cities, hard to reach, and comprised millions of acres, Roger W. Toll, the Superintendent of Rocky Mountain National Park foresaw the issue of over-development in and around the National Parks. In 1922 he composed a letter on the issue of over-development to be incorporated as a “concern” for National Park management. Superintendent Toll, counseled on the need for vigilance concerning over-development in the National Parks. He forewarned his colleagues in his letter entitled Superintendents’ Resolution on Overdevelopment prepared at the National Park Service Conference, Nov. 13-17, 1922, Yosemite Park, Calif. Superintendent Toll emphasized:

BE IT RESOLVED by the officers and superintendents of the National Park Service, that the best interests of the nation will be served by a more adequate development of the national parks. Roads and trails should be improved and
extended, ample accommodations should be provided for visitors, and other improvements carried out, so that the parks may better fulfill their mission of healthful recreation and education to a larger number of people.

It is, however, stated as a policy of the National Park Service, that over-development of any national park, or any portion of a national park, is undesirable and should be avoided. Certain areas should be reserved in each park, with a minimum amount of development, in order that animals, forest, flowers and all native life shall be preserved under natural conditions.

One of the objects of the National Park Service is to preserve some of the finest of our scenery for future generations, that they may always know the quiet dignity of our forests and the rugged grandeur of our mountains. In the development of the parks, some of these areas should be made possible of access, but they should be protected from anything that will impair them.

Plans for the development of each national park should be outlined as far ahead as possible, in order that the park may receive adequate development, without over-development. (Toll, 1922, para. 1-4)

Why was Superintendent Toll’s prophetic insight and guidance about the threat of over-development neglected by so many National Park Superintendents? Superintendent Toll showed incredible foresight and uncanny prescience concerning future issues facing Superintendents of National Parks. His letter stands as a literal beacon in the wilderness, that continues to highlight the dangers and pressures of overdevelopment. Toll’s letter as well as Lane’s letter and, yet to be discussed Albright’s letter, serve as the nexus and guide for an enlightened National Park management policy, still desired, yet not always accomplished under present-day visitation pressures. Since 2013 overdevelopment has robbed Springdale, Utah, the gateway town to Zion National Park, of its pastoral fields, beautiful river views and the long-standing ecosystem continuity between National Park holdings and the local environment. Nonetheless, the vision inherent in the foresight that the wild lands could lose their innate power and presence to transform the human spirit,
displayed outstanding understanding of the intent of the Organic Act by Director Lane and Superintendent Toll.

In the formative years of 1914-1916 many lawmakers considered that the U. S. Forest Service could better and more economically administer these National Park lands of scenic grandeur. Mather and Albright, determined to instill autonomy and preservation into management policy of the National Park Service, thought it also prudent to promote public use to accommodate the attitudes of the early 1900s. It was considered both democratic and prudent to promote use (Swain, 1970). The parks were so remote and with such limited access both Mather and Albright understood that they would have to team up with large scale concessionaires and transportation monopolies such as the railroads, in order to develop accommodations in the National Parks for access to these new national wonders. Mather and Albright did the best they could with creating sound flora and fauna management policies. Dilsaver (1994) described Mather’s and Albright’s dilemma concerning preservation in the light of “Good Old Boy” or to put policy another way, local and regional management policy. “Science was too underdeveloped to provide hard evidence against many popular wildlife management practices. It would be another decade before scientists would be heeded and then only for an interim” (Chapter 2, para 2).

Despite this lack of scientific management practice, a balance between preservation for future generations and enjoyment of the public was always on the minds of “the Mather Men.” A group consisting of Mather, Albright, Secretary of the Interior Lane, Robert Toll, and others Mather had gathered around him to manifest this most unique mission of administering and preserving a selection of the “Crown Jewels” of
American Democracy, the National Parks. Lary Dilsaver, in his book *America’s National Park System: The Critical Documents*, explained:

In 1931, after a decade and a half, Director Horace Albright could reflect on many issues affecting the growing system of parks. Two issues in particular needed addressing. First, park planning, despite the adoption of a program for five-year plans in 1926, was haphazard and varied from park to park…The second problem was the quality of care and preservation being voted to the natural resources of the parks. Early anthropocentric ideas had led to predator destruction, vista clearing of forests, introduction of exotics, and use of herbicides and pesticides in the parks… In an article for the *Journal of Mammalogy*, Albright rejected predator destruction and promoted the parks as the homes of all species. (1994, Chapter 2 para. 6)

In 1931 Horace Albright, then Director of the National Park Service distributed a letter describing National Park Predator Policy. It was a landmark clarification of the status of wildlife in National Parks. The new management policy realized the possibility of extinction for some species and offered the National Parks as protected habitats for all animals. He once again declared the three premises or principles stated in the Lane Letter of 1918. These being:

The National Park Service is attempting to put the parks to their highest use. Every policy developed is an attempt to meet the purposes for which the parks were formed; First, the national parks must be maintained in absolutely unimpaired form for the use of future generations as well as those of our own time; second, they are set apart for the use, observation, health, pleasure, and inspiration of the people: and third, the national interest must dictate all decisions affecting public or private enterprise in the parks. (Dilsaver, 1994, Chapter 2)

Albright then steadfastly declared that wildlife is an essential element of the National Parks and as a result wildlife is entitled to protection within the National Park System. Albright asserted:

Certainly, one of the great contributions to the welfare of the Nation that national parks may make is that of wild life protection. It is one of the understood functions of the parks to give total protection to animal life… Many disappearing species are to be found within park areas, so that in some instances we may speak of the parks as providing “last stands.”… The National Park Service believes that
predatory animals have a real place in nature, and that all animal life should be kept inviolate within the parks. (Dilsaver, 1994, Chapter 2)

**Early Management and Wildlife Eradication in Zion National Park**

Horace Albright’s focus on conservation 90 years later represents a sound goal for the National Park Service, but it needs to be rekindled in the 21st Century. Conservation was not a part of early ZNP management. Examples of regional and reactionary management thinking reside in the archived Superintendent Reports. Extermination programs in Zion National Park were common. These policies eliminated wildlife without compunction and without understanding their place in the web of life. Gophers, skunk, deer, and cougars considered a nuisance to visitors were relocated or “dispatched” a euphuism for killed, by several Zion National Park administrators.

Following are examples of early wildlife eradication documented in the 1928-1940 Annual Administrative reports of Zion National Park Superintendents. These incidents point to the haphazard and non-scientific way Zion National Park managed its wildlife in its early years. Superintendent E. T. Scoyen pointed out in his July 1928 monthly report (1928b) the problem with skunks in the Canyon:

> The animal mostly in residence this past month was the skunk. I quote from a report of Chief Ranger Jolley, “numerous complaints have been made against this friendly skunk who has gotten the idea that the world, especially the campers, owe him a living. He and his friends are frequently discovered in a tent or car helping themselves to eat palatable food. On one or two occasions people have tried to drive them out of the tent in the night and either became too rough or too close and were damaged by the skunks’ only weapon. The skunk is taking control of the camp and if people are going to continue to use it, it will be necessary to take some control measures. We have already taken control of this situation. (p. 4)

What “control of this situation” meant is not clear. But the words insinuate that the killing of the skunk probably occurred. People were new arrivals at Zion National Park and food may have been left in the open at campsites. In the 1930 Annual Report
(1930b), Superintendent Scoyen describes additional skunk problems at the Auto Camp located about halfway up the nine-mile Zion Canyon. He describes the situation:

During the summer, the skunks became so numerous and tame around Zion Lodge and the public auto camp that it was either a question of doing some control work or moving the people out and letting the skunks have the park. About 35 were disposed of. (p. 9)

The skunks had the canyon as a home for a millennium, but in Zion Canyon as a “park,” they did not fit into a place where humans drive their cars and camp by the river at the Auto Camp, presently the site of the Grotto shuttle-stop. Skunks have their place in the ecosystem though most of us have no idea what it is. Upon searching several google sites I found out that they eat common pests like field mice, moles, and insects, and serve as prey for other animals such as owls and coyotes. They also do a bit of gardening, by spreading seeds and plants through their scat and aerate the soil by churning up to eat grubs, which are the immature form of Japanese Beetles, June “bugs” and the European Chafer beetle (Bioadvanced.com, 2021; Behrens et al., 2013).

In December 1928 gophers also became a problem at the new Auto Camp, the first camping area within Zion National Park. Superintendent Scoyen (1928d) reports that Mr. V.I. Johnson is called in to help with the rodent problem. Gophers have been eating off the roots of young trees. Scoyen (1928d) remarked:

In the public auto camp, we have been trying for several years to build up a growth of nice trees in order that we may extend the camp grounds to handle the increasing number of campers. This little animal has been consistently destroying some of the trees planted. He has also destroyed trees planted by the Union Pacific around Zion Lodge. Mr. Johnson reports that the situation is very bad, and that intensive control must be started this spring or the situation is liable to get entirely out of hand. He instructed rangers in methods of control, and we expect to handle the situation early this spring. (p. 3)
Another example of small mammal extermination in Zion Canyon occurred when administrators saw porcupines eating pine bark. In the April 1932, Monthly Report (1932b) Superintendent Patraw stated that “25 porcupines had been killed because they were eating pine bark” (p. 4). Trees were considered a vital component of keeping “park” areas healthy and attractive. The value of trees for their calming capacity providing shade, oxygen, and beauty had been established in the European and American urban park movements.

No one thought to study the range and relationship of the small mammals in Zion Canyon. How many gophers, skunks, and porcupines might be a natural and healthy population for a riparian area in a canyon? Might there be a finite number in the canyon at any point in time? Were the animals clustered long term on the same flat ground as people or were they drawn to the delicacies left behind by their new human neighbors? How might the presence of water in the riparian area, which serves as an oasis in miles of harsh desert adjacent to Zion Canyon, affect the populations of these species within the canyon and the region? The early administrators did not initially document any base population levels of animals in the park, especially the small mammals, that proved a nuisance to human visitors or that were involved in “unexplained behavior” such as eating bark.

In the same December 1928 report cited above, Superintendent Scoyen (1928d) spoke about ridding the park of another undesirable animal, the cougar. He declared:

Mr. George E. Holman, Predatory Animal Control Leader for this State Bureau of Biological Survey has offered his services in ridding the park of a few of the many mountain lions we know are ranging on the East Rim of the Park. Chief Ranger Jolly will assist Mr. Holman’s man in hunting down some of these animals during the coming month. The situation with reference to the mountain lion needs attention especially because the only band of mountain sheep known to
exist in this section of the Utah ranges in this area and in order to build it up into a thriving band, we must give them every protection possible. (1928d, p. 3)

Superintendent Scoyen’s following comments (1929a) illustrated the contradictions and confusion around predatory animals. He mentions government hunters killing cougars in his 1929 Annual Report. But he does not identify what governmental agency would be hunting the cougars. This situation begs the question, as Zion National Park Superintendent would not, he have some influence over a governmental hunt so close to Zion National Park? He (1929a) reported:

Predatory animals have not yet been bothersome, and no special effort has been made to hunt them. During the winter government hunters were very active outside of the park and were very successful in their operations. No doubt they secured a number of these animals whose range extends into Zion Park. (p. 6)

Scoyen (1929a) continued relating another encounter with cougars and wishes to see one for himself. He commented with a hint of mixed emotions and chagrin:

Last Fall Chief Ranger Jolly had the unusual experience of seeing four lions at one time and met them in a blind canyon in very close quarters. However, the brush was very thick, and the animals quickly made their escape. In all the years I have spent roaming over one or another of the National Parks I have never seen a mountain lion running wild. (p. 6)

In superintendent Scoyen (1930b) Annual Report he comments on cougars again. He reported:

Cougars leave signs frequently in the higher elevations of the park. We make no effort to hunt them down within our boundaries as it is felt that outside hunting by professional hunters should result in a reasonable control within the park itself. None have been reported in the valley, and if they do start to range on the valley floor, it will perhaps be necessary to do some hunting. (p. 8)

It is not clear how the administrators of Zion National Park knew how many mountain lions were ranging on the East Rim at that time. The administrators did not understand the benefit of intact predator prey relationships within an ecosystem. In early
administrative reports deer were mentioned being seen in the canyon in winter. Later administrators noted that the deer numbers increased and by 1938 trapping and moving programs were initiated. But none of the Superintendents connected increase in the deer numbers to the decrease in cougar population, which had been diminished by hunting. Deer were trapped in Zion Canyon and transported to Bryce Canyon National Park about 90 miles away. In 1938 removable measures began in hopes of improving conditions for flora and the remaining deer in the Zion Canyon. In the 1940 Annual Report, Acting Superintendent of ZNP, John M. Davis, exhibits concern about the health of the Rocky Mountain mule deer, native to Zion Canyon. He observed:

Since the beginning of the wildlife control measure in 1938, 192 deer have been removed from the canyon floor. Very little change has been noted in the condition of the remaining deer, and the increase in the amount of palatable food for them has not noticeably increased. Further study will be made to determine the cause for the poor condition of deer; it is possible that inbreeding may be partly responsible. (1940, p. 3-4)

**Scientific Management in the Parks**

The 1930s began a period of more thoughtful National Park management policy beginning to be based on scientific study. Mather and Albright displayed insight in realizing that nature needed to be studied, and that from these observations and analysis of gathered data, resource management could be crafted. However, as was much the case with many aspects of the early National Park movement, its existence relied upon the vigor, persistence, and wealth of one visionary or another, so too, did the application of scientific study to National Park management.

Albright’s new policy which intended to include science, relied on the strength and personality of one man, George Wright, a biology graduate student at University of California Berkeley. Wright, like Stephen Mather, came from a wealthy family, who
financed Wright’s two-year survey of wildlife in all the national parks (Albright & Cahn, 1985). His three-person team traveled over 11,000 miles studying wildlife in Yosemite, Yellowstone, Sequoia, and Zion. The Chief Naturalist of the National Park Service, Ansel Hall, valued Wright’s efforts to bring an accurate appraisal of how the parks could successfully carry out the preservation mandate of the Organic Act of 1916. Hall mentored Wright, and with Albright and Mather, saw Wright as the nexus of a new Wildlife Division (Albright & Cahn, 1985). Fate tragically waylaid these important efforts towards a more scientific based response to National Park management, Wright unexpectedly died, resulting in a thirty-year delay for the application of the natural sciences to comprehensive National Park management. Dilsaver (1994) concluded:

> Coming on the heels of the “predator policy” letter was one of the most advanced and profound statements about the parks for this era. Wildlife scientist George Wright and a staff he hired and personally funded and released a seminal work in 1932 entitled Fauna of the National Parks. Wright and his colleagues laid down the ground rules for scientific wildlife management and for the provision of further research to shape decision-making. It was a piece ahead of its time and for a while led to a Wildlife Division with Wright as its head. However, after his untimely death in 1936, many of his ideas were ignored until the Leopold report of 1963 resurrected them. (Chapter 2)

**Impact of Early Funding of National Parks on Park Management**

It is of interest to note that Congressional funding for the National Parks was sparse in the early years of the National Park Service. Personal donations like those that accompanied Wright’s expertise often determined the fate and future focus of National Park management. Stephen Mather, the first Director of the National Park Service, with contributions from his personal bank accounts, often made the difference between success or failure for a project or an addition to the Park Service lands (Albright & Cahn, 1985). Superintendent P. P. Patraw in his 1934 Superintendent Annual Report of Zion
National Park, documents a pertinent example of this “noblesse oblige” that occurred in the building of the Rockville Bridge over the Virgin River in 1924. At this time no reliable and commercial avenue to Zion National Park existed. Other new western National Parks such as the Grand Canyon, Bryce and Zion had only dirt roads and horse trails running into them. The only trail into Zion National Park was across the dry and windy desert by horse or wagon, then over the Virgin River by old wooden flat bridges or by fording the river (Larson, 1961). The NPS teamed up with the Union Pacific Railroad to plan for a lodge and a metal bridge to be built over the Virgin River. According to Superintendent Patraw, Congress allocated $40,000 and Stephen Mather chipped in the remaining funds to build the now famous, historic and beloved Rockville Bridge. The amount of Mather’s contribution was not documented (Patraw, 1934).

**Predator Policy in Zion National Park**

The 1931 Annual Report of ZNP composed by Thos. J. Allen, the new Superintendent, mentions the first survey of animals and range conditions in Zion National Park. It was in response to Albright’s letter on Predator Policy because the survey was conducted by Mr. Joseph Dixon and Mr. Ben Thompson of the Park Service (Albright & Cahn, 1985). Allen (1931) wrote: “These fellows estimated that even though cougars had been hunted in 1930 by the Bureau of Biological Survey, it was estimated the 25 cougars remained in the park” (p. 10).

Wright’s premature death may have indirectly affected Zion National Park management policy in relation to the Virgin River and the Fremont Cottonwoods trees. River management and the riparian ecosystem may or may not have been included in George Wright’s vision for the application of scientific study to resource management.
As it was in the 1920s everything was roaring, even the rivers of the Southwest. No scientific study was applied to the Virgin River management in Zion Canyon. How this lack of scientific understanding of the riparian area in Zion Canyon resulted in the loss of the Fremont Cottonwood Forest in Zion Canyon will be addressed in Chapter 5.

Park Versus Natural Management

Eradications of feared cougars and the simultaneous structural modifications in Zion National Park such as: hardened trails, the macadam canyon road, the Lodge, campsites, and plans for a tunnel, provided for the Zion National Park visitor, the appearance of a safe and secure environment within Zion Canyon. Actually, a transformation from a wild environment to a park environment was happening to the healthy and wild riparian area in Zion Canyon. This most visited area of Zion National Park, the area along the Virgin River in Zion Canyon was becoming a controlled river system and Zion Canyon, a controlled “protected park” experience. From the archives there is no record of anyone asking the question, “Was this change from a natural state to a convenience state fulfilling the mandate for “preservation” in the Organic Act of 1916 in Zion National Park”? In not posing this question and focusing solely on “visitor use” did Zion National Park administration forget the Secretary of the Interior, Franklin Lane’s mandate that “Every activity of the Service is subordinate to the duties imposed upon it to faithfully preserve the parks for posterity in essentially their natural state” (Dilsaver, 1994)? Zion National Park administrators’ management patterns from this time have appeared to minimize the mandate from the Organic Act itself “which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave
them unimpaired for the enjoyment of future generations (NPS, 2021). Herein lies the most important distinction that needs to be clearly and carefully understood about present management in the National Park Service: what is being managed and to what end? Is it solely a reactionary “use” policy management resulting in a “park” environment and an unhealthy ecosystem or is management policy focused on preserving the “natural state” and the health of the Zion Canyon ecosystem?

The word “park” is defined by Webster as “an area of land, usually in a largely natural state, for the enjoyment of the public, having facilities for rest and recreation, often owned, set apart, and managed by a city, state, or nation” basically a predictable outdoor environment. This term “park” stands opposed to “wild” indicating “living in a state of nature; not tamed or domesticated and growing or produced without cultivation or the care of humans.” Wouldn’t this definition of wild be considered “the natural state” as Secretary Lane described and mandated? Humans have been intimately involved with many aspects of the Zion Canyon ecosystem management and visitor experience for a century. As a result of the National Park Service management the word “park” now describes Zion Canyon. Furthermore, one must ask, “Has management of Zion Canyon sacrificed the health of Zion Canyon to “use” while attempting to balance the 50-50 preservation use relationship, with the remaining not nearly visited and used back country lands in Zion National Park?

Once the National Park Service moved from that of a visionary idea to the status of an Act of Congress, Stephen Mather, the Director, and his assistant and successor, Horace Albright with handpicked Superintendents began to mold and define operating policies. The wildlands set aside by Congress as National Parks began their transition
from “living in a state of nature” to “being under the care of humans.” The visionary idea of the National Parks originally, one of “natural state” park lands set aside for the inspiration and the edification of the public, now slowly moved to include recreation (Dilsaver 1994).

National Park management continued to evolve. The exuberance that Lee (1917) described when visiting Zion National Park began to be transposed from the intimate Muir experience of transcendent relationship to an expansion of the Teddy Roosevelt action and accomplishment of experiences now known as recreation. When a National Park has millions of people wanting the Teddy Roosevelt physical exertion transformation, the land becomes worn, the fish lose their lips to numerous hooks being yanked from their mouths, and the “natural state” cannot rejuvenate because there is no recuperation time between one visitor-use experience and the next. This constant visitor-use experience results in the death and decay of natural organisms and of the very ecosystems that provide freely the opportunity for outdoor adventure and skill attainment. National Park animals and plants cannot adapt to the present-day high speed and density of “visitor use”! The high volume of National Park visitors, tax and strain the ability for plants and animals to rejuvenate under the vast numbers of visitors that demand a vigorous recreation experience. Presently this idea of “use” has become a high-volume recreation “demand.” This kind of “use as demand” in turn creates overdevelopment necessary to meet the associated human needs which accompany recreation demand, such as: more and larger latrines, no longer just at National Park Service Visitor centers, but at many trail heads, water stations, food kiosks, trash sites, gift shops, coffee bars, convenience and the city has been invited into the once “natural state” that Zion Canyon
formerly offered. This “natural state” in Zion Canyon once provided a sense of
“sanctuary” related to the Muir experience of peace and intimacy with nature. In 2021 as
a result of the high demand for use in Zion Canyon the sanctuary experience is gone or
seldom experienced in the Front Country of Zion Canyon. Zion Canyon is now a
Disneyland type of experience where outfitters run vans up and down the canyon road,
while visitors line up atop of Scouts’ Look Out and wait at times 30-60 minutes for
access to climb the last half mile to Angels Landing. Memorial Day 2017 there were
30,000 people, the population of a small city, in the six miles of Front Country Zion
Canyon (Jack Burns, Chief Concessions Management ZNP, personal communication,
2018). How did Zion National Park and other National Park administrations, particularly
in Utah, step further and further away from preservation abandoning the 50-50 deal the
Organic Act mandated? In so doing present day management policy moves closer and
closer to an unbalanced ratio of 70-80% use to a 30-20 % preservation policy. This
skewed relationship is not sustainable for a healthy riparian management policy for Zion
Canyon, so worthy of protection and preservation due to its National Park status and
innate grandeur.

Advertising and Recreation Affecting ZNP Management

How is it that concerns for over-development cautioned against by visionaries like
Superintendent Toll over 100 years ago are missing from the National Park Service
management in the 21st Century? An increase of over one million new visitors over the
three-year period 2014-2017 created a record 4.5 million visitors a year. However, in
2020-2021 the visitor record reached 5 million. This density of visitation has pressed the
Zion National Park’s management team and the Town of Springdale toward over-
development. How did this unprecedented and unexpected increase in visitation happen so fast? In 2013 and subsequent years, the Utah Tourist Board crafted a catchy campaign called “The Mighty Five” and broadcasted this campaign worldwide! The advertising scheme focused on trumpeting the beauty of the five National Parks in Utah: Arches, Canyonlands, Bryce, Zion, and Natural Bridges. However, no one on the Utah Tourist Board thought to notify the Superintendents, the Mayors or Town Councils of the small towns that stand as gateways to the “Mighty Five” National Parks, that such an advertising campaign was underway (former Springdale Mayor Pat Cluff, personal communication, 2014, Zion National Park Superintendent Bradybaugh, personal communication, 2017). The Utah Tourist Board did not even think to include or ask any one of these community stakeholders for their thoughts on this game changing advertising campaign! The result of this lack of communication, and international advertising has led to unexpected and unprepared for overcrowding at all the National Parks in Utah and their gateway towns.

For the 550 residents in Springdale, UT, the gateway town for Zion National Park, with only one lane of traffic entering and exiting the town, this increase in visitation has been destructive. It has caused a loss of sanctuary, peace and quiet, and a beautiful natural viewshed with an accompanying constant increase in construction, large vehicle traffic, a sharp increase in property values, parking problems, loud noise, dust and litter. All the commercial development via the massive development of open space into hotels and restaurants by investor groups, and visitor density has caused an acute loss of community relationships. From my personal observations and conversations with other residents there is a sense that the town is experiencing the colonization of a beautiful
rural town and landscape by out-of-town investors for the purpose of development and profit. An expansion of the entry kiosks at the South Entrance of Zion National Park as well as new bathrooms and infrastructure on trails all diminish the natural state of Zion Canyon and Springdale.

Presently Zion National Park has been attempting to respond with new management policies to this rapid increase of visitors since 2013. But Zion National Park, in an effort to be thorough and build a case towards reservations and visitor limitations, has been too slow to respond. Zion Canyon and Springdale now resemble an urbanized environment. Rather than skyscrapers to marvel at, the tall Mesas stand in, evincing awe, but the visitor experience in Springdale and Zion Canyon is now far too often loud, bustling, and commercialized. Many residents are saying who needs it when there isn’t even a gym in town, and one must drive 50 miles to reach ordinary retailers. I am grateful that I knew Springdale when it was listed in 2009 by an organization, I can no longer find on google, as one of the ten best small towns to live in the United States. All of this “use” has caused so much, Koyaanisqatsi: Life out of Balance, the name of a film made in 1982 that depicted in time lapse photography the change of landscapes from original natural to urbanized. The unrestrained development in Springdale and in Washington County, where Springdale is located, has led many residents to cash in on the rise of property values, sell their property, and leave town. Many other residents are chronically irritated and frustrated. From personal conversations with residents many of whom are my friends many Springdale present day residents came to Zion Canyon because the Canyon spoke to them in some way, and to get away from the commercialized corporate experience of
America. Many of these residents’ state that they have found healing and solace within the sanctuary that Zion Canyon once offered.

Before 2013 the Springdale community was diverse and respectful of each other’s point of view at least during the period 2000-2013. Federal employees, farmers, decedents of the original Mormon settlers, climbers, locally owned merchants, artists, people who stayed and made their way respected one and another. People listened well to each other. Even with different religious and political views, the shared experience of living in Zion Canyon took precedent and created a strong commonality where respect for the individual’s experience prevailed. It was a marvelous quintessential experience of small-town American democracy. Commercial interests now supplant community in Springdale. However, Springdale residents are showing signs of resilience and recovery. Community projects, such as the 4-year mosaic projects, the Alternative book club, and traumatic events like the recent cloudburst flash flood in June 2021 have again created a shared experience that is slowly knitting back together the resident community.

Environmental Perception of the Virgin River by Mormon Settlers 1860s and 1880s

The Virgin River did not make a good impression on the 300 Mormon families sent by Brigham Young, head of the Mormon Church, to southern Utah in 1861 to start the Cotton Mission, so named because cotton was grown in southern Utah as a cash crop during the Civil War years. After five years growing cotton the mission and the region of southern Utah became known as “Dixie.” The success of the Cotton Mission depended a great deal on the water of the Virgin River, yet why are so few kind words on record describing the Virgin River after 1859? In that year, Nephi Johnson, an explorer and one of the first Mormons to settle in southern Utah may have been the last Mormon settler to
speak mildly of the Virgin River! In 1859 as the leader of an irrigation canal in Virgin, a small settlement about ten miles west of Zion Canyon,

[Johnson described the task of damming the Virgin River as an] infinitely simple task, the river course was narrow...the banks sodded with wire grass... a large cottonwood log was laid across the river...they laid brush and weighted the whole mass with rocks. In this manner the water was raised to ditch level. (Larson, 1961, p. 86)

But in the next few years, unbeknownst to the settlers, the inklings of the fifth wettest period in the Southwest 1865-1869 was beginning (Salzer & Kipfmueller, 2005). How did the onset of this pluvial, forge a new and long-lasting perception of the Virgin River? How did this new environmental impression affect the channeling of the Virgin River and therefore the Fremont Cottonwood trees in Zion Canyon?

Nephi Johnson had completed his irrigation canal for the Virgin settlement also known as Pocketville, in April 1859, but within two years it was washed away in a desert environment. The weather took an unexpected turn changing from the known hot arid desert with accompanying low river streamflow to a seemingly impossible 40 days of rain, arriving in late December 1861 and drenching the arriving Mormon settlers throughout late December 1861 and January 1862 (Larson, 1961; Ingram & Malamud-Roam, 2013; Reid, 1964). Chapman Duncan the leader of the Virgin Mission, acknowledged the loss of Nephi Johnson’s hand dug canal from the “great rain and consequent flood of January 1862,” He lamented:

On the 17th and 18th, it rained here tolerable heavy and the water in the river rose to an unusual height, washing away a very large portion of our bottom farming lands which were not extensive in the first place. Old cottonwoods were uprooted, and the old irrigating canal has been entirely destroyed. (Larson, 1961, p. 87)

The Virgin River had not seen this kind of streamflow for centuries (Salzer & Kipfmueller, 2005). The Virgin River’s channel was not entrenched, and the increased
streamflow volume poured over its sandy banks flooding the nascent agricultural fields, the irrigation canals, and any structures nearby (Gregory, 1950; Hereford et al., 1995; Larson, 1861). The newcomers were not prepared for this unexpected increase in rainfall. The drenching left them overwhelmed and vulnerable to exposure, both physically and emotionally. For this lack of expected compliance, the Virgin River, was assigned the feminine gender, along with accompanying unsavory attributions assigned to uncompliant women. The Virgin River had expressed itself with more than the expected irrigating role assigned to it by men. The Virgin River was now described as having “a capricious and erratic mood whose rampages were fated to drive from her banks many of those who sought to make their homes at Pocketville” (Larson, 1961, p. 87). The low streamflow and docile Virgin River of the dry years of the 1850s, had behaved, been polite, and had served the needs of those few Mormon settlers sent to scout out southern Utah in the 1850s. Then in 1861 the rain began just as the 300 families sent south by Brigham Young arrived. The description of the Virgin River, sent north by scouting parties, as a shallow narrow river easy to tap for irrigation did not match what these new immigrants to southern Utah met when they set up camp.

Descriptions of flooding dominate the narrative of immigrant life in southern Utah. The pluvial poured its moisture upon the desert sands engorging the streamflow of the Virgin River. In St. George, the unforeseen rains began on Christmas Day 1961 and continued until January 30, 1862. The Virgin River streamflow was high, and the water ran over the riverbanks gouging out the sandy channel. Earlier scouts and their families had set up grist mills, homes, and small towns. Many of which were washed away in the winter floods of 1862 (Larson, 1961). Everything was soaked for weeks. The large
contingent of immigrants had recently arrived, were compelled to camp in the winter’s cold in wet covered wagons and tents. The narrow channel of the Virgin River unpredictably had flooded the lands surrounding them. These forty days of unanticipated rain in the desert environment left a legendary stamp upon the memories of those first settlers. Generations of their families have kept the memories of their ancestors’ trials and tribulations alive not only for the distinctive anomaly of the long duration of moisture in an arid desert, but also as an inspiring example of endurance and persistence overcoming impossible odds and uncomfortable conditions for the glory of God. The memories were also well documented because Joseph Smith, the founder of the Church of Jesus Christ of the Latter-Day Saints encouraged his disciples to keep records and journals (LDS, 2007). Additionally, the isolation of Utah and especially southern Utah, kept the stories intact and alive.

At this point in the geomorphological history of the Virgin River, the river’s channel was not entrenched, and the riverbanks were sandy and at the same level as the streamflow (Gregory, 1950; Hereford et al., 1995). As the precipitation continued to increase the streamflow began increasingly to pour over the sandy banks effortlessly moving the sandy banks in wide swaths. The Virgin River had become an “angry” river and a “Devil” river (Larson, 1961, p. 205). Where it was raining in St. George during the pluvial it was snowing in the high Mesa regions of Zion Canyon with elevations between 6700 – 8700 ft. Melting snow in spring created more opportunities for flooding and negative feelings towards the Virgin River. “There was no doubt in the minds of many people that this land was cursed and that the devil controlled the Virgin River (Alder & Brooks, 2007).
Flooding occurred often during the decades of the 1860s and early 1870s. The rain let-up in the mid-1870s. But then there was a return of unusual precipitation mixed with intense drought in the 1880s. The Virgin River was now called the angry river. “Its turbid waters swelling in angry crescendo as the years passed, tore out dams as fast as the tired settlers on the uneasy banks could put them in” (Larson, 1961, p. 363). In 1881 a heavy downpour flooded Orderville, a town east of Zion Canyon.

[Another flood drenched Orderville in 1885] washing out dams and cutting deep gorges in the valley...the flood destroyed fourteen acres of wheat, six acres of corn, five acres of potatoes and every bridge on the (Virgin) stream except one was destroyed...Brother Fackrell found the water in and around his house and had to carry his children waist deep through the angry raging flood. (Larson, 1961, p. 363-364)

The Virgin River was not only angry, but also a usurper, robbing unsuspecting men and women of their hard won and hoped for, yet false security.

The Virgin River could turn the honest labor of many weeks into mud in an afternoon. In December 1889 in Washington, Utah about 40 miles west of Zion Canyon a flood two feet higher than the flood of 1861 came down the river washing out irrigation ditches, dams and fields as well as widening and deepening the river channel (Larson,
In 1890 a Conference of Mormon settlers met and determined that since the town was settled in 1862 “one half of the land had been washed away” (Larson, 1961, p. 365). Many towns in the Virgin River valley had experienced similar proportionate losses. The rains let up in the 1890s. But then in 1905 the longest wettest period in 1425 years began (Salzer & Kipfmueller, 2005). The floods commenced again in these arid lands resulting once more in valuable flatlands, dams and irrigation schemes being washed down river.

**Documentation of the Mormon Settlers’ Experience of Flooding During the Pluvial: 1905-1922 and the Resulting Environmental Perception of the Virgin River**

**The Nature of Cloudbursts**

In St. George, a rock dam that had been built in 1875 that had withstood the floods of the 1880s, finally met its match in the flood of 1912. In that year a huge flood took out the dam and widened the river’s channel to nearly one-half mile rendering the site no longer practical for a dam (Larson, 1961). These flooding incidents were not only local events occurring in southern Utah, but the weather had changed in northern Utah as well. Throughout the entire Southwest region of the United States the arid lands had surprisingly become mud. But why were there so many floods when it rained in Utah, pluvial or not?

Ralf Woolley in his 1946 Water-Supply Paper 994 for the Department of the Interior entitled *Cloudburst Floods in Utah 1850-1938* studied the history of notable floods as reported by the Deseret News, a bi-weekly newspaper started in 1850 by the Church of Jesus Christ of Latter-day Saints. The Deseret News, the oldest news reporting group in Utah, had a history of reporting these floods because they were: sudden, destructive, and more frequent than the pioneers had known storms to be in their former regions of Europe or the eastern United States, and flood reports sold newspapers.
Woolley meticulously gathered accounts of flood events from 1850-1938 throughout Utah that were published in the Deseret News to understand the unique Utah precipitation phenomenon called cloudbursts. Today’s terminology labels cloudbursts as micro-storms or micro-bursts. Rain falling in the Southwest seldom blankets large areas as it does in the East or Mid-West. This form of precipitation often arrives suddenly in a concentrated downpour delivering copious amounts of moisture over small unpredictable locales. Cloudbursts are the most common way rain falls in Utah, especially in southern Utah. Sometimes in Utah the rain is heavy yet contained saturating only small areas, other times it is virga and never reaches the desert floor. Woolley (1946) defined a cloudburst as rain:

From a torrential downpour which by its spottiness and relatively high intensity suggests the bursting and discharge of a whole cloud at once. They are common in the hilly and mountainous districts of the West, and the resulting floods pouring out from the small precipitous catchment basins are flashy and often destructive. (p. ii)

Woolley (1946) continued to describe the weather phenomenon cloudburst that resulted in fast forming short duration floods as: “a violent downpour of rain in large quantity and over a limited area. In Utah it is of thunderstorm origin. A flood produced by a cloudburst is usually a flash peak discharge followed by a quickly diminishing flow” (p. 53). Many factors influence the damaging effects of heavy rains from a cloudburst. Elements of topography such as: altitude, elevation, slope, bedrock and soil composition as well as soil absorption, depth, and range of vegetation coverage, rate of runoff, and rate of rainfall all affect the outcome of a cloudburst. Additionally, cloudbursts often send large amounts of rain into small areas with small catch basements that easily clog up from the debris loosened by the force of the downpour. The clogged small basins allow
for large volumes of water to back-up and then suddenly burst sending a flood down the mountain or river. “Thunderstorms and cloudbursts are most common in the mountains and upland areas, and therefore these areas undergo greater erosion owing to the greater volume and intensity of precipitation and the steep declivities and well-defined catchment basins” (Woolley, 1946, p. 39). From this author’s observation each dry wash in a locale in the Southwest will receive a cloudburst or two over a ten to twenty-year timeframe. However, this frequency can change radically due to long summer monsoons or a pluvial. Unpredictability in location, timing, and intensity stand as hallmarks of cloudbursts.

Woolley’s research on cloudbursts began to paint a picture of why the Virgin River has had numerous destructive flash floods. The intensity of these cloudbursts explains the source of the force in a Virgin River flash flood that could wash away the flatlands of Zion Canyon. Additionally, Woolley’s (1946) study provides evidence that the early settlers noticed a change in their known weather patterns and that these micro-storms initially novel to them became part of life in the Southwest. He commented:

Five years after the first settlement was made in Utah, at Salt Lake City in 1847, it became manifest to the settlers both there and at Manti that "cloudbursts" were of common occurrence in this region. Other settlements were made and gradually expanded on the steep alluvial fans of the 'mountain streams, and reports of cloudburst storms and their attendant floods became increasingly numerous as farms and homes were damaged by them. (p. 15)

Most observers of increased precipitation searching for the cause of the frequent floods throughout Utah during the first decade of the 20th Century determined that excessive grazing was the most common “cause and effect” theory proposed for the flooding that followed a cloudburst. The Mormon pioneers brought cattle with them, and ranching became a common livelihood. The result of which left many hillsides devoid of native vegetation. Although a contributor to run-off later scientific observations noticed
that when vegetation grew back flooding continued to occur at the same rate. Moreover, it was also understood that more newcomers settling on rich alluvial river soils would enhance the perception of flooding. New settlers placed houses and barns in the paths of age-old usually dry water courses. Unsuspectedly these washes would swell with run-off under cloudburst circumstances, destroying hard-won homesteads. This flood event would make it into the Deseret News giving the impression that there were more floods, when heretofore that uninhabited watercourse would flood but no one would be around to notice it or to be affected by the muddied rainfall.

Woolley (1946) did not completely accept that over grazing caused flooding. He thought that more geographic and geologic aspects of the environment had to be taken into consideration when evaluating the path and behavior of intense precipitation with subsequent river flooding in the regions of Utah. He defended his thinking:

In 1890 the theory was advanced that these floods occurred because the sheep and cattle had eaten off the vegetation in the hills, leaving nothing to hold the water back. This indictment of man's flocks and herds has become so common that during the past 20 years considerable study has been given to it. Most of the study, however, has been devoted to runoff from the catchment basins and factors involved in its control and little of it to an adequate scientific analysis of the relationship between physiographic and geologic features and the meteorologic phenomena involved in the storms. (p. 15)

Woolley (1946) also illuminated the fact that grazing might have some effect on higher flood volume, but he pointed out in 1946 that excessive grazing had been discontinued and that vegetation might not be the main factor causing the cloudburst flooding. He explained:

Suggestions are not uncommon that the effects of cloudburst floods might be minimized if the catchment basins of the flood ravaged canyons could be planted to a denser vegetative cover. In attempts of this kind, however, the fact should be borne in mind that practically all the canyon lands are now bearing a plant cover which, in its original condition, is predetermined by natural conditions of
precipitation, percolation, evaporation, transpiration, temperature, and situation, and that any widespread attempt to "overload" the watershed will no doubt be disappointing. (p. 51)

Woolley sought to apply the science of geology and geography to the cloudburst flood pattern that he believed had been antecedent to the arrival of the Mormon settlers. He believed cloudbursts were a constant meteorological event in Utah, that over time had carved much of the terrain of Utah. He noticed that these floods occurred below 8.000 feet in altitude and that the watershed for many of the waterways that flooded was in the order of 10 square miles or less. Woolley believed this small drainage area concentrated the volume of the precipitation and channeled it thru narrow mountainous course ways in which debris would gather creating temporary blockages that would cause high volumes of water to back-up, which would breakthrough and surge forward as a flood.

The cloudburst phenomenon with ensuing flood occurred recently in Springdale, UT. On June 28, 2021, a concentrated micro-burst rained hard, for about an hour, upon the south facing wall of the West Temple, the highest stone mesa in Zion Canyon. Although not near the Virgin River a massive flood of soil laden water over 16 inches in height coursed through the area of town along Lions Boulevard moving trucks, cars, sheds, and accumulating water and thick mud in several buildings and on the streets all the way to the South Entrance stations of Zion National Park a distance of a mile or more. The accumulated water originally came down its natural wash course however debris accumulated at the small bridge over the wash to the town’s baseball field causing the water to back up and spill over onto town properties causing far more damage than if the water had been able to follow its natural wash course. This unexpected amount of water and mud coming not from the river, but from the cloudburst as its rain coursed down the
mountainside shocked and educated Town folk, firsthand, as to the amount of water coming from a cloudburst and its destructive power. Several businesses took a total loss. Others continue to clean up the deposits of mud. Residents continue to share photos and videos of the flood and the wreckage. This flood was not due to the Virgin River, nor did it occur near the Virgin River banks. Yet the volume of water acted like a small river able to move vehicles and enter buildings. This event made it ever so clear that if this single source flood could do so much damage, the Virgin River under the influence of a cloudburst could certainly wash away the flatlands up canyon.

This 2021 event evinced the age-old conditions for destruction that Woolley (1946) had observed from a cloudburst:

Probably in no State west of the Rocky Mountains are plains so restricted in extent as in Utah. The steep gradients of the smaller streams, their confinement in narrow canyons, and their abrupt change of gradient when they spread upon the alluvial fan at the bases of the slopes are major factors in the destructiveness of cloudburst floods, as these fans are choice agricultural spots and are thickly settled. (p. 18)

Qualitative Data: Deseret News Descriptions of Floods During the Early 20th Century Pluvial

The Deseret News stories provided qualitative data pointing to an increase in precipitation. The published accounts of flood events described the lived experience of the settlers during periods of increased precipitation. Through these personal and at times traumatically lived experiences of flood events, an impression of the behavior of rivers and in southern Utah the behavior of the Virgin River would have been formed and over time reinforced with every new flooding event.

The result of these flood accounts published in the main artery of communication for Utahans, the Deseret News, coupled with the actual increased precipitation
engendered an environmental impression of the Virgin River as a flood maker. This reputation has clung to the Virgin River even, when for decades, the average streamflow has been near or below 160 cfs. Despite occurring over decades ago, the memory of pluvial years haunts the collective memories of locals and continues to influence the perception of Virgin River. Despite the prevailing arid weather, in the environmental perception of those living in southwestern Utah, the Virgin River remains a perennial threat. But was this threat due to the river or could it have been from the type of precipitation common in Utah, the cloudburst that Woolley (1946) described? Woolley’s data may not be a complete or even an accurate list of the description of the increased precipitation and flooding events. He, like others, noticed the increase in precipitation in the early 20th Century. Yet he took a scientific approach to identifying the cause for the increased precipitation which included meteorological, geographic, and geological frameworks as well as qualitative data from newspaper reports.

As was stated earlier in this dissertation little data for the pluvial period 1904-1922 exists within the archives of Mukuntuweap National Monument and later Zion National Park. As a result, Woolley’s data supplies extensive qualitative descriptions of flooding events from 1850-1938. Another researcher might compare all the flood reports in Woolley lists between 1850-1938 as a source for or against a pluvial. However, there is enough quantitative evidence supplied in Chapter 2 to support the evidence for the pluvials. Including Woolley’s research herein provides an opportunity to add qualitative descriptive research that supports how an environmental perception might be formed in

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5 Please note these microburst precipitation events are different from the wind phenomena of a down draft found in tornados also named microbursts.
the minds and memories of residents of this geographical region. Included herein are
tlood events from 1904-1938 taken from Woolley’s (1946) lists, that occurred in places
within 65 miles of Zion Canyon. However, in the Deseret Newspaper flood events from
the entire state were reported. For readers of the Deseret Newspaper, this statewide
reporting likely magnified their perception of the destruction accompanying increased
precipitation.

Woolley’s data may not be accurate and could have been influenced in several
ways. The need for sensationalism to sell newspapers can bias the accuracy of the
descriptions of the flood events. Those who shared first-hand eye-witness reports of the
tlood events may inadvertantly have exaggerated the destruction and extent of the
looded area. Additionally, northern Utah was far more populated and economically
developed than southern Utah during the early 20th Century thereby the range of floods
reported and amount of damage due to an increase in precipitation would have affected
many more people in northern Utah as well as more infrastructure and investment. As
well, the number of Deseret News reporters in southern Utah is unknown but likely few
in number, and how the data from southern Utah was observed and transmitted is also
unknown. Nonetheless, this body of qualitative flood data with the dating and description
of precipitation events and resultant destruction is outstanding.

Following (see Table 4-1) is a list of flood events in southern Utah 1904-1938
within 65 miles of Zion Canyon taken from the lists in Woolley (1946).
Table 4-1

Deseret News Descriptions of Floods in Southern Utah 1904-1938

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904</td>
<td>St. George July 21- The St. George-Cottonwood canal was filled up with boulders and sand for miles as a result of several recent showers. Repairs estimated at $200. (DN Aug. 1, 1904.)</td>
</tr>
<tr>
<td>1904</td>
<td>Bloomington July 21- Recent flood down the Rio Virgin and Santa Clara washed out the Bloomington Dam. Big floods came down the wash west of Washington and tore away a telephone pole. Little other damage reported. (DN Aug. 2, 1904.)</td>
</tr>
<tr>
<td>1904</td>
<td>Cedar City July 22 - Coal Creek Largest flood for at least 36 years.&quot; Main part of flood down main canyon, and the rest from the east range of mountains through Fiddlers Canyon, about 3 miles northeast of town. Parts of town flooded. Damage to barns, hog pens, chicken coops, etc. Crops covered. Dams torn out, and ditches filled up with mud. (DN July 27, 1904.)</td>
</tr>
<tr>
<td>1904</td>
<td>St. George July 26 - Ash Creek, a tributary of the Virgin River, was about 4 feet higher than it was ever known to be before. (DN Aug. 1, 1904.)</td>
</tr>
<tr>
<td>1904</td>
<td>New Harmony July 27 - A cloudburst broke with fury upon the village of New Harmony, driving the inhabitants from their homes. A few homes were washed from their foundations and wrecked, roadways were torn up, gardens and orchards flooded, covering a strip half a mile wide and several miles long. Narrow escapes were numerous. (DN June 27, 1904.)</td>
</tr>
<tr>
<td>1905</td>
<td>St. George August 24 - A cloudburst up the Virgin caused the largest flood in the history of St. George to sweep down the river. Price Dam was carried away entirely, and the current cut the Jarvis Field Dam and nearly destroyed the Washington Field Dam. Animals and debris were swept away, and cropland flooded in many places. (DN Sept. 13, 1905.)</td>
</tr>
<tr>
<td>1907</td>
<td>Cedar City August 12 - one of the heaviest cloudbursts ever witnessed in Cedar. Torrents of mud laden water filled the streets of the town. (DN Aug. 13, 1907.)</td>
</tr>
<tr>
<td>1907</td>
<td>Cedar City August 22 - cloudburst water poured into the town 2 ft or more in depth, streets flooded, and basements filled fields covered and crops destroyed worse storm than one of Aug 12 (DN Aug. 23, 1907.)</td>
</tr>
<tr>
<td>1909</td>
<td>St. George Sept 1 - Virgin River Santa Clara Creek Greatest flood in the history of the county&quot; went down the Virgin River, removing dams and washing many acres of bottom lands. A canal was damaged, and crops suffered from heavy rains. Santa Clara Creek also washed away some adjacent farming land. (DN Sept. 8,1909.)</td>
</tr>
<tr>
<td>1909</td>
<td>Orderville Sept 1 - Virgin River About $3,000 damage ensued from recent storms. The river cut away much cropland and destroyed bridges at its height on Aug. 31.</td>
</tr>
</tbody>
</table>
Grain in the shock was spoiled by heavy rains, and canyon roads were washed out in many places. (DN Sept. 8, 1909.)

1909 Bloomington Sept 4 - The recent floods damaged 100 rods of the canal and destroyed some bottom lands. (DN Sept. 10, 1909.)

1911 St George July 20 - A heavy rain brought damage to roads, canals, and crops, especially hay that had been cut. (DN July 25, 1911.)


1920 Springdale Aug 23 - North Creek Newly completed bridge on Zion National Park highway swept away. Springdale Bridge of Zion Canyon highway destroyed by terrific cloudburst.

1920 Zion National Park Aug 23 - Several mudslides on Zion Park dugway. (DN Aug 23, 1920.)

1921 Cedar City Aug 21 - Cloudburst flooded town and caused considerable damage. Houses damaged, cellars flooded, and ground floors of many homes flooded to depth of few inches to 4 or 5 feet. Cattle, pigs, and chickens drowned. Bridges washed away and crops damaged. Damage estimated at more than $20,000. Boulders and mud covered farmlands and part of town. (DN Aug. 22, 1921.)

1930 St George Aug 13 Flood hit Shivwits Indian Reservation. Traffic delayed when culvert washed out of highway.

1930 Zion National Park Aug 13 - Road to Andersen Ranch hit by mudslides. Damage to Iron and Washington Counties' State highways estimated to be $5,000

1930 Hurricane Sept 7 - "Cloudburst caused much damage." (DN Sept. 9, 1930.)

1936 Cedar City July 11 - For third successive day city was center of heavy rains. City was covered with red mud from flood waters.

1938 Cedar City Aug 30 - Spectacular electrical storm flooded streets and basements of Iron and Wayne Counties. U. S. Highway 91, between Kanarraville and Parowan, was flooded with mud and water.

Source: Woolley (1946)

Even though the Deseret News list is extensive it did not capture the local flooding in Zion National Park. Dave Sharrow (2018) Zion National Park hydrologist compiled an unpublished list of Notable Flood Events in Zion National Park and some
notable geological events. His list included 2 flood events to add to the Woolley (1946) descriptive list above (see Table 4-2):

**Table 4-2**

*Additional Local Flooding Events in the 1920s*

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
<td>Zion National Park Floods take out 1 bridge and the road in two places.</td>
</tr>
<tr>
<td>1929</td>
<td>September 4 - Zion National Park One of the largest floods in recent years came down through the canyon after a cloudburst on September 4, 1929. USGS recorded this event at 3,900 cfs</td>
</tr>
</tbody>
</table>

Source: Sharrow (2018)

All lands abutting the Virgin River were susceptible to flooding. In addition to Sharrow (2018) comments of two flood events within Zion Canyon in the 1920s several residents recalled their memories of floods. In Eileen Smith-Cavros’s 2006 book *Pioneer Voices of Zion Canyon* interviewees spoke about their common experience of witnessing Virgin River floods in Zion Canyon in the 20th Century.

The Virgin would flood a lot. We had a lot of summer storms that were through July and August, we’d have so much rain. If it got stormy…we stayed away from the river…it did affect the crops because it washed the dams out of the river, then our ditches would be dry until they put in a new dam. It was washing away the dams and then we couldn’t water the fields. (p. 66)

Flood losses were ubiquitous for most families living along the Virgin River in the Zion Canyon communities of Springdale and Rockville. Smith-Carvos related another local resident’s memory:

Every once in a while, the river would take up people’s crops. But one time it flooded, and it was so heavy that my Uncle Freeborn had his barn down by the river so that the horses and the animals could get water without him having to
carry it- and it took out his barn and all of his animals. It was what we called “The Hundred Year Floods” because they really had some big ones in those days. (p. 66)

The purpose of using data from Woolley (1946), Sharrow (2018) and Smith-Carvos (2006) in this chapter expects to link the personal lived experience of flooding to the pluvial of 1905-1922. Additionally, to elicit and understand how perception of the Virgin River was created and conveyed, even exaggerated by the newspaper reporting and first-hand accounts published in the Deseret News. Also, to attribute the cloudburst pattern of precipitation that Woolley described as an essential component in creating the flooding that became an ominous attribute of the Virgin River.

The numerous accounts of flood destruction in the Deseret News would have influenced the environmental perception of the Virgin River. This perception would in turn have likely affected how early Superintendents at Zion National Park understood the pivotal position of the Virgin River in Zion Canyon. Further, this author wanted to underscore how the 17-year official length of the 20th Century pluvial arrived only 16 years after the wet years of the late 1880s. Thus, reviving the traumatic memories from former destructive flood events chronicled from the pluvial of 1865-1869 and the intermittent wet years of the 1880s. The new period of increased rain would have activated a latent fear of the Virgin River residing in the collective memory of the region. This fear would have informed the environmental perception that administrators of the new Zion National Park would have brought to managing the anthropomorphized “angry,” “capricious” and “devilish” Virgin River.

Rather than seeing the Virgin River as the foundational source of life in the arid lands, nurturing the riparian zone, which in turn nourishes the many species of fauna and
flora in Zion Canyon, the focus of Superintendents was on controlling the water of the river. This management strategy excluded the riparian ecosystem, the rich habitat full of life in Zion Canyon. When this author arrived in 2000, the second year of a drought that continued for five more years, the specter of flood years lived on in numerous comments by Park Rangers, locals and Old Timers. Few perceived the Virgin River’s water as a blessing, rather, the streamflow was an element that could spill out of its banks quickly and unpredictably like water from an overturned glass creating a mess. The prevailing perception was that this kind of flood event must be prevented. Consequently, the biological imperative for the Virgin River waters to feed the riparian flora such as the Fremont Cottonwood trees and fauna of Zion Canyon was overlooked and certainly not preserved for future generations (Sharrow, personal communication, 2006; Steen, 1999). Fresh water in the desert acres of southern Utah can arise from springs and underground aquifers, however these sources are difficult to find and access. If it were not for the Virgin River, the desert lands of southern Utah would never have bloomed for the Mormon settlers. Without the precious perennial Virgin River water, the Mormon settlements would have vanished.

The pluvials added periods in which these settlements were able to add agricultural surplus and a sense of security to their settlements. Nonetheless, the floods described above attest to the fact that the Virgin River had performed feats of destruction that no white person before 1860 had imagined possible in the desert. The destruction was personal and traumatic. All aspects of life for the settlers had been hand-made, home grown, and hard won. When all was destroyed in a flash flood, the settlers had to find the will as well as the materials to start over and rebuild their homes. The trauma of these
flood incidents and losses resided in the body and community memory and did not easily fade. These traumatic years of flooding became legendary, remaining in the cultural memory of the people of southwestern Utah for generations.

The Virgin River had an unsuspecting, expanding, and destructive power. But what was the source of this ruinous force? The unique qualities of cloudbursts in Utah contributed directly to these destructive floods. The location and timing of cloudbursts remain unpredictable. Cloudbursts contribute to an almost spontaneous corresponding increase in Virgin River streamflow due to run off from steep grades, high elevations, and the lack of water retention in desert soils. The nature of a cloudburst with its high volume of moisture from one or two clouds dumping their entire concentration of moisture on a small often confined area in a short amount of time, unexpectedly added high volumes of water to a watershed and subsequently this moisture raised river streamflow rapidly, usually causing unpredictable flooding. If the early Zion National Park Superintendents had better, understood, the relationship between cloudbursts and the rapid increased Virgin River streamflow, would the design for channeling of the Virgin River been less intrusive and extensive?

The pluvials of 1860-1869 and 1905-1922 seared the environmental reputation of the Virgin River as a destructive force into the minds of the southwestern Utah residents. This destructive impression likely amplified the sense for the Zion National Park Administrators that the Virgin River in Zion National Park was a greater threat than it was in the long term.

But what were the complex parameters that caused these floods and resultant human tragedies? Was it the increased precipitation arriving in the pluvials, the
distinctive cloudburst precipitation pattern, the geomorphic structures of the land and the riverbed, settlers building and growing crops on the flood plain? All these factors created a complex set of interactions that caused the destruction and ensuing trauma that has remained with the long-term residents surrounding Virgin River flooding. However, if one wanted to find a prime cause it would be the unusual and increased rainfall due to the cloudburst pattern of precipitation not so much the Virgin River itself. However, the cloudburst becomes the river in a matter of seconds. The river and the cloudburst are intimately related.

Even with this understanding and analysis that the pluvial is another prime cause behind the cloudburst, climate change scientists still do not know enough about the complex interconnected relationships in the atmosphere, on the earth or in the solar system that interact to create regional weather patterns and climate changes. Cayan and Peterson (1989) suggest North Pacific Ocean climate forcing as the prime cause. Kahya and Kalayci (2004) offer Large Atmospheric Circulation. B. I. Cook et al. (2010) maintain possible Sea Surface Temperature correlations. B. I. Cook et al. (2011) stated, who knows, pluvials happen! Yet for a person living through these monumental climatic events experiencing trauma from flooding post-traumatic stress syndrome would likely occur even if at that time the term was yet unknown.6

Trauma is often resistant to change. Trauma tends to live within the self unless one is intentional in their efforts to remove it. Trauma leaves an impression; in turn an impression creates a perception. From perceptions decisions are often made albeit

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6 According to psychiatrist Bessel Van der Kolk (2021) interview On Being November 2021 “People were very aware of trauma and its long-term effects in the 1880s and after the Civil War.”
clouded and inaccurate. Perceptions about the Virgin River were clouded by the human trauma of destructive flooding resulting from the increased precipitation engendered by the two pluvials of 1865-1869 and 1905-1922. This culturally pervasive perception likely influenced early ZNP Superintendents to keep the need to control the Virgin River as a eventual necessity

**Perception: The Problem with Discerning Incremental Changes**

The environmental perceptions formed around these climatic and traumatic flood events would translate into environmental policy, which in the early 20th Century was focused upon control. Besides grazing, and Woolley’s perception of the physiognomy of the Utah lands, opinions differed as to what was causing the flooding or if more precipitation had been perceived. Woolley (1946) understood and noticed the confusion among the residents of Utah. He observed:

> Opinion differs, however, as to whether there have actually been more floods that have caused disaster, as some observers believe, or whether there have been no more or worse, floods but that more have been reported because there were more settlements and therefore more lives and property in jeopardy. (p. 1)

Perceiving the breadth, depth and truth of a weather change due to the geologic, geographic, long, and short term consistent or novel climatic patterns and other circumstances surrounding cloudbursts required gathering complex data. Then applying critical thinking skills, and complex analysis, to an intermittent yet appearing more constant occurrence. Was it really raining more? Discerning this was illusive. Why? Because discerning small incremental change is no easy task.

For the pioneers new to the region, the question arose, was it really raining more? Take for example two modern metaphors for realizing or not realizing change. The frog in warm water does not notice the temperature is increasing and does not hop out to save
his life before the water boils because he did not notice the incremental changes in temperature. Does the fish know it is swimming in water that may be increasing in acidity such that its eggs and sperm all die after spawning? For modern times one could say human fertility is dropping due to the increase in chemicals in the environment. For the settlers, facing drought, or Utah residents in June of 2021 “Has it really, not rained for over 150 days”? Or the situation that haunted me as a child. Why did so many Jewish people stay in Germany where they succumbed to concentration camps? Why didn’t these people get out of Germany in the late 1920s and early 1930s? More recently the conundrum faced by Americans initiated by the President of the United States, Donald Trump, who daily made incremental changes in Federal Agencies and Federal policy. Was this man fundamentally changing the structure of the United States government? Many Americans listening to President Trump’s small but noticeable changes were akin to those 19th Century settlers in trying to assess an increase in rain. Are these daily changes moving the US government away from a government of checks and balances toward an executive branch dictatorship? Was it really raining more in the Southwest in 1905-1922? It made sense that no one knew whether it was really raining more, flooding more than usual? At this point John Wesley Powell comes to mind again. He did know. It may be raining more but Powell (1879) knew that the essential nature of the Southwest was arid. With this fundamental understanding of the climate in the American Southwest would Powell have armored the full length of the Virgin River in Zion Canyon?

These examples highlight how hard it is to believe that change is real when it comes in small daily doses. Furthermore, these examples underscore how difficult it can be to understand the source and implications of incremental changes observed in the
environment for a person living through incremental weather change. Is what I am sensing real? Is my perception overblown? Changes in climate act the same way on personal perception and behavior as does any other type of incremental change.

Confusion, uncertainty and at times hubris present themselves. Would an astute settler self -reflect and ask, “Am I imagining that these floods are caused by more rain”? Is it hotter in 2021 than it was in 2012? Occasionally people perceive the truth of a situation. This does not always mean one can respond any differently but sometimes it does allow people to make decisions based on the awareness that the circumstances are uniquely different. To this end some of the pioneers did consider that the climate had changed, and that flooding was due to more than excessive grazing or even that flooding was just due to the terrain. Woolley’s focus was on topography, but he did make note of the possibility that the climate had grown wetter in Utah. He contemplates:

With respect to "cloudburst channels" in this region, that precipitation here, as in other desert regions, is extremely irregular and often violent, and sooner or later the 'cloudburst' visits every tract, and when it comes the local drainageway discharges in a few hours more water than is yielded to it by the ordinary precipitation of many years. The deluge scours out a channel which is far too deep and broad for ordinary needs and which centuries may not suffice to efface. The abundance of these trenches, in various stages of obliteration, but all manifestly unsuited to the everyday conditions of the country, has naturally led many to believe that an age of excessive rainfall has but just ceased. (p. 54)

Woolley (1946) and John Wesley Powell (1879) shared an ability to grasp the complexity inherent in the climate of the Southwest during their respective eras. They both were able to notice small incremental changes. Yet they both were scientists who added the larger context as well as the details on the ground to support their analysis of the cause of climate conditions they observed. One can envision a Sherlock Holmes and Mr. Watson scenario between John Wesley Powel and Mr. Woolley. Mr. Woolley: “I do
believe an age of excessive rainfall has but just ceased.” Mr. Holmes: Yes, Mr. Woolley, an age of excessive rainfall has but just ceased. Holmes would respond to validate Mr. Woolley persistent efforts. “Excellent,” Mr. Woolley cried. Mr. Powell, the consummate observer, and analyst would reply simply, “Elementary, My Dear, Woolley”!

**The Wash as Indicator of Cloudburst Frequency**

In southern Utah cloudbursts (microbursts) continue to be the prime delivery system of precipitation to the region. Although unpredictable in timing there is a way to understand where the waters of a cloudburst might travel. The chronically dry wash that receives little or no attention in city planning, at least in Springdale, tells the truth about flow and drainage patterns in desert environments. If a cloudburst occurs as they have been doing in Utah for millennia, they have left a history of their frequency in the depth and breadth of the washes in a locale. Most people think only a river can cause a flash flood. However, in southwestern Utah where many washes reside most of them have no source of water to explain why a water course exists in that locale. These washes exist because they represent natural flow regimes for that landscape and elevation. What controls the location of a cloudburst, which provides the water that flows through a wash is a worthy subject for another dissertation, but there has been a pattern and the unassuming wash tells that pattern. As noted, earlier Springdale, UT experienced a cloudburst flash flood on June 28, 2021. Structures built adjacent to the wash were flooded. What is interesting to note is that in the last two years the owner of the campsite and hotel adjacent to the main wash in this discussion just put in pipes to channel the wash and covered the wash to create more land upon which to extend his business. As a result of this cloudburst his hotel had to be demolished and he suffered a total insurance
loss. What adds more interest to this story is that there have been no monsoons for the
last two years and in the last five to ten years summer monsoons have not been strong.
Yet, during the summer of 2021 throughout Utah frequent monsoon flooding occurred. If
this has any significance to the present drought in the Southwest or is in any way
indicative of winter precipitation to come, further climatic research will be needed.

Woolley (1946) speculated that not all flood destruction documented in the
Deseret News was solely due to natural causes. Destruction was exacerbated because as
human beings continued to immigrate to Utah many built either on or adjacent to washes,
flood plains, and rivers or at the base of high elevation natural features. The source of a
flash flood is important to discern, because of the negative perception associated with
flash flooding built up over the years in Utah. When people hear the term “flash flood”
they think river and want to blame the river rather than negligent zoning and free-for-all
development in flood prone areas. Even though rivers are the source of precious water
and have sustained life in Utah for the Mormon settlers, rivers have been totally
associated with the term flash flood. This has been the case for the Virgin River and other
rivers in Utah. This misplaced blame results in flood control projects that often cause
unintended consequences such as what has happened to the Fremont cottonwood forest in
Zion Canyon. Human beings defiantly refuse to be accountable or to blame themselves
for some of the flood damage caused by flash flooding in Utah. Their decisions to build
in vulnerable areas such as flood plains, near washes and rivers etc. are additional reasons
for the resulting damage to their property. The blame cannot lie with just the natural flow
of drainage in the landscapes of Utah. Better understanding of precipitation patterns,
cloebursts, and general drainage flow patterns make for more successful planning.
Cloudburst Tragedies in More Recent Times

As stated previously cloudbursts are the main form of precipitation in spring, summer, and fall in Utah. The unpredictability of a cloudburst is usually not understood by visitors to the Southwest. Many come from regions where rain blankets an area falling at a steady pace over long lengths of time. This is different from the brief period of an hour or less for precipitation resulting from a cloudburst. This misperception has been the cause of tragic events in southern Utah and particularly in Zion National Park. With excellent meteorological technology and weather forecasting as well as lessons learned from historical research such as Woolley (1946), the distinct cloudburst weather pattern has become well known and anticipated. Nonetheless, despite daily weather forecasts for southern Utah, Springdale, and Zion Canyon via Zion National Park daily weather reports, cloudbursts (microbursts) continue to come upon the visitors of the region with little warning resulting in tragic consequences.

Presently those most vulnerable to these cloudbursts are people recreating in the National Parks of southern Utah, particularly in Zion National Park. Living for almost two decades with Zion Canyon as my backyard, these fatalities are well known. Books have been written on the consistency of death in Zion Canyon. My mythic self has sought to explain this surprising frequency of death in Zion as the Canyon eating people every year or two. Looking at Zion Canyon through this primaeval lens affords the viewer a glimpse of an ancient past, which engenders fleeting feelings of understanding why the Paiute people chose not to visit the Canyon especially at night. Or why peoples of ancient times might feel the impulse to offer human sacrifice to satisfy the God and Goddesses residing in powerful places like Zion Canyon.
In Woolley’s (1946) list of cloudburst narrations there are mentions of human and animal deaths because of micro-storms. In the Annual Reports between 1927 and 1940 there were deaths mentioned in Zion National Park. But few, and all were from a physical ailment or a fall from a cliff face. However, in the early 1960s Zion National Park became more well-known as a destination for tourism and hiking. The Narrows hike took on the aura of unique adventure. The Narrows hike requires that a hiker walk in and out of the streamflow of the Virgin River as it passes between 2500 feet high sheer sandstone cliff faces. In most of this narrow river channel there is no available high ground to climb upon for safety should there be rainfall further up the drainage swelling the river into a flash flood. In addition, canyoneering in recent years has become extremely popular and at times these narrow lateral canyons fill with flood waters. As a result, human deaths have occurred in Zion National Park due to cloudbursts since the 1960s.

In the following rendition of the Narrows Tragedy of 1961 described in Dave Sharrow (2018) edition of Notable Flood Occurrences in Zion National Park, a microburst weather pattern caused the death of five hikers in the Narrows on September 17, 1961. Sharrow (2018) related the story as a cautionary tale for the modern hiker of the Narrows. Sharrow recalled:

A Brief Outline of the Narrows “Tragedy” of 1961

The flood which hit on Sept. 17, 1961, was not the usual summer flood. The peak discharge of 5,880 cfs was the highest recorded since 1938 and the 4th highest flood peak in the 1926 to 2008 record. The flood waters washed out 50 yards of the canyon road below the Temple of Sinawava, destroyed the foot bridge at Birch Creek and damaged the Highway 9 bridge over Coalpits Wash, stopping traffic on the highway until a temporary bridge could be built.
The hikers were not a troop of Boy Scouts as was reported in some sources. There were in fact 7 girls in the party. The group was called Socotwa Expedition, Inc., a non-profit group organized to explore the remote areas of Utah. The participants were all from the Salt Lake area. The director and founder of Socotwa was killed in the flood. Twenty-six hikers started the walk, 21 finished alive, 5 perished including 2 whose bodies were never recovered.

Here is the sequence of events:

Sept. 17, 1961 - The hikers begin an early morning hike upstream into the Narrows, apparently with the intent to travel above Orderville Gulch and Big Spring, before returning back downstream were caught at 11 am by the flood waters. Apparently, they were walking in three groups: 19 hikers below Orderville, 5 hikers in the narrowest section just above Orderville, and 2 hikers above the narrowest section. Those 5 in the narrowest section were killed. The Park was unaware that anyone was in the Narrows.

Sept. 18, 1961 - A young boy watching the flood waters in Springdale sees legs sticking out of a pile of driftwood. He alerts the authorities. A search is started. Two more bodies were found; one behind the Driftwood Lodge, and one in the river in South Campground. The first body was found at 10:30 am, 3 hours before the surviving hikers came out of the Narrows. At 1:30 pm 19 hikers came out of the Narrows, 2 more emerged at 5pm. 2 boys were still missing and were never found. The hikers had spent 22-27 hours in the Narrows waiting out the flood. The flood that hit the people in the Narrows preceded any rain in the lower part of Zion Canyon by ½ hour. It was not raining in the canyon when the flood hit. Once rain began 1.29 inches of rain fell in Zion Canyon that day. (Rainfall spanned the 4:00 pm daily reading so it is recorded over two days.) A survivor estimated the flood crest at 10 feet. The bodies found in Springdale had been moved 10 miles by the flood.

This account illustrates several points to remember about floods in the Narrows.

- Floods do not all occur in the afternoon. The rainfall that created this flood probably fell between 7:00 and 9:00 am.
- 21 people caught in the biggest flood in many decades survived. Being in the right location helps, but with quick, smart, decisive action survival is possible.
- All 5 in the tightest narrows (Big Spring to Orderville Gulch) died. In this area, flood refuge is very limited.
- It did not rain in Zion Canyon until well after the flood.
- The bodies were carried many miles downstream and found terribly smashed up.

The scenario of a large group up the Narrows, that had split up, with no NPS knowledge of their whereabouts could very likely happen today. (p. 3-4)
It is hard for those who have not lived in the Southwest to grasp how an early morning rain shower fifty miles away covering a small area, can cause such a large flash flood so far from the source of the precipitation. This type of weather pattern is quite different from the extensive blanketing weather patterns seen in other parts of the United States such as in the Northwest, Northeast, and Mid-West, where precipitation falls consistently over a wide region all day or night. Since many visitors to Zion National Park come from areas where blanketing precipitation is the norm, they do not understand the immediacy and quick increase in volume and force that accompanies cloudburst precipitation. The events of the *Tragedy of the Narrows in 1961* and the lessons it teaches about preparedness and the power of precipitation in and around the Virgin River watershed have become covered through the thick veils of time, hardly making themselves known to present day hikers despite the efforts of daily weather communication and warnings by Rangers at Zion National Park.

The National Park Service continually warns visitors to Zion National Park about weather danger. But intermittent cell phone coverage as well as people’s personal sense of hubris can cause personal over-reach and death. Visitors think they have researched the region, because of their past expertise they have the skills required for recreation in Zion National Park. Visitors unwittingly leave themselves vulnerable due to mistaken assessments and decision making that does not account for the actual context of the Southwest climate and conditions. It is the Park vs Wild dilemma that the National Parks find themselves in, that was addressed earlier in this chapter.

An unfortunate example of this situation combined with a Zion Canyon microburst that caused the death of seven experienced visitors, who were canyoneering in
Zion Canyon, in Pine Creek and Keyhole on September 14, 2015. The article: *Seven Hikers Descent into Doom at Zion National Park* September 20, 2015, found at the *Los Angeles Times* website illustrates the danger that continues to arise from microbursts in the Virgin River drainage even with modern communication channels.

4:30 to 5:30 p.m. In less than one hour, 0.63 inches of rain falls in Zion Canyon. Flash floods hit Keyhole and several other canyons. In 15 minutes, the flow of the North Fork of the Virgin River rises from 55 cubic feet per second to 2,630 cubic feet per second (Yardly et al., 2015, An Ill-fated adventure, para. 8)

The seven experienced hikers were trapped in a narrow horizontal canyon about twenty-five to forty feet deep and three-four feet wide. There was no way to swim up or out of the narrow long horizontal canyon. In casual conversations with other locals that morning the dark clouds up canyon were noticed and mentioned in conversation. No locals would go up the Canyon with those clouds present. However, these seven hikers from California did not understand the intensity and resulting flash floods arising from microburst precipitation in Zion Canyon.

Most historic accounts indicate that the Virgin River has done more damage to property than to human life. The deaths in both unexpected high-water events in Zion Canyon occurred where the geomorphology of the Virgin River or its tributaries consisted of narrow riverbeds lined by high walls of smooth stone. The volume and speed of streamflow rapidly accelerates due to the narrowness and steepness of the varied elevations within the Zion Canyon drainage. The mocha brown water carrying soil, boulders, and organic debris can easily overcome and drown even the best swimmers. These stories of death at the hands of Zion Canyon continue to feed the perception of danger associated with the Virgin River and the high elevation hiking trails. Yet most visitors do not understand the nature of precipitation in a canyon environment. With so
many people recreating in the riparian ecosystem of Zion National Park, who know nothing of the microburst style of precipitation in the Southwest, it becomes an ethical obligation to present this ominous face of the Virgin River and Zion Canyon to the unsuspecting public. Because for about every day of the year the Virgin River flows serenely at a low streamflow resembling a harmless, peaceful, and pastoral creek.

Woolley published his research in 1946 after most of the channeling of the Virgin River was complete. From my reading of the Superintendent reports it does not appear that any of them understood the cloudburst pattern of precipitation that occurred in and around Zion Canyon and the Virgin River drainage. The term “storm” was used to describe precipitation events in Zion National Park. But does the word storm truly capture the uniqueness of a Utah cloudburst/microburst? If this pattern of precipitation had been better understood in the early 20th Century, would flood control, deemed necessary to keep the flatlands intact and later the Zion Lodge protected, have been designed differently? Can a restoration plan be designed to allow for the next generation of Fremont Cottonwood in the riparian ecosystem in Zion Canyon to thrive once again in Zion Canyon? Can a restoration plan for Zion Canyon and the Virgin River include designing for protection from cloudbursts and concomitant high streamflow, yet preserve flood plain flooding?

The National Geographic Society Standard 6: entitled: How culture and experience influence people's perceptions of places and regions, defines perception as: “the basis for understanding a place’s location, extent, characteristics, and significance. Throughout our lives, culture and experience shape our worldviews, which in turn influence our perceptions of places and regions” (National Geographic Society, 2021).
The place, Zion Canyon, was formed by the Virgin River. The precipitation in the
Southwest aided in creating the Virgin River and Zion Canyon. This precipitation
presently arrives in the form of cloudbursts, monsoon and winter rains, and spring
snowmelt. The small area intense inundations (cloudbursts) cause the Virgin River to rise
quickly often topping its banks where there are no revetments flooding and eroding the
surrounding lands. These floods can cause destruction of human infrastructure. But
flooding also allows for Fremont cottonwood propagation as well as for riparian
ecosystem processes many of which remain unknown. Highwaters also carved Zion
Canyon out of the Navajo Sandstone and are a necessary part of the Zion Canyon
ecosystem.

News reports and first-hand descriptions of losses from microburst caused floods,
painted scenes of traumatic experience at the hands of the Virgin River. When the US
Federal government wanted to develop Zion Canyon, it was logical that they would look
to tales and experiences from the locals to gain an understanding of the landscape and the
Virgin River. Assumptions would be made as to the character and behavior of the
elements in Zion Canyon, more specifically the streamflow of the Virgin River. Initial
policy and management decisions would arise from the local generalized experience and
past reports of the behavior of the Virgin River streamflow.

This type of reactive or assumption based environmental management resembles
how uninformed school officials will often judge and discipline misbehaving children.
The child’s behavior is usually interpreted as being disconnected from the social,
psychological, physical, economic, and family contexts in which the child is embedded.
In comparison one might say that the early Administrators of Zion National Park treated
the Virgin River with the same limited and biased assessments attributed to a
troublemaking child that had to be dealt with. There is no evidence that Administrators at
Zion National Park included or researched the multiple contextual relationships any river
has with its riparian zone and as well as with its regional context. The varied contexts of
the Virgin River and its flooding were never thoroughly researched nor were the inherent
relationships the river had with every organic and inorganic form in Zion Canyon.

Perception is too often formed as a reaction to behaviors not well understood.
This could be because individuals and institutions are not encouraged or taught to
regularly self-reflect or to examine contextual relationships. As the National Geographic
Society observed, culture and experience affect what are called attributions, the
explanations a person forms for the behavior of others or elements in an environment.
Attributions have two forms: internal and external. Internal attributions (explanations)
denote the cause for a behavior as coming from a personal or intrinsic choice or aspect of
character. External attributions denote behavior as deriving from the influence of external
forces outside of one’s control, that is, contextual. Accompanying the creation of
attributions, one must be aware of the fundamental attribution error. This occurs when an
explanation of a behavior is incorrectly attributed to an internal source when it is due to
an external force. Assumptions are made about a dynamic person or environmental force,
such as: a river or cloudburst without the contextual influences upon that force or person
being taken into consideration as an explanation for the behavior. The resulting
explanations riddled with assumptions, biased perceptions, implicit judgements, etc. are
usually incorrect. Decisions made based on these incorrect attributions often are wrong,
have poor outcomes, are not comprehensive, lead to stereotyping of people, and places,
and elemental processes such as in the case of the behavior of Virgin River. This river was not seen as connected in any way to the riparian zone, the native riparian forest of Fremont cottonwoods, willows, box elders and ash, the fish, the animals, and plants that needed it to survive. And in terms of the surrounding floodplain the relationship was only considered destructive. The Virgin River was simply seen as an unpredictable body of water that could destroy human-made objects and plans.

This kind of perception is usually biased, influenced by many prejudicial factors: culture, experience, religion, gender, trauma, investment, pre-conceived goals, etc. A study of a phenomenon includes so much more than a reaction. A study needs to derive its resulting conclusions from: critical thinking skills, scientific methodology, hypothesis, gathering of data, time spent, inclusion of as many parameters as one can think of: relationships between observed and unobserved phenomenon, seasonality, context, etc. The cause for the increased volume and force of the Virgin River that created flooding was not well understood or researched. As a result, it was perceived from a reactionary point of view due to the emotional and economic investment of the early settlers, Superintendents of Zion National Park, and the visitation goals of the National Park Service. This is not to say that destruction did not occur, nor that settlers did not build in the flood plain. But that the long-term perception of fear derived from destruction due to flooding contributed to the decision to excessively channel the Virgin River. Thereby, removing the nourishing river from its flood plain. This desertification of the adjacent lands that comprised the Virgin River’s flood plain destroyed the native intermittently flooded sandy substrate the wispy cottonwood propagules evolved to land upon and sprout.
If one adds Woolley (1946) cloudburst observations to Powell’s grasp of the essential aridity of the Southwest, suddenly the complexity of the Virgin River’s responses to precipitation arriving as cloudbursts in a desert environment reveal themselves. Cloudbursts and flash flooding go hand in hand. A large amount of precipitation falling quickly on a small area of arid land is not absorbed and runs off quickly into the drainage. Especially if the surface has little absorption ability due to its composition of sandstone or sandy desert soils, combined with a steep and elevated topography or flat desert flood plain.

What does this mean for the riparian ecosystem in Zion Canyon? The riparian ecosystem and all its component members, flora and fauna evolved with flooding and cloudbursts. For the Fremont Cottonwood trees flooding provided opportunities for propagation. Once the relationships between dynamic climate phenomena such as cloudbursts and flash flooding are considered with the understanding of the flora and fauna relationships to the land water ecotone in the flood plains, a more comprehensive complexity begins to reveal itself and must be considered and researched before further long-term policy decisions are made. This was not the scientific process in the National Park System in the 1920s and 1930s. However, perception of the Virgin River must change to contextual and nurturing framework. ZNP management can no longer be a simple reaction. Riparian ecosystem management must become comprehensive and restorative. This means first acknowledging the disturbance that the revetments have created in the riparian zone. Then identifying the phenomena, the problem, and understanding as many of the dynamic relationships existing among forces such as: cloudbursts, streamflow, riverbank composition, Fremont Cottonwood trees, willows,
fish, road, and Zion Lodge protection and more to establish a better way solve competing needs in the riparian zone between healthy ecology and protection of infrastructure.

Shifting the perception of the Virgin River from “devil” or “capricious” to “source,” “nourisher,” “mother,” composed of a set of dynamic relationships allows for a clearer understanding of the energy patterns and interacting forces in an ecosystem. Following the links among relationships will provide a better way to manage the riparian ecosystem in Zion Canyon and to restore the Virgin River ecosystem and the magnificent Fremont Cottonwood Forest.

Management policies for most of the 20th Century have focused on extracting natural resources for use by humans or by channeling a resource to utilize it for energy generation (Barrow, 1999). Natural landscapes were like grocery stores only full of valuable components of the Earth, to be taken from an environment separated and controlled. The goal of channeling the Virgin River was to control streamflow. Not necessarily exploitative but unfortunately destructive to the ecosystem. Resource management has not always been inclusive of the environment as a whole or considered the dynamic, biological, and vulnerable relationships within an ecosystem. Natural resource management often was and still is a reactive process relying on quick responses that fix the problem for the moment. This fix often employs technology of some sort. For the Virgin River the technology was civil engineering that could design and build giant false riverbanks: the revetments. A wonder to behold! The Virgin River streamflow went where the engineers wanted it to flow. In the last 92 years the river has almost never touched again its elevated flood plains in Zion Canyon.
CHAPTER 5

COTTONWOOD PROPAGATION

This 4-mile journey from camp to the Narrows is full of startling surprises and replete with canyon scenery such as found in few other places. The pathway winds in and out among cottonwoods, box elders, and other varieties of trees, which stand thick wherever the stream has left standing room; crosses and re-crosses the boulder-strewn bed; and swings to right and to left following the sinuosity of the canyon. (Lee, 1917, p. 60)

The Fremont Cottonwood Trees in Zion Canyon: Introduction

The camp Lee mentions above in the description of the trail to the Narrows (see Figure 5-1), would have been the Wylie Camp, located near the present site of the Zion Lodge, about four miles south of the Temple of Sinawava. Presently, a shuttle stop exists

Figure 5-1

*William Hopkins on Original Sandy Trail to the Narrows in ZNP 1917*

Source: Dolph (1917)
at the Temple of Sinawava, at the beginning of the paved Riverside Walk trail. This trail, discussed previously in this dissertation, was originally thick with deep sand as can be seen in this photograph, and leads a visitor to the Narrows, a trail through the Virgin River to a slender gap between towering 2500 ft high sandstone walls. The photo in Figure 5-1 from 1917 was taken the same year Lee (1917) completed his unpublished Ph.D. and 11 years before Lee (1928) completed his geological survey in Zion National Park. Both Willis Lee and Andrus Dolph and his wife were some of the earliest visitors to Zion National Park, who photographed and documented their impressions of the Zion Canyon. The Dolph couple documented their “motorized tour” of Monument Valley, Zion, and Bryce National Parks. Motorized is in quotes because in this Utah State University collection of Dolph’s photographs, the car is often being pulled by horses, pushed up rocky roads by occupants, or traveling through thick sand. Dolph’s stunning picture of the original landscape of the trail to the Narrows in Zion National Park shows the Virgin River on the right of the picture, its banks contingent with the floodplain, the original sandy floor of Zion Canyon, and middle-aged towering native Fremont cottonwood trees.

If Lee or Dolph were to walk the trail now, they would see some of those same cottonwood trees now at the top range of their lifespan. Many of the trees would be fallen and their trunks strewn everywhere on the floor of Zion Canyon (see Figure 5-2).
Each fallen tree creates a hole in the riparian ecosystem habitat and in the magnificent shade canopy provided by the majestic cottonwoods. This canopy extends through much of Zion Canyon and cools the heat-soaked air of the noon day sun the source of temperatures over 100 F. in June, July, August, and September. The Canyon winds blowing through the leaves of these living cathedrals create a pleasant and soothing tree whisper. Each fallen cottonwood moves the chorus ever closer to an unnatural silence for Zion Canyon. The shade and the sound of the wind through the leaves makes visiting Zion Canyon in the intense heat of the summer bearable. The bright yellow cottonwood leaves of fall make an autumn visit unusually glorious and picturesque. But more importantly as the generation of trees that propagated during the wet years of the early 20th Century falls, there are few if any to take their place in the native riparian forest (see Figure 5-3).

The soft sandy riverbanks once nurseries for young cottonwood trees now lie hidden under tons of rock and wire. For most of the length of Zion Canyon the Virgin
River flows well below its floodplain straight rather than sinewy. Its streamflow stays obedient within its rock lined narrow course. With such confined geomorphology the river is deprived of giving its water to the surrounding floodplain which would nourish and nurture multi-aged riparian Fremont cottonwood forest and other native flora and fauna of Zion Canyon (see Figure 5-30).

When the pluvial of 1905-1922 brought clouds a plenty, they did burst their invisible seams, sending drenching rain into the stonewalled nooks and canyons of the Virgin River drainage. High water came rushing down the river worrying: Engineer Hunlly (1923), Kitteredge, (1928), Scoyen, (1929b, c), Allen, (1931), Patraw, (1932a) that the flatlands in Zion Canyon would wash away and with it any infrastructure that was on these acres. After the increased precipitation and climate change of 17 years, dryer conditions slowly returned throughout the Southwest and Zion Canyon. It took a flash flood in 1929 to activate the building of flood protection in Zion Canyon. Soon thereafter under the whispers of the Fremont cottonwood trees, the sound of the steam shovel could be heard chugging up the Zion Canyon Road. On its heels, came the thud of the boots of the men in the Civilian Conservation Corps, who would do the work of channeling the Virgin River (see Figures 5-4, Figure 5-5).

Understanding the relationship among factors governing the health and success of cottonwood riparian forests will be discussed in this section. Factors such as: seed propagation resulting from a combination of wind and water seed dispersal, the physiology and limitations of the cottonwood propagule, the conditions of the substrate necessary to support germination of the propagule, the supply of moisture provided by streamflow and the relationship of floodplain architecture and human intervention all
combine to affect the health of the Fremont cottonwood riparian forest.

**Figure 5-3**

_Fremont Cottonwood in Zion Canyon, 2019_

Source: Corr (2019)
Figure 5-4

Armored Bank of the Virgin River in Zion Canyon, ZNP 1930-1934

Source: Box 15450, Zion National Park Archives.
Figure 5-5

CCC Work on Revetments for the Virgin River in Zion Canyon, ZNP

Source: Box 15450, Zion National Park Archives
Virgin River Riparian Zone

Riparian zones are unique aquatic ecosystems that include the lands bordering rivers and other bodies of surface water. Also included in the riparian zone are the floodplains and surrounding lands that act as buffers to the floodplain. Fluvial and upland geomorphic activities fashion riparian zones resulting in spatially and temporally dynamic regions that link terrestrial and aquatic environments. In semi-arid and arid landscapes common in the west and Southwest of the United States, and present in Zion Canyon, riparian zones function as a remarkable feature of the environment containing substantial biodiversity (Auble et al., 1994).

The importance of riparian zones has been well established scientifically. Even though small in areal extent, riparian zones provide critical flora and fauna habitat as well as essential human recreational areas. Riparian shrubs and forests provide structural habitat that foster biological diversity. Numerous species of birds, mammals, reptiles, bats, fish, and insects find essential moisture and nutrition in the varying moisture gradients moving across the riparian landscape. Riparian ecosystems also regulate freshwater quality and quantity as well as a range of human economic opportunities (Arthington et al., 2010; Auble & Scott, 1998; Rood et al., 2003).

Traditional riparian vegetation in the American Southwest consists of cottonwood trees (Populus), willows (Salix), salt cedar (Tamarix), arrowhead and seep-willow, rushes, sedges, watercress, and cattails (Scott et al., 1994a; Utah State Water Plan, 1993). Vegetation found in the riparian zone plays many roles in the ecosystem: creating habitat, dictating species composition of fish and birds, their population size, providing available nutrients for the ecosystem, and moderating the thermal input of the sun (Utah State
Water Plan, 1993). In Zion Canyon, the Virgin River riparian zone impacts the quality of the habitat of several federally endangered species including the southwest willow flycatcher, and several freshwater fish species: the Virgin River spinedace, the wound fin minnow, and the Virgin River chub. (Fridell, 2003; Utah State Water Plan, 1993; Zion National Park, 2001). It is important to note that the 1993 Utah State Water Plan for Kanab Creek/ Virgin River is the most recent state water resources plan for this drainage as of 2021.

Of Zion National Park’s six habitat zones, the riparian zone consists of less than five percent of the land area yet contains over 80 percent of the plant and wildlife diversity (Utah State Water Plan, 1993). Within the front country of Zion National Park, the riparian zone is adjacent to the Virgin River and extends 9 miles within Zion Canyon. This 9-mile riparian ecosystem forms the focus of this dissertation and discussion of riparian zone form, function, flora, and fauna. The riparian zone extends beyond Zion Canyon and accompanies the Virgin River from its origin in Navajo Lake, 50 miles north of Zion Canyon, to its meeting with the Colorado River at Lake Mead another 110 miles further south and west from Zion Canyon.

The composition of riparian habitats changes as the Virgin River runs through changing geological formations and climate bands, notwithstanding; “Riparian zones are among the most ecologically productive and diverse terrestrial environments by virtue of an extensive land-water ecotone” (Naiman et al., 1993, p. 209). An ecotone is a transition boundary between two biological systems in this case, water, and land, allowing for two biological communities to integrate. Dynamic river changes allow for the intermingling of land and water ecosystems, which result in varied moisture gradients that create
distinct physical environments, which in turn form a mosaic of habitats within the riparian zone (p. 209).

The annual precipitation in the region of Zion National Park is less than 15 inches per year and the temperatures in summer consistently reach over 100 degrees Fahrenheit. Additionally, over 5 million visitors a year come to hike and recreate in the riparian zone of Zion Canyon, which comprises the centerpiece of Zion National Park (Zion National Park, 2017). The waters of the Virgin River allow for and nurture a diversity of species within the surrounding arid landscape of southern Utah.

**Fremont Cottonwood: Importance in the American Southwest**

The importance of the riparian woody species Fremont cottonwood (Populus fremontii) cannot be underestimated. Many plant biologists consider Fremont cottonwood (Populus fremontii) to be the most important cottonwood tree species of the Southwestern United States. Often, it is the only tree species in the desert riverine system, therefore; many species of flora and fauna are dependent upon this tree for their existence (Young & Clements, 2003). McShane et al. (2015) indicate the importance of Fremont cottonwood vegetation to the Southwestern United States. They maintain: Fremont cottonwood (Populus fremontii) is found along rivers in semi-arid and arid regions (drylands) of the western United States where it acts as a foundation species, that is, it defines floodplain forest structure and controls ecosystem dynamics.

Riparian forests in the Southwest have been declining due to flood control, grazing, diversion of water to agricultural uses, insect infestations, and competition from exotic plant species, especially salt cedar (Tamarix ramosissima Ledeb) and Russian
olive (Elaeagnus angustifolia). As a result, the lack of Fremont cottonwood seedling recruitment is of concern in many areas of the Southwest.

**Important Factors in Fremont Cottonwood Seed Propagation**

Young and Clements (2003) stress the importance of seed physiology and dispersal in the cottonwood germination process as a necessary first step in understanding the health, management, and restoration of the cottonwood riparian forest (p. 661). The phenology of the Fremont cottonwood tree is highly tuned to the seasonal and interannual variations in climate and river streamflow within the riparian ecosystem. Cottonwoods are dioecious having both male and female reproduction in separate individuals. They have developed a reproduction strategy in which females release prolific amounts of seeds but, the lightweight seeds contain minimal nutrient resources limiting the time in which the cottonwood propagule is viable (see Figure 5-6).

**Figure 5-6**

*Fremont Cottonwood Seeds*

Source: Corr (2020)
The wind disperses cottonwood seeds in mid-May, which look like tiny wisps of cotton (see Figure 5-6). The seeds fly like snow and attach themselves to everything. They find their way into cracks along the edges of sidewalks and driveways, between piles of rocks, inside shoes, on car mats, stick to screens, and hair. The tiny wisps collect into threads that twist into soft seed strands that resemble “cotton.” The seeds thrive and often germinate in bare moist sandy soils, in cracks between garden walls, at driveway edges as well as in niches or edges wherever moisture may collect.

Length of daylight, which is constant at a given site across long spans of time, partly determines cottonwood seed release. Temperature also affects seed release and the duration of seed dispersal, which typically occurs over one month. The Fremont cottonwood tends to inhabit warmer areas in the Southwestern United States, resulting in the release of its seeds sooner than other western cottonwood species (Mahoney & Rood, 1998, p. 637). Cottonwood seed has almost 100% viability but the ability to germinate is limited to a short timespan between one to four weeks. Young and Clements (2003) emphasize the relationship between cottonwood seed size and viability. They concluded:

The lack of detailed seed physiology research on seeds of Fremont cottonwood is partially a function of the short viability period of the seeds. In laboratory storage, seeds of Fremont cottonwood lost all viability after 7 weeks (Horton et al., 1960 as quoted in Young and Clements, 2003). In commercial forest tree nurseries, cottonwood seeds were reported to have markedly reduced emergence if planting was delayed 2 days after harvest (Engstrom [1948] as quoted in Young & Clements, 2003, p. 661).

**Fremont Cottonwood Propagation Relationship to Streamflow**

John Mahoney and Stewart Rood (1998) researched cottonwood propagation and found that the short period of viability of cottonwood seeds “defines the period for cottonwood seedling establishment… thus, a model describing stream-flow requirements
for cottonwood seedling establishment begins with a temporal framework related to cottonwood phenology” (p. 637). In other words, for the best chance at germination, the release of cottonwoods seeds is timed to spring streamflow levels in the Southwest of the United States. This phenomenon highlights the importance of seasonal climate patterns on successful cottonwood propagation. During years of increased precipitation, the chances for increased cottonwood recruitment may be higher due to increased moisture in the soil over longer periods in the spring.

Cottonwoods are a primary succession species of the floodplain forest in the Southwest: therefore, they have a direct and correlating relationship with the water source of the riparian system in which they grow. Fremont cottonwood are phreatophytes. These are plants, whose roots are constantly in touch with moisture. This can be either surface water or water from a constant source above or under the ground. Impacts on riparian ecosystems affect this species in particular because reproduction requires bare moist soils, elevated and distant enough from the channel to be safe from channel scour (Auble & Scott, 1998; Friedman, 1995; Scott et al., 1999).

McShane et al. (2015), explain that it is important to understand the relationship between physical and ecological factors such as climate, river flow, floodplain geometry when evaluating cottonwood seed dispersal and recruitment. They noted that “patterns of establishment in any year are influenced by flow timing, magnitude, and duration as well as channel geometry and weather” (p. 1254).

Mahoney and Rood (1998) discussed the conditions for and the survival rate of cottonwood seedlings. Their observations identified the intimate relationship between cottonwood seedlings and sources of water, especially in the first months and year of
germination. Survival of seedlings in the first year is rare due to drought stress, receding streamflow and water table levels. The success of cottonwood seedlings appears to be determined by the ability for the seedling roots to maintain contact with the receding moisture zones as summer comes on. Mahoney and Rood observed that cottonwood “root elongation is typically 1cm per day or less and that many seedlings can survive water table decline rates of 2 to 4 cm per day…The presence of a moist zone remaining temporarily above the receding water table may explain the difference between root growth rate and survivable water-table-decline rate” (p. 641).

The timing of cottonwood seed release and the pattern of stream stage change are intricately linked and must coincide for cottonwood seedling survival. Mahoney and Rood’s observations revealed this relationship:

The stream stage should be declining to expose saturated sites for initial seedling establishment during the period of seed dispersal (mid-June) (mid-May for the Fremont cottonwood). Ideally, streambanks between 0.6 and 2.0 m above the base stage should be exposed at this time. Subsequent gradual stage decline of less than 2.5 cm per day should permit seedling survival, with improved health and survival accompanying more gradual rates of stage decline…The annual peak flow has passed prior to the onset of seed release, and the river stage is declining rapidly. The river-stage decline exposes new areas for seedling establishment over a range of elevations. The rate of river-stage decline affects cottonwood seedling establishment. Seeds germinating at the start of the period of seed release will have a low probability of survival due to high rates of river stage decline that will contribute to drought stress and mortality. Seeds germinating at the end of the seed release period will also have a low probability of survival due to mortality from ice scour and subsequent flooding. (p. 642)
Therefore, successful cottonwood recruitment depends on timing of release being in the middle of the seed dispersal period and at an elevation to escape both drought in the initial months of life, and then subsequent precipitation events from summer monsoons or winter flooding or freezing.

Mahoney and Rood were systematically searching for a streamflow stage pattern and an elevation pattern that could support cottonwood recruitment for the purpose of restoration. They called their findings, “the cottonwood recruitment box model” (see Figure 5-7). Due to the complexity of factors at any site, developing a common reference stage would be difficult but they were able to recognize consistent over-arching patterns in eight sites especially in reference to successful elevations for recruitment which were
about 60-150 cm above base flow. Additionally, they noticed that abrupt flow fluctuations, unless mitigated by multiple tributary flows, contributed to seedling death. This observation illustrates the long-term evolution of cottonwood recruitment with the natural braided multi tributary geomorphology of the Southwestern rivers. My research at the Union Pacific Railroad archives found photographs of the Virgin River in its natural state with braided channels (see Figure 5-8, 5-9).

This geomorphology allowed protection from flood scour and access to numerous moisture gradients which engendered Fremont cottonwood propagation and recruitment in Zion Canyon in the time before Zion Canyon was managed by the National Park Service. Another unintended consequence of the channeling of the Virgin River, resulting

**Figure 5-8**

*Multiple Channels of the Natural Floodplain of the Virgin River Before Armoring*

Source: Union Pacific Railroad Museum 1910-1928
from the removal of all secondary and tertiary river channels, was less protection for Fremont cottonwood seedlings. In a single river channel, there would be increased volume and speed of streamflow offering no protection for Fremont cottonwood seedlings. This is another factor that has affected Fremont Cottonwood propagation since the Virgin River was armored with revetments 1930-34.

Mahoney and Rood (1998) also realized that seedling recruitment “is episodic and relatively rare even in free-flowing streams” (p. 635). What has been concluded not only by Mahoney and Rood but by other researchers is that these recruitment episodes tend to derive from flood events. They believe that moderate to large “flood events enable cottonwood seedling recruitment both through geomorphic impacts and direct hydrologic patterns (p. 635). Correlations between dendrochronological studies of cottonwood recruitment years with high stream flows have consistently indicated that a “1 in 5 to a 1 in 10-year overflood event is associated with cottonwood recruitment” (Mahoney & Rood, 1998, p. 635). Moderate to large flood events cause unique erosion and deposition that create bare moist soil sites above traditional seasonal patterns of streamflow that become nursery sites favoring cottonwood seed establishment. There may even be huge fluvial-geomorphic changes that create sites for cottonwood recruitment both through that only occur as a result of extreme flooding in areas often slightly higher or more distant
Figure 5-9

Braided Channels of Virgin River Covering Floor of Zion Canyon

Source: Union Pacific Railroad Museum circa 1910-1928
patterns (p. 635). Correlations between dendrochronological studies of cottonwood recruitment years with high stream flows have consistently indicated that a “1 in 5 to a 1 in 10-year overflood event is associated with cottonwood recruitment” (Mahoney & Rood, 1998, p. 635) (see Figure 5-10).

Moderate to large flood events cause unique erosion and deposition that create bare moist soil sites above traditional seasonal patterns of streamflow that become nursery sites favoring cottonwood seed establishment. There may even be huge fluvial-geomorphic changes that create sites for cottonwood recruitment that only occur as a result of extreme flooding in areas often slightly higher or more distant from normal main channel streamflow levels. Previous cottonwood recruitment due to a large flood event is

**Figure 5-10**

*Site 1: Example of the 1 in 5 to 1 in 10-year Overflood Cottonwood Propagation*

Notes: Thicker trees propagated after the 2005 Virgin River high streamflow; thinner trees propagated after the 2010 Virgin River high streamflow. Source: Corr (2021)
often seen in groups of older cottonwood trees that grow at higher elevations more distant from the main channel or in bands of young cottonwoods all the same age (Friedman et al., 1996; Kalischuk et al., 2001; Rood et al. 1998; Stromberg et al., 2007).

This pattern of older cottonwoods being more distant from the present streamflow can be seen along a small tributary of the Virgin River in the ZNP Coal Pits Wash.

**Figure 5-11**

*Site 2: Coal Pits Wash*

Notes: Old cottonwoods in foreground younger in background. Source: Corr (2021)

cottonwood riparian forest 7.3 miles west of the ZNP South Entrance Station along route 9, which I call Site 2 (see Figure 5-11). This pattern of groups of older cottonwood trees being further back and away from the main streamflow channel can also be seen in parts of Zion Canyon outside of the ZNP boundaries such as the Springdale Town Park, where the available space is compressed but the pattern remains (see Figure 5-12).
Fremont Cottonwood Propagation Relationship to River Geomorphology

The typical southwestern river geomorphology consists of a main channel and shallower rivulets of water winding back and forth in a braided pattern. Main channel streamflow levels are often contingent with the riverbank edges and at times shallow yet flowing. Secondary channels lay adjacent to the main river channel providing varying degrees of moisture via slower river flow rates and varying water table levels. These channels also offer protection for riparian vegetation by sheltering seedlings from seasonal flood scour. Snow melts and summer monsoon showers in undammed rivers

Figure 5-12

*Old and Young Cottonwoods Along the Virgin River. Springdale, UT Town Park*

Source: Corr (2021)
such as the Virgin River affect streamflow rate directly. These secondary and tertiary channels (see Figures 5-8 and 5-9) become ideal substrates for the germination of cottonwood trees, the primary riparian forest species in the Southwest (Scott et al., 1994b).

This streamflow pattern varies daily leaving changing areas of bare substrate, one of the mosaic habitats in the land-water ecotone of the riparian ecosystem. Kenneth Asplund and Michael Gooch (1988) rejuvenated the ecological concern for understanding the important ecological relationship between river geomorphology and cottonwood vitality. Their research explored the link between geomorphology and a healthy riparian cottonwood forest. They concluded:

The importance of the secondary channels for the survival of stands of cottonwoods cannot be overstated. The importance lies in the fact that the secondary channels provide reliable water at all times of year, while providing various degrees of protection from scouring during flooding, depending upon distance from channel constraints. (p. 22)

In Zion Canyon the germination of cottonwood seeds can be seen in early summer in the intermittent sandbars of the Virgin River in stretches of the river where revetments have fallen or in the process of falling away. The seedlings on these sandbars reside in the center of the river at low early summer streamflow levels. Few if any of these sprouting seedlings survive to become a member of the cottonwood population, a stage of plant growth defined as “cottonwood recruitment,” Summer monsoon higher stream flow will rip them from the sandbars in the middle of the river. Asplund and Gooch (1988) described the requirements for successful cottonwood recruitment:

While germination in cottonwoods is relatively widespread, populations that show recruitment are most common where there is aggradation of materials derived from upstream degradation and erosion. Particularly important are secondary and tertiary channels, abandoned by braiding and channel shifting, where subsurface
water is reliably present and maximum protection from scouring is afforded. (p. 25)

Muldavin et al. (2017) also noticed the importance of natural flood debris and woody material on the successful germination of cottonwood seeds. They observed:

A surprise came in the New Bar Zone where sediment accumulated naturally. Herbaceous communities quickly became established followed by dense willow shrublands intermixed with cottonwood saplings established from seed, and now tall (10 m+) cottonwood stands dominate these sites after only ten years (the trees in the New Bar Zone are taller than those on the older Lower Bar Zone). This was an unplanned outcome of the project, which bolsters the concept that having large woody debris available in large river systems is a key element for successful restoration and supports the idea that the more natural the configuration in restoration efforts, the better. (p. 349-350)

The death of cottonwood seedlings is due primarily to the lack of moisture or to flood scour in the following summer monsoon or winter season. Secondary and tertiary river channels create pockets of protection for seedlings during flood scour and pockets of moisture during the crucial period about a month after germination when tiny fragile root fibers are using the water table to grow. Lack of moisture due to low river flow and lower water tables also cause cottonwood seedling mortality. These conditions occur in the early summer after the snow melts in early spring has passed and the harsh heat of June and early July begins to bear down on the seedlings. Mortality rates are high during this time and remain such until the monsoon rains of July and August arrive, if indeed they do come. In 2019 and 2020 the Monsoons did not arrive. There was a 150-day five-month drought from June until November 2019. Once again in 2020 the monsoons did not arrive in the summer months in southern Utah prompting the newly 2020 elected Utah governor, Spencer Cox, to initiate water conservation measures and drought regulations limiting lawn watering in early 2021. The summer monsoons returned with full force in late June, July and August of 2021 causing flooding in numerous sites.
throughout Utah. But these precious rains are not enough to ease the underlying drought conditions in the arid lands of Utah in 2021. It is also unlikely that these summer floods will initiate much cottonwood propagation because they are occurring three months after the Fremont cottonwood seeds have fallen. As mentioned, earlier cottonwood propagule viability on average is four weeks-seven weeks (Young & Clements, 2003). However, nature is resilient with room for unique occurrences. In the landscaped area outside of my apartment there is a 4-inch-high August seedling that has sprouted due to the intermittent monsoon rains falling in the summer 2021.

**Changes in the Virgin River Geomorphology in Zion Canyon**

The Virgin River geomorphology originally displayed the natural channeled geomorphology of a southwestern river. Photos of Zion Canyon from the Union Pacific Railroad archives clearly indicate this natural braided geomorphology (see Figures 5-8, 5-9, and 6-1). However, when the National Park Service took over ownership of the Virgin River Canyon in 1909, and resource management began in earnest in the late 1920s, in a span of about 15 years, almost all the secondary and tertiary channels of the Virgin River were eliminated. Moved to the western edge of the canyon, only one main channel of the Virgin River remained with raised riverbanks no longer composed of deep sands or contingent with the river’s water level. The National Park Service replaced the perennial ecologically sound braided river geomorphology with a single channel geomorphology bound by iron cages called revetments filled with rock that had been dynamited off the top of the sandstone Mesa tops in Springdale (see Figure 5-13, A). These cages implemented to hold the river into a single channel were then covered with soil to hide their metallic and unnatural façade (see Figure 5-13, B). In some places young
cottonwood trees transplanted from the original riparian forest were replanted on top of and within these manufactured riverbanks when backfilling was added to the revetments (see Figure 5-13, C) (Patraw, 1932a, b).

Young cottonwoods depend on shallow water tables. David Cooper, David Merritt, Douglas Anderson, and Rodney Chimner (1999) found that in a seedling’s third or fourth year, the budding cottonwood taproot begins to draw from the water table. If the flood plain were elevated well above the river, as it is in the areas of the revetments in Zion Canyon, seedling survival rate would be lowered. If deterrents to cottonwood recruitment are mitigated the question arises as to what conditions would support spontaneous Fremont cottonwood recruitment. Research points to the importance of geomorphologic-hydrologic conditions in riparian habitats as controlling safe sites for Fremont and other cottonwood species seed germination and seedling establishment (Scott et al., 1994b; Young & Clements, 2003).
Figure 5-13

Construction of Revetments

Notes: A: dynamiting the West Rim Mesa tops in Springdale for rock to fill iron cages of revetments. Close up of revetment. B. River is lower than riverbank and removed from the flood plain. See extension of revetment into ground on left. This area was covered with dirt to look natural. C: Cottonwood tress transplanted from forest into back fill of revetment at Temple of Sinawava.
The cottonwood floodplain forest structure is a mosaic of various aged isochrones, a series of parallel bands of equal age trees, growing in spatially distinct lines (see Figures 5-14, 5-15). The term isochrones derive from the Greek “iso” meaning “equal” and “chrones” from Greek “Khranos” meaning “time," Another name.
for the isochrone spatial pattern is the term “banding.” In undisturbed riparian ecosystems cottonwood trees tend to naturally grow in age related bands with younger
trees growing close to primary or secondary river channels because “floating seeds deposited directly along the stream edge are deposited in bands of constant elevation” (Mahoney & Rood, 1998, p. 636).

These time and age-related bands of cottonwood trees tell a story of streamflow levels and the rate of their receding levels over time. Older trees tend to grow on upper terraces distant from present river channel edges. Trees of middle age lying between the older trees and the youngest saplings, which stand closest to the present streamflow (see Figure 5-15).

Any of the isochrones can reveal signs of former spring flood levels that may have occurred during or shortly thereafter the spring seed dispersal period. Older cottonwood isochrones can indicate river geomorphology movement from a former channel of the river and or these older cottonwood trees can indicate previous flood levels. Seeds may land on higher flood water. The seeds will be dropped onto moist stream edges as the river levels recede. This process explains some of the common banding in riparian forests. The isochrones are the result of “moist sites occurring at specific elevations paralleling the receding stream, and thus, seedlings are more likely to survive in bands indicating receding soil moisture at the time of seed propagation” (see Figures 5-14, 5-15, 5-16, and 5-17) (Mahoney & Rood, 1998, p. 636).

The constraining of the Virgin River into a single narrow channel and the removal of almost all secondary and tertiary channels of the Virgin River in Zion Canyon have amplified the conditions that add to seedling mortality in Zion Canyon, and therefore the loss of cottonwood recruitment (Scott & Auble, 1996) in Zion Canyon. Herein lies the
essence of the need for restoration of the Virgin River. Without the constantly changing river geomorphology the bare yet periodically moistened substrate needed for cottonwood propagation is not created. The revetments that line the Virgin River deny the river its historic dynamic change and therefore the opportunity to create micro-habitats (ecotones), without which cottonwood seeds cannot grow and mature.

**Figure 5-16**

*Site 1: 2-3-Year-Old Cottonwood Isochrone*

Source: Corr (2021)
Assessing Signs of Cottonwood Decline in Zion Canyon

Fremont Cottonwood trees live to be about 120-140 years old. In the late 1990’s employees from the Resource Management and Research Division at Zion National Park observed a lack of young members of the Fremont cottonwood species in the riparian forest floor of Zion Canyon. An internal Zion National Park project proposal states that, “since the elimination of the flooding, due to channel-bank alteration in the 1930s, the cottonwood trees have not reproduced successfully with the consequence that the youngest trees are about 60-70 years old” (ZNP Proposal quoted in Steen 1999, p.1). “since youngest trees are about 60-70 years old” (ZNP Proposal quoted in Steen 1999, p. 1).

A survey of the ZNP floodplain forest structure provides a spatial and age-related analysis of the effect of armoring of the Virgin River channel. Cottonwood isochrone

Figure 5-17

80–90-Year-Old Cottonwoods in Zion Canyon

Note: There are no young cottonwood trees or diverse aged cottonwood trees. Source: Corr (2019)
bandings are evidence of a healthy riparian ecosystem. Cottonwood isochrones are groups of cottonwood trees that occur in horizontal strings of trees that are near the same age. In the area of Zion Canyon within Zion National Park most of the isochrone banding is not visible. This is in part due to the major removal of the original riverbanks through much of the nine-mile canyon for flood control during the revetment building period from 1930 through the 1934. In the area of channel constraint, the depth of the North Fork Virgin River channel averages 10-20 feet deep. The river has steep banks, no longer meanders, and rarely overflows its banks. More importantly there are few young cottonwood trees near the edge of the Virgin River stream channel.

The Virgin River floodplain in Zion Canyon stands elevated and removed from the river. It contains two broken isochrones of aging cottonwoods. Trees near the age of 80 years old form one isochrone and can be found between 25-100 feet from the river channel. These trees were either planted during the revetment period or remained undisturbed young trees during this period (see Figure 5-17).

Another isochrone of gnarled and older cottonwoods stands more than 150 feet from the river at the edge of the road and near the canyon walls. There are no isochrones of adolescent or young adult trees. I surveyed the channeled portion of the river in May 2006 and counted fewer than ten established cottonwood trees between the ages of 5 and 30 years old and recently in October 2020, the results were a bit better 20-30 young cottonwood trees along the Virgin River banks in Zion Canyon. However, this situation in no way resembles a healthy Fremont cottonwood forest of dense young and multi-aged cottonwood trees.
Healthy Stretches of Fremont Cottonwood Forests in Zion Canyon Outside of Zion National Park

Present day healthy cottonwood banding in the Virgin River riparian ecosystem can be seen in three sites that I have been observing for several years. Two sites are outside of the Zion National Park boundaries, with one site in Zion Canyon and the other 2 sites within 8 miles of the South Entrance Station to ZNP. Site 1 is near the south boundary of the town of Springdale, UT within Zion Canyon yet outside of the nine-mile front country of Zion Canyon in Zion National Park. It is only 2.9 miles west of the South Entrance Station of ZNP and about 5 miles from where Virgin River channeling begins in This Site 1 begins behind the lower units of the Majestic Lodge adjacent to the Virgin River on the south side of Utah Route 9. This site is also at the east boundary of Paul Allen’s 2000-acre property formerly called Tree’s Ranch. A healthy Fremont Cottonwood Forest thrives at Site 1 with numerous densely packed adolescent and young adult Fremont Cottonwood trees. This healthy forest is adjacent to the sandy natural state Virgin River stream edge. Most of these saplings are about the same height and width and the same age. In the winter of 2010 stream flow in the Virgin River ran high with flooding occurring intermittently between Springdale and St. George. These trees have the structure and height of ten-year-old Fremont cottonwoods and are likely the result of the high water in 2010. This riparian area has escaped the recent onslaught of development in Springdale and Washington county because it was purchased by Paul Allen in 2015. The surface of the riverbanks is sandy and level with the Virgin River streamflow. The banks are covered with random pieces of driftwood and layers of cottonwood leaves from previous autumn foliage. The dense young forest represents a
delightfully wild natural riparian area of the Virgin River so close to development and to Zion Canyon in ZNP! (see Figure 5-18).

**Figure 5-18**

*Site 1. Healthy Multi-Aged Cottonwood Forest on the Virgin River with 10-Year-Old Trees from 2010 High Streamflow*

Source: Corr (2020)
Site 2 is Coal Pits Wash which stands within the ZNP boundary 7.3 miles from the ZNP South Entrance Station (see Figure 5-11). Here a healthy riparian Fremont cottonwood forest can be seen in the traditional ecotone arrangement with young trees closer to the stream edge middle-aged and older tress further away from the center of the stream.

In searching for undisturbed stretches of the Virgin River I found Site 3 (see Figure 5-19), which is 7.9 miles west on Route 9 from the South Entrance Station of ZNP. This stretch of the Virgin River flows just outside the National Park boundary between Rockville, UT and the town of Virgin, UT. In this section of the river channel, the Virgin River maintains this natural S curve morphology, soft sandy riverbanks, with river level contiguous with the sulfured colored riverbanks. Additionally, the sand at this stretch of the Virgin River extends about 100 feet into the flood plain and is so deep that it resembles the beaches at the ocean side and the descriptions of the Virgin River found in the Superintendent Annual Reports of the late 1920s before revetement building began.

Not surprisingly this stretch of the Virgin River’s sandy riverbanks and floodplain contain hundreds of juvenile cottonwoods. In Site 3, adjoining a free-flowing Virgin River numerous bands of similar aged cottonwoods stand in rows differentiated into parallel lines or bands by age with the youngest saplings often closest to the river’s edge. However, at Site 3 there are ecotones of young trees farther away from the river’s edge where flood waters would have reached. Young cottonwood tree isochrones are not presently observable anywhere in Zion Canyon. Yet in this short stretch of the Virgin River designated Site 3, resides a living portrait of what administrators likely found in the upper areas of Mukuntuweap Canyon when the canyon became Zion National Park.
Figure 5-19

Site 3: Eureka! A Living Portrait of a Healthy Fremont Cottonwood Forest Along the Virgin River

Note: This landscape is similar to historic descriptions of the Zion Canyon riparian ecosystem. Source: Corr (2021)
This portion of the river between Rockville and Virgin resembled all the descriptions of Zion Canyon as documented and seen from the eyes of the original inhabitants, early visitors, and administrators as described in Chapters 3 and 4. I was thrilled to come upon this stretch of the Virgin River because it gave me the experience that people one hundred years ago had when visiting the Canyon. A living vision of a healthy riparian zone along the Virgin River also provided hope that the Virgin River in Zion Canyon might someday return to its healthy natural state.

Each of my monitored sites clearly display traditional healthy southwest river riparian zones. Each can serve as an example of what restoration of the floodplain in Zion Canyon would resemble. These sites serve as living portraits of what a healthy riparian one in Zion Canyon could once again achieve. These sites provide healthy examples and a goal to aim for in restoration of the flood plain in Zion Canyon.

Assessing Cottonwood Decline by Comparison of Zion Canyon with Parunuweap Canyon

Michelle Steen (1999) compared Fremont cottonwood trees growing along the North Fork of the Virgin River in Zion Canyon with Fremont cottonwood trees growing along the East Fork of the Virgin River in Parunuweap Canyon. Steen compared the cottonwood trees in Zion Canyon where flood control revetments had been installed with the Fremont cottonwood trees on the East Fork of the Virgin River, where no human flood control intervention had occurred. Human intervention has constrained the North Fork of the Virgin River while the East Fork of the Virgin River has remained wild.

Parunuweap is a sister canyon parallel and directly east of Zion Canyon. The geomorphology and ecology of the North Fork and East Fork of the Virgin River are similar and allow for comparative analysis of the Fremont cottonwood. The two forks
share similar alluvial and geomorphic histories (Hereford et al, 1995). Ecologically the two forks share many riparian species in common including herbs, shrubs, and trees (Taylor, 1989). The two canyons have some variations to be considered when comparing them, such as: higher temperatures, lakebed sediments only in Zion Canyon, different channel size, and aspect. Steen compared cottonwood density, cottonwood size, and direction of cottonwood vegetation change between these two similar canyons.

Steen found that the East Fork of the Virgin River flowing through Parunuweap Canyon maintains a much more stable community of cottonwoods with few gaps in age classes (Steen, 1999, p. 68). This pattern of continuous aged trees located in bands of similar aged trees at similar distances from channel edge indicates a traditional pattern of isochrones of cottonwood forest growth. The pattern resembles younger trees growing in isochrones close to the channel edge, middle-aged trees growing further away from the channels edge, and older larger cottonwood trees located farthest away from channel edge and streamflow. Steen’s research (see Figures 5-20-23) found that:

Cottonwood density was significantly higher on the East Fork than on the North Fork, when comparing trees growing in transects with revetments to trees in transects without revetments. The analysis of data for trees located near to the channel edge (0-20 meters) showed that tree size does differ statistically between the two river forks as well. Channel edge trees growing on the North Fork are larger on average than those of the East Fork, indicating that the population is generally older. (Steen, 1999, p. 68)

Steen also found that on the East Fork in the distance 0-20 meters from channel edge there were more young trees in the banding and ecotone pattern known to indicate healthy riparian cottonwood forest recruitment.

Steen had a surprising result when she measured cottonwood density limited to the North Fork. She measured cottonwood density in transects behind solid and
continuous revetments and the transects behind deteriorating revetments. She expected
the density to be lower behind the solid and continuous transects, but what she found was
that the cottonwood density was higher behind the solid and continuous revetments.
Although Steen had reasonable explanations for this higher density found behind the
solid and continuous revetments there is another explanation that she may not have
known about, that I discovered in my archival research at ZNP.

The photo in Figure 5-24 is from the 1934 Superintendent Annual Report by P. P.
Patraw and taken at the Temple of Sinawava. The photo depicts an example of one of the
references I found indicating transplanting of cottonwood trees in Zion Canyon. It was
part of the revetment engineering to transplant cottonwood trees behind revetments in dirt
placed as backfill to add support to the rock-filled wire cages composing the revetments.
On the left side of the photo behind the new revetment stand at least ten sapling
cottonwood trees. Trees of this height are usually between 7-9 years old and have
developed a tap root increasing their survival rate. The main stem is flexible, and these
trees can survive transplanting if there is sufficient sunlight and moisture. Usually for
these transplanted trees both sunlight and water were available. Sunlight was ample
because to build the revetments huge earth moving had taken place at the river’s edge
creating wide open areas in which sunlight at least in the middle of the day would reach
the canyon floor. Also, once the river water was released to flow in the new channel the
water table would rise and since trees of this age had taproots they would usually survive.
Figure 5-20

*Cottonwood Density Virgin River*

Source: Steen (1999)

Figure 5-21

*Cottonwood Density With and Without Revetments, Virgin River*

Source: Steen (1999)
Figure 5-22

*Histogram of Tree Size, Virgin River, Comparing North Fork to East Fork*

Note: These are 20m x50m2 transects. Source: Steen (1999)
Figure 5-23

Comparisons of Cottonwood Density, North Fork of the Virgin River, With and Without Revetments

Source: Steen (1999)
It is important to note that many of the cottonwood trees in Zion Canyon in 2019 are likely these transplanted cottonwood trees. This pattern is readily observed between the west side of the Zion Canyon along the road and the east bank of the Virgin River in the area of Birch Creek, the Court of the Patriarchs Shuttle stop, north to the Zion Lodge riverbank and shuttle stop. Then again north to the Grotto shuttle stop and riverbank continuing north to Big Bend shuttle stop. Most of the cottonwood trees along the east bank of the Virgin River are all the same age, looking as if they were in an urban park lacking any underbrush and most are behind revetments. It is likely that most of these

**Figure 5-24**

*Transplanted Cottonwoods, Temple of Sinawava, 1934*
Fremont Cottonwoods were transplanted when the revetments were completed as part of the landscaping or were far enough away from the river construction that they were a part of the native Fremont cottonwood forest.

Another mention of tree planting is from Superintendent Scoyen’s December 1928 ZNP monthly report (1928d). Superintendent Scoyen writes,

In the public auto camp we have been trying for several years to build up a growth of nice trees in order that we may extend the campgrounds to handle the increasing number of campers. This little animal (gopher) has been consistently destroying some of the trees planted. He has also destroyed trees planted by the Union Pacific around Zion Lodge. (p. 3)

Statements and actions by early Superintendents reveal the protective attitude that early Superintendents had for the riparian forest in Zion Canyon. Their statements also validate their recognition of the status of the Fremont cottonwood tree as the major riparian forest tree specie in Zion Canyon that needed protection from gophers, porcupines, and insects. The vast, wild, and beautiful forests of the west including the Fremont cottonwood forest in Zion Canyon and throughout the Southwest were an essential componenet of the lore that attracted Roosevelt and Muir to work for their protection. Decisions such as those: to transplant trees, and then seek and receive funding to limit insect infestations indicate the value that the early Superintendents placed on the trees as an essential part of the beauty and peacefulness of the Zion Canyon. These qualities were inherent in the purpose set forth for the National Park Service. More particularly Cottonwoods are tall trees. Their height and shade became attractions for tourism, recreation, and personal restoration in the new Zion National Park. The Fremnot cottonwood trees were fundamental to the visitor experience in ZNP and needed to be
protected and preserved. These trees need even more preservation, protection and restoration in 2021.

On several occasions in the ZNP archives in the Annual or Monthly Reports written by the Superintendents of Zion National Park, these men mentioned containing insect infestations in the ash and cottonwoods trees by spraying the trees with insecticide. This would have helped young, transplanted trees to survive infestations. Following are excerpts taken from the archives that indicate measures taken to protect the riparian forest of Fremont cottonwood, split leaf ash and box elder from insect infestations by spraying.

In the 1929 Annual Report Superintendent Scoyen (1929a) first mentioned his concern about insect infestations in the riparian ecosystem. Under the section entitled: Insect Epidemic, he explained:

Early in the spring a defoliating caterpillar attacked the white ash trees in the canyon and completely stripped them of leaves. Although most of the trees recovered from the attack, they can hardly be expected to survive many of these epidemics, and it is possible that we will have to engage in control work next spring if the infestation is as virulent as was the one this year. (p. 8)

Superintendent Scoyen’s 1930 Annual Report (1930b) updated the status of the insect infestation a year later. He noted: “The ash tree caterpillar again made its appearance and although the attack was not as extensive as last year considerable damage was done. Control measures will be taken next spring if funds are provided (p. 10). When Scoyen left his position as Superintendent in 1931 Thomas Allen took over as Superintendent. In his first Annual Report (1931a), also listed under the heading: Insect Epidemic, he described the state of the infestation with some alarm:

Probably the worst infestation in many years occurred this spring when the park was literally overrun by caterpillars. Heretofore their activities were practically confined to the ash tree, but this year they attacked the cottonwoods as well, and since this is the major deciduous tree of the park it became necessary to take
control measures on a rather large scale. A large spray pump was rented from the State Board of Agriculture and in all about 3500 gallons of lead arsenate spray was used. The treatment proved very successful, but it is quite apparent that it should be repeated each year in order to keep the caterpillars in check. (p. 11)

In the 1932 Annual Report composed by the new Superintendent Patraw it appears that funding was found to treat the infestation for another year. Patraw (1932a) observed:

Trees were sprayed with a mixture of arsenate of lead and lime for control of caterpillars and box elder bugs as soon as the leaves came out in April and the operation repeated in May. The spraying was unusually effective, being aided by the cool weather of the spring months which helped to retard the insects. (p. 10)

The above citations indicate extensive insect protection for the Fremont cottonwoods, Ash and other trees by Superintendents Scoyen, Allen, and Patraw. Their protective efforts to keep the riparian forest healthy have not been carried forth by later Superintendents. Would these early Superintendents be surprised and dismayed at the present demise of the Fremont cottonwood forest in Zion Canyon?

The Initial Revetment Building Period 1930-1934: Why did the Zion Canyon Fremont Cottonwood Riparian Forest Decline?

The story of the decline of the riparian Fremont cottonwood can be simply stated as a result of flood control in the west. But more specifically in ZNP as the result of over reaction to the pluvial of 1905-1922 and higher than normal precipitation in late 1920s. Thinking that weather records since 1904 were an accurate account of the climate in southern Utah not only the Superintendents of Zion National Park but many others including those crafting the Colorado Compact of 1922 assumed that the weather of the first two decades of the 20th Century in the Southwest was the norm. Therefore, this meant that whether it was the Colorado River or the Virgin River, people thought that streamflow would continue at the levels of the first two decades of the 20th Century for a
long time! The pluvial meant increased rainfall, snow and cooler temperatures. This was by far not the norm in the Southwest. Yet for unknown reasons policy makers not only at Zion National Park but also numerous state representatives crafting the Colorado Compact, did not consider data, from the late 1800s when the arid nature of the Southwest showed its true norm in drought periods.

The new Century emerged with its inventions of automobiles, electricity, phonographs, telephones. etc. and with the ability to mass produce these items. Big projects were in the minds of United States politicians and people. Examples of this big project mindset of the first decades of 20th Century were: the Chicago World Fair, the Panama Canal, wining World War I, Suffrage for women, and creation of the National Park Service, etc. An attitude emerged: if America can think it, then America can do it. The knowledge that the arid lands of the Southwest were primarily dry lands was lost in the mists of the moister years of the pluvial 1905-1922. Even the memory of the recent drought years of the 1890-1904 in the American Southwest appeared to be clouded by the pluvial of 1905-1922. The past would not to be an impediment to future progress. The United States was turning a page and not looking back even to John Wesley Powell and his 1879 treatise on The Lands of the Arid Regions with Detailed Account of the Lands of Utah. The knowledge gained from the experiences of 1800s in southern Utah and elsewhere appeared to be consigned to the dustbins of the Old West. The United States government had bent the Indigenous peoples and their inspiring warriors to its will, now it would turn to the elements and in particular to water.

Mahoney and Rood (1990) as well as other plant biologists researched the long-term relationships between water, land, and vegetation in the riparian ecosystems. Many
of these scientists have come to a similar conclusion that flooding in riparian ecosystems played an essential role in the health of the riparian ecosystem especially in relationship to habitat for plant species such as the Fremont cottonwood. Mahoney and Rood recorded:

One common major impact of river damming in western North America has been a reduction of cottonwood seedling recruitment (reviewed in Rood and Mahoney, 1990; Braatne et al. 1996). This failure has been partially caused by the imposition of artificial patterns on stream flow (stage) in which (i) flood events are often attenuated, (ii) flow changes and particularly declines can be abrupt, and (iii) insufficient flows may be delivered in mid- through late summer. These artificial patterns may prevent the initial establishment of seedlings at appropriate streambank elevations and/or exaggerate drought stress, increasing mortality of the small, vulnerable seedlings. The attenuation of flooding also prevents the essential geomorphic disturbance that creates new nursery sites essential for cottonwood recruitment. (p. 634-635)

In Zion National Park flood control took the form of channeling and armoring the Virgin River with revetments. The artificial flow pattern established for the Virgin River installed between 1930-34 with later additions of revetments resulted in all the above negative conditions including removal of the river from the floodplain that have prevented Fremont cottonwood regeneration in Zion Canyon in ZNP.

In Chapter 3 I discussed the data that I found in the Zion National Park archives that documented that the fundamental motivation for channeling the Virgin River in Zion Canyon was the need to preserve the valuable and scarce flat lands that lie in Zion Canyon. It was upon these porous, soft shifting sandy flood plain flatlands that the Fremont cottonwood seeds needed to land in order to sprout and successfully grow. The fine roots of the Fremont cottonwood seedling take hold in the moist sand. If situated far enough out of the stream channel in protected secondary and tertiary channels Fremont cottonwood trees will grow quickly. However, the National Park Service needed these same flatlands in the heart of narrow Zion Canyon upon which to build a lodge. This initial centerpiece of infrastructure would allow visitors an overnight stay within the
magnificent and towering walls of Zion Canyon. So as previously mentioned, the northern flat piece of land in Zion Canyon was hardened with a four-inch layer of clay which created an area called the Autocamp which accommodated tents and cars. Then on the southern flat parcel a rustic lodge was built which provided scenic hotel accommodation. These structures placed adjacent to former channels of the Virgin River and upon the sandy flatlands found themselves vulnerable to the streamflow changes of the Virgin River (see Figure 5-25).

**Figure 5-25**

*Rare Photo of the Lodge Built Adjacent to a Loop Channel of the Virgin River*

Note: The high streamflow in this channel during the storm of September, 1929 described by Superintendent Scoyen initiated revetment building. This loop channel can be found in the 1929 Virgin River Map (see Figure 3-2), and was completely removed to create flatland near the Zion Lodge. Source: Union Pacific Railroad Museum, Council Bluffs, IA
Over millennia with every winter rain or late summer monsoon, the Virgin River would swing back and forth pushing its sandy bottom and banks into braided primary, secondary and tertiary channels with S shaped curves. The Virgin River’s movement back and forth across the narrow width of Zion Canyon less than .40 miles across displayed the natural geomorphic braided structure of a shallow southwestern river. Before channelization, the water in the Virgin River was level with its soft and sandy riverbanks. These moist yellow sandy banks, as mentioned earlier in this chapter, provided the ideal substrate upon which the Fremont cottonwood seeds would sprout and propagate. Channelization in Zion Canyon removed the sandy banks that once served as the nursery for young Fremont cottonwood trees (see Figure 5-26).

Sandbars of this fertile moist substrate ideal for Fremont cottonwood propagation can still be found midstream in the Virgin River. I have often observed in early summer these islands densely covered with sprouted cottonwood seedlings. However, these midstream cottonwood nurseries seldom if ever survive late summer storm streamflow scour. Nonetheless, they serve as one source of evidence that if the riverbanks were lowered and allowed to return to the original sandy soil composition and floodplain elevation, cottonwood seeds would sprout and propagate upon the riverbanks (Auchincloss et al., 2012, p. 324).
Figure 5-26

The Sandy Riverbanks of the Virgin River Totally Remade in Zion Canyon

Note: This project removed the sandy banks that cottonwoods need to propagate.
Source: Box 15450. Zion National Park Archives
The additional proof of the possibility of a renewed healthy Fremont cottonwood forest in Zion Canyon is seen in the three sites that I mentioned earlier along the Virgin River just outside of Zion National Park.

The natural process of Fremont cottonwood propagation and growth is seen in Site 1 as mentioned earlier in this chapter, along the Virgin River at the south end and east side of the town of Springdale below the south side hotel rooms of the Majestic Lodge at the boundary of Paul Allen’s property (see Figure 5-27). The owners of the Majestic Lodge have stripped all vegetation from the Virgin River banks at this Site 1,

**Figure 5-27**

*Site 1: Healthy Fremont Cottonwood Forest on Paul Allen Property North Bank of Virgin River, South of Rt 9 Behind Lower Majestic Lodge Buildings*

Source: Corr (2019)
leaving it as compacted yellow sand in hopes of developing the two acres of land adjacent to the Virgin River. On the Paul Allen side of the riverbank young cottonwoods are densely growing (see Figure 5-28). This denuded riverbank area which lacks revetments and maintains the natural river geomorphology with sandy banks and river level contingent with the floodplain would be a wonderful place for the natural

**Figure 5-28**

*Site 1: Numerous Young Cottonwood Trees Along the Virgin River Where Riverbanks Remain Sandy and Natural*

Source: Corr (2019)
restoration of Fremont cottonwood riparian ecosystem integrated within the commercial zone of the town of Springdale.

Channelization also deepened the river channel so that the flood plain was removed from the Virgin River. It was hardened by bulldozing the sand away and replacing it with trapezoidal iron mesh cages filled with rock. These manufactured riverbanks were then covered with dirt. The top of the cages became the new riverbank level and is now between 12-20 feet higher than the river. The lack of moist sandy substrate along the flood plain that in the past received the cottonwood seeds in May, no longer existed. As a result, the Fremont cottonwood trees have not been able to reproduce for the last ninety years (see Figure 5-29). The number of wild young cottonwood trees

**Figure 5-29**

*Although Revetments have Fallen Away, There are No Young Cottonwood Trees Growing Along this Section of the Virgin River Between the Grotto and Big Bend*

![Image](image.png)

Source: Corr (2017)
along the Virgin River where channelization occurred in Zion Canyon is virtually nonexistent, low and easy to count (see Figures 5-29 and 5-30) whereas in areas where sandy riverbanks exist in the Virgin River riparian area the young trees are numerous (see Figure 5-28).

Figures 5-31 and 5-32 show the massive extent of the revetments with rock instead of sand or dirt as the riverbank substrate. Many people have no idea that these structures exist under the ground that they walk on while visiting Zion Canyon.

**Figure 5-30**

*No Young Cottonwood Trees Along the Virgin River Banks in Zion Canyon Where Revetments were Placed*

Note: The Virgin River is below its floodplain by 12-20 ft. Source: Corr (2021)
Figure 5-31

Massive Extent of the Revetments Constructed Along the Virgin River in Zion Canyon, 1930-1934

Source: Box 15450, Zion National Park Archives

Figure 5-32

An Enormous Revetment Extending Well into what had been the Virgin River bank and Sandy Floodplain

Note: This revetment was used to widen the flatland in Zion Canyon and to constrain the Virgin River into one straight channel. The wire, still embedded in the trail, that initiated this dissertation belongs to a huge revetment like this one! Source: Box 15450, Zion National Park Archives
These structures protected, hardened and extended the flatlands in Zion Canyon, thereby making room for infrastructure and tourists. However, this channelization destroyed almost all the sandy riverbank substrate essential for Fremont Cottonwood propagation. The result has been the destruction of the native riparian Fremont Cottonwood Forest in Zion Canyon because the seeds of Fremont cottonwood trees since 1930 have fallen on revetments rather than the native riverbank sand (see Figures 5-29, 5-30, 5-31, and 5-32).
CHAPTER 6

CHANNELING THE VIRGIN RIVER

A total of 4,775 cubic yards of rock was quarried and hand-placed in seven basket dams or dikes, which were enclosed in heavy wire mesh. In addition, 1557 cubic yards of earth were evacuated for the dams, and 10,560 cubic yards for channel change...in the future a regular item for work on this river should be carried in the park appropriation, the same as is done for maintenance or other such features such as road, trails, buildings, etc. A total of $16,739.40 was spent on this work in Zion Canyon this past year. (Scoyen, 1930b, p. 5)

Until late 1917 the Virgin River for all previous time had done what rivers do, expanded its banks during wet years and narrowed its river course in dry years. The braided channels of the river were elastic and uninhibited, bound only by the canyon walls which in wet years the river with other erosive forces in Zion Canyon, slowly

Figure 6-1

1924 Virgin River Streamflow Occupies the Base of Zion Canyon with Braided Channel Geomorphology

Note: Historic 1924 photo of Virgin River wide flood plain with braided channel geomorphology in Zion Canyon from Observation Point on East Rim. Source: Crawford (1985)
eroded away. Until the Virgin River was channeled its nourishing waters dominated the ecosystem in Zion Canyon taking up the whole bed of the canyon floor.

Then humans moved into the riparian zone creating a relationship in which they demanded that the river move over and share that Canyon bed. The riparian ecosystem had moved sinewy through the Zion Canyon floor. This movable river course nourished the flora and fauna of the ecosystem but left little space for unmovable hardened tourist accommodations; therefore, room had to be made on the Canyon floor for National Park visitors.

The Virgin River has maintained a reputation for being unpredictable in response to precipitation in its watershed. Since there have been records kept by the Mormon pioneers from 1861 the Virgin River has been known for its unexpected flooding. As has been discussed in Chapter 4, many of the pioneers lived through two of the wettest longest periods in 1425 years (Salzer & Kipfmüller, 2005). The Virgin River they knew ran high and flooded its low-lying sandy banks so much so that one pioneer called it “the Devil River”! As documented in Chapter 3, the fear by early National Park Service administrators that the Virgin River would wash away the few acres of flat land that existed in Zion Canyon, was a veritable concern. Fear, being the great motivator that it is, beginning in 1929 the National Park Service made plans to armor the Virgin River for almost the entire length of Zion Canyon from Birch Creek to the Temple of Sinawava about 6 miles (Scoyen, 1929b). This chapter examines the multiple motivations for building the revetments as well as the process of revetment construction and repair as it has been carried out in Zion National Park.
To Develop “Tourist Gold”

The unpredictable movement and flash flooding of the Virgin River concerned early NPS park officials. As mentioned in Chapter 3 all the National Parks needed to establish infrastructure that would enable public use of these exceptional lands to ensure continued federal funding. The administrators of Zion National Park envisioned and planned for: an auto camp, trails, a road, a lodge, and an administrative building that would support tourists visiting deep within the canyon at the base of the majestic 2500 feet high red rock peaks of Zion Canyon (see Figure 6-2).
Stephan Mather, Horace Albright, and Robert Sterling Yard, founders of the National Park Service knew it was a necessity to sell the idea of an American Park system to the United States Congress. But first they strategized that they must sell the idea to the American public. They painted in words and with images of the exquisite natural beauty contained within the lands of the National Parks and referred to these acquisitions as: rare American gems. In numerous newspaper and magazine articles Mather, Albright, and especially Yard, a newspaper man, emphasized the tourist and subsequent economic opportunities that these special lands offered (Swain, 1970). These reports emphasized the aesthetic beauty of the National Parks, conservation of magnificent forests and landscapes, opportunities for physical challenge, peaceful reflection and restoration of wellbeing awaiting the visitor to the National Parks. In the wake of WWI raging in Europe these authors emphasized the importance that American conservation and tourism meant to national pride. The advertisement campaign endeavored to rally Americans of all persuasions and positions to support the National Park Service (Swain, 1970).

In his exquisitely written book Wilderness Defender: Horace M. Albright and Conservation, Donald Swain described this salesmanship effort. He noted that this effort to introduce the idea of the of National Parks system to the public gained momentum after the Berkeley Conference of 1915 which was convened to gather all the Superintendents of existing National Parks, as well as other National Park enthusiasts and aesthetic conservationists. Swain (1970) recounted:

Mather’s Washington contingent returned to the East via Salt Lake City, Denver, and Chicago. All along the way, they talked to “governors, mayors, civic leaders, mountain club officers, and good road proponents” to whom they preached the “economic importance of the tourist business” and with whom they mapped the
strategy for a projected national parks publicity campaign. Editors and publishers received Mather’s special attention. His object was to make friends and win converts to the idea that “if properly promoted and advertised, the parks would attract “tourist gold” to the West. (p. 44-45)

These efforts proved effective as can be seen from the January 1919 report offered by Walter Ruesch, the first Superintendent overseeing Zion National Park wherein, he mentions the increased publicity and inquiries that he has received about visiting Zion National Park and its accommodation. Ruesch noted in his report the section he labeled “PUBLICITY”:

Zion as a National Park is gaining very wide publicity by newspapers and railroads most especially by the Salt Lake Rute which is spending considerable money advertising Zion National Park and the scenic wonders of southeastern Utah because of the extensive advertising of Zion I am receiving letters of inquiry regarding the way and means of reaching us, what are the accommodations. etc. (p. 2)

The pressure was on to build infrastructure that could receive visitors to Zion National Park.

Zion Canyon continues to offer up “tourist gold” to southern Utah and particularly to Springdale. In 2014 almost a Century after Mather, Albright and Yard commenced advertising Zion National Monument, the Utah Tourist Board ushered in a new wave of international advertising dubbed “The Mighty Five,” As a result, attendance at ZNP increased 500,000 in less than eighteen months overwhelming Zion National Park and its gateway town Springdale as well as other National Park gateway towns such as: Moab. By 2019 St. George located in Washington County, which also includes Zion National Park, had been listed within the top six fastest growing metro regions in the United States (Stebbins, 2019).
Tourism pressure in Zion Canyon has further intensified. Between 2014-2019 attendance increased to 4.5 million visitors a year. However, since Covid-19 arrived in 2020 tourist pressure ratcheted-up immensely! With international travel at a standstill and confinement at home lasting over a year, cabin fever has driven residents from major metropolitan areas to the National Parks and especially to Zion. Zion National Park is three hours from Las Vegas, eight hours from Los Angeles, six hours from Phoenix and five hours from Salt Lake City. Because people are relatively safe from the covid virus from each other, when outdoors, tourism has once again like the virus multiplied rapidly. In June 2021, alone, over 650,000 people visited Zion National Park! What is “Tourist Gold” for merchants and investors is tourist toxic for residents and perhaps Zion National Park. The Park has struggled with how to limit visitation to Zion Canyon since 2014. To reduce impacts to visitation ZNP administration has entered the famous hike Angel’s Landing into the permitting system.

Returning to the prospects of tourist gold in 1915, to successfully mine the “tourist gold” from Zion National Park that Mather, Albright and Yard had promised, two problems had to be solved. The first being the creation of dependable roads and a tunnel providing automobile access to Zion Canyon. Secondly, the Virgin River would have to be controlled. To accomplish the first objective from 1926-1932 a series of highways and tunnels were built by the state of Utah and the United States Federal government. This combined effort connected the remote region of southwestern Utah with Los Angeles, Las Vegas, Salt Lake City, and Phoenix and to the further south and east, as well as to the other regional National Parks: Bryce Canyon and The Grand Canyon. Linking these three major National Parks created a hub of grandeur within easy reach of millions of people
via a car. What has become known as the Grand Circle continues to provide relatively quick access to scenic splendor over a long weekend getaway for major metropolitan dwellers as well as international tourists. As for the second objective, the Virgin River’s natural course had to be hardened with faux riverbanks created of rock and iron that would brace and ensure that the river’s water would flow only into one deep, straight, narrow, and predictable channel on the western edge of the Zion Canyon floor (see Figure 6-3).

**The Virgin River Ensures Survival**

For long stretches in southern Utah the Virgin River runs through sandy soils allowing the river to easily move and shift its geomorphology especially during high volume and force. These sandy soils originated from the erosion of the Navajo sandstone, the major geologic sedimentation formation that comprises the top layer of the towering

**Figure 6-3**

*Virgin River Straightened by Channeling with Revetments Seen on Left Side Riverbank and Moved to the West Side of Zion Canyon*

Source: Corr (2021)
The sandy composition of the Virgin River’s bed and riverbanks had ensured difficulty in controlling the course of the river by the early Mormon settlers because the sand could not provide a firm foundation upon which to build irrigation ditches or dams. Nonetheless, attempts to control and harness the Virgin River’s waters for the agricultural aims of the Mormon pioneers began in earnest soon after they arrived in larger numbers to southern Utah in late 1861. Andrew Karl Larson (1961) in his book, *I was Called to Dixie*, detailed the Mormon expansion into southern Utah. Larson chronicled how moving the Virgin River water topped the list of the expedition’s priorities. Thus, began decades of pioneers fighting with the Virgin River to dam and direct the Virgin River’s waters. Most often the pioneers lost to the river’s unexpected streamflow force and volume within its movable sandy geomorphology. Additionally, another factor, the cloudburst also called microburst nature of the precipitation in Utah proved another impediment for controlling and understanding the changing water levels of the Virgin River (Woolley, 1946). Larson described the constant failures in accessing the water of the Virgin River:

One of the very first things attempted at St. George was to get the water of the Virgin to the land along its right bank directly below the new city. These attempts were not attended with even moderate success…the canal and tunnel were pretty well completed by mid-February of 1862, but the flood of January-February of that year washed the channel deeper and necessitated going upriver two miles above the tunnel to build a dam. It was at this time that the pioneers decided to abandon temporarily the efforts to get the water to the land under the Virgin Ditch and to concentrate their labors in the Santa Clara fields. (Larson, 1961, p. 157)

The settlers returned to work on the Virgin Ditch and tunnel for another year, but they were again met with discouraging results. One of those toiling at this project
described hours of backbreaking work being erased overnight by the Virgin River shifting course. Larson conveyed this worker’s lament:

Finally...the water was turned in, but by the next morning we found the canal was full of sand with no water...some twenty men were required to dig out the sand...a brush and rock dam was next constructed, but the volume of quicksand carried by the stream would either permit the water to burrow under the dam and wash the dam out or would pile up against the dam and allow the stream to carry over the top and fill the canal with sand...Thus the struggle continued for the next five years building dams, digging sand, and mending breaks .(Larson, 1961, p. 175)

Paiutes and Mormons, flora and fauna needed the water from the Virgin River to survive and to eventually thrive in the hot dry desert terrain of southern Utah.

Unexpected variations in the volume and velocity of flow came hand and hand with this need for water. These uncertainties and irrigation disasters led to perceptions of the Virgin River that were emotional responses to the difficulty of harnessing the vital water. Add to these irrigation disappointments were the uncertain climate changes which caused drought and famine one year with floods and devastation in the next. H. Lorenzo Reid in his 1964 book entitled Dixie of the Desert rendered the Mormon pioneer history of southern Utah. This history included the unexpected and complete devastation that pioneers experienced after the floods of 1862, which welcomed the 300 families that came to reinforce and grow the small contingent of settlers sent by Brigham Young as scouts in the 1850s. Reid (1964) reported:

The following day, after the water had subsided, through our fields and where the gristmill and our homes had stood was a gulch several rods wide and forty or fifty feet deep...In this flood went down one town, a Fort, a grist-mill, and much of the farming land on which stood many beautiful shade trees and fruit trees, The result of toil and privation passed away like a dream or vision, down to the Colorado River and to the sea (p. 111). [A rod is a surveying unit of measure equal to 16.5 feet].
These unfortunate events due to the geomorphology of the Virgin River as well as religious beliefs helped set the tone of dominance and frustration towards controlling the Virgin River. This dominance was enhanced by the advancement of construction engineering in the early 20th Century. This advancement in hydrology technology applied to the rivers and lakes of the East initially then throughout the west became known as the “Hydraulic Era.”

The 20th Century has been called the ‘hydraulic era’ in the American West. During this Century, water resources of all forms in the west were brought under the control of water engineers and politicians for the sake of trapping winter rains in reservoirs, transporting water across vast terrains or controlling flooding. Natural hydrology was re-engineered with money from enormous public works programs consisting of dams, aqueducts, pipes, and revetments. (Ingram & Malamud-Roam, 2013, p. 175)

With the arrival of the Hydraulic era the long-desired ability to direct the water of the Virgin River would finally be achieved.

The lifeblood giving waters of the Virgin River in arid southern Utah have always been the source and sustainment of human settlement in southern Utah and the American Southwest. But the human relationship to the Virgin River, source of life, has been clouded with this human sense of dominance over nature. This attitude prevailed in Zion National Park management thinking and revetments were added to Virgin River in Zion Canyon during the Hydraulic Era. Evaluating nature within a context and set of essential biological relationships was far-fetched to the settlers of southern Utah. Water was a resource that had to be extracted, made readily available and controlled (Barrow, 1999). Alexander Humboldt’s awareness of Gaia and the comprehensive understanding of connected relationships still does not receive priority in Utah politics and National
Park management. A restoration proposal for the Virgin River Riparian area when introduced in 2001 received no traction.

**Arguments for Channeling the River**

The archives of Zion National Park contain little administration commentary or information from 1909-1926. The first mention that I found of constraining the water courses in Zion Canyon after it became a National Monument in 1909, was a report dated January 1919 thought to be penned by Walter Ruesch, Zion National Park’s first Custodian, the position now known as Superintendent. It was discovered with another one-page report from 1918 signed by Mr. Ruesch. He mentioned creating a brush dam to protect commercial camping infrastructure in the area just south of the present-day Zion Lodge. This comment indicated that infrastructure protection for a commercial enterprise in Zion National Park was a concern along with flatland being washed away. Ruesch, a local of Springdale, UT who grew up less than a half mile from the Virgin River loved and respected Zion National Park. Ruesch knew the Virgin River running at high streamflow and flooding. His concern for the first camping enterprise in Zion Canyon was neighborly as well as official (personal communication with his two granddaughters, Janice and Betsy, September 2021). The Wylie Camp fulfilled the need for accommodation in Zion Canyon in the late 1910s. In a section entitled “Road Conditions” Ruesch (1919) wrote:

> Road conditions have made it impossible for travel in the Park, the people that operate a sawmill on the eastern rim have proffered (sic) to help clear the road, so in a very short time the road should be in first class condition, will also construct a breast work of woven wire and rock for a distance of six rods to protect the Wylie Camp from being washed away by the waters of the wash, which during the rainy season carries much water. (p. 2)
With these comments are seen the first concern by a Superintendent of Zion National Park for the washing away of a commercial entity and infrastructure in Zion National Park.

**Brief Interlude: Wylie Camp**

Pause with me for a moment to digress and imagine a visit to the Wylie Camp in Zion Canyon circa 1917. Canvas tents over a wooden platform under the tall cottonwood trees near the towering orange sandstone canyon walls (see Figure 6-4). It sounds glorious! One would likely have taken the railroad to Lund, the rail head in southern Utah and would have been met by a Union Pacific Railroad Carriage for the two-day horse drawn 35-mile road trip to Zion National Park. Or if one had an automobile one would have had to come into Zion National Park from the steep dirt road down from Apple Valley and crossed the river via wooden flat bridges and drive on rutted dirt roads. After one arrived, at the Wylie Camp, one might be inclined to stay a while. This camp was in operation from 1917 until 1928 and upon reading the description found on Geyser Bob's website, I grew nostalgic for these early days in Zion Canyon!

The Wylie camp during these years consisted of a simple tent camp which lay against the cliffs in a shady grove of trees just south of today's Zion Lodge. The camp featured a central assembly hall, dining room, and 10 wood-floored tent-cabins with partial board walls. Each tent-cabin had two double beds separated by a canvas wall down the center, and a separate dressing area. The tents were kept clean, were watertight, had screen doors and were lighted with gas lanterns. Meals were served in the dining room tent on oilcloth-covered tables with linen napkins. Mrs. Wylie and two girls waited on the tables, serving traditional old-fashioned meals. Entertainment included an evening campfire, horse rentals and daily excursions up the canyon. In 1917 patrons could plunk down $26.50 for the 8-hour auto ride to and from Lund via the Parry brothers auto stages. The plan included two meals along the route at Cedar City, with two nights' lodging and five meals. Visitors arriving on their own terms or those who continued on beyond the two-night plan paid $3.50/day or $21.00/week. Horses were available for $3.00/day, guides for $4.00/day, and auto tours ran 75 cents/hour. (Goss, 2014)
Those days aren’t so far away anymore. Glam camping at an enterprise called “Under Canvas,” using tents like those described above has become popular again, although outside of Zion National Park, about 15 miles south of Zion Canyon in the town of Virgin. Are we in 2019 or 1919? My mother who followed fashion trends often pointed out to me that style trends repeated themselves every twenty to thirty years. Glam camping appears to have a one-hundred-year trend cycle in and around Zion National Park! Camping in Zion National Park whether in 1919 or 2021 is in all ways a special event infusing the camper with awe and peace. It is one of the experiences Zion Canyon is known for. Also note in two of these photos the tall Fremont Cottonwood trees adding proof that a native healthy native Fremont cottonwood forest was present in Zion Canyon before revetment building 1930-1934. Interlude over!

As mentioned earlier in this dissertation, during the periods of pioneer settlement and National Park establishment the increased precipitation in southern Utah was noticed but not completely understood by the inhabitants of the Southwest. The large volume of water in the river was, considered to be the “new normal.” Anyone but John Wesley Powell was likely to agree that the moisture would continue because the climate had been wet for 17 years! Don’t forget it had also been wet for a few years in the 1880s and again in the 1860s. It only made sense that the weather would be getting wet! Consequently, the application of flood control was considered necessary and permanent for the success of the new National Park (Patraw, 1932a; Scoyen, 1929a, b).

Reactionary responses prevailed. The framework for thinking of flood control included only fluid mechanics. The engineers and administrators deciding on “river protection” as it was called in National Park reports, left out the long-term climate history of the region and the needs of flora and fauna in the river floodplain. This lack of understanding of the intimate connections among the Virgin River geomorphology, streamflow, and the riparian area ultimately prevented “the essential geomorphic
Figure 6-4

*The Wylie Camp*

Source: Box 15450 Zion National Park Archives
disturbance that create new nursery sites essential for Fremont cottonwood recruitment” (Mahoney & Rood, 1998, p. 634-635). The flood control of the Virgin River consisting of ironworks and rocks replacing sandy riverbanks prevented the regeneration of the native Fremont cottonwood forest in Zion Canyon.

**Flooding and Flood Control**

A flood event in September 1929 described in both the Annual and Monthly reports of Superintendent Scoyen kick-started in earnest the building of revetments and the channeling of the Virgin River in Zion Canyon. Of course, Zion Canyon had seen floods before, but these had not been well chronicled. However, the Federal government was now taking note (see Figure 6-5).

The description of the September 1929 flood became the second mention of river control in the Superintendent Reports that were present in the ZNP archives. However, this commentary mentions that two rock cribs protecting the road were carried away. Therefore, some flood protection had been constructed before 1929. But when and if they were noted, other than seen while patrolling the Park is unknown. Superintendent Scoyen wrote with a sense of urgency for flood and flatland protection in his October 5, 1929, Monthly Report for September of 1929:

> With the exception of the afternoon of the 2nd and the early morning of the 3rd, when the worst storm in years broke over Zion Canyon, bringing 3.56 inches of precipitation, the past month has been ideal from the weather standpoint and there has been very little interruption of tourist travel.

The storm mentioned above caused the worst floods in ten years in the Mukuntuweap and Parunuweap Rivers, our gauge on the former, showing a rise of 7 feet. At Rockville, below the junction of these rivers, which forms the Virgin, the flood went three feet over the diversion dam we built last spring to protect the Rockville Bridge, and as this stands 8 feet above low water, a flood with a head of 11 feet was indicated. However, the dam was entirely adequate and kept the water from undermining the bridge approaches. In Zion, two rock cribs protecting the
road were carried away, level ground of utmost value to future developments at both the auto camp and the lodge sites was carried away, and the channel has moved over so close to these developments that it is urgently necessary that the river be put back in the old channel as a matter of protection of life and property.

(p. 1)

This same flood was described much more dramatically later by Scoyen (1930b) in the 1930 Annual Report. In this description his focus was upon the danger to the Lodge and to propose an extreme and broad construction project to control the Virgin River. He wrote with urgency:

One of the largest floods in recent years came down through the canyon after a cloudburst on September 4, 1929. (USGS recorded this event at 3,900 cfs) Even in the wide sections of the channel the head amounted to 7 feet. At three points, especially, the river started to wash a new channel, putting Zion Lodge and the Public Auto Camp in grave danger of destruction when another such flood occurred. At one point the river cut its channel 120 feet towards the Deluxe Cabins area at ZION Lodge, and when it subsided, the river bank was only 70 feet from the edge of the road in front of the cabins.

A deficiency estimate was submitted making $16,740.00 to control the situation. It was submitted that work would be started by February in order to give protection during the spring high water. However, the appropriation did not become available until May 1, and the work was not started until after high highwater had passed. Fortunately, the spring stage of the river was the lowest on record and no further damage was done.

The park force was faced with the necessity of completing this work by July 1, as a flood may occur at any time after that date. Trucks and teams were hired, equipment purchased, and work carried on a two-shift basis until June 25, when the job was completed. A total of 4,775 cubic yards of rock was quarried and hand placed in seven basket dams or dikes, which were enclosed in heavy wire mesh. In addition, 1,557 cubic yards of earth were excavated for the dams, and 10,660 cubic yards for channel changes. A full carload of fencing wire with No. 9 cross wires and 6-inch centers was used in enclosing the dikes. The problem of controlling this river will be one that will never cease to trouble officials of the park. In the future a regular item for work in this river should be carried in the park appropriation, the same is done for maintenance of other features such as road, trails, buildings, etc. A total of $16,739.40 was spent on this work in Zion Canyon the past year. (Sharrow, 2018, p. 1) (see Figure 5-26)
Figure 6-5

Design Drawings for Revetments Along the North Fork of the Virgin River in Zion Canyon by NPS, circa 1929-1933

Source: ZNP, 1929; Box 15450. Zion National Park Archives
The intensity and emergency nature of the double shift work and appropriations mentioned as well as Scoyen’s comments that the “problem of controlling the river will never cease” illustrates the regional and reactionary pattern of resource management at that time (Barrow, 1999). This regional gusto for channeling the Virgin River was supported by the national zeal for water control that had been developing in the west as previously mentioned and known as “The Hydraulic Era,” Scoyen’s gusto made some sense considering the increase in and intensity of precipitation of the pluvial, but what was never considered were the possibilities of drought or the effects of flood control upon the hydrology of the Virgin River and the biology of Zion Canyon. Although German explorer and scientist, Alexander Von Humboldt, in several of his writings notably *The Geography of Plants* had by 1850, outlined the foundation for ecology and earth science. Von Humboldt had described the Earth as an interconnected living system on the biological, hydrological, and geographical level and was the first to use the concept of Gaia, one of the pantheons of Greek Deities as a term for the Earth’s Living system (Wulf, 2015). Unfortunately, Humboldt was not well known in North America. The term ecology had to wait until the 1970s to enter the lexicon between human engineering and nature.

Stromberg et al. (2012). writing ninety years after the pluvial more accurately commented on the precipitation patterns in the arid American Southwest that affect riparian ecosystems. They observed:

Precipitation and stream flow in the region have large temporal variability, reflecting in part the interacting effects of annual (El Niño Southern Oscillation) and multidecadal (Pacific Decadal Oscillation) shifts in sea surface temperatures and atmospheric circulation patterns. Drought and intense floods are recurring
features (Ely et al. 1993; Woodhouse 2004). In some areas, multiyear droughts of sufficient intensity to cause famine among farmers and ranchers have occurred repeatedly in recent centuries (Stromberg et al., 2012, p. 344).

In Chapter 2 John Wesley Powell and his *Report on the Lands of the Arid Region of the United States with More Detailed Account of the Lands of Utah* was discussed. He clearly understood the fundamental dry nature of the American Southwest as he explained in 1879. Why didn’t the early Superintendents of Zion understand the true nature of the region that they managed? Instead, the resource management of early Zion National Park derived from only a highly local framework together with a specific set of weather records from 1904. Also, since the centralized management concepts of the National Park Service were just beginning to be written and codified, Superintendents acted from their own experience (Albright & Cahn, 1985). Even after the Organic Act passed the United State Congress in 1916 establishing the National Park Service, due to political feuding, appropriation battles, and WWI the focus of the NPS for the first decade was on survival not practice (Swain, 1970).

The precipitation pattern of flooding and then drought evident in Zion Canyon and described by the Superintendents of Zion National Park in their Annual and Monthly Reports that reside in the archives of Zion National Park is also the pattern I have noticed from my lived experience in Zion Canyon since 2000. However, after seventeen years of moister weather due to the pluvial of 1905-1922, the pattern of dryness that Powell described had been obscured by almost 20 years of lower temperatures, increased precipitation and increased Virgin River streamflow (see Figure 2-12). Moister conditions became the norm while the dryer months during these first two decades of the 20th Century were considered the anomaly. Scoyen’s mention above that the Virgin River
was at its lowest level in 10 years (since 1919) point to this notion that less streamflow
and less precipitation were uncommon at that time. The high-water event that changed
the river channel right before their very eyes might be considered propitious in that it
brought money via appropriations to the new National Park. Equipment might have been
needed and employment for Springdale’s residents would foster good relationships
between Zion National Park, the new Federal agency on the block, and the town’s
community. The September 4, 1929, high streamflow event occurred a little under two
months before the stock market crash of 1929. Superintendent Scoyen might have seen
the need to protect the Zion Lodge as an opportunity for integrating the cost for items that
a new National Park would need, River Protection or not, into his urgent flood protection
appropriations. It could be assumed that the US Treasury was doing well before the
impact of the stock-market crash set-in nationwide. It might also be supposed that any
new Superintendent with a reputation to build and sustain, might carry the responsibility
coined in the maxim “Not on my watch would the Lodge be flooded” as one of a suite of
personal motivation factors for changing the course of the Virgin River.

Fremont cottonwood trees were plentiful in the canyon at that time partially due
to the increased moisture of the pluvial years. No one would have thought that adding
revetments to the riverbanks would change the ability for the Fremont cottonwood trees
to reproduce. From the comments about spraying the trees in the canyon and planting
trees at the Autocamp, it can be derived that trees held a high place in resource
management concerns during the late 1920s and through the 1930s. A return to
prioritizing the health of trees in the riparian zone is now crucial for ZNP resource
management because the last members of the native Zion Canyon riparian forest are falling.

The description of the September 4, 1929, flood with its 7-foot head by Scoyen raises alarm by any stretch of the imagination. The amount of water that a 7 ft head represents flowing in the river seems on the order of a deluge. This would instill fear in employees at ZNP, especially when considering the Virgin River’s proximity to the new Zion Lodge. In reading the Monthly reports for the fall months after September 4, 1929, storm, and flood, I expected more mention of the event and of further highwater concerns. Contrary to my expectations for the next three months October, November, and December 1929 there was only mention of “little or no precipitation and drought.” The description of the September 4, 1929, flood begins to fit the pattern for climate seen in long term studies of tree rings, streamflow records, and the last one hundred years of weather records in southern Utah. This pattern contains short wet periods followed by a return to long stretches of aridness with limited precipitation. The rain that did fall would have arrived in microbursts or cloudbursts, as Woolley (1946) described the intense short-lived precipitation pattern throughout Utah. This precipitation pattern, whether it bursts over a river or over dry ground is known to be a precursor to flash floods.

This unpredictable and intermittent precipitation watered the region by falling sporadically, here and there, flowing through long established geomorphological drainage patterns called washes. In the western U.S., the dry bed of a stream which flows only occasionally is called a wash. After staring at dry wash after dry wash in a desert landscape one must assume that over some period water has run in the wash even if all around them is bone dry. In southern Utah and Nevada, the two driest states in the United
States, one might estimate, that every wash would run with water at least once in a quarter Century. I have lived adjacent to a major wash in Springdale and have observed its long term dry and sporadic and short-term running pattern. No drainage flowed through this wash for over ten years. Then unexpectedly during one cloudburst water flowed through it. Yet even though the next cloudburst was within a mile or so, no water ran through this local wash. Yet in 2021 with a full-on summer monsoon season the wash has seen three flow events in two months. The unpredictability of when and where precipitation will fall is one of the interesting and puzzling meteorological observations that a geoscientist can observe living in the Southwest.

In the Monthly Report for October 1929, written November 6, 1929, surprisingly Scoyen makes no mention of the Virgin River or what will become known as the line item in future NPS Monthly and Annual reports as River Protection. But he did mention the weather. In the line item General, he wrote: “In contrast to the previous three months October was unusually dry. At Springdale, 2 miles below the park, the official gauge did not record any precipitation. The normal based on a 25-year record is 1.34 inches” (p. 1). Scoyen looked at the records that he had in hand to provide an historical context for the weather in Zion Canyon. The fact that he did this offers some local evidence of the effect of the pluvial upon the perspectives that Scoyen formed in his reports. Scoyen references the 1904-1929 weather reports as if they are true norm for southern Utah. Using only these records, he draws the conclusion that there ought to be precipitation in the fall in Zion Canyon. This is another example of how the pluvial played tricks on the understanding of climate for people living under the wet 17 years plus. The only data that many people had was weather data during the pluvial. Even though folks noticed it was
raining more as previously mentioned in this dissertation it had become unusual for the rain to stop. Looking for comparisons to earlier autumns in the weather records to which he could compare the fall of 1929 Scoyen remarked, “In Zion, park records show one storm in which 1.03 inches of rain fell on the 16th. In higher elevations on the rims, snow fell on the 29th, 30 and 31st. From the standpoint of the tourist and of construction activities, this month has been ideal because it has been sunny everyday” (p. 1). As temperatures have risen and the aridness of the Southwest has returned over the last one hundred years October continues to be considered the best month for sightseeing and hiking in the American Southwest. The intense heat of the afternoons has abated, the traditional summer monsoons have gone, while the leaves on the Fremont cottonwood trees have turned golden yellow creating a spectacular band of gold along the Virgin River riparian zone, the biological form of “tourist gold”!

Superintendent Scoyen, whose anecdotal comments add much feeling and color to his reporting wrote in the November Monthly Report dated December 10, 1929:

For the second consecutive month not even a trace of precipitation occurred at our official weather observing station in Springdale. Day after day the sun smiled across a sky that was as blue as only a southwestern sky can be. The mean temperature for the month was slightly below normal, due no doubt to the fact that clear nights are always cooler than cloudy. As a result of the lack of precipitation ranges are exceptionally dry. (p. 1).

Yet Scoyen still requested funding for: River Protection. On January 8, 1930, Scoyen writing the December 1929 Monthly Report described the dry December days:

The drought which continued throughout the months of October and November was unbroken in December, making three successive months that we did not have a measurable amount of precipitation. I have checked back the records of Springdale. station to their beginning in 1904, and there is nothing on record which indicates such a distressing period has ever occurred before.
There was very little snow anywhere in southern Utah at the close of the month even in higher mountains. Cars were able to cross Cedar Mountain the entire month of December which is the first time this has been possible since the road was constructed. At the end of the month the road through the Kaibab Forest to the North Rim was entirely clear of snow as was the road and rim at Bryce Canyon. The road over Cedar Mountain reaches an elevation of more than 10,000 feet. Stockman are suffering heavy losses on account of the dry weather. Grass is poor on the range and there is no water on the deserts of southern Utah which would allow stock to be moved to better feed. (p. 1)

In the same December Monthly 1929 report, under the subheading, General Weather Conditions, Scoyen makes another comment about weather, supporting his determination of the uniqueness of the three dry months. He added:

The fact that the mean temperature of 45dg. was 5 dg. above normal, and that there was no precipitation compared to the normal for the month of 1.40 inches, should be eloquent in supporting the above statement. Another feature of the month was the entire lack of high winds which are so much a part of southwestern weather. (p. 4)

Scoyen’s conclusion written in the December 1929 monthly report that after three months of no precipitation “there is nothing on record which indicates such a distressing period has ever occurred before” (p. 4) illustrates several startling conditions. Did Scoyen not notice that Zion National Park was in a desert? Could the desert have been so obscured by the increased precipitation due to the pluvial? Weather records had been kept in Zion National Park only since (1904) the year before the longest wettest period in 1425 years had begun. Could Superintendent Scoyen have really thought that these 24 years of statistics told the full story of climate in southern Utah and Zion Canyon? Scoyen obviously did not know of Powell’s research! In any case the power of the pluvial to influence the perception of long-term weather for those living through it was great! One must wonder whether Scoyen considered cancelling his request for funding for River Protection after the drought that he described had continued. No indication of changing
his request for River Protection appropriations exists in his Monthly and Annual Superintendent reports.

On the contrary in Scoyen’s Annual Report for 1930 he listed construction progress as substantial. Five buildings were completed including a residence and the checking station at the South Entrance as well as two bridges, a three-span steel “I” beam design over the Virgin River, which stands today at Canyon Junction, and one over Pine Creek also well designed and built to last also standing strong in 2021. Major utility improvements were finished including water, sewer, phone, and electric systems as well as trails to Hidden Canyon and the Narrows, and much more (Scoyen, 1930b). What a builder Scoyen was! He excelled in doing his part in facilitating the vision for “tourist gold” for the new Zion National Park. His focus on essential foundational infrastructure remains impressive even for the modern-day reader. Additionally, the weather did an about face as it often does in southern Utah and snow bringing winter moisture into Zion Canyon fell. Scoyen (1930b) noted:

The month of January started off with one of the worst storms ever to swoop over the Southern Utah section. Starting on January 9 it snowed practically without a break until the 18th. Twenty-seven inches of snow was measured on the ground at the Temple of Sinawava., the greatest depth ever recorded on the floor of the canyon. (p. 1)

Scoyen’s last sentence about 27 inches of snow depth in Zion Canyon indicates pluvial type conditions intermittently dispersed in the years following the 1922 technical end of the pluvial. This event listed as “the greatest depth ever recorded on the canyon floor” did not last long but also makes one wonder how much snow fell at the Temple of Sinawava between 1905-1922 when there were no Superintendents logging the data into reports. Wet periods either with rain or snow are rare in southern Utah. In 2021 drought
has been declared by both the state of Utah and the Bureau of Land Management, even
during a summer with monsoon rains. Although intermittent flash floods raced
throughout Utah in the summer of 2021 these floods do not make a dent in the drought. It
is the snow that refills the reservoirs.

The essential aridness of the Southwest has always been in evidence in the
landscape of the deserts of this region of the United States. The type of vegetation,
incredibly low humidity, elevated temperatures, and dearth of water signify a desert to
most people. Yet even in modern times this dryness has receded into the background of
people’s minds. The last significant drought ended after 7 years in 2005. Since then
although dry and a desert, enough minimal precipitation has fallen to cause policy makers
to allow development everywhere in Utah with no concerns about drought. In 2016 I
went to Springdale’s town planner and asked to look at Springdale’s drought plan. Tom
Dancie looked at me and simply said, “We don’t have a drought plan, Kavarra! But that’s
a good idea!” Since then, due to investment schemes by groups of investors from Salt
Lake City, hundreds more hotel rooms have been added to Springdale’s inventory. As we
all know when paying over $300.00 a night for a hotel room few vacationers are going to
think about conserving water while bathing after a long day of walking or hiking in Zion
National Park.

Why has the aridness of Utah been constantly in the background in Utah politics,
people, and their perceptions? The religious Mormon culture of Utah preaches that God
not human conservation handles all issues for Mormon believers. Presently this type of
thinking has been evident in that it is only in 2021 that a drought has been declared by the
Governor of Utah. Why not sooner when reports of the decline the state’s reservoir levels
have been in the news for over four years. Another example of theist thinking is evident in the “no mask mandates” issued by the Utah State legislature in 2021. Utahans do not have to protect themselves or others from the covid-19 virus. Despite hospital ICU beds approaching full for the second time in a year. Go figure? Another factor that has influenced state water policy has been the low population of the state of Utah. With a small number of residents, most problems although of concern have not overburdened public policy. Additionally, until recently most of the population has shared the same religious beliefs and one could say the state has been governed at times as a theocracy. The hierarchical arrangement of power and obedience moving from the church to the Utah State legislature made it relatively easy to solve problems. A few people are ordained to make decisions and others follow suit. But Utah has been discovered. 2020 census figures indicate Utah’s population has grown by 18.4 % making it the fastest growing state in the United States. The national growth average was 7.4% (Census.gov, 2020). How the increase in residential water use will be met is only speculation. Everyone prays for snow in the mountains. But anyone who has lived in Utah knows that there is less and less snow on average each year.

The first Superintendent of Zion National Park, Walter Ruecsh, grew up in Springdale. His grand-daughters, Janice Kali and Betsy Alford, who both also grew up in Zion Canyon stated recently “There was much more snow in the Canyon when we were adolescents! We remember several years when down by our house the Virgin River froze over and we would walk across it” (personal ommunication, August 19, 2021). Janice was born in 1936 and Betsy in 1938. From my experience of living in Zion Canyon since
2000 the weather has never been cold enough to freeze the Virgin River! Cool temperatures were an indicator of the pluvial of 1905-1922.

Scoyen (1930b) pointed out that “the mean temperature for 1930 was 63 F the highest ever recorded, while the total precipitation of 8.96 was the smallest amount to fall with one exception” adding that the “the stage of the river was the lowest on record and no further damage was done” (by the Virgin River) (p. 2, 4). Yet, even with these indicators of arid conditions, Scoyen pressed on with urgency to begin the first major armoring of the Virgin River. Revetment building started on May 1, 1930, when appropriations arrived. “Trucks and teams were hired, equipment purchased, and work was carried on a two-shift basis until June 25, when the job was completed (p. 5). Scoyen was rushing the work because he had it in his mind that after July 1 a flash flood could occur at any time due to unpredictable monsoon summer rains. The amount of revetment construction that year set the pace for armoring the Virgin River. As noted in the epigraph for this chapter, Scoyen (1930b) documented the accomplishment:

A total of 4,775 cubic yards of rock was quarried and hand-placed in seven basket dams or dikes, which were enclosed in heavy wire mesh. In addition, 1557 cubic yards of earth were evacuated for the dams, and 10,560 cubic yards for channel change…in the future a regular item for work on this river should be carried in the park appropriation, the same as is done for maintenance or other such features such as road, trails, buildings, etc. A total of $16,739.40 was spent on this work in Zion Canyon this past year. (p. 5)

In 2021 dollars this appropriation amounts to: $ 273,647.09 (CPI Inflation Calculator, 2021). Scoyen’s enthusiasm for initiating the revetment project makes sense if one considers the long-term worry over what to do to keep the flatlands in Zion Canyon from washing away. Scoyen had the opportunity to initiate the important project of anchoring the flatlands and protecting the new infrastructure of Zion National Park. In
so doing he would solve a big problem for the National Park Service. However, in a
desert environment with less than 15 inches of precipitation a year, this problem appeared
more severe than perhaps it really was because of the increased precipitation during
pluvial of 1905-1922.

Even with the 27 inches record snow of early 1930, the first line of the 1931
annual report stated: “The past year has been the driest in the history of Zion Park”
(Allen, 1931a, p. 1). Superintendent Allen went on to detail the situation in the Canyon:

Precipitation for the whole year was less than half the normal amount, and in only
one month, June did it exceed normal. Only one snowstorm of importance
occurred when about fifteen inches of snow fell on the higher levels, in
November, and none at all fell in the valley of the canyon. The past year will also
be remembered for the extremely high temperature which prevailed uniformly
throughout the year. During July especially all records for hot weather were
broken throughout the entire state of Utah. (p. 2)

In 1931 the revetment work continued adding two 1500 ft. long revetments to the Virgin
River close to the Zion Lodge. As reported by Scoyen (1929b), a channel of the Virgin
River had made a bend close to the flatland upon which the Zion Lodge had been built,
after a flood stopped 70 ft from cabins adjacent to the Lodge (see Figure 6-6).

These 1931 revetments captured this Virgin River channel by moving the Virgin
River to the west edge of Zion Canyon. In so doing the revetment removed this bend in
the river and captured this piece of former riverbed adding it to the flatlands. This land
was made into a parking lot and an area for other proposed construction projects (see
Figure 3-12) (Allen, 1931a, p. 5). Allen (1931a) summarized the channeling work when
he wrote:

Work of controlling the Mukuntuweap River in order to prevent its breaking
channels and laying waste to the valuable canyon lands has been continued, and
results at this time indicate very valuable returns from all funds so far extended in
the last two years. Zion Lodge is now well protected and the most dangerous
points on the road locations have been taken care of. The work, however, will not be completed without considerable additional funds. (p. 1)

Superintendent Allen (1931a) begins with a statement that the weather has been the driest in Zion Canyon history. A history that for data gathering reasons started in 1904 for the National Park Service. But then Allen declares that the Zion Lodge is now well protected yet there has been no high streamflow to test the revetments or to assess whether more are necessary. It seems that in one year the river controlling project was somehow deemed necessary and not reevaluated in terms of the levels of precipitations or over kill. It appears that this River Protection project was fast becoming a self-perpetuating bureaucratic expenditure. A line item was now listed as a funding item. Therefore, money would be allocated to the line item in the annual budget.

Figure 6-6

*Lodge Built Next to Virgin River Natural Channel*

Note: Scoyen described this channel in September 1929 flood report. Source: Union Pacific Railroad Museum circa 1926.
The new Superintendent Patraw reported three high river flow events in 1932 testing the new and recently built river control work completed in 1932. 5000 ft of river was shoveled out and 1800 ft. of revetments were constructed. High water in May from spring snow melt and several monsoon storms in July and August tested the revetments. One storm on August 23, 1932, caused the river to rise 12 ft. above the mean. Patraw noticed that this streamflow was higher than in the last few years and noted that the revetments passed the test and held the Virgin River waters in one channel created by the revetments, with little damage to this area of the flatlands. Additionally, he commented that unchanneled riverbanks succumbed to erosion cutting into the riverbanks thereby losing valuable flatland. Patraw saw this as an inevitable process that would eventually take out all the flat land in the upper part of the canyon (Patraw, 1932a, b) If this were the case, then revetements made good sense.

Patraw did not have the benefit of the geological studies mentioned in Chapter 3 of this dissertation. Patraw was unaware of the lacustrine lake sediments below the flatlands. He likely did not know about the erosion and aggregation cycles of the Virgin River which are dependent upon climate patterns. The increased rain would bring erosion while drought would cause deposition. Nonetheless, the original and natural sandy riverbanks necessary for cottonwood regeneration were being shoveled away and replaced by large rocks in wire cages at the behest of the National Park Service.

Superintendent Patraw described 1933 as a year with extremes in mean monthly temperatures. The mean for February was 34.1 F, the lowest on record. The mean for December was 34.5 6 degrees lower than normal for December. The mean for July was 85.4 degrees and in the last thirty years was only exceeded with the June of 1931
temperature of 87.4 F. December 13 and February had the lowest one-day temperature of
1 degree while on July 12 and 13 the temperature hit 107 the highest since 1931. Further
the temperature for July 1933 went under 100 degrees only 3 days in July. The 1933
spring was late. Sleet, flurries, and snow were seen until May 20. The 27 inches of snow
that Scoyen had deemed a record for Zion National Park just 2 years earlier was broken
by a storm that blew from January 17-31 with 48.5 inches measured at the Temple of
Sinawava with five feet measured at the east entrance of ZNP! Yet total precipitation for
1933 was only 9.21 inches (Patraw, 1933, p. 3). The winter precipitation described by
Patraw and Scoyen hasn’t fallen much in Zion National Park since 2000. In December
2010 snow fell continuously for a day and part of the night and left 12 inches on the
ground in the center of Springdale. After this 2010 snowstorm, snow fell in 2015 for a
day but the accumulation was about 5 inches in Springdale. When snow does arrive in
Springdale most of it melts by the afternoon. Winter moisture is the main source of water
in the Southwest. Winter snowpack refills the reservoirs in Utah not the flash floods of
the summer monsoons.

In 1933 the Federal government allocated $294,250.00 to Zion National Park for
Public Works projects. Administrations at Zion National Park established Emergency
Conservation Work summer camps in Zion and Bryce National Parks. Three hundred-
seventy-four men were hired into the Civilian Conservation Corps and lived in camps in
both Zion and Bryce National Parks. The Public Works projects included road work,
construction of buildings, restoration of grazing lands, campground and utility
development, as well as erosion control and flood control. These funds kept the building
of basket dams, another term for the revetments, going. Revetment work to confine the
river in a defined channel and to protect the Canyon valley from floods continued in
1933. Patraw noted that he had ordered another forty thousand square feet of six-inch
square mesh wire to be used on the Stream Protection project (Patraw, 1933, p. 8).

It becomes clear in reading the Superintendent Annual Reports that since 1933 the
goal for the revetment project had evolved into armoring the entire Virgin River. A
storm in Patraw’s first year 1932 had shown him how the iron and stone riverbanks had
kept the river in one artificial channel. He had simultaneously seen how the river could
swiftly gouge out the sandy riverbanks at high streamflow in areas without basket dams.
Zion National Park now had evidence that channeling worked. The manpower to get the
job done was supplied by Federally financed national employment programs: the
Emergency Conservation Works (EWC) and the Civilian Conservation Corps (CCC).
These Federal programs not only supplied the labor for the channeling project but also
purchased the building materials. It was a win-win situation for the National Park
Service and President Franklin Roosevelt’s plan to counteract the effects of the
Depression. Two great opportunities for Americans in one Federal Expenditure
employment program for out of work Americans and revetments for Zion Canyon. For
Administrators at Zion National Park, it only made “sense” when resources were
plentiful to use them to take advantage of the windfall of money and men and to go
ahead and completely channel the Virgin River in Zion Canyon. “Sense” in the case of
channeling the Virgin River in Zion Canyon meant expediency and opportunity. In
sentences like this when one writes “it only made sense” the meaning of the Talking
Heads song “Stop Making Sense” becomes so utterly and painfully clear.
Most problems are often more complex than many people understand them to be. Sense isn’t always what is needed or the right thing to do, especially when it comes to understanding and managing environmental issues or ecosystems. “It just makes sense” is a euphuism for expediency not planning and forethought. In the realm of the environment, the type of thinking that would say it just makes sense to get the job done because we have plenty of resources right now, becomes equivalent to simplifying the complexity of nature as well as supports the dominance of human knows best over the complexity of ecosystem relationships. The sense of channeling the entire Virgin River floodplain in Zion Canyon was misconceived and did not make sense for the Fremont cottonwood or the entire riparian ecosystem. The trees, even though appreciated by the National Park Service, were not represented in the design plans for keeping the flatlands from eroding away. The Fremont cottonwood riparian forest in Zion Canyon was thriving and healthy after 17 years of increased moisture. Yet as a result of channeling the Virgin River in Zion Canyon, the dynamic Fremont cottonwood forest would soon become barren when the next cottonwood seeds fell onto rock and wire rather than moist sandy floodplain.

In the 1934 Annual Report Superintendent Patraw wrote:

January was more like spring than a winter month grass took on a green color and buds began swelling on broad leaf trees. There was almost a complete lack of snowfall in the winter months and during this period when 300 to 550 men were employed on various programs within the park there was not a single day lost to inclement weather.

The Park area has to some extent felt the effects of the drought which has prevailed throughout the western United States during this period, but probably not as severely as in outside regions. In the valleys themselves where permanent streams flow the effects have been minimized. In spite of the drought conditions, however, the domestic supply of the park has been ample at all times (p. 2).
Reading this paragraph recalled the winter drought of 1996-97 when not even 1 inch of snow fell on the Philadelphia South Jersey region. Such a complete lack of snowfall had not happened in 100 years. The severe lack of snowfall extended throughout the northeast region of the United States. That winter is remembered because in the oil business traders buy cargo ships of oil at future anticipated prices. The price of oil fell so low that many traders who held future contracts went bankrupt because no one was buying heating oil to warm their homes. Yet the futures contracts had to be paid for at the price purchased before winter weather began. Could there be any connection between the lack of winter moisture in 1934 in southern Utah and that same occurrence in early 1997 in a different region of North America? Could a researcher locate all the times that this has happened in the 20th Century throughout North American regions and connect the dots to reveal a larger picture of climate connections? Would a larger weather process emerge? Of course, the effects of a warming atmosphere were evident in the 1990s but what might cause the same lack of snow in southern Utah in 1934? This would be another research project, but it was a question like this one that led me to the Great 20th Century Pluvial.

Yes, the Dust Bowl was starting to take shape at this point in the 1930s. This begs the question of whether the winter storms in 1931 and 1933 in Zion National Park were the tail end of the Early 20th Century Pluvial or simply winter moisture in southern Utah. If this were so, then the amount of snowfall during the pluvial years though not directly measured at the Temple of Sinawava would have been greater than 48.5 inch at the Temple of Sinawava. The amount of fallen snow can be seen indirectly in the streamflow
records addressed in Chapter 2 of this dissertation. But unfortunately, the direct inches of snow at the Temple of Sinawava from 1905 - 1922 were not recorded.

As stream protection grew in scope in Zion Canyon the amount of water in the Virgin River was decreasing and would continue to decrease for most of the 20th Century. In 1934 1742 linear ft of revetment replaced the Virgin River streambank at Big Bend and 1300 linear ft. of revetment project was constructed at the Temple of Sinawava at the uppermost area of Zion Canyon. The lack of precipitation and the ample manpower in 1934 allowed for a banner year of completed construction on Public Work projects of all types in ZNP. The South Campground was started, more sewer and water projects were brought to the Autocamp, and new employee housing was built. The Checking Station at the East Entrance to Zion National Park was completed. Electrical systems were developed throughout the Canyon. Comfort Stations were built. The East Rim trail made its appearance, and the Ancestral Puebloan archeological sites in Parunuweap Canyon were surveyed and a 75-mile area of Zion National Park was topographically mapped (Patraw, 1934).

The drought mentioned in 1934 continued in 1935 and the blue skies and sunshine allowed for all kinds of additional projects to be completed: campground fireplaces, boundary fences, road work and grading, a lecture circle, transplanting of trees, oil surfacing of roads, clean up, etc. Now that revetments were in place from below the Zion Lodge up to the Temple of Sinawava revetement building slowed down in 1935. The term cribbing came into the administrative reports. In construction this means creating a temporary wooden structure. It is not clear what Patraw meant by using the term cribbing in the 1935 Annual Report. But Superintendent Patraw wrote the reports from 1932-1937
and possibly 1938. In the 1934 reports written by Superintendent Patraw he used the term “basket dam” to describe revetments therefore it is likely that cribbing meant forms for the revetments. Only two mentions of cribbing were made in 1935. “Channel changes in connection to cribbing operations are being handled in a satisfactory manner,” Surveying for a location plan for additional stream protection work continued. (Patraw, 1935). No annual reports for 1936, 1938, 1939, were found in the archives at Zion National Park, 

In 1937 the weather was colder in winter. There was only a cursory and general comment about River Protection: Construction of basket dams in the Virgin River to prevent erosion by flood waters; also repair of existing dams was mentioned. Many other projects were underway, for example: Eradication of tamaris, an exotic plant that competes with the Fremont cottonwood, the Oak Creek Bridge was rebuilt, highway maintenance, and transplanting of Fremont cottonwood trees were in the works.

In 1940 heavy rains totaling 6 inches fell between September 4 and 12 breaking the long period of drought of about 6 years. The rain also damaged roads, trails and water systems. Despite the heavy rain little was written about the revetments just a simple statement exists: 300 lineal feet of rock filled basket dam on the Virgin River (Davis, 1940). Nothing about revetements was mentioned in 1941. In 1942 the last Zion National Park administrative report that I reviewed stated that the Civilian Conservation Corps, which first came to Zion National Park in 1933 left on June 30, 1942. Before they left, they rushed to complete a revetment to protect the utility area from Oak Creek flood waters. But the weather conditions had been dry. Again, another indication that even though the creek ran low or not at all in Zion Canyon these elements were seen primarily as flood makers not the essence of survival in southern Utah or even Zion Canyon.
Fremont cottonwood and other trees were sprayed and because war had been declared. Ranger patrols for the summer of 1942 were increased including night patrolman (Franke, 1942).

Today, the existing revetments are consistent with the original designs from 1929-1933 (see Figures 6-6 and 6-7). According to ZNP hydrologist Dave Sharrow (2003) about 28% of the north fork of the Virgin River in Zion Canyon is armored by either revetments or levees (see Table 6-1).

In perusing other Superintendent reports revetment building and repairing along the Virgin River in Zion Canyon occurred in the 1950s and 1960s. But the bulk of the revetment building had occurred in the very short period between 1930-1934. Even though the building and installation period was relatively short, this project was thorough and vast, almost completely covering all the sandy riverbed edges in Zion Canyon. The revetment project removed necessary and nourishing high streamflow from the flatlands and flood plains of the Virgin River in Zion Canyon. For almost a Century the revetments have deprived the riparian ecosystem of Zion Canyon of the Virgin River’s vital water with a disastrous result of preventing the once thriving Fremont cottonwood forest from propagating and replenishing itself. It is time to restore the Virgin River riparian area by removing some of revetments to allow the restoration of the sandy riverbanks that will allow the native Fremont cottonwood forest in Zion Canyon to grow and thrive again.

**The 2001 Plan to Remove the Revetments and Restore the Virgin River Riparian Zone that Never Happened**

In 1997 Zion National Park administrators suddenly saw the empty space below the towering older cottonwood trees in the Zion Canyon. Where in a healthy Fremont cottonwood forest, middle-aged and young trees would be growing in ecotones, the
young and middle-aged trees of the last 3-20 generations of Fremont cottonwood were missing. There were no young Fremont cottonwood trees in Zion Canyon. I certainly did not notice this lack of young trees in 2000 when I first visited Zion Canyon. American and International visitors accustomed to urban parks like New York’s Central Park or San Francisco’s Golden Gate Park, where open space under trees is kept empty for safety reasons, would not have noticed the lack of younger trees.

This open space understory contributes to a “Park” aesthetic that unfortunately has become the unhealthy aesthetic of Zion Canyon. Urban Parks with spacious open understory are maintained by employed staff. I certainly thought National Parks were monitoring and maintaining the natural ecosystems within their most used visitor areas, but of course using a more natural preservation process. But this has not been the case for Zion Canyon in Zion National Park.

Sixty-eight years after revetment building began, Zion National Park initiated a study to determine what could be done to restore conditions in the Virgin River riparian zone that would foster Fremont cottonwood regrowth in Zion Canyon. Financed by the Grand Canyon Trust in St. George, Utah the proposal, “The Potential for Restoration along the Virgin River in Zion National Park” thoroughly evaluated the status of the Fremont cottonwood trees in Zion Canyon, crafting six restoration options as well as a budget for each option. The goal of the study was to assess “the potential for restoring a broad, functioning floodplain to the channelized reaches of the Virgin River through Zion Canyon” by creating a “set of alternatives ranging from maintaining the current conditions to complete reconstruction of a channel and floodplain…Two approaches, differing in cost and risk, were identified that met the multiple Zion National
Figure 6-7

1929 Map of Natural Virgin River Morphology

Note: Black lines indicate plans for revetment construction
Source: ZNP, 1929; Box 15450. Zion National Park Archives
### Thalweg (line of lowest elevation) of River

<table>
<thead>
<tr>
<th>Segment</th>
<th>feet</th>
<th>miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temple of Sinawava to Weeping Rock</td>
<td>9,550</td>
<td>1.809</td>
</tr>
<tr>
<td>Weeping Rock to Emerald Pools Bridge</td>
<td>11,262</td>
<td>2.133</td>
</tr>
<tr>
<td>Emerald Pools Bridge to Birch Creek Bridge</td>
<td>6,913</td>
<td>1.309</td>
</tr>
<tr>
<td>Birch Creek Bridge to Junction Bridge</td>
<td>9,558</td>
<td>1.810</td>
</tr>
<tr>
<td>Junction Bridge to South Boundary</td>
<td>12,122</td>
<td>2.296</td>
</tr>
<tr>
<td><strong>Total distance</strong></td>
<td><strong>49,405</strong></td>
<td><strong>9.357</strong></td>
</tr>
</tbody>
</table>

### Lengths of Levees near Lodge

<table>
<thead>
<tr>
<th>Segment</th>
<th>feet</th>
<th>miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length (with gap for breakout area upstream of lodge)</td>
<td>7,355</td>
<td>1.392</td>
</tr>
</tbody>
</table>

### Lengths of Bank Armoring and Channel Obstructions

<table>
<thead>
<tr>
<th>Segment</th>
<th>feet</th>
<th>miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC/Watchman Levee</td>
<td>1,500</td>
<td>0.284</td>
</tr>
<tr>
<td>Flanigan Diversion</td>
<td>100</td>
<td>0.019</td>
</tr>
<tr>
<td>Oak Creek Diversion</td>
<td>80</td>
<td>0.015</td>
</tr>
<tr>
<td>Sentinel Slide (road project)</td>
<td>550</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>0.057</td>
</tr>
<tr>
<td>Valley Floor to Temple</td>
<td>155</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>770</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>640</td>
<td>0.121</td>
</tr>
<tr>
<td>At Temple</td>
<td>1,400</td>
<td>0.265</td>
</tr>
<tr>
<td><strong>Total Length</strong></td>
<td><strong>6,595</strong></td>
<td><strong>1.249</strong></td>
</tr>
</tbody>
</table>

Portion of stream length influenced by Bank Armoring: 13.3%
Portion of stream length influenced by Levees near Lodge: 14.8%
Portion of stream length influenced by both Bank Armoring and Levees near lodge: 28.2%
These lengths were estimated using Google Earth 10-17-2014 by Dave Sharrow ZNP hydrologist. Source: Sharrow (2018)
Park objectives of infrastructure protection, public safety, flood control, and riparian enhancement (McMahon & Moody, 2001, p. v). The six restoration options were:

1) **Retain Levees** - The levees would be maintained for the foreseeable future. This would require repair and some replacement of gabions.

2) **Benign Neglect** - Allow the gabions to deteriorate and the river to slowly remove the levees.

3) **Remove Wire Only** - The wire would be removed from the gabions to hasten the river's actions and reduce hazards.

4) **Breach Levees and Construct Selected Meanders** - Wire would be entirely removed, the levees physically breached in a few places and 2-4 meanders constructed outside of the levees to hasten lateral movement of the channel.

5) **Remove Levees** - The levee material and rock filling the gabions would be removed and deposited in the channel to raise the streambed or disposed of elsewhere.

6) **Remove Levees and Construct Channel with Natural Characteristics** - The levees would be removed, and a channel would be physically constructed for the entire 1.5-mile reach, with dimensions and patterns similar to natural conditions and consistent with a channel in equilibrium (McMahon & Moody, 2001, p. 3,4).

The report recommended options 5 and 6 as the best choices for meeting the objectives established by the project. Both choices move the protection of infrastructure and the flatlands from the Virgin River’s geomorphology to the Zion Canyon Road. This would include removing two plus miles of revetments from riverbanks at Birch Creek, north to those in front of the Zion Lodge and further north to the Grotto area. This would create a strip of new floodplain land that varies from 65 ft to 100 ft between the Virgin River and the Zion Canyon Road (see Figure 6-8).

The result would return the riverbanks to their original sandy composition allowing the level of the Virgin River streamflow to be contingent with its riverbanks.
This would broaden and reconnect the floodplain to the Virgin River. To accommodate the increased width of the new floodplain the present footbridges across the Virgin River would be lengthened to allow for safe visitor movement to trails on the west side of Virgin River. The 2001 costs for either of these choices seemed reasonable for healing a National Park Service inflicted wound to the riparian ecosystem in a highly visible and visited Zion Canyon in Zion National Park (see Figure 6-9).

**Figure 6-8**

*Potential Restoration Areas*

Notes: White circles indicate possible restoration areas between Virgin River (brown on left) & canyon road (thin white line) that could be returned to Virgin River floodplain. River break-out of revetments & return to S curve course of river is seen in lower white circle. Source: Adapted from Google Earth Image, 2021
Figure 6-9

Costs for Option 5 and Option 6

Option 5 Estimated costs:

- Remove wire: $50,000
- Remove rock: $150,000
- Earthwork/ transport of spoils: $350,000
- Replace or lengthen footbridges: $200,000
- Relocate utility line below Lodge: $50,000
- Relocate utility line below Lodge: $50,000
- Revegetation of meander reach: $100,000
- Planning/supervision: $50,000
- Permitting/compliance (CWA, NHPA, ESA, others): $50,000
- Monitoring: $50,000

TOTAL ESTIMATED COST: $1,000,000

(McMahon & Moody, 2001, p. 48)

Option 6 Estimated costs:

- Remove wire: $50,000
- Remove rock: $150,000
- Earthwork on site: $750,000
- Transporting soil from site: $2,500,000
- Bioengineering and stabilization: $200,000
- Replace or lengthen footbridges: $200,000
- Relocate utility line below Lodge: $50,000
- Planning/supervision: $100,000
- Permitting (CWA, NHPA, ESA, others): $100,000

TOTAL ESTIMATED COST: $4,100,000

(McMahon & Moody, 2001, p. 49)

The report also clarified expectations for Fremont cottonwood regrowth after restoration of natural riverbank geomorphology. The report authors noted that the gorgeous Zion Canyon wide shade canopy created by the Fremont cottonwood trees would not be reproduced by restoration. McMahon and Moody made an obtuse
reference to the pluvial when they acknowledged that “a rare event” caused the
dense Fremont cottonwood canopy presently found yet dying in Zion Canyon.
Restoring the flood plain the authors clarified would likely allow individual, small
groups, and bands of Fremont cottonwoods to re-establish as an ecologically
important component of the riparian zone. The restoration of the Virgin River would
not necessarily recreate the near complete canopy experienced in Zion Canyon
during the 20th Century. However, from my observations of Sites 1 and 3 along the
Virgin River numerous cottonwood trees of varying ages were growing in narrow
flood plain along the Virgin River. The canopy may not be recreated because this
canopy was the result of the river being able to freely move across the canyon floor
for centuries. Nonetheless, allowing for a 65-100ft wide strip of land 2 miles long
may well form a foundation for healthy Fremont cottonwood recruitment in Zion
Canyon.

The results of McMahon and Moody’s study were presented on April 10-11,
2001, at Zion Lodge to Park staff, knowledgeable professionals, interested agencies
in order to discuss and critique the concept plan. Additionally, discussion occurred
about whether the plan would meet requirements of important Federal Standards as
required by: National Environmental Policy Act (NEPA), The National Historic
Preservation Act (NHPA) and the Endangered Species Act. Each of these laws was
reviewed. Many non-technical factors such as: funding, politics, local cultures,
roads, lodge, visitors, utilities, and bridges were considered considering the above
Federal laws as well as whether staging would occur in one or two years (Sharrow,
2003) Recommendations were incorporated into a final draft. This draft report was
clearly written, easy to understand, straightforward, and offered realistic options at a fair cost. So why didn’t either one of the options chosen to move forward?

From personal communications with Zion National Park officials in 2003 and 2004 several possibilities emerged. The first challenge was with politics. The idea of restoration had been conceived during the last term of President Bill Clinton who supported National Park ideals and needs. However, when McMahon and Moody’s report was completed in 2001, President George W. Bush was in office. It is well known from daily news sources during President Bush’s terms that he wanted to privatize the National Park Service thinking that corporations could better finance and manage the National Parks, rather than public tax dollars. President Bush had wanted for-profit music concerts and other large money-making ventures to be allowed to use National Parks infrastructure. A Britney Spears concert in a National Park was one of a proposed ideas that was supported by President Bush. I was told by a recent ZNP Superintendent that the only thing that kept privatization of the National Park Service at bay was the political strength and connections of the Directors of the National Park Service at that time: Roger Stanton and Fran Mainella. Another huge factor that skewed the perception of need for river restoration at Zion National Park were the September 11, 2001, attacks on the USA followed by the costly and confusing wars in Iraq and Afghanistan. Suddenly the 9 trillion-dollar surplus the Federal government had amassed under the Clinton administration became earmarked for war in the Middle East.
More recently in 2021 via personal communication via email I asked Dave Sharrow hydrologist for Zion National Park at that time for his thoughts on why the restoration project did not go forward. Dave thoughtfully responded:

Both Jock and Jeff Bradybaugh tried to get interest from the Utah Congressional delegation and the NPS WASO Office (Washington, D.C. Area Support Office). The option to remove the levees (with or without constructing a new channel) was very expensive, beginning at about $5 million and growing over the years to $7.5 million. For such a big price it would have had to have been a line item in the NPS budget from Congress, so it would have had to have been championed by a congressman or a senator. None was interested.

There may have been influence due to the new administration, and tightening budgets, but this would have been temporary, and the lack of interest lasted for many years. I think that the problem was that the project simply wasn't sexy. It wasn't the Orrin Hatch Visitor Center. Instead, we were going to take a river that looked perfectly good to most people and bring in a bunch of huge earth movers and tear it up and make a mess. If that weren't enough, we were going to remove the levees, and everybody knows that you need levees to control floods. When we were done the river wouldn't look a whole lot different to a person not versed in natural river morphology. It might well have been that none of us, myself included, were the best salesmen for the project.

There was also a catch 22 regarding NEPA. We couldn't get funding to do the NEPA because we did not have a commitment to construction funding, and the higher ups our lack of NEPA compliance as a reason not to go after construction funding. We would have had to use scarce park funds to do our own NEPA, and that magnitude of a project in the most visited part of the park would have been plenty controversial, speculating that we could then get construction funding. The bottom line was that with no funding, we had no choice but benign neglect.

We did get levee removal as an objective specifically mentioned in the General Management plan. And going back into the 1980s the park stopped repairing the levees. The river has been doing its job and has progressively eaten away at the levees. I hope that when the big flood comes and the river diverts out of the channel and takes out the Emerald Pools Trailhead and Horse Corral, that we have left a sufficient paper trail so that the park doesn't go into a panic and rebuild the levees. We'll see because that is going to happen. I think one more flood the size of 2010 or 2005 should do the trick, so long as they adopt the road as their levee the river should be OK in the long run (Sharrow, personal communication, April, 2021).
Sharrow added in a follow-up email (personal communication, May, 2021) that with so much visitor use bearing down on the riparian area in Zion Canyon maybe the need for restoration would now be better received by Utah’s Federal Congressional delegation. However, at a Springdale community social event in 2019, I asked the present ZNP Superintendent Jeff Bradybaugh his thoughts on the possibility of pursuing the McMahon and Moody restoration options. His solemn response was: “Kavarra, the cottonwood issue is way down the list of my concerns.” Since Superintendent Bradybaugh came to lead ZNP on October 20, 2014, visitor use has increased by over 1 million persons per year. First the Mighty Five Utah Tourist Board International advertising campaign (addressed in Chapter 4) then the recent need for people to escape Covid-19 pandemic and visit the National Parks have overwhelmed Zion National Park management and the Zion Canyon ecosystem.

Dave Sharrow’s comments about the possibility of rebuilding revetments in the future on the Virgin River were a surprise. Even though the Virgin River was declared a Wild and Scenic River in 2009, it turns out that in the Virgin River Comprehensive Management Plan 2014 the right to build levees on the Wild and Scenic Virgin River would be allowed under section 7 of the Wild and Scenic Rivers Act in order to preserve human health and safety (Virgin River Comprehensive Management Plan, 2014, p. 7). Canyon De Chelly National Monument created a ten-year plan to restore the riparian zone adjacent to the stream running though that Canyon. If they can do it why can’t Zion Canyon restore the vitality of its riparian zone? If restoration is costly then why not like Canyon de Chelly, restore the riverbanks over an extended period? I recently sent Superintendent Bradybaugh an email inviting him to look at the natural healthy Fremont
cottonwood forest successfully growing at the Majestic Lodge Site 1. This site was mentioned earlier in this chapter. So many young trees are growing at Site 1 simply by allowing the original conditions of the Virgin River flood plain to exist. Hopefully, a visit will inspire him to realize that a restoration project could be successful. One problem that needs to be considered is if restoration is postponed too long is that the seed source provided by the living trees now in Zion Canyon will be gone. This condition will further hinder the ability for propagation of the next generation of Fremont cottonwood forest in Zion Canyon. As mentioned earlier in this chapter, the vitality of cottonwood seeds is measured in weeks not years.

As the last generation of native Fremont cottonwoods in Zion Canyon are dying let us hope providing for shade that makes visiting Zion Canyon pleasant in summer, has enough sexiness to appeal to Utah’s Congressional delegates! Zion Canyon is the heart and soul of Zion National Park. The riparian zone although only 5% of the total area of Zion National Park is home to over 87% of all the species in Zion National Park. This statement is repeated over and over in ZNP brochures and during Ranger Talks. However, without the native Fremont cottonwood forest this diversity will diminish. The restoration of Virgin River is required by the Organic Act of 1916:

The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations” (National Park Service, 2021).

Must legal action by an environmental group have to be taken for Zion National Park to prioritize preservation of the Zion Canyon riparian area as the mandate of the
Organic Act requires? Why should Zion Canyon and the native Fremont Cottonwood Forest be left out of this mandate? The riparian ecosystem is meant to be preserved in its original state for future generations. If not now, when? If not by the people who love Zion Canyon, then by whom?
CHAPTER 7

CONCLUSION, DISCUSSION, AND RECOMMENDATIONS

Curiosity initiated this dissertation research with her forces of intuition and synchronicity energizing the search to understand why the Virgin River was armored and channelled in a desert environment. Love for the experience of hiking in magnificent Zion Canyon surrounded by towering Fremont cottonwood trees, whose height and beauty perfectly match that of the exquisite sandstone Mesas of Zion Canyon, motivated my concern for the demise of this incredible native riparian Fremont Cottonwood forest. The research was a process of leads being discovered by chance as well as by meticulous archival research.

This doctoral research investigated the effect of a perceived climate change created by the pluvial of 1905-1922 on the decision to channel the Virgin River in the early 1930s. Technically a climate change would permanently change the long term regional weather of a region. The long term arid climate of the Southwest was not changed by the moister years of the pluvials of 1865-69 or 1905-1922. But the 1905-1922 seventeen plus years of wet weather in the arid climate left the perception that a climate change had occurred for residents of the American Southwest. Channelizing and armoring the Virgin River created an ongoing major disturbance to the natural geomorphic riverbed of the Virgin River. This disturbance resulted in the demise of the native riparian Fremont Cottonwood forest in Zion Canyon.

This case study analysis was framed in terms of four fundamental goals: (1) to discover the prime reason why the National Park service armored and channelled the Virgin River in Zion Canyon when Zion Canyon is located in an arid region receiving
less than 15 inches of precipitation per annum, (2) to understand how the anthropomorphized negative perception of the Virgin River arose and how this cultural and climate framework may have influenced environmental management of the Virgin River, (3) to document why the native riparian Fremont Cottonwood forest has not been able to reproduce since channeling of the Virgin River in Zion Canyon was undertaken 1931-1934, 4) to research options for restoring the Virgin River to its original healthy geomorphic status in order to encourage the regeneration of the native Fremont Cottonwood forest.

Based on archival research in Zion National Park, Springdale, UT and at the Union Pacific Railroad Museum Archives in Council Bluffs, IA, and in scientific databases it can be concluded that the pluvials of 1905-1922 and 1865-69 influenced early Zion National Park Management policy in two ways. 1) Due to the increased streamflow of the Virgin River arising from the increased precipitation during the 1905-1922 pluvial, Superintendents at Zion National Park as well as administrators of the National Park Service feared that the scarce few acres of flatland in Zion Canyon, were going to completely wash away leaving no flat ground in the narrow and high-walled Zion Canyon upon which to establish visitor infrastructure for the nascent Zion National Park. 2) As a result of Virgin River flooding that accompanied these two significant wet climate changes in a normally dry desert climate, a chronic and long-standing perception of fear developed among the residents in southwest Utah towards the Virgin River. The river was anthropomorphized as an unsuspecting usurper, an angry woman, a devil and destroyer of hard-won property and community efforts comprising: irrigation ditches, dams, agricultural fields, and National Park infrastructure. Local cultural perception of
the Virgin River thus contributed to framing the need for controlling the Virgin River streamflow. No one appears to have considered the result of armoring the Virgin River on the riparian ecosystem.

The Park Service itself did not attribute religious attributes of evil or anger upon the Virgin River instead comments such as “the river would always have to be controlled” were found in the Zion National Park archives even when periods of drought occurred (Allen, 1931a; Patraw, 1932a, b; Scoyen, 1928b, c). Despite the following facts that 1) Virgin River streamflow runs calm and on average at 100-400 cfs most of the year even in periods of higher-than-normal precipitation, and 2) the Virgin River allowed for National Park success, as well as the agricultural and ranching success of Mormon settlers and others in the desert lands of southwest Utah by bringing much needed perennial water to people, pastures, and agricultural fields. The beneficent properties of the Virgin River were forgotten when the increased streamflow during the 1865-69 pluvial caused flooding as Mormon settlers first arrived in southern Utah. These settlers were extremely dependent and vulnerable to their new environment. They found the inability to control the Virgin River exasperating. In response to their futile efforts to control the Virgin River, a hardened perception grew that the “devil” river must be controlled. This perception prevailed over three generations of Mormon settlers and became an overarching common response to discussions about the Virgin River. This negative perception of the Virgin River supplanted a more rational, appreciative, and environmentally balanced view of river management, albeit that environmental perception barely existed in the scientific and cultural Weltenschauung of that period.
When the National Park Service took management control of the Virgin River in 1919 and several late summer highwater events occurred in the late 1928 and 1929, six miles of the Virgin River in Zion Canyon from Birch Creek to the Temple of Sinawava were armored between 1930-1934. The natural curving river channel was straightened and pushed to the west side of Zion Canyon. This resulted in creating more dry flatland for Zion National Park infrastructure. But this revetment building also removed the Virgin River from its floodplain and destroyed the natural secondary and tertiary sandy river channels which served as nurseries for successful Fremont cottonwood propagation in Zion Canyon.

In researching the details surrounding the channeling of the Virgin River this dissertation contributes to the field of historical geography and environmental history. It connects the influence of two wet climate changes, pluvials, that occurred during the early Mormon settlement in southwestern Utah to the fearful perception of the Virgin River and this perception to early National Park Service River management policy. In southern Utah, the 1865-69 pluvial the fifth wettest period in the American Southwest in 1425 years (Salzer & Kipfmueller, 2005) flooded out new Mormon settlements and irrigation projects. In northern Utah this pluvial raised the level of the Great Salt Lake by 9 ft from its levels in 1850 (Powell, 1879). The second pluvial 1905-1922, named the Great Early 20th Century Pluvial is considered to be the longest wettest period in the American Southwest in 1425 years (Salzer & Kipfmueller, 2005). The increased moisture in an arid region changed the environmental perception of the people who were living through it. The cultural framework that arose in response to increased streamflow was focused on controlling the Virgin River and this was accomplished by the National Park
Service in the early years of Zion National Park 1930-34. In each pluvial people did not know why the rain had increased. This dissertation found that people used their common cultural frameworks to find an answer. If a person was religious the rain was a reward for serving the Lord well. If the cultural framework was scientific the rain arrived because telegraph wires created electrical forces in the air, or rain followed the plow. Those with boots on the ground had little idea if the change in the weather was a permanent change or if the moister and cooler conditions would ever revert back to the previous longstanding dry and drought conditions. The comments and perceptions of the pioneers became important indicators of the prevailing cultural and social attitudes of southwestern Utah as well as an indicator that the weather had significantly changed. These perceptions were how people of their times understood the change in weather. The human characterizations of the climate formed relationships with the surrounding geography and ecology of Zion Canyon and the Virgin River, which few residents of the region really understood. Yet they had firm opinions about the river and why it needed to be controlled.

Analyzing historical relationships and the cultural frameworks of a period can provide insights to scientists and National Park managers in the following ways:

1) Does implicit bias exist in the form of beliefs about human dominance over nature or that humans have the right to extract resources from nature even if the projects negatively affect elements or the whole of an ecosystem?

2) Is the resource being affected, seen for only its advantage to human beings or as something that ust be extrated and taken away for human use?

3) Is the resource being evaluated within the context of the benefit it offers to the ecosystem in which it is embedded?

4) What seen and unseen biological relationships will be affected by the proposed project and disturbance to an ecosystem?
One outcome of this study would be for National Park interpretive and educational presentations to focus on illustrating to the public the benefits that an ecosystem offers to human beings. An successful example of this type of inclusion of the value of natural process to humand beings exists on the campus of the University of Massachusetts Amherst. Signs have been posted listing how a specific tree contributes to cleaning the air, water or creates habitat. Offering this information to Zion National Park visitors as they hike around Zion Canyon would be a quiet but perhaps significant awareness building opportunity. Also developing more intentional and cooperative relationships between the National Parks and regional university systems could provide young scientists with research opportunities to complete analytical environmental studies the outcomes of which could assist National Park environmental management. This dissertation provides information about past environmental decision making and the contexts that affected the frameworks for Zion National Park early management. Elucidating the components of past decision-making processes can guide present and future management options and restoration processes to be more contextual, comprehensive, and sustainable (Dunwiddie, 2001; Moore & Witham, 1996).

Past ecological disturbances, especially large-scale disturbances, leave their signature on the ecology of an environment. Large scale disturbances can shape the ecosystem composition and ecological processes of an ecosystem for decades and long after the original purpose of the disturbance is gone (Foster et al., 1998; Harding et al., 1998; Motzkin & Foster, 2002; Motzin et al., 1996; Turner & Dale, 1998). Initially land managers and owners have changed landscapes with the goal of progress in mind, nonetheless; over time they unwittingly becoming partners in sweeping ecological
changes that often tarnish the envisioned progress. This has been the case for the native riparian Fremont cottonwood forest in Zion Canyon after revetments were used to armor the Virgin River in Zion national Park 1930-34.

This dissertation asserts that replacing the natural sandy riverbanks and floodplain of the Virgin River with revetments, the giant wire cages filled with rock that became the new riverbanks, which Zion National Park covered with dirt to look natural, created an impediment to preserving the natural state of the riparian ecosystem in Zion Canyon as required by the Organic Act of 1916. This disturbance to the natural geomorphology of the Virgin River resulted in the National Park Service removing significant areas where Fremont cottonwood propagation successfully occurred in Zion Canyon. Thus, preventing regeneration of the native Fremont cottonwood forest for the last 90 years.

The actions of armoring and channeling the Virgin River were reactive rather than comprehensive National Park Service environmental management. This solution to recover flatland and prevent flooding has hastened the demise of the magnificent native Fremont cottonwood forest in Zion Canyon a protected ecosystem within Zion National Park. The placements of revetments removed moist sandy substrate necessary for propagation from the Virgin River riverbanks. The streamflow of the Virgin River was removed from the floodplain leaving it dry and lowering the water table in areas where Fremont Cottonwood propagation would normally occur.

To comply with the Organic Act of 1916, it would be environmentally proactive for Zion National Park administrators to consider revitalizing the Zion Canyon riparian ecosystem by removing revetments especially near the Zion Lodge and the Grotto rather than allowing the revetments, to deteriorate over time via benign neglect. Doing nothing
will add another Century to the timeframe of rejuvenation of the native Fremont cottonwood forest in Zion Canyon if it can rejuvenate at all under the benign neglect option (Moody & McMahon, 2001).

Landscape is a reciprocal history of relationships between the culture of its inhabitants and the physical geography of the area and environment (Cronon, 1983; Crumley, 1994; White, 1980). This case study of the channeling of the Virgin River offers a cautionary tale. It is an example where essential ecological relationships were left out of planning and the decision-making process. It is a story where cultural concepts and single-minded goals dominated the forefront of the environmental management. The case study suggests that including as many ecological relationships as possible into planning environmental management, especially in ecologically sensitive areas such as riparian zones and other areas protected within the National Park Service, is essential for long lasing healthy outcomes for ecosystem and National Park preservation. National Parks were created to uniquely preserve ecology and environments unlike National Forests which were meant to create economic opportunity.

Additionally, since studies in historical geography and environmental history have proven useful to restoration, this dissertation research found and observed healthy Fremont Cottonwood riparian forest sites. Three areas outside of Zion National Park yet within ten miles of Zion Canyon along the Virgin River were found where conditions resemble the original geomorphology of Virgin River as described by early administrators of the Zion National Park and early settlers in Springdale and Rockville. These sites demonstrate that 1) present day healthy Fremont cottonwood forests exist in small areas thriving upon the Virgin River’s sandy riverbanks, 2) the essential structural
aspect of the riparian forest ecosystem is intact when the Virgin River streamflow remains level with and connected to its floodplain, 3) these remarkably relatively pristine areas can serve as living portraits to guide the restoration of the Virgin River in Zion Canyon and indicate the restoration success that may be achieved if revetments are removed and the sandy riverbanks are restored.

This dissertation research also adds to the body of knowledge in the area of ecological restoration. There is a body of research that supports the process of probing the environmental conditions of the past to gain valuable guidance for future restoration goals (Christensen, 1989; D. Egan & Howell, 2001; Swetnam et al., 1999). Including the broad array of biological, ecological, climatic, physical as well as cultural factors at play in a landscape improves environmental stewardship. Understanding how decisions were made concerning land management in the past and what factors were at play in the past influencing decisions, can elucidate patterns of anthropogenic, cultural, and economic constraints active in present ecosystem management. Comparing past parameters with present parameters offers a systems analysis application to present management strategies which ideally will lead to more successful restoration planning and policy with the hope of sustaining healthy ecosystems in protected National Park lands.

Land-use, settlement history, precipitation patterns, and National Park Service culture have influenced the Virgin River’s management history and in particular the rationale for constraining the channel of the Virgin River in Zion Canyon. One of the essential factors necessary for successful restoration and informed management is a detailed awareness of the biological, ecological, management history of the system to be rehabilitated. Swtum et al. (1999) established: “Historical perspectives increase our
understanding of the dynamic nature of landscapes and provide a frame of reference for assessing modern patterns and processes” (p. 1189).

This dissertation found that in 2001 a study was undertaken to discover the potential for restoration of the Virgin River financed by the Grand Canyon Trust. Restoration meant removal of revetments in areas of the Zion National Park between Birch Creek and the Grotto. Six restoration options were presented to stakeholders in April 2001 (Moody and McMahon, 2001). However due to the proposed budget being over $2 million dollars a member of the Utah Congressional delegation would have had to propose the expenditure to the United States Congress. At that time interest for the restoration project could not be garnered by the Zion National Park officials. Additionally due to lack of funds to complete a National Environmental Policy Act (NEPA) assessment the excellent proposal has remained dormant and the option of Benign Neglect (Option 2) became the default action towards restoration of the Virgin River (Sharrow, personal communication, 2021). As a result of not being able to manifest the Moody and McMahon proposal 20 years ago the Zion National Park riparian area is strewn with dead and fallen Fremont cottonwood trees. The flood plain is dry with very little healthy native forest growth. It is of note that the recent December 2, 2021 Federal legislation named the American Infrastructue Investment and Jobs Act contains funding for restoration in the Colorado River watershed. In a recent personal communication with Superintendent Bradybaugh about this funding he said “that ZNP was keeping a look-out for funding opportunites for restoration” (Bradybaugh, personal communication, December, 2021).
In light of the excessive visitor use in Zion Canyon (nearly 5 million in 2021) the time might be ripe once again for proposing restoration for the Virgin River to the Utah Congressional delegation. The quality of the riparian area has deteriorated in the last twenty years. The last of the generation of Fremont cottonwood that propagated during the pluvial of 1905-1922 are dead or dying. Tourism has become one of the main drivers of economic development in southwestern Utah’s Washington county. Presently visitor use appears to be more important than preservation at Zion National Park due to the building of comfort stations, lotteries for limiting hiking at Angels Landing and obtaining campsites, reservations for riding the Zion Canyon shuttle, etc. Yet few restoration and preservation projects are apparent. The restoration of the Virgin River would revitalize Zion Canyon riparian ecology. The project could be a learning tool for the public displaying the Organic Act of 1916 in action. Also restoration would display to the next generation of National Park enthusiasts proactive use of visitor fees and public tax dollars in Zion National Park for regeneration and preservation of native species, biodiversity and healthy ecosystems.

One unexpected result of this dissertation was the realization that the role of the cloudburst/microburst precipitation pattern needs to be considered as an important element in future Virgin River restoration design. This precipitation form has not received enough attention as to the role it plays in flash flooding in the unique steep and elevated topography of Utah. Understanding this weather phenomenon as well as tracking the layout of a region’s wash patterns may provide valuable insight into flash flooding patterns. Innovative patterns of flood control may exist or be developed that can sustainably dissipate the hydraulic forces of these cloudbursts without the need for
revetments. Additionally mapping the wash patterns in a region could provide insight into flash flooding patterns that could influence development and zoning design. Through this doctoral research it also became apparent that National Parks could become scientific centers of research in many biological, metrological, and ecological fields. The cloudburst issue or the influence that beavers are having on the Virgin River, and the riparian flora could be studied by student researchers aligned with National Park needs and personnel. This joint research could be furthered by National Parks, universities and other research centers partnering together to match National Park needs with graduate student research.

Additionally, on a personal note curiosity guided this doctoral research teaching me to trust and validate my instincts even when I am alone in having them! The Virgin River and Zion Canyon have given me strength, insight and healing ever since I arrived in 2000 to recover from the grief of my mother’s unexpected death by immersing myself into something different on purpose as a Park Ranger. The power of Zion Canyon to teach and guide me has continued as I have unraveled the mystery surrounding the armoring of the Virgin River. What an exceptional gift and an exciting journey this research process has been with the Canyon as my guide!
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