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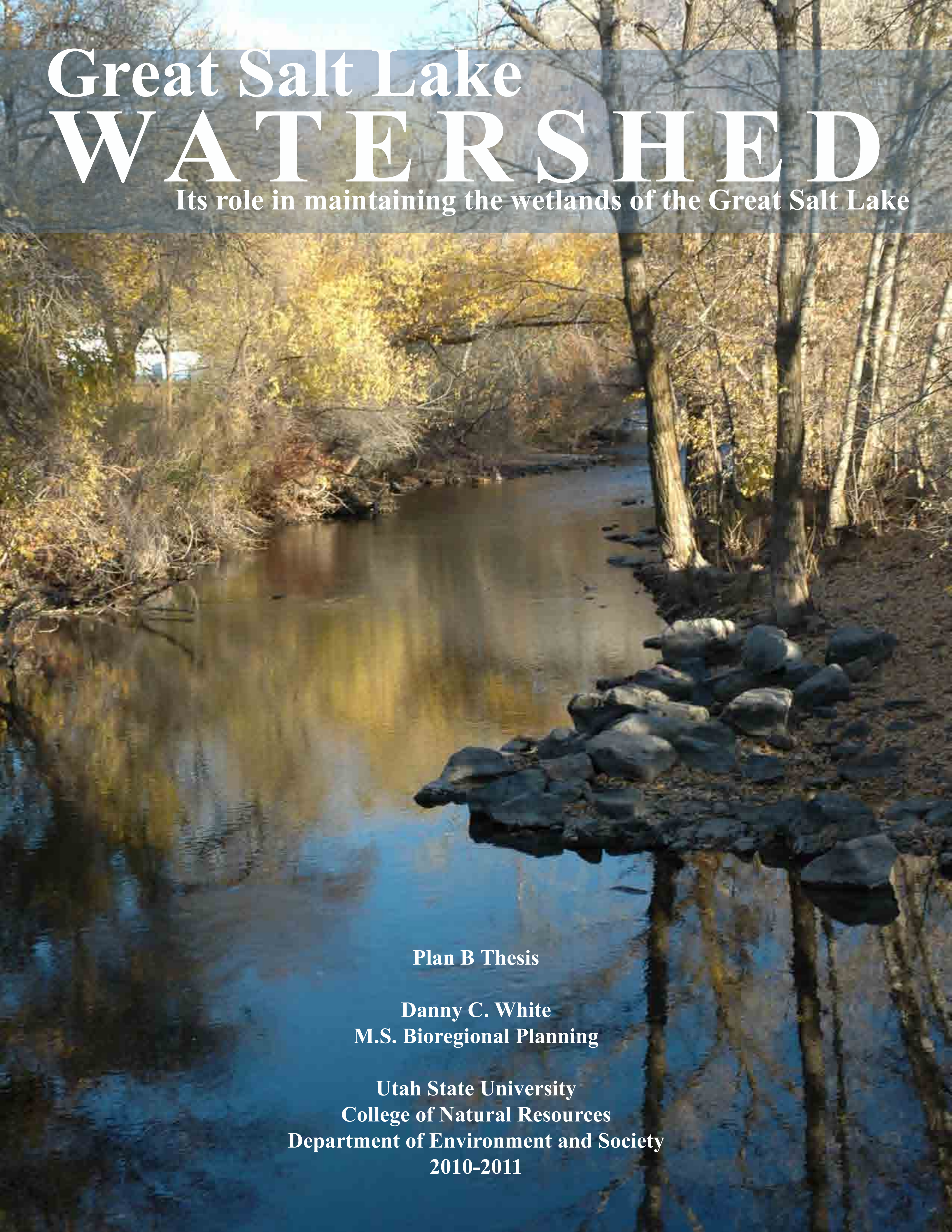
Great Salt Lake Watershed: Its Role in Maintaining the Wetlands of the Great Salt Lake

Danny C. White Jr.
Utah State University



Great Salt Lake WATERSHED

Its role in maintaining the wetlands of the Great Salt Lake

Plan B Thesis

Danny C. White
M.S. Bioregional Planning

Utah State University
College of Natural Resources
Department of Environment and Society

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Plan B Project

Danny C. White
MS ï Bioregional Planning
Utah State University

Committee Chair: Richard E. Toth
Committee Members: Karin M. Kettenring, and Joseph Wheaton

Utah State University
College of Natural Resources
Department of Environment and Society
Bioregional Planning Program
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I would also like to thank my amazing wife Stephanie for without her tireless efforts and patience I would never have been able to complete this project.

Lastly I would like to thank my son Parker, for providing me with inspiration and motivation throughout this entire process.

Preface

The following bioregional planning study is a direct result of the 2009-2010 studio project initiated by the United States Fish and Wildlife Service (FWS). The FWS contacted the study team and asked them to determine how the future growth and development of the Bear River Watershed would impact the Bear River Migratory Bird Refuge (BRMBR). The study looked at all of the physical and biophysical systems within the Bear River Watershed to identify the issues that had an effect on the BRMBR.

It became apparent from the original project that the future of the BRMBR and other Great Salt Lake wetlands was dependent upon the future use of water within the Bear River Watershed and the Great Salt Lake Watershed as a whole.

Further research uncovered significant proposed withdrawals to the tributaries of the Great Salt Lake as well as some directly from the lake itself. After discussions with multiple stakeholders that rely on water from Great Salt Lake tributaries and water from the lake, it became clear that there was a need for a study to determine how the proposed future use of water within the Great Salt Lake Watershed would affect the wetlands that border the lake.

It is the goal of this study to determine how the future growth and development within the Great Salt Lake Watershed will affect the wetlands of the Great Salt Lake (both managed wetlands and naturally occurring wetlands). This study will focus on how future water development and urban growth will impact wetland size and function.

Potential for Water Development
According to the Utah Division of Water Resources 1,945,000 acre-feet of water per year is delivered to the Great Salt Lake through its three major tributaries the Bear, Weber, and Provo/Jordan Rivers and from the West Desert. A total of 690,000 acre-feet of water is proposed to be developed within the watershed (see pages 6-7 and 21-22).

Climate Change and Water Volume
It is estimated that climate change will result in a 30% reduction in the annual water balance, resulting in a major decrease in the volume of water arriving at the Great Salt Lake (see pages 17 and 22).

Water Development and Lake Level
Much research has been done to determine the effects of water withdrawals on the level of the Great Salt Lake. According to (DeFault & and Carter, 2000), a reduction of 100,000 acre feet of water will result in a one foot reduction in lake level (see page 45). This model provides a close approximation to the relationship between water withdrawal and lake level; however, since it assumes a linear relationship between lake level and water reduction, it is not precise enough to predict how fluctuations in flow will affect the shoreline. To fully understand how reductions of flow to the Great Salt Lake will affect lake levels and shoreline location, the bathymetry of the entire lake must be mapped (see page 90).

Impact of Water Development on Wetlands
The wetlands of the Great Salt Lake lie at the bottom of an internally drained basin making them vulnerable to activities that affect water quality and quantity upstream. This study has determined that the proposed development of water in the region will have a significant impact on the wetlands bordering the Great Salt Lake (see page 46). For the managed wetlands such as the Bear River Migratory Bird Refuge, the major impact from water development will be a decrease in freshwater inflow to flush out highly saline sediments, resulting in increased stress for wetland vegetation (see page 47). An increase of invasive species such as *Phragmites australis* can be expected as water is developed in the region (see page 47).

Impact of Urban Growth on Wetlands
Using current planning practices a model was developed to predict future urban growth; this study determined that as much as 301 acres of wetlands in the Great Salt Lake Watershed will be destroyed due to current development practices in the near future (see page 87). A total of 116 acres are likely to be lost from wetlands adjacent to the Great Salt Lake.

Recommendations
The Development practices of LEED were utilized in this study to illustrate the benefits of adopting a more sustainable growth pattern. The LEED future scenario resulted in less of an impact to the critical components of the watershed identified in this study (see page 83). Adopting LEED principles will also reduce the municipal and industrial use of water by as much as 50% (see page 80). An even more significant reduction of water can be achieved by utilizing greater conservation measures for agricultural irrigation (see page 90).

Introduction

The Great Salt Lake Watershed is a vast basin of approximately 34,000 mi^2 and includes much of northern Utah, parts of western Wyoming, southeastern Idaho and eastern Nevada see figure 1.1. The region is home to beautiful landscapes that were formed through a number of geologic forces. Water in particular played a large part in carving much of the watershedôs natural beauty. ñGlaciers, prehistoric lakes, rain, and rivers and streams have all contributed to the formation of the dramatic landscapesò (Utah Division of Water Resources, May, 2001).

Three major river systems are at the heart of the watershed and include the Bear, the Weber, and the Provo. Each of these river systems originate along the western part of the high Uinta Mountains along the eastern edge of the watershed boundary. Another contributor to the Great Salt Lake, although to a smaller extent, is the West Desert which comes primarily in the form of groundwater.

Approximately 85% of Utahôs population or 1.4 million people live within the boundaries of the watershed, primarily along the western slopes of the Wasatch Front. This population is expected to increase from 2.8 million to 6.8 million by the year 2060, which is a growth of over 243% (Utah Governor's Office of Planning and Budget, January, 2010).

Aerial view of Bear River Migratory Bird Refuge (Danny White)

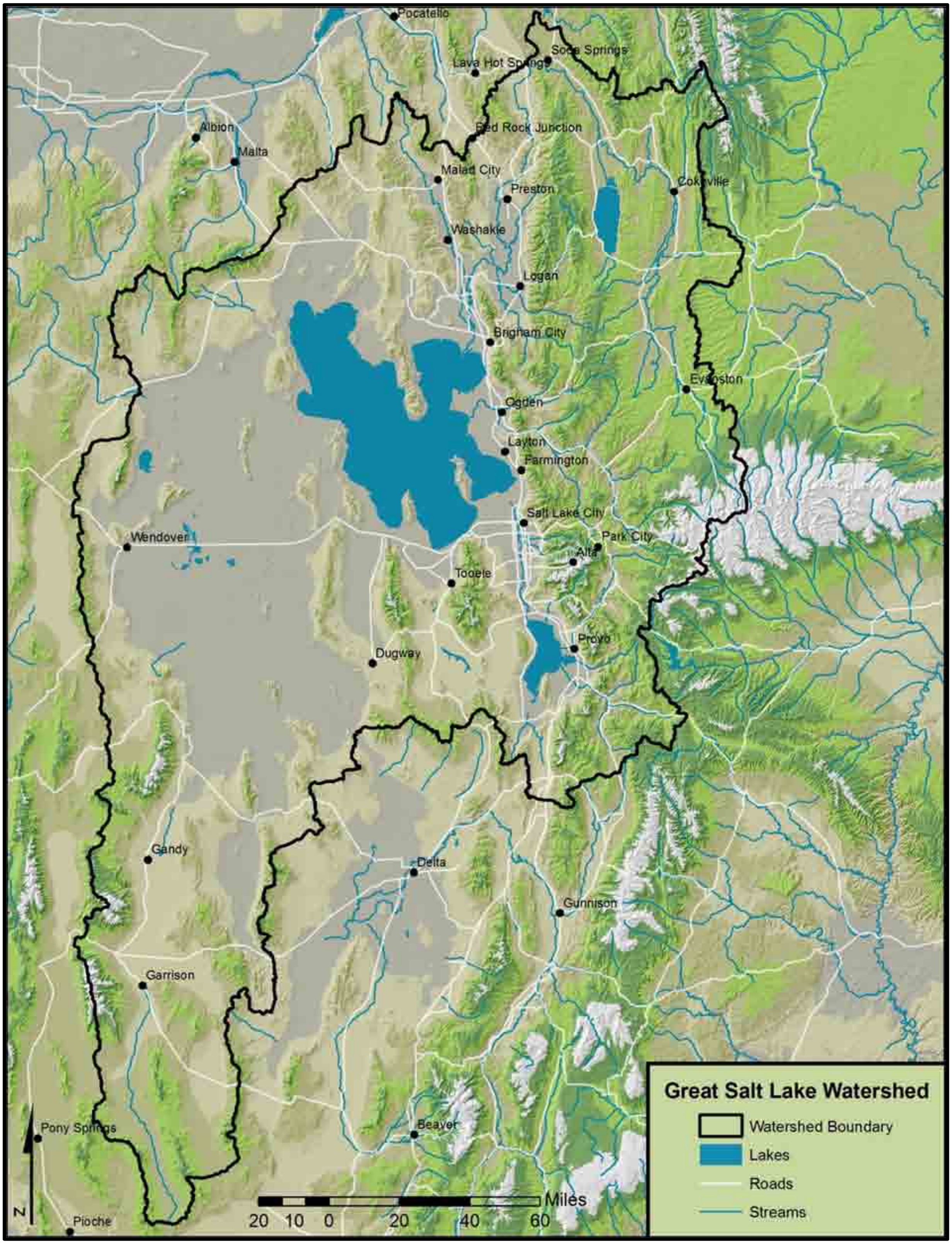


Figure 1.1 Great Salt Lake Watershed

Methodology

Bioregional planning is a process that relies on both scientific and social knowledge from a wide range of areas of expertise. When dealing with the complexity of large scale issues and systems, an iterative approach is needed to allow the researcher to adapt when new information is acquired and as feedback from models is obtained. It is important that the methodology facilitate the process of research and take into consideration the unique elements of each landscape.

This study was adapted from the methodological work of Richard Toth (Toth, 1972) and the bioregional planning studio of 2009-2010 (Toth, Edwards, Perschon, & White, 2010). This methodology utilizes an approach that is flexible, logical, and iterative; it was designed to carefully research the complex systems within the watershed and evaluate the viability of alternative futures with respect to assessment models (see figure 1.2).

The primary phases of this methodology are:

- Site Selection
- Pre-analysis
- Research and Analysis
- Development of Models
- Evaluation of Alternative Futures
- Implementation Strategies

Site Selection: The project extent of this study is the entirety of the Great Salt Lake Watershed, with consideration of the surrounding region for greater context. This project will also entail a more detailed analysis that will consist of the wetlands adjacent to the Great Salt Lake.

Pre-analysis: This phase of the project included reconnaissance trips to many areas within the project area, including an over flight of the Bear River Watershed (the largest contributor of water to the Great Salt Lake), a review of relevant case studies and other literature for familiarization, discussions with professionals, various professors from both Utah State University

Snow covered field south of Smithfield Utah (Danny White)

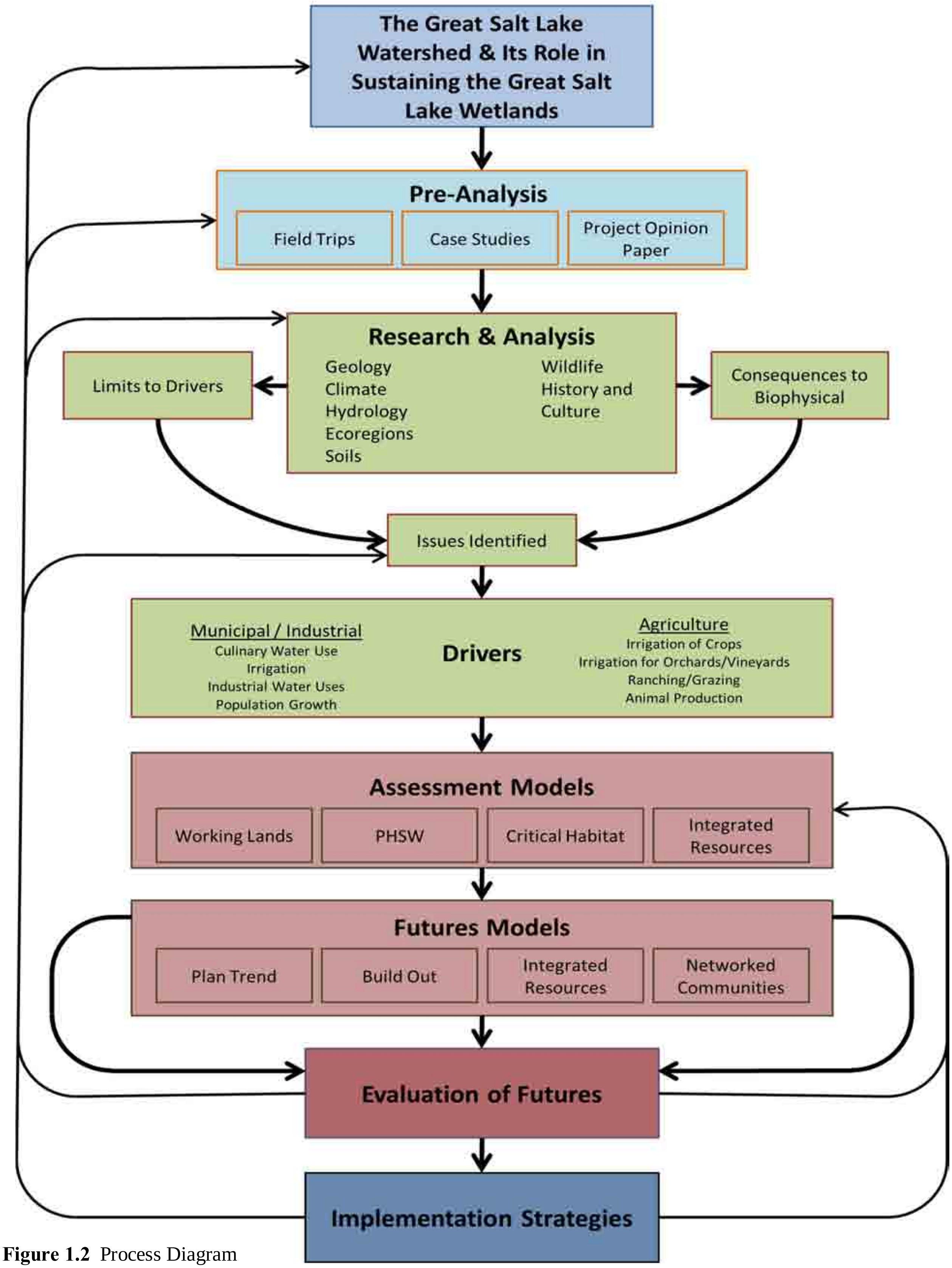


Figure 1.2 Process Diagram

and the University of Utah, and stakeholders with a wide range of backgrounds and disciplines.

Research and Analysis: One of the main elements of this research project was the identification of key issues affecting the wetlands of the Great Salt Lake. In order to determine the key issues an analysis of the function and structure of the region was performed.

Development of Models: Existing data was used to develop assessment and alternative future models that were based on and created to address the key issues identified within the watershed. The assessment models were designed to visually represent the physical and biological attributes and were used to determine the impacts of the future models on the key issues within the watershed.

Alternative future models were used to depict what the watershed might look like based on a multitude of scenarios, including business as usual.

Evaluation of Models: The effectiveness of the future models in preserving the wetlands of the Great Salt Lake will be evaluated based upon their impact to the assessment models. Using these evaluation criteria, a preferred alternative future was identified and the effect each future has on the wetlands was detailed.

Implementation Strategies:
Implementation strategies were developed based on the research process and model evaluations. These strategies try to bring balance to water development for human needs and the vitality of the Great Salt Lake Wetlands.

View over the BRMBR visitor center (Danny White)

Issues of Concern

Given the propensity of population growth within the watershed, planning for the future use of water is of great concern not only to planners of the region, but to the growing population as well. For this reason the Utah Division of Water Resources (DWR) has been forecasting the future water needs for the state and its individual watersheds. According to DWR, the future of water in Utah is bright, but to achieve that future further development of water will be necessary.

Water Development of Tributaries to the Great Salt Lake

Currently there are several public water development projects proposed within the Great Salt Lake Watershed that may have an impact on the Great Salt Lake wetlands. The largest project proposes to withdrawal 120,000 acre-feet of water per year from the Bear River for use by Cache and Box Elder Counties and export an additional 100,000 acre-feet of water per year to the growing population of the Wasatch Front. According to the Utah Division of Water Resources the water allocated for the Wasatch Front will only be diverted during high flow years (Short, 2011).

Within the Weber River Basin there is the potential to develop more water since during parts of the year in Park City, many of the water systems are running at or near capacity (Utah Division of Water Resources, September 2009). In order to accommodate population growth 17,100 acre-feet of water per year may be piped from the Weber River to Park City (Utah Division of Water Resources, September 2009).

Within the Utah Lake Watershed there is the potential when proven feasible, to tap additional sources of water for municipal and industrial use. Although the Division of Water Resources does not give a specific amount of developable water, it can be assumed that it is somewhere in the range of 10,000 to 50,000 acre-feet per year (Utah Division of Water Resources, 2010). Additionally there is the potential to develop additional water from the Jordan River once the ability to treat the water becomes economically feasible.

Although the West Dessert is much dryer than the rest of the region there is still the potential to develop some its water supply. Nevada has plans to siphon 50,000 acre-feet of water per year out of an underground aquifer in Snake Valley and export it to Las Vegas. The trouble for the Great Salt Lake wetlands is that this groundwater supply flows downhill towards the Great Salt Lake, contributing to its annual inflow of water.

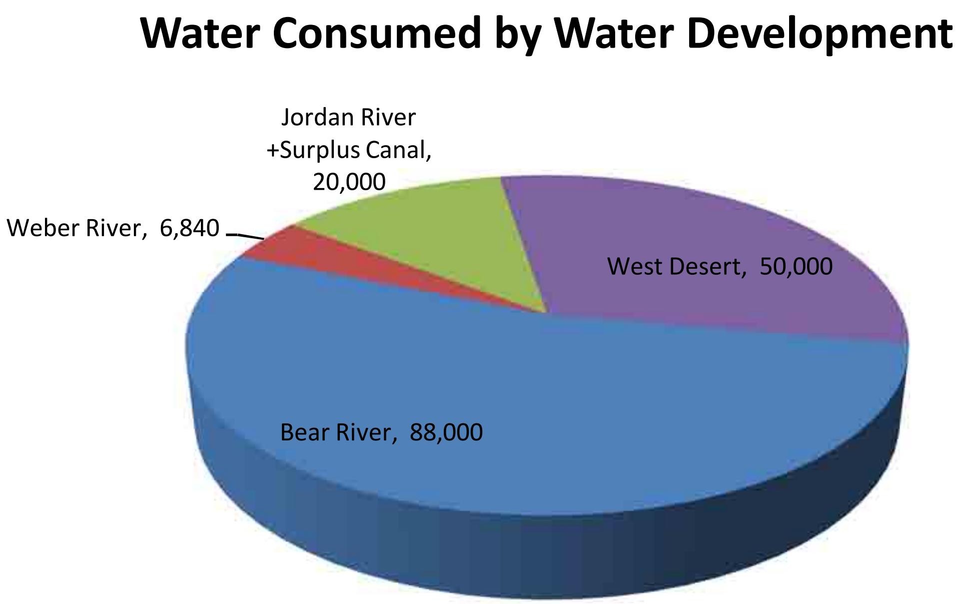


Figure 1.3 Surface water reductions to the Great Salt Lake post water development (acre-feet)

It is important to note that not all of the water developed for municipal and industrial use is completely lost; up to 60% of the water used for these purposes will eventually arrive at the Great Salt Lake (DeFault & and Carter, 2000). However, water developed in the West Desert will result in a total loss for the Great Salt Lake as a result of being pumped out of the Great Salt Lake Watershed. Figure 1.3 illustrates the relative amounts of water that will be lost to the system due to municipal and industrial consumption, assuming a 60% recovery.

Development
of Water from the Great Salt Lake

There are also proposals from industries to withdrawal water out of the Great Salt Lake. One such industry is Great Salt Lake Minerals, which proposes to enlarge its operation by flooding up to 91,000 additional acres with up to 353,000 acre-feet of water. Their proposed use of would completely consume the entire 353,000 acre-feet.

Geology

The processes that formed the landscape in which the Great Salt Lake Watershed is located plays a significant role in the natural water quality of the region. The following provides a brief history of the geologic past of the watershed.

To describe the geology of United States the continent was subdivided into characteristic landforms called physiographic provinces. The features that distinguish one province from another are determined by the areas unique geologic history and its erosional characteristics. Utah contains parts of three physiographic provinces as shown in figure 1.1.

Figure 2.1 Major Physiographic Provinces of Utah (Milligan, 2000).

The Middle Rocky Mountains and the Basin and Range provinces are the dominant physiographic provinces from the above figure that fall within the Great Salt Lake Watershed, so that is where this report will focus.

Basin and Range Province

The topography of the Basin and Range Province is characterized by north-trending, steep, narrow, mountain ranges dissected by sediment filled valleys that are wide and flat (Milligan, 2000). The mountains of this province began to form after the deformed rocks of the Precambrian (over 570 million years old) and Paleozoic (570 to 240 million years old) were slowly pushed upward and then broke into large fault blocks by the forces that continue to deform the earthôs crust in our day (Milligan, 2000).

Much of the sediment that shed from the mountain ranges is slowly filling the dissecting wide valley basins (Milligan, 2000). Most of these valleys were modified even further by the shorelines of ancient lakes that once covered the valley floors. Lake Bonneville was one of these ancient lakes and will be furthered discussed in this chapter.

Middle Rocky Mountains Province

Streams and glaciers have carved the high mountains that typify the topography of the Middle Rocky Mountain Province. The Uinta and the Wasatch mountain ranges are found within the Utah portion of this province. Both ranges are composed of Precambrian rocks some of which are more than 2.6 million years old, and contain cores that have been influenced by many cycles of building and burial (Milligan, 2000).

Within the last 12 to 17 million years the Wasatch Range began to uplift (Milligan, 2000). Previous to this uplift during the Cretaceous Period (138 to 66 million years ago), forces within the earthôs surface began to form mountains thrusting and stacking large rock sheets in the northeast-most region of Utah, including the region with the Wasatch Mountain Range. Over time, this area of thrust and stacking was heavily eroded. About 38 to 24 million years ago magma in large quantities began to infiltrate parts of the Wasatch Range. ñThese granitic intrusions, eroded thrust sheets, and the older sedimentary rocks to form the uplifted Wasatch Range as it is seen todayò (Milligan, 2000).

Approximately 60 to 65 million years ago the Uinta Mountains began to uplift after compressional forces formed a buckle in the surface of the earth, known as an anticline (Milligan, 2000). This uniquely oriented mountain range was heavily eroded, but started to rise once more around 15 million years ago to their current elevation of 13,000 feet.

Further characterization of the Middle Rocky Mountains province includes glacial lakes, u-shaped valleys, sharp ridges, and large piles of debris (known as glacial moraines) which were created by mountain glaciers during the Pleistocene (during the last 1.5 million years) (Biek, Willis, & Ehler, 2010).

Lake Bonneville

During the late Pleistocene epoch a large inland sea, Lake Bonneville, covered much of the western half of Utah and south eastern corner of Idaho (see figure 2.2). At its highest level it covered over 20,000 mi^2 and was as much as 1,000 feet above the present day Great Salt Lake (approximately 4,200 feet) (Hunt, Varnes, & Thomas, 1953).

Lake Bonneville had two major stages, the Bonneville and the Provo. The Bonneville stage was the largest and earliest of the two stages, with elevation of around 5,100 feet (Baskin, Waddell, Thiros, & Giddings, 2002). Conditions were much wetter and cooler during the most recent ice age, producing more water for the lake. Lake Bonneville continued to rise to an elevation of 5,250 feet, at which point it broke through an ice dam near Red Rock Pass and flooded the Snake River Basin.

Lake Bonneville continued to decline until it reached the Provo level at approximately 4,740 feet above sea level and remained there for nearly 1,000 years. This new lake level exposed freshly deposited sediments which rivers and streams easily cut deep channels through and deposited the sediment further down in the valleys, forming broad fans.

After the Provo stage Lake Bonneville declined relatively quickly as a result of climate change, forming what is now known as the Great Salt Lake. Although Lake Bonneville accounts for just a short portion of Utahôs geologic history, it contributed to much of the sands and gravels that are mined from within the watershed. It also formed the benches that are visible throughout many of the Great Salt Lake Watershed valleys. These benches, although considered prime for development, are also highly susceptible to landslide due to their erosion potential (Baskin, Waddell, Thiros, & Giddings, 2002).

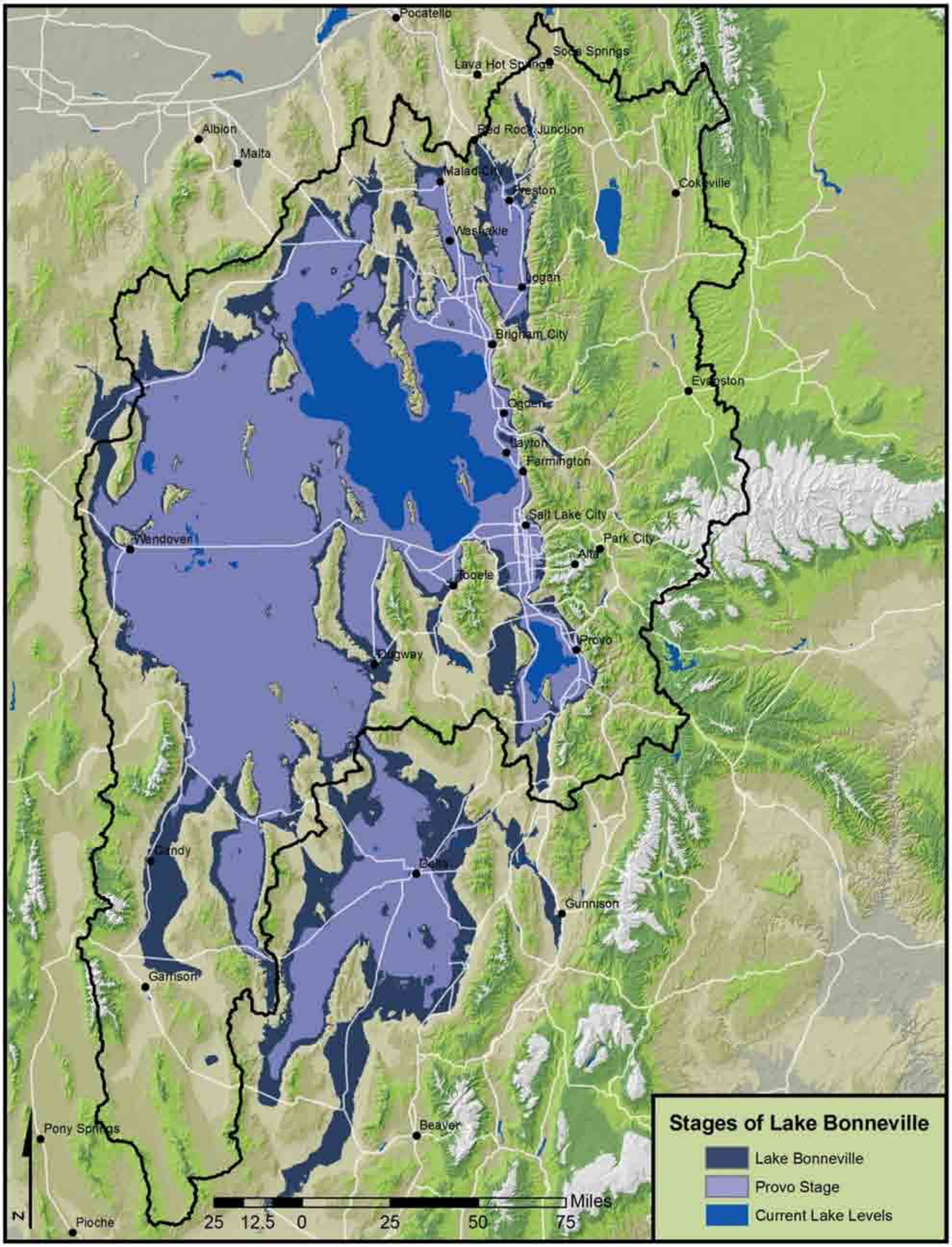


Figure 2.2 Stages of the Pleistocene Lake Bonneville.

Climate

The climate of the Great Salt Lake Watershed is typical for the mountainous regions of the Western United Sates where temperatures tend to fluctuate greatly between day and night, and summer and winter months. Higher elevations have long, frigid winters and cool short summers. Areas of lower elevation such as valleys tend to be more moderate, with less variance between minimum and maximum temperatures. Temperatures vary widely throughout the watershed, but the average annual temperature tends to fall between 32° F and 52° F. There are locations within the region that experience extremely cold temperatures. During the winter of 1984-85 Peterȏs Sink (located in the Bear River Range) a record low temperature for the state was set at -69.3° F (NOAA, 2002).

Each of the sub-basins within the watershed receives the majority of their precipitation as snowfall in the winter months. During the spring and summer months the sub-basins receive most of their runoff as snowmelt. Precipitation amounts also vary widely throughout the watershed, dependent primarily upon elevation. Annual precipitation for the region ranges from 10 to 16 inches in the valleys and greater than 70 inches in the higher elevations (Fig 2.3).

Precipitation occurs in the mountainous regions of the watershed during the cold months as snow and is generated by eastward moving storms move across the land mass from the Pacific Ocean. As these warm air masses move up the west facing slopes of mountain ranges precipitation increases, and as they move down the east facing slopes precipitation decreases. An abundance of water runoff is produced when the snow melts in the spring and summer months. Much of this snowmelt percolates through the fractured bedrock of the Wasatch Range recharging the nearby aquifers (Baskin, Waddell, Thiros, & Giddings, 2002).

Variable Weather

The Great Salt Lake Watershed is also impacted by variable weather which ranges from epic snow storms in the winter to flash floods during the summer monsoon season. Flooding can also be problematic when heavy snow pack begins to melt in the spring and early summer. Rare events such as tornadoes, do occur and are typically short lived. Hurricane force winds are also possible, especially from canyons along the west facing slopes of the Wasatch Mountains.

Lake effect is a phenomenon that tends to enhance the amount of precipitation off the southern and eastern shores of the Great Salt Lake (Alder, The National Weather Service, Weather Across Utah in the 1980s, and Its Effect on Great Salt Lake, 2000). The lake effect occurs most frequently during the fall and spring and typically generates several cm of precipitation, although during more intense and longer duration storms, it can produce much heavier accumulations (Steenburgh, Halvorson, & Onton, Climatology of Lake-Effect Snowstorms of the Great Salt Lake, 1999).

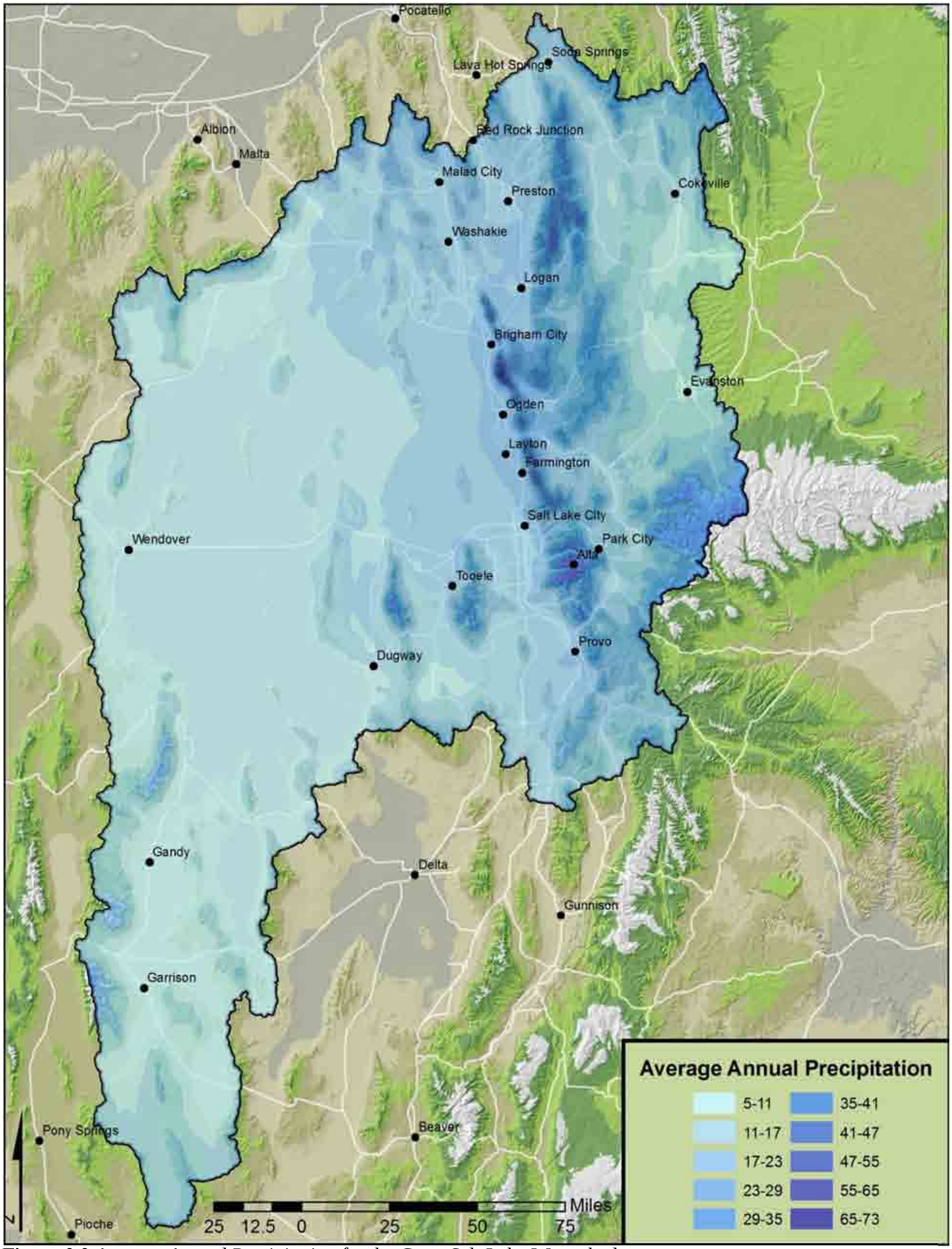


Figure 2.3 Average Annual Precipitation for the Great Salt Lake Watershed.

The Great Salt Lake has a high level of salinity, which prevents much of the lake from freezing over during the winter months. The open water of the lake acts like a hot spot, which lowers the atmospheric pressure over the lake, compared with that over the ground. When this occurs it causes warm air to converge over the lake which produces intense snow bands (Alder, The National Weather Service, Weather Across Utah in the 1980s, and Its Effect on Great Salt Lake, 2000). What typically triggers the lake effect is when a northwesterly cold front moves across the lake with a temperature difference of at least 17° C and the absence of stable layers or inversions (Steenburgh & Orton, 2000).

The watershed is also affected by **El Nino and La Nina weather patterns.** Both El Nino and La Nina are naturally occurring climate cycles collectively referred to as the El Nino/Southern Oscillation the cause of which is a large scale change in surface temperatures of the tropical eastern Pacific Ocean (Alder, 2000). These changes in sea-surface temperatures have an impact on the atmosphere and climate. The impacts of these and other cyclical climate patterns are found in Figure 2.4.

Climate Change

It is becoming increasingly evident that the only aspect of earthös climate that has remained constant is that it is ever changing. There have been changes in hot and cold periods and in wet and dry periods.

One of the topics of particular interest is whether the earth is warming. According to a report by Utah Department of Natural Resources human influence on climate is greater now than ever before in earthös history. ñGreenhouse gases are contributing

El Niño Southern Oscillation (ENSO) is described by it two phases, El Niño and La Niña and also by the Southern Oscillation.

El Niño is the warming of se-surface temperatures (SSTs) of the eastern and central tropical Pacific Ocean, which interacts with atmospheric conditions, with 2 to 7 year phases. Generally this results in drier winters in the Pacific Northwest and wetter winters in the Southwest United States.

La Niña events (or cold events) are the cooling of SSTs across the eastern and central tropical Pacific Ocean, which tends to be associated with wetter winters in the Pacific Northwest and drier winters in the Southwest United States.

Southern Oscillation is an inverse relationship in atmospheric surface pressure between Tahiti and Darwin (Australia). When lower than average pressure exists at Tahiti and higher than average at Darwin, El Niño is generally present. The normalized pressure difference between the two locations is known as the **Southern Oscillation Index (SOI)**.

Pacific Decadal Oscillation (PDO) is a long-term El Niño-like pattern of climate variability in the Pacific, with 20-30 year phases. The warm or positive phase is indicative of cooler than average SSTs (in the main Pacific) and warmer than average SSTs near the coast of California, enhancing El Niño effects. The cooler or negative phase tends to enhance weather conditions associated with La Niña.

Atlantic Multidecadal Oscillation (AMO) refers to long-duration changes in the SSTs of the North Atlantic Ocean, with phases lasting 30-40 years. During the warm or positive phases, droughts tend to be more frequent and/or severe.

Figure 2.4 Definitions of climate patterns affecting the Great Salt Lake Watershed (Utah Division of Water Resources, 2007) to overall climate change, however, it looks as though that even with strict regulation of greenhouse gases, climate change will continue and mankind will have to adapt to whatever the resultant climate may beò (Utah Division of Water Resources, 2007).

It is not fully understood what the implications of a warmer climate will be on the Great Salt Lake Watershed. The implication of climate change on precipitation for this region is also not agreed upon.

As of 2007 there have been no significant precipitation trends within the region that has been forecasted or detected (Utah Division of Water Resources, 2007). ñThrough statistical analysis of Utahôs snowpack, conducted by Randall Julander of the Natural Resources Conservation Service, no statistically significant trends with regard to snowpack accumulation, melt or ablation have been identified. This conclusion is reinforced as precipitation trends have not been identified in the Colorado River Basin as wellò (Utah Division of Water Resources, 2007). There have been numerous studies that provide some possible consequences of increasing temperatures, several of these studies have documented these changes in the west (Utah Division of Water Resources, 2007). The potential consequences of climate change are as follows:

- The growing season will potentially last longer and begin earlier.
- There will be a potential increase in evapotranspiration.
- Due to higher evaporation rates snowpack will be less and will melt earlier in the year.
- There may be a decrease in summer precipitation while precipitation in the fall and winter may increase. Much of this fall and winter precipitation may come in the form of rain instead of snow.

A possible future scenario is provided by the National Oceanic and Atmospheric Administration (NOAA). Recent research by the Intergovernmental Panel on Climate Change has allowed NOAA to provide some preliminary data for Utah. Since the majority of the watershed falls within the State of Utah, it will be used as a surrogate for the entire watershed. Figure 2.5 represents projections that are predicted to occur statewide, unless otherwise noted and should take place by 2060:

Air temperature is projected to increase in Utah by 5.4 to 6.3° F. The Northern Mountains and Uinta Basin, climatic regions 5 and 6 are projected to be the national epicenter of temperature increase. The Colorado River Basin has already warmed more than any other region in the United States.
Annual precipitation is projected to change within a range of -1.2 to +1.2 inches. Precipitation in the Dixie area, climatic region 2, is projected to decrease by 1.2 to 2.8 inches.
Annual evapotranspiration is projected to increase by 5.1 to 6.7 inches. Evapotranspiration in the Dixie area, climatic region 2, is projected to increase by 6.7 to 7.9 inches.

Annual water balance (precipitation minus evapotranspiration) is projected to decrease by 30%, indicating a deficit in the water balanceð higher loss than recovery.

Drought, due to the estimated air temperature increase, is projected to be more severe early on in the 21st Century (severe drought = PDSI< -3). On average this will have an areal extent that will affect 50% of the Interior West and on average last for 12 years (similar to severe droughts expressed in the reconstructed PDSI records).

Figure 2.5 Predicted changes to the State of Utahôs climate by 2060 (Utah Division of Water Resources, 2007).

If the annual water balance decreases 30% as predicted by NOAA, it will result in a loss of water to and from the tributaries of the Great Salt Lake see figure 2.6. In addition, an increase in evapotranspiration of this magnitude will result in increased water demands for irrigated crops. It is also possible that crops that are currently grown in the region without irrigation will require some amount of irrigation to prove successful in the future. To assure a high quality of life for future generations it is critical that the impacts of climate change be better understood and integrated into the development and use of water in the watershed.

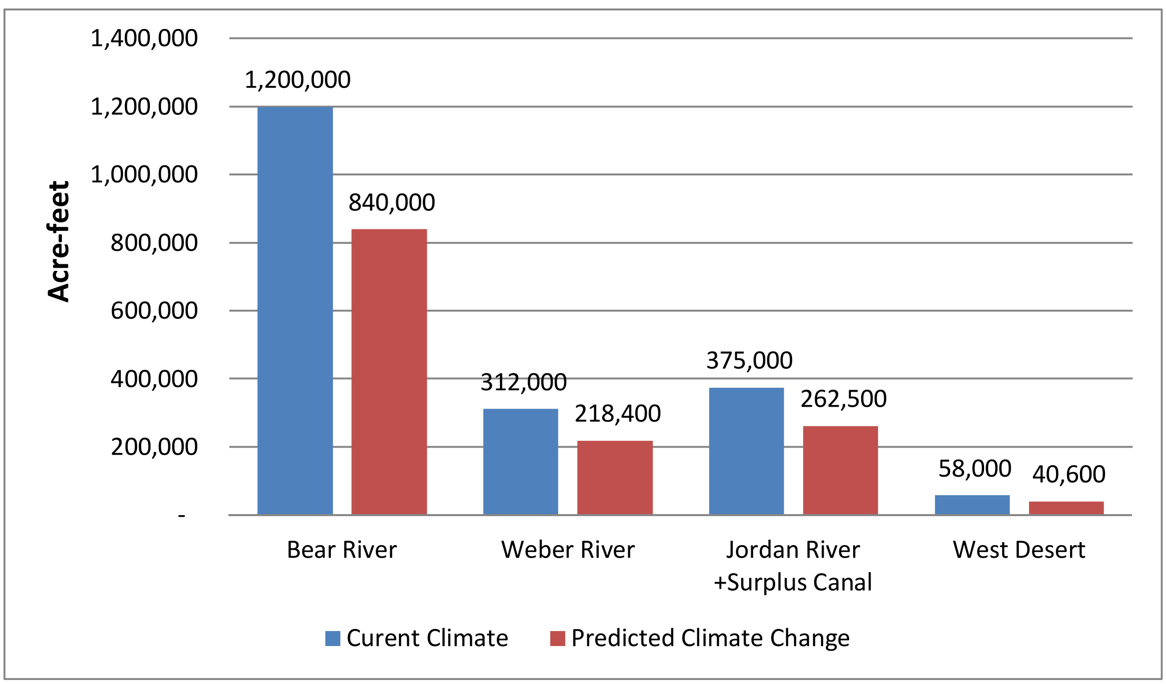


Figure 2.6 Changes to water volume in the tributaries of the Great Salt Lake due to climate change.

Hydrology

The hydrologic system (see figure 2.7) within the Great Salt Lake Watershed can be broken up into two components. First is the surface water component, which contains lakes, reservoirs, rivers, and springs. The second component is groundwater which includes aquifers and recharge areas. These two components work in concert to form the hydrologic system of the Great Salt Lake Watershed.

Surface Water

Surface water within the Great Salt Lake Watershed can be broken up into four separate, smaller basins, which include the Bear River, Utah Lake, Weber River, and the West Desert Basins (see figure 2.8). according to the Utah Division of Water Resources the total water contributions from the four sub-basins is 1,945,000 acre-ft/yr (Utah Division of Water Resources, 2001, 2004, 2009, and 2010). Of the total discharge into the Great Salt Lake, 62% is from the Bear River Basin, with 16% being discharged by the Weber River Basin, and 19% discharged by the Utah Lake Basin, and 3% discharged by the West Desert Basin (Utah Division of Water Resources, 2001, 2004, 2009, and 2010). More detail on discharge can be found on the scaled discharge schematic in figure 2.9.

The **Bear River Watershed** is a vast basin that includes roughly 7,500 mi^2 of territory, from high mountain ranges to valleys. It occupies portions of three states including roughly 1,500 square miles in Wyoming, 2,700 square miles in Idaho, and 3,300 square miles in Utah (Utah Division of Water Resources, 2002). The Bear River is situated in the northeastern portion of the Great Basin, which is surrounded on all sides by mountains, forming a large bowl and restricting any water from escaping. The Bear River itself is the largest river in the world that does not drain into an ocean.

The headwaters of the Bear River are located on the north slope of the Uinta Mountains and are located nearly due east of Salt Lake City. From its headwaters the Bear

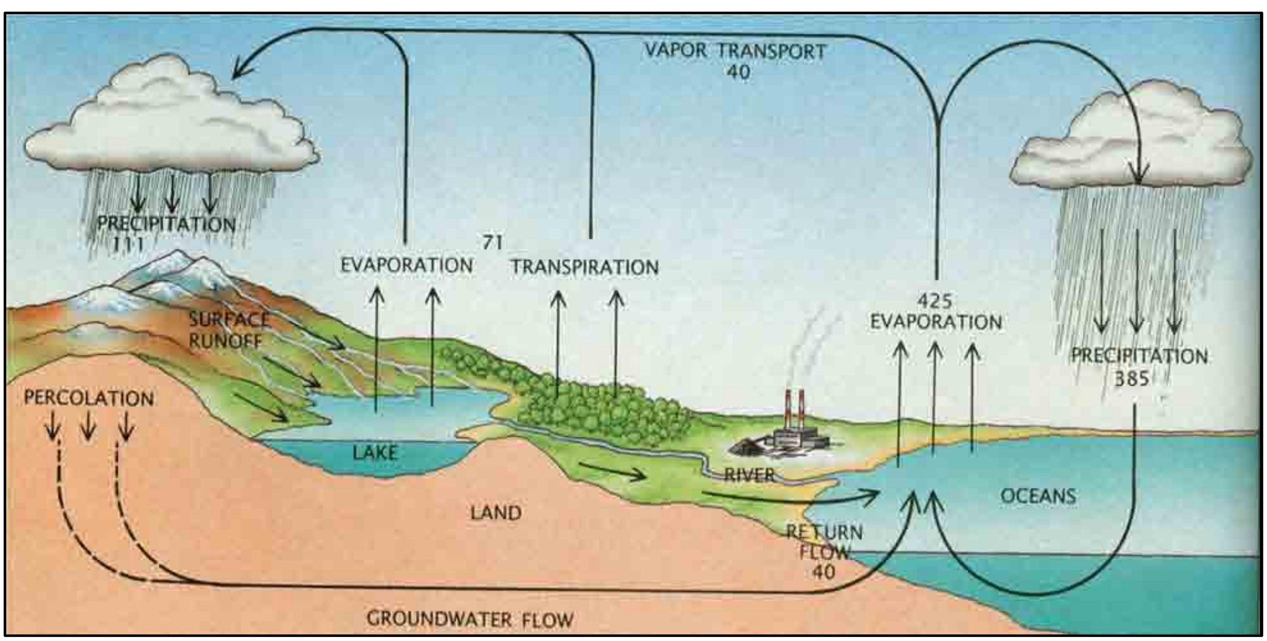


Figure 2.7 The hydrologic cycle (Scientific American, 1989)

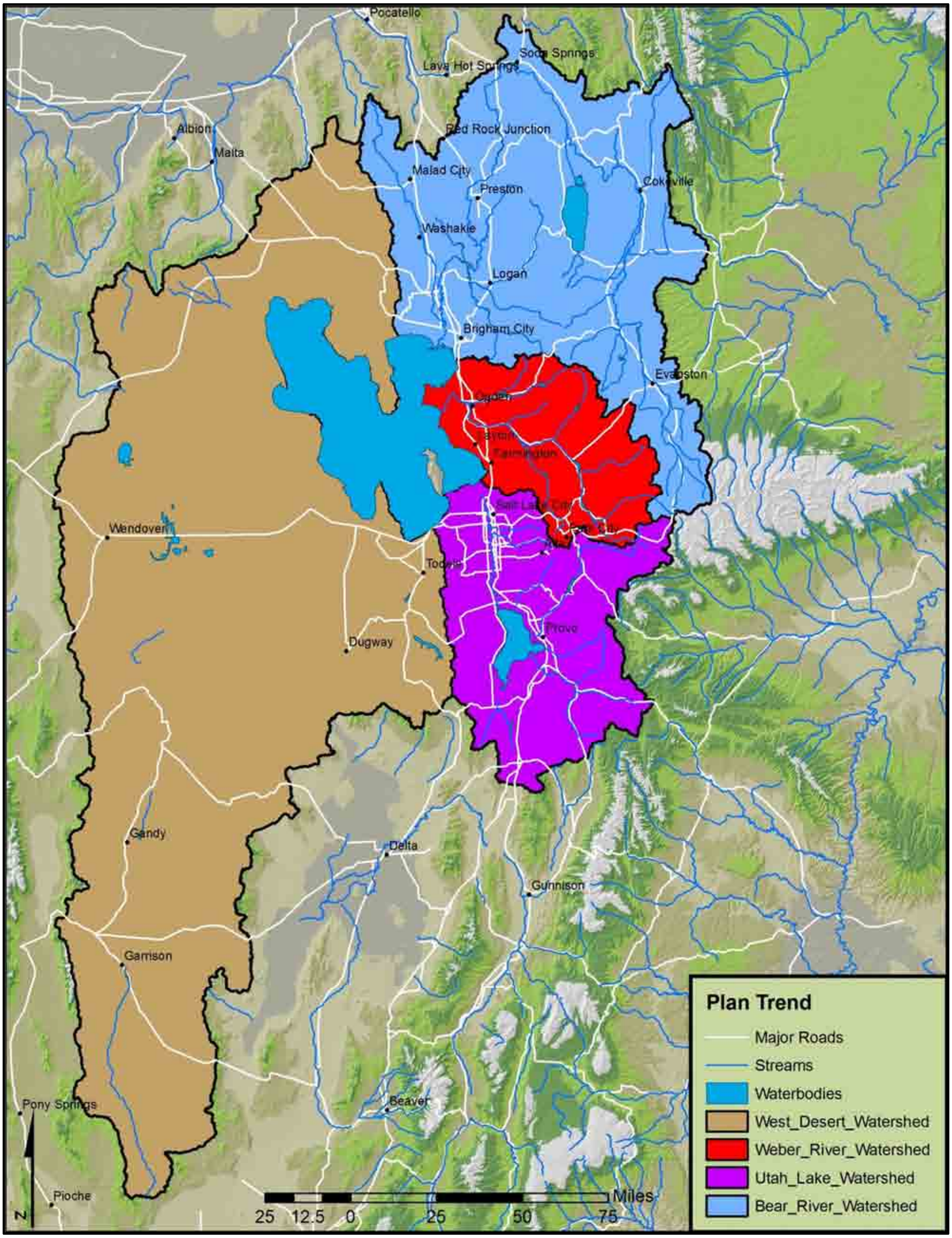


Figure 2.8 Sub-basins of the Great Salt Lake Watershed.

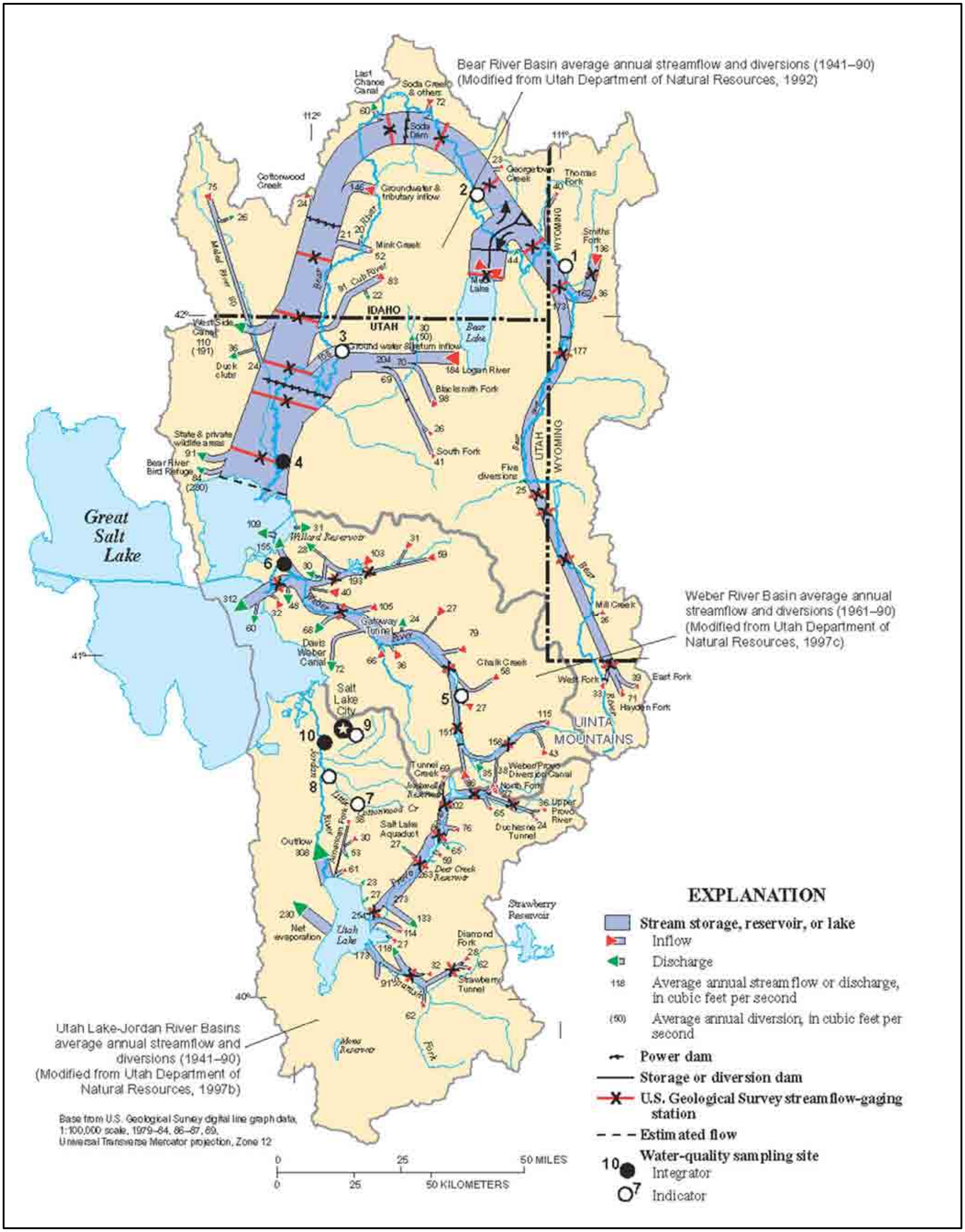


Figure 2.9 Scaled schematic of average annual discharge within the watershed minus the West Desert (Baskin, Waddell, Thiros, & Giddings, 2002).

River travels in a generally northern direction, crossing over the Utah-Wyoming border multiple times before flowing into Idaho. The river continues on its northern path until it starts turning south just north of Soda Springs, Idaho. At the end of its nearly 500-mile journey (with an elevation loss of 8,500 feet), the Bear spills into the Great Salt Lake less than 100 miles from its origin.

Average annual precipitation in the Bear River Watershed is 21 inches with a maximum of 61 inches in the higher elevations. Elevation in the basin ranges from 4,198 feet to 12,673 feet.

The **Utah Lake Watershed** covers 3,846 mi^2 and contains Utah Lake, which is one of the largest naturally occurring freshwater lakes in the western states. While the size of the lake is large, its average depth is only ten feet. This shallow depth allows wind to disturb sediment along the lake bottom, causing turbid water.

Average annual precipitation is approximately 20 inches and the elevation ranges from 4,196 feet to 11,899 feet (Utah State, 2010). The primary flow of water comes from the Provo, American Fork, and the Spanish Fork Rivers, while the Jordan River drains the water from Utah Lake to the Great Salt Lake.

The **Weber River Watershed** is made up of 2,476 mi^2 of territory and the Weber River begins at an elevation of 11,708 feet in Summit County Utah. It travels nearly 125 miles before it reaches the Great Salt Lake.

The average annual precipitation in the basin is 26 inches, with a maximum of 73 inches in the higher terrain, and elevation ranges from 4,198 feet to 11,961 feet (Utah State, 2010).

Although the **West Desert** is the largest in terms of size, 18,964 mi^2, it only contributes 58,000 acre-feet of groundwater and surface runoff to the Great Galt Lake per year (Utah State, 2010). On average the West Desert receives only 11 inches of precipitation, most of which comes in the form of snow (Utah State, 2010). The area receives so little water that there are virtually no streams except during periods of snowmelt.

Surface Water Development

As mentioned on page 6, there is the potential for significant water development within the Watershed. When coupled with climate change, the volume of water lost to the Great Salt Lake and its wetlands increases substantially (see figure 2.10). It is important that planers take into consideration all of the potential limits to the water resources before allocating any amount of water for future development.

Ground Water

Within the Great Salt Lake Watershed ground water is contained in consolidated rocks in the mountains and basin-fill deposits in the valleys (Baskin, Waddell, Thiros, & Giddings, 2002). The primary water source for municipal and irrigated crops is from basin-fill aquifers.

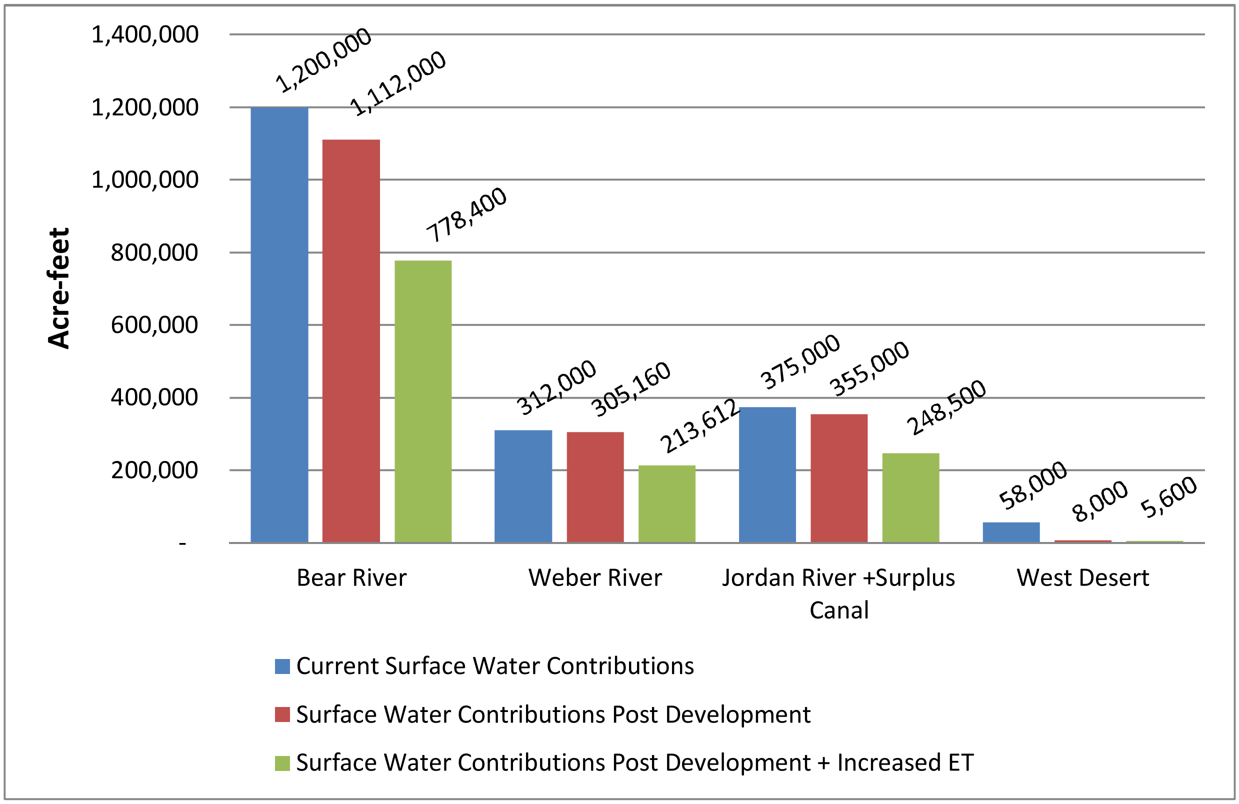


Figure 2.10 Current and proposed contributions to the Great Salt Lake, (Utah Division of Water Resources, 2001, 2004, 2009, and 2010)

Basin-fill aquifers within the watershed can be broken up into two types: principle aquifers and shallow aquifers (Baskin, Waddell, Thiros, & Giddings, 2002). Shallow aquifers are typically unconfined and composed primarily of coarse-grained deposits. These shallow aquifers are separated from the principle aquifers by a layer of fine-grained sediments. The land surface within the Great Salt Lake Watershed that occurs above shallow aquifers is typically developed for residential, agricultural, and industrial uses. Shallow aquifers typically occur within 50 feet of the ground surface making them highly susceptible to contamination from the above mentioned human uses (Baskin, Waddell, Thiros, & Giddings, 2002).

Principle aquifers within the watershed contain deep unconfined aquifers, which are typically found along mountain fronts and confined aquifers where they are overlain by impermeable layers. The deeper unconfined portion of the principle aquifer is usually found near the primary recharge zone. Depth to water table is typically between 150 to 500 feet below the ground surface (Baskin, Waddell, Thiros, & Giddings, 2002). Principle aquifers are a primary source of drinking water and are also susceptible to contamination from human activities.

The recharge of ground water within the watershed comes primarily from precipitation on the valleys and mountains. Precipitation and snowmelt percolate down through the soil and basin-fill deposits into the primary aquifers. Ground water flows from the principle aquifer toward the center of valleys where it slowly discharges into lakes, rivers, and springs (Baskin, Waddell, Thiros, & Giddings, 2002).

Primary recharge area ï These are regions ñwhere fine-grained basin-fill deposits that form confining layers between the land surface and the water table are not thicker than about 20 ft. The occurrence of the deeper unconfined aquifer corresponds with that of primary recharge areaò (Baskin, Waddell, Thiros, & Giddings, 2002).

Secondary recharge areas ï Are regions ñwhere a confining layer is present between the land surface and the principal aquifer. Where a shallow aquifer is present above the first confining layer, the direction of groundwater movement between the shallow aquifer and the confined part of the principal aquifer generally is downwardò (Baskin, Waddell, Thiros, & Giddings, 2002).

Discharge Area ï This is the region ñwhere the direction of ground-water movement is upward from the confined part of the principal aquifer to the shallow unconfined aquifer. Discharge areas generally occur in the topographically lowest parts of the valleysò (Baskin, Waddell, Thiros, & Giddings, 2002).

Ecoregions of the Great Salt Lake Watershed

Ecoregions Defined

Ecoregions represent areas of general similarity in ecosystems and in the quality, quantity, and type of environmental resources. They were created to provide a ñspatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem componentsò (Woods, et al., 2001). They are applicable to the needs of federal and state agencies; and can be used for the development of water quality standards, biological criteria, and to establish management goals for nonpoint-source pollution (Woods, et al., 2001). They are also essential for the integration of environmental resource management, which is an overarching goal for most state and federal agencies.

The ecoregions of the Great Salt Lake Watershed are composed of 5 major ecoregions consisting of the Central Basin and Range, the Middle Rockies, the Northern Basin and Range, the Wyoming Basin and Range, and the Wasatch and Uinta Mountains. These major ecoregions are subdivided into 28 sub-ecoregions within the Great Salt Lake Watershed as illustrated in figures 2.11a and 2.11b.

The following are the ecoregions that are most critical to the delivery of water quality and quantity to the wetlands of the Great Salt Lake. This was determined by examining which receive the greatest amounts of precipitation. They are ordered from greatest to least amount of impact from future development see table 2.1. Impact from future development was determined using the build out alternative future that will be discussed later in the chapter on alternative futures and is illustrated in appendix B. For a complete description of the ecoregions of the watershed see appendix A.

The **Moist Wasatch Front Footslopes** ecoregion supports the majority of Utahôs population as well as its commercial activity. Perennial streams from the adjacent Wasatch Mountains provide water to this population. Outside the urban environment irrigated crops support the growth of alfalfa, vegetables, small grains, and orchards. Land use practices, including irrigation diversions, have affected the quality and quantity of stream flow. This region also has the greatest

The **Malad and Cache Valleys** ecoregion is composed of narrow floodplains, wide terraces, and alluvial fans. Perennial streams and canals provide mountain water to crops and municipalities. Potential vegetation along the Bear River Range resembles that of the Upper Sagebrush-Grass ecoregion, with occasional mountain mahogany woodlands. Across the valley the Wellsville Mountains are dominated by big-tooth maple, interspersed with quaking aspen and limber pine at higher elevations and on north facing slopes.

This region has a shorter growing season but is extensively farmed as a result of the increased availability of water from regions to the south.

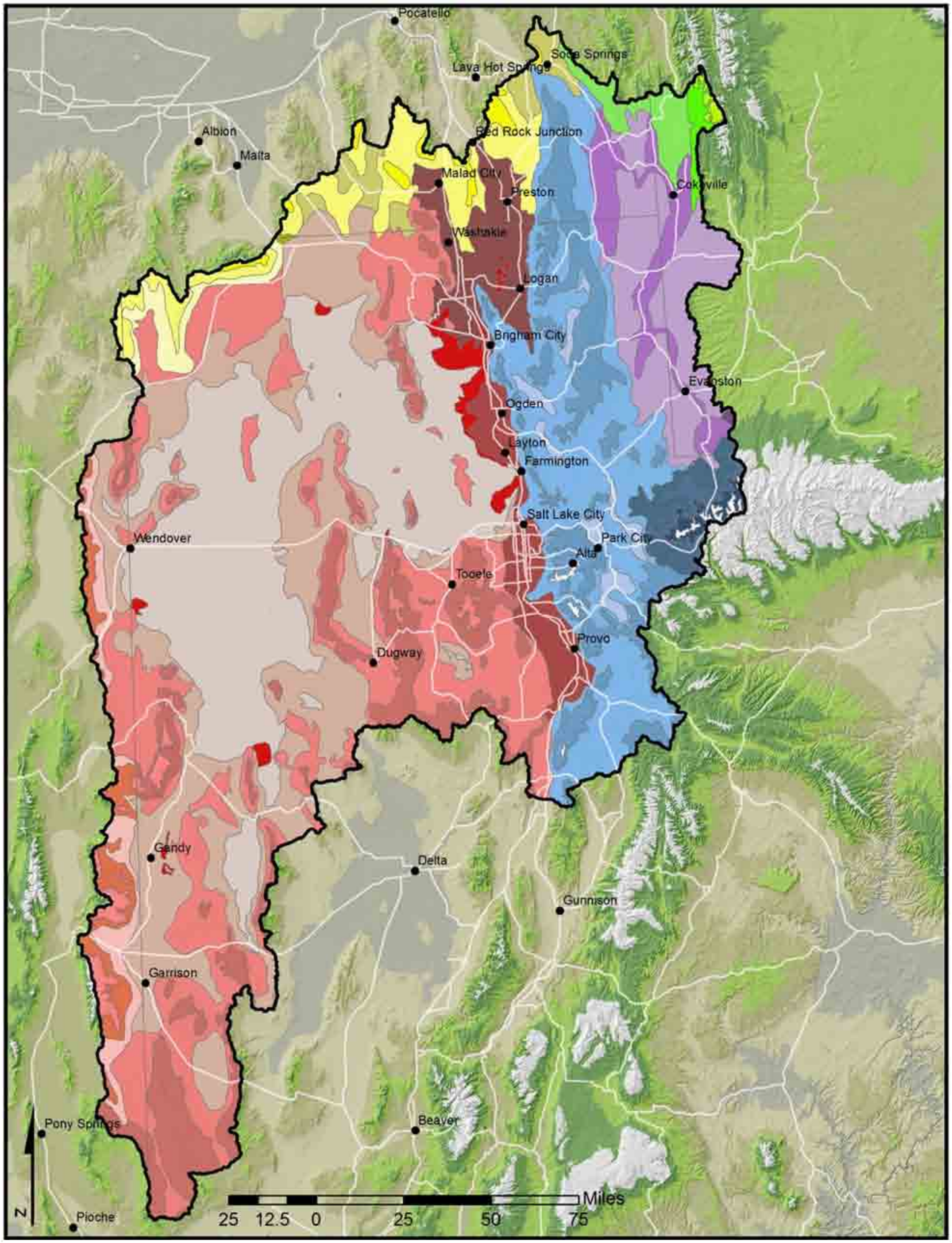


Figure 2.11a Ecoregions of the Great Salt Lake Watershed

Figure 2.11b Legend for ecoregions of the Great Salt Lake

Ecoregions	Existing Development (acres)	Potential for New Development (acres)	After New Development (acres)
Moist Wasatch Front Footslopes	9,249	4,348	13,596
Malad and Cache Valleys	1,786	7,422	9,208
Semiarid Foothills	1,005	6,964	7,969
Semiarid Hills and Low Mountains	261	4,783	5,045
High Elevation Forests and Shrublands	2,380	1,310	3,690
Wetlands	231	2,313	2,545
Wasatch Montane Zone	93	1,651	1,745
Partly Forested Mountains	180	267	447
Mountain Valleys	80	302	381
Mid-Elevation Uinta Mountains	5	157	161

Table 2.1 Impacts to key ecoregions from future growth and development within the watershed

The **Semiarid Foothills** ecoregion is located between the elevation range of 5,000 to 8,000 feet. ñWidely spaced juniper and pinyon typically occur in a matrix of sagebrush, grama grass, mountain mahogany, and Gambel oak. Maple-oak scrub is common in the north but, southward, it is gradually replaced by pinyon-juniper woodland at lower elevations and ponderosa pine at upper elevationsò (Woods, et al., 2001).

The **Semiarid Hills and Low Mountains** ecoregion can be found in the low elevation range between the Sagebrush Steppe Valleys and the Dissected High Lava Plateau ecoregions. Natural vegetation consists primarily of sagebrush steppe communities. Forest components, although much less common, consist of juniper woodland and are found primarily on rock outcrops (McGrath, et al., 2002). The primary land use is grazing.

The High Elevation Forests and Shrublands ecoregion is located in the higher elevational band above the Semiarid Hills and Low Mountains ecoregion. Typical vegetative communities include a mixture of sagebrush grassland, mountain brush, and conifers (McGrath, et al., 2002). Found along north-facing slopes are lodgepole pine, Douglas fir, and aspen. Winters in this ecoregion are cold and average annual precipitation is much greater than ecoregions found at lower elevations.

The **High Elevation Forests and Shrublands** ecoregion is located above the elevation of the semiarid hills and low mountains and is composed of a mix of mountain brush, conifers, and sagebrush grasslands (McGrath, et al., 2002). Aspen, Douglas fir, and lodgepole pine can be found on the north-facing slopes of this ecoregion. Annual precipitation is far greater in this region than in other portions of the Northern Basin and Range.

The **Wetlands** ecoregion is composed of a variety of rushes, reed grasses, and open water. This region is critical wildlife habitat for millions of migratory birds and contains a multitude of state and federal wildlife refuges. Water levels within these wetlands are often managed, however marshes can be temporarily inundated by rising Great Salt Lake water, or impacted by seasonal drought. Potential vegetation consists of tule marshes (Woods, et al., 2001), however for agricultural purposes most of these marshes have been diked and drained (Toth, Edwards, & Lilieholm, 2004). As a result of the dikes the system is now static, making it susceptible to flooding, causing damage to the vegetation. ñIn past times this was not a problem because adjacent areas could absorb some of the floodwater as well as provide marsh habitat for wildlife dependent on marsh ecosystemsò (Toth, Edwards, & Lilieholm, 2004).

"With increasing municipal water needs, fresh water that reaches the lake is likely to decrease, which will result in an increase in the salinity of the lake. Also, with increased municipal areas being built, the amount of polluted runoff reaching the lake will increase. The trigger point is not known, but at some increased level of salinity, brine shrimp will not survive. The conse-

quences of such a loss could be enormous. First of all, the brine shrimp and their eggs comprise the majority of the diet for the birds which flock to the region annually. Lack of food, combined with decreased habitat, might cause the displaced birds to seek new habitat already occupied by other birds. Or, as has happened in the past, they might try to inhabit lower quality habitats like local golf courses or parks, creating a nuisance for area residents and ultimately not sustaining the birds' dietary needs. In short, numbers of shorebirds will be drastically reduced. Another consequence of loss of brine shrimp could be a drastic increase in algae, their food supply. Without the shrimp to control algae levels, huge amounts will wash up on the shores of the Great Salt Lake and start to decay, resulting in odor and water quality problems that could affect the quality of life of area residents" (Toth, Edwards, & Lilieholm, 2004)

The partially glaciated **Wasatch Montane Zone** is composed of ñforested mountains and plateaus underlain by sedimentary and metamorphic rocksò (Woods, et al., 2001). Common in this region are aspen parkland and Douglas fir, while on the steep north facing slopes grow subalpine fir and Engelmann spruce. Snow melt from this region provides water to the more arid, lower ecoregions.

The **Partly Forested Mountains** of the Northern Basin and Range vary in elevation from 6,000 to over 9,000 feet. Typical vegetation includes lodgepole pine, Douglas fir, and aspen along the north-facing slopes, with mountain brush and mountain big sagebrush dominate the warmer dryer, south-facing slopes. This ecoregion is utilized as summer range as well as timber production (McGrath, et al., 2002).

The unforested **Mountain Valleys** ecoregion is composed of hills, terraces, alluvial fans, and flood plains. This region is highly impacted by a cold climate and has a relatively short growing season. Natural vegetation consists primarily of Great Basin sagebrush.

Primary land use includes irrigated pastures and crops, as well as rangeland. At the local level dairies, feedlots, and turkey farms are common.

The **Mid-elevation Uinta Mountains** ecoregion is forested and highly glaciated. Elevations range from 8,000 to 10,000 feet, and vegetation includes ponderosa pine, Douglas fir, aspen parkland, and lodgpole pine (found in the northern extent).

Mid-elevation Uinta Mountains (Danny White)

Of particular interest is the loss of aspen stands, for according to Utah State professor Ron Ryel:

> *"The prevention of coniferous trees moving into aspen habitat through succession is of particular interest to municipalities within the same watershed. Aspen stands have a much higher water storage capacity when compared with conifer stands. Aspen defoliates in the autumn. The bare canopies of winter aspen stands allow snow to fall to the forest floor. In conifer stands, snow gets caught on the needles and branches. A significant amount of this precipitation is lost directly to the atmosphere through evaporation and sublimation. This, combined with transpiration, results in a much lower amount of water that actually reaches the forest floor and enters the watershed"* (Toth, Edwards, & Lilieholm, 2004)

The Mid-elevation Uinta Mountains terrain is much more rugged than the Uinta Subalpine Forests, and its deep canyons provide numerous good quality, ephemeral streams that receive meltwater from the Uinta Mountains. This ecoregion also provides water to the more arid, lower ecoregions.

The following two ecoregions are under no immediate threat to development, but by virtue of their location within the watershed they receive some of the highest amounts of precipitation and therefore are of significant importance with respect to protecting water quality and quantity.

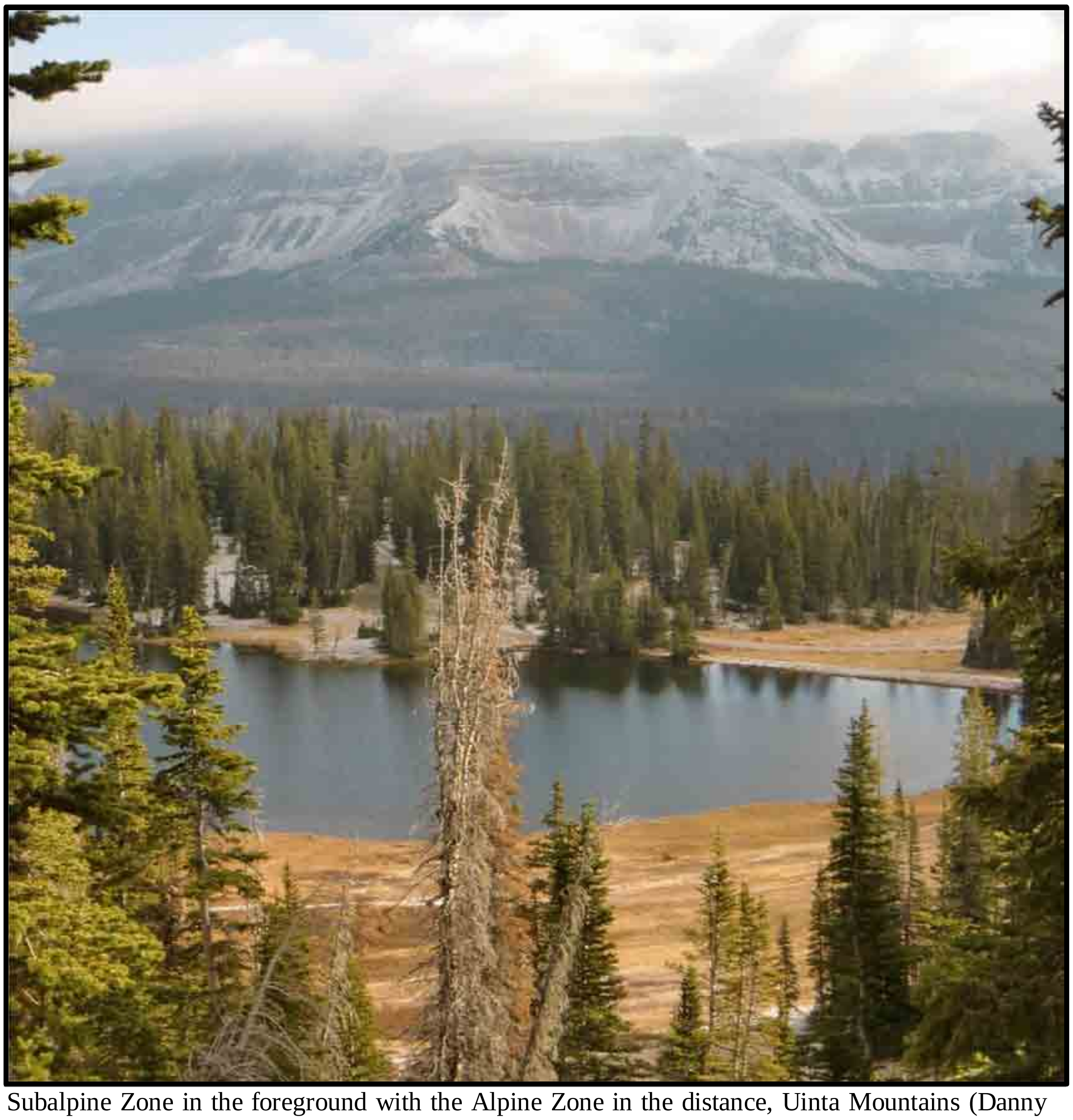
Uinta Subalpine Forests ecoregion is composed of a multitude of lakes, glaciated basins, deep canyons, and high mountains. This ecoregion is higher, with elevations from 10,000 to 11,000 feet. There is more moisture and less rugged terrain than the Mid-elevation Uinta Mountains ecoregion, but this area does not receive as much precipitation as the Alpine Zone. The soils ñsupport Engelmann spruce, lodgepole pine, and subalpine fir. These subalpine forests are far more extensive in the Uinta Mountains than in the less massive Wasatch Rangeò (Woods, et al., 2001).

Land use activities include recreation, logging, and seasonal grazing. Snow melt from this region provides water to the more arid, lower ecoregions.

Uinta Subalpine Forests (Danny White)

The **Alpine Zone** is found above the timberline which is around 11,000 feet and is especially common in the high Uinta Mountains. This landscape is dominated by features formed by glacial processes. ñMeadows and rockland are common and contrast with the dense forests of neighboring, lower ecoregionsò (Woods, et al., 2001). However, in the Uintaôs, the landscape is dominated by gently undulating terrain that provides an environment more similar to those found in the arctic. ñHayward (1945) lists 127 of the common plants found in this zone. Of these, 33 percent are also found in the Arctic regionsò (Toth, Edwards, & Lilieholm, 2004). The conditions in this region can be just as severe as in the arctic. At these high elevations incoming solar radiation has less of the atmosphere to pass through, so temperatures at the surface can easily reach90° F and then as a cloud passes overhead, drop to near freezing temperatures in a matter of minutes. Strong winds also shape the vegetation, which can be seen in the krummholz growth form of trees found near the tree line and herbaceous species often exhibit short flowering stalks (Toth, Edwards, & Lilieholm, 2004).

The Alpine ecoregion receives a greater abundance of precipitation resulting from its altitude than other ecoregions within the Wasatch and Uinta Mountains. A major source of spring and summer runoff for lower ecoregions is the deep snowpack that accumulates in the Alpine Zone. This Zone is primarily used for recreation and seasonal recreation.



Subalpine Zone in the foreground with the Alpine Zone in the distance, Uinta Mountains (Danny White)

Critical Wildlife Habitat

The great diversity of species within the Great Salt Lake Watershed is directly related to its variability of ecosystems. With high elevation forests to desert wetlands, the region is composed of a wide variety of landscapes and a great wealth of habitats for both aquatic and terrestrial species. Throughout the region, the maintenance of healthy and abundant wildlife has been a historic role of land management and continues to be very important today. Many of the wildlife species found in the watershed play an important role in the economics of the region, as well as provide an aesthetic quality that people associate with the area.

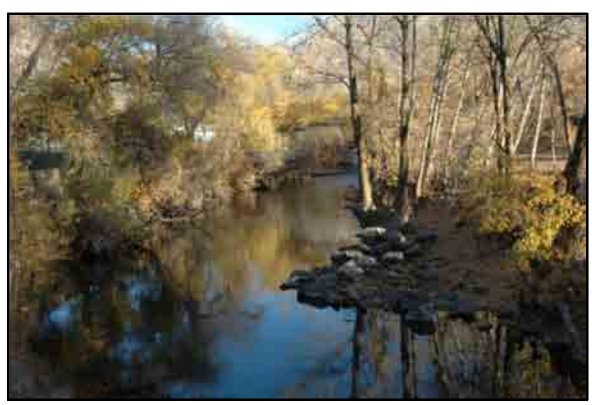
Habitat can be described as the suitable environment for a particular species and typically consists of the appropriate topography, food, climate, water, and shelter (Benyus, 1989; Lindenmayer & Fischer, 2006). In order to provide details about the habitat of the Great Salt Lake Watershed *Utah's Comprehensive Wildlife Strategy* was utilized. This wildlife strategy identifies three separate tiers where species are placed based on conservation need; the first tier is comprised of federally threatened and endangered species.

Since no critical habitat information exists for the Great Salt Lake Watershed, the stateǒs tiering system is used as proxy. For more detailed information about the methodology used to develop this data see page 60.

Once a model representing the critical habitat of the Great Salt Lake Watershed was developed, it became clear that the most important habitat in the watershed are those that are heavily dependent upon water (see figure 2.12). The level of habitat significance was based on the number of species from tier one that utilized a particular habitat type. This section of the report will focus on the most critical habitat in the watershed which are wetlands and riparia. For information regarding all of the habitat types of the Great Salt Lake Watershed see appendix C.

As rivers and streams depart mountain slopes and reach the valleys their water begins to slow and form **Lowland Riparian habitat**. These riparian communities are typically found at an elevation of less than 5,500 feet and are composed of Fremont cottonwood, salt cedar, tamarisk, netleaf hackberry, velvet ash, desert willow, and other willow species (Gorrell, et al., 2005).

Riparian communities are transitional zones between terrestrial and aquatic habitat and are frequently areas of concentrated biodiversity at both regional and continental scales (Naiman, 2005). Wildlife species that


Lowland Riparian (Danny White)

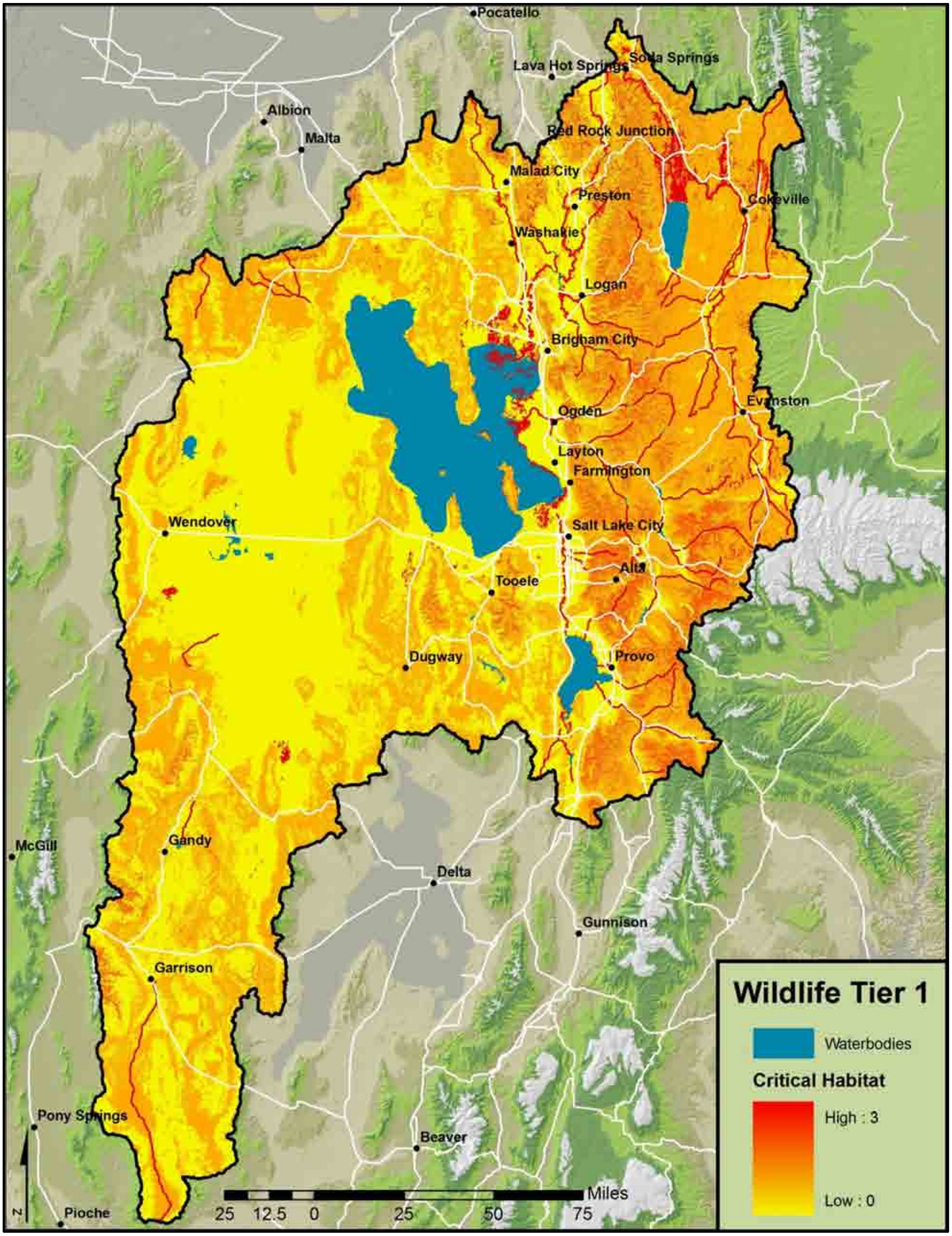


Figure 2.12 Critical habitat of the Great Salt Lake Watershed based on tier 1 of *Utah's Comprehensive Wildlife Strategy*

utilize this habitat include: bald eagle, southwestern willow flycatcher, black swift, broad-tailed hummingbird, and western threadsnake (Gorrell, et al., 2005).

Mountain Riparian habitat refers to the rivers and streams that are above 5,500 feet and are composed of steep slopes and swift water. Vegetation in this habitat consists of primarily woody species such as willow, narrowleaf cottonwood, thinleaf alder, black hawthorn, water birch, rocky mountain maple, wild rose, and redosier dogwood (Rood, Pan, Franks, Samualson, & Shepard, 2008).

The steams that create this habitat are cold and consist of rocky bottoms; they are however, highly productive and biologically diverse areas (Benyus, 1989). Mountain riparian wildlife may include: rubber boa, smooth greensnake, northern river otter, black gloss, and Montane snaggletooth (Gorrell, et al., 2005).

Wet Meadow habitats can be found from 3,000 to 9,000 feet and are composed of grasses, sedges, forbs, and rushes. Dominant plant species include: sedges, reedgrass, haigrass, rushes, willowherb, cinquefoil, saxifrage, willow, water birch, and honeysuckle (Gorrell, et al., 2005).

Common wildlife to this habitat include: smooth greensnake, gartersnake, bobolink, Columbia spotted frog, and several other amphibians and birds (Benyus, 1989) (Gorrell, et al., 2005). This habitat is highly sensitive to a variety of disturbances in the watershed Including human disturbance, improper grazing practices, and water development projects.

Wetland habitat is typically found at an elevation lower than 5,500 feet and consists of vegetation such as bulrush, cattail, and sedges.

Perhaps the richest habitat in terms of species diversity in the watershed is the wetlands of the Great Salt Lake. Within this small portion of the region hundreds of thousands of birds gather each year as they migrate to their summer and winter homes. In fact the wetlands of the Great Salt Lake are one of the most important migration stops in the western United Sates (see figure 2.13) as it provides habitat for both the central and western flyways.

An account from Jim Bridger in the fall of 1824 describes the volume of wildlife that once relied on the Great Salt Lake wetlands; as he drifted toward the mouth of the Bear River, ñEverywhere he looked ï in the sky, on the open water, over the marshy borders of the lake ï there were birdsò (Maltsby & Barker, 2009). When he reported his experience it is said that on that day he saw millions of ducks and geese.

Although the population of birds may no longer be as large as reported by the late Jim Bridger, the wetlands still provide essential habitat for a staggering population of bird species. See figure 2.14 for information regarding the most populous species found in Great Salt Lake wetlands.

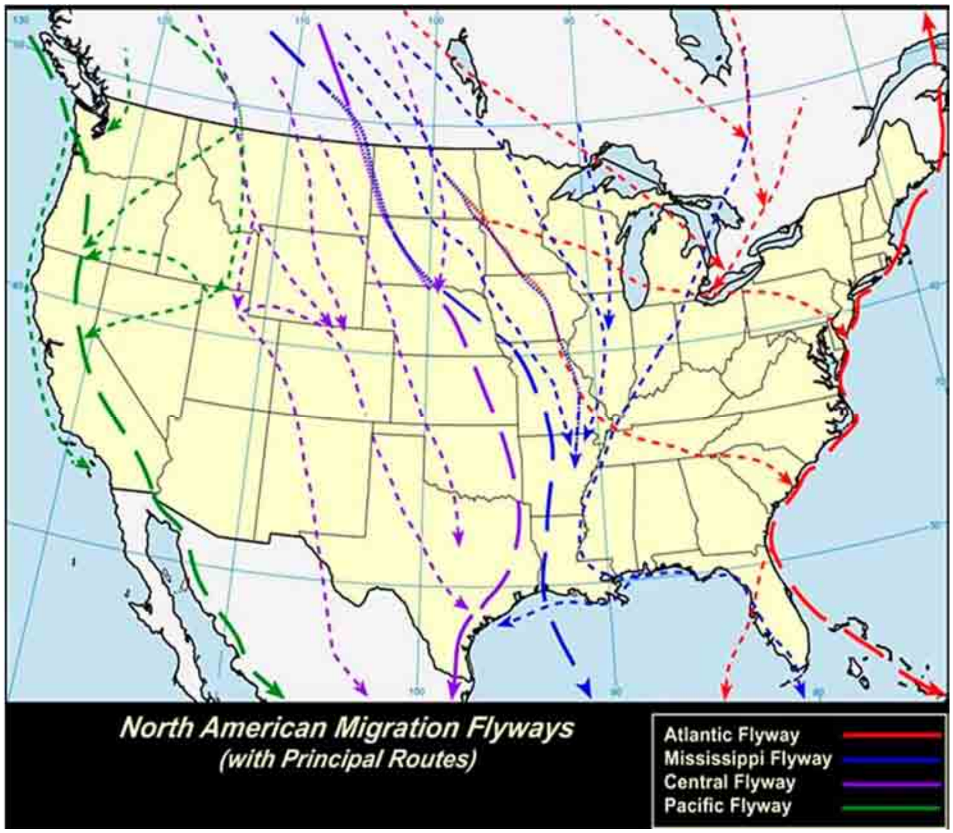


Figure 2.13 Illustration of the Nationốs flyways (Birdnature.com, 1998)

Bird Species	GSL Wetland Population
White-faced ibis	18,000
American avocets	10,000
American white pelican*	50,000
Cinnamon teal	60% of the continents breeding population
Wilson's phalaropes**	500,000
Snowy plovers	50% of the continents breeding population
Marbled godwits	26% of global population
Black-necked stilts***	>65,000

Figure 2.14 Tallies of various bird species that rely on the Bear River Migratory Bird Refuge (U.S. Fish and Wildlife Service, 2011).

* One of North Americaốs three largest colonies.

** The worldốs largest fall staging concentration.

*** More than anywhere else in the United States.

History and Culture

Prehistory

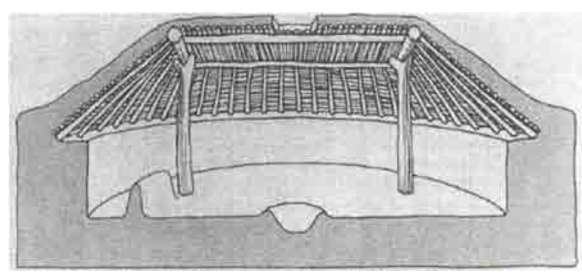
As the earth began to emerge from the last ice age around 11,000 B.C., the area now known as Utah saw its first human inhabitants known as Paleo-Indians (Alexander T. , 2003). These early hunter-gatherers lived in caves or small wooden shelters and subsisted through either a sedentary or nomadic lifestyle. Many chose to live along the shorelines of ancient lakes such as Lake Gilbert (one of Lake Bonnevilleôs lower levels) due to their abundance of food and shelter.

As hunting and subsistence technology progressed people continued to live a hunter gatherer and nomadic lifestyle, however, permanent settlements began to be established (Rood & Thatcher, 2010). Some of these permanent settlements included rock or cave structures typically located near fresh water springs that were found along the periphery of what is now the Great Salt Lake as well as other ancient lakes.

As the weather began to warm these ancient lakes began to recede and competition for land around these lakes increased. Once this occurred people began to hunt game found in the higher elevations away from the lakes. Paleo-Indians continued to thrive throughout Utah until they were succeeded by the Great Basin and Plateau Archaic peoples around 6500 B.C. (Alexander T. , 2003).

These new inhabitants lived a similar lifestyle as the Paleo-Indians, however they developed new technology that perhaps helped them succeed. This new technology included fluted Folsom spear points and a type of spear that included an atlatl or paddle-like device used to add leverage to the spear when thrown. The Archaic people continued to live in Utah until around 0 B.C. (Alexander T. , 2003).

The Anasazi and the Fremont people began to establish themselves in the territory 300 B.C. and 400 A.D. respectively (Alexander T. , 2003), (Poll, 1978) with the Fremont culture dominating the Great Salt Lake Watershed and the Anasazi living just south of the watershed (See figure 2.15). The Fremont and Anasazi cultures retained many of the traits of the earlier inhabitants but added some of the ñBasket Maker-Pueblo characteristicsò (Poll, 1978). Fremont culture was distinctly different from the previous cultures in that squash, corn, and beans were raised and by 800-900 A.D. people were living in permanent settlements consisting of pit houses.



Fremont pit house (Alexander T. , 2003).

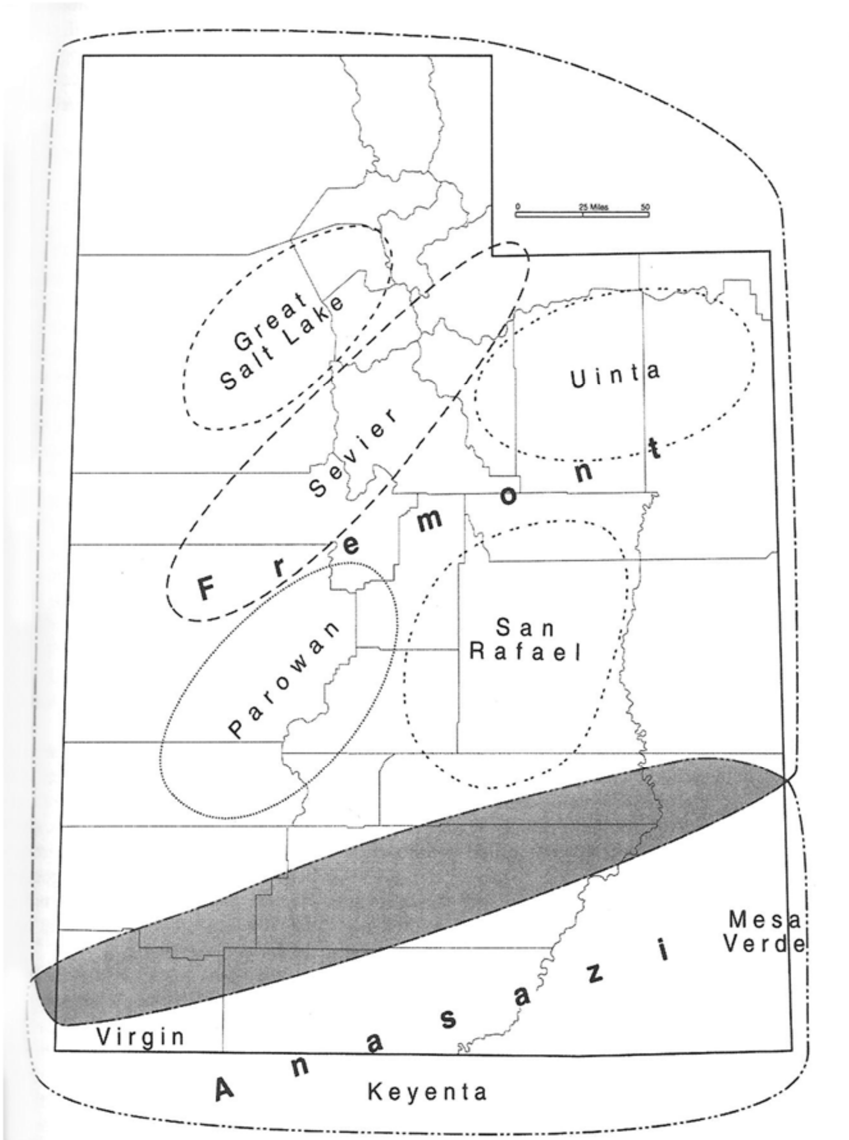
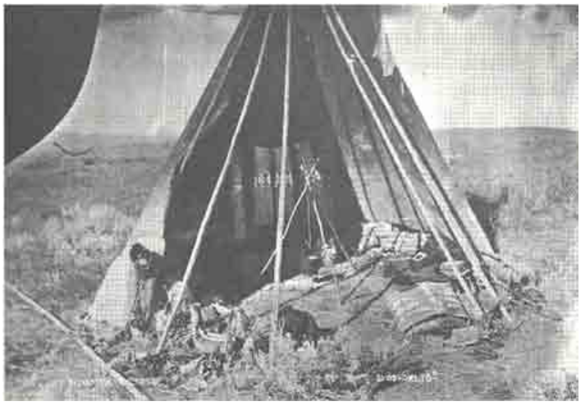


Figure 2.15 Map of the dispersion of Fremont and Anasazi peoples (Alexander T. , 2003).

American Indians

Around 1100 A.D., before the Fremont and the Anasazi people left Utah, the Numic peoples (the Northern and Western Shoshone) began to migrate to Utah from Southern California (Alexander T. , 2003). These settlers quickly spread across much of Utah and the Great Salt Lake Watershed and consisted of the Goshute, Southern Piute, and the Northern Ute tribes. A distribution of the Numic peoples can be seen in Figure 2.16. With only a few exceptions the Numic people lived a hunter-gatherer lifestyle and many introduced fish as an additional source of nutrition (Rood & Thatcher, 2010). Most of the Shoshone people lived in simple shelters or tepees that were conical in shape and wrapped in buffalo hide. These shelters provided a small hole at the top to allow smoke to ventilate, and included flaps that could be adjusted depending on wind direction (Cuch, 2000). Tepees were well ventilated providing escape from the summer sun and warmth during the winter.



Shoshone tepee (Cuch, 2000).

Around 1620 the Navajo began to inhabit Utah. The Navajo who were originally from western Canada were largely nomadic people and highly adaptable to Utahȏs climate and landscape. As they took over the territory they quickly adopted many of the cultural habits they came in contact with such as food, weaving horticulture, and religion (Alexander T. , 2003).

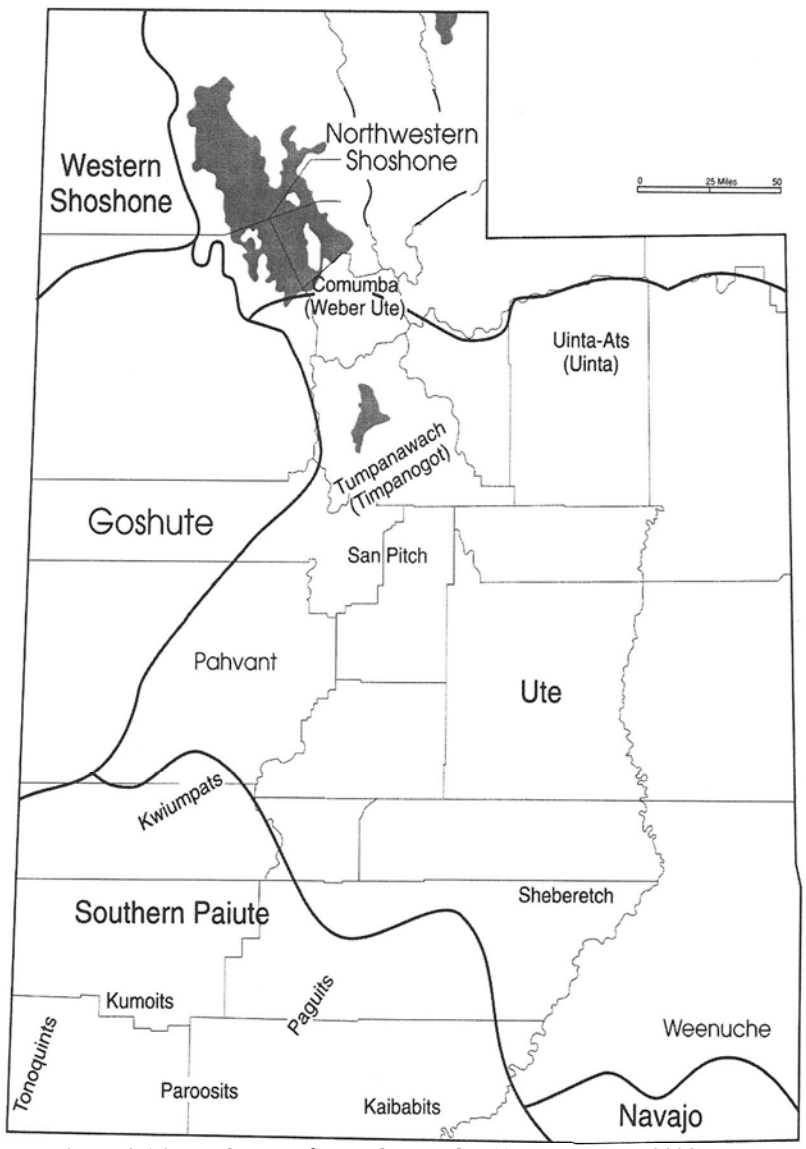


Figure 2.16 Distribution of nomadic peoples **(Alexander T. , 2003)**

Explorers and Trappers

Exploration of North America and much of Utah was promoted by the quest for furs, for lands of great wealth, and for a water passage through the Great Basin (Cline, 1963). This was also the primary force behind the Spanish advance to the north. These first non-Indian explorers to enter Utah arrived in July of 1776 with an expedition of ten men led by Franciscan priests Francisco Atanasio Dominguez and Silvestre Velez de Escalante. This expedition entered Utah near the town of Jensen, crossed the Uinta Basin, traversed the Wasatch Mountains, and visited a Native American tribe camped along the shore of Utah Lake. As they traveled south, the expedition crossed the Colorado River and arrived in Santa Fe in January 1777. This journey proved to be useful to future travelers to Utah because of the detail Father Escalante recorded in his journal Including information about geography, plant and animal life, and the life of the Utes and Paiutes (Poll, 1978).

For nearly two centuries fur trade was the primary business, possibly the only one, practiced on the American frontier (Cline, 1963). It didnœt take long for fur companies and traders to begin filtering into Utah to take advantage of the tremendous wealth of game in the region. These early trappers began sending back reports of the ñrich booty in fursò found in the region which opened up the area to further exploration (Poll, 1978). By the late 1820s trappers had explored most of the rivers and valleys in Utah, including some of its deserts. Through the exploration of Jedediah Smith, the South Pass in Wyoming was opened and would later be used by thousands of immigrants heading west. Smith also spent much of his time exploring areas to the west of the Great Salt Lake. James Bridger was another famous trapper who is credited as being one of the first white men to lay eyes on the Great Salt Lake. Bridgerœs journey to the Great Salt Lake started in Franklin Idaho, where he most likely set out on horseback until he arrived at the marshes bordering the lake (Poll, 1978). Many of these early trappers were ñinstrumental in unwittingly locating some of Utahœs historic townsò (Toth, Edwards, & Lilieholm, 2004). Some of the trails discovered by these men were later used by migrants and continue to exist as highways today (Alexander T. , 2003).

Two of the more noteworthy explorations of the time were performed by the Donner Party and John C. Fremont. The Donner Party attained their infamy in 1846 when they blazed a trail west into the Salt Lake Valley that would later be followed by the Mormon pioneers. Fremont was a government surveyor and trained topographical engineer, which gave him the capability of producing maps of the region that were unprecedented for the day (Alexander T. , 2003). Fremontœs description of the Great Basin dispelled any expectations of finding a water passage to the Pacific; his detailed delineation of valleys and plant and animal life provided future settlers with the tools they would need to conquer the region.

Mormon Migration

In April of 1847 the Mormons left Winter Quarterôs in Nebraska on their trek west to Utah. Reports from Fremont and other explorers helped solidify their desire to travel west. On the 24th of July 1847, the party of Mormon pioneers emerged from Emigration Canyon and entered the Great Salt Lake Valley (Peterson, 1977). Upon arrival the Mormons wasted little time planting and irrigating fields. Until this point in history no other people had manipulated the water of the Great Salt Lake Watershed as extensively as the Mormon pioneers (Worster, 1941).

Soon after arriving in the valley the first company of pioneers began converting the desert into an oasis (Worster, 1941). Water was diverted from City Creek within days upon arrival to quench the dry desert landscape. Explorations and colonization of the outlying areas began almost immediately, with the establishment of Ogden, Farmington, Bountiful, Provo, Tooele, and Manti being established by 1850 (Rood & Thatcher, 2010). From 1847 to 1900 500 Mormon settlements were established throughout the state of Utah, bringing with them similar irrigation practices as initiated in Salt Lake Valley. The success, location, and size of these early settlements depended greatly upon the soil conditions, the amount of local precipitation, and the gradient of nearby mountain streams.

Building A Desert Oasis

In the early years of Mormon colonization the construction of irrigation canals required a large supply of money which the Mormonôs did not have, so their leader Brigham Young instructed his people to raise their crops on small plots of land to save on water consumption. The success of these early settlements was dependent on the efforts of each individual providing for the needs of the community and ñthe individual discipline of irrigators to use beneficially the limited water available to themò (Powell, 1994).

The first and most important utility available in Utah was the irrigation canal. At one of the first public meetings held in the state, a watermaster was appointed. Watermasters continue to be an important position in Utahôs local governments.

In the early days of irrigation small canals were constructed near the mouths of canyons diverting flow from perennial streams. These early canals had a relatively small capacity for carrying water and conveyed water only short distances from the waterôs source. To ensure the canals had the proper gradient, pans were filled with water and placed along the proposed route; a worker would sight over the pan to a man holding a pole on which the top of the pan was marked (Thomas, 1920). To construct the canals, teams of horses or oxen pulled ñA-shaped wooden frames and slip scrapers were used to dig shallow ditchesò (Worster, 1941; Powell, 1994). Men would follow these teams using shovels and picks to finish the excavation of the canals. Dams were constructed at the heads of canals to divert water from the streams and were made from simple material such as logs, straw, dirt, and rock.

Farmers in the northern settlements such as the Cache Valley had more success than those in southern Utah as a result of greater precipitation and fertile soils. In addition to being dryer, settlements to the south often had to work with sandy soils which tended to lose much of the water carried in early canals. Other complications in the south included hardpan soils or slick rocks which provided little resistance to flowing water, much of which was gone before they could utilize it.

Development of water law and basic irrigation practices occurred during this early time in Utahôs history. Irrigators in Utah quickly abandoned the eastern conviction of riparian water rights for the doctrine of prior appropriation and beneficial use. Riparian water rights state that streams cannot be diminished for consumptive use (Thomas, 1920). The idea of prior appropriation was developed on the ideas of ñindividual stewardship, public ownership, and beneficial useò (Powell, 1994). These ideas worked in concert with the fact that there was a lack of water in the region. As a result of these ideas and limitations, water rights were only granted to individuals who used the water to benefit the community. If it were determined that the individual no longer used the water for a beneficial use, the rights would be taken from that individual and allocated for public use.

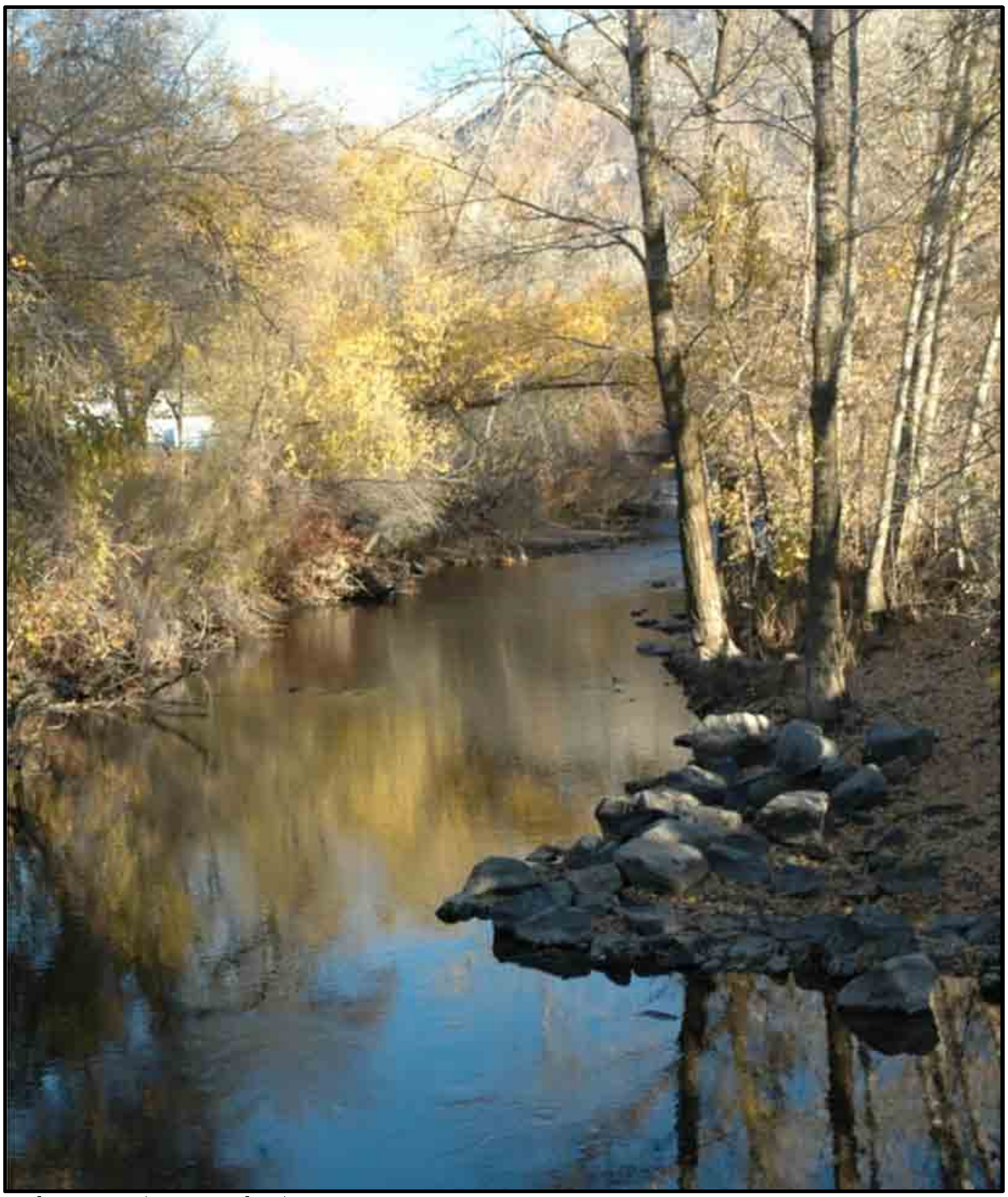
The next change in irrigation came during the 1880s. During this time of change water rights were given to anyone who wished to put it to beneficial use. Farmers began expanding their farms from the once small self-sufficient crops, to much larger fields to increase their personal wealth. Not only was the size of these farms growing, but so were their numbers. In order to keep up with the increased demand for irrigation, the original low capacity canals were expanded and moved further up into the foothills. Some farmers such as in Wasatch and Sanpete counties took matters into their own hand and built a pair of ñtransmontane tunnelsò as well as diversion canals in order to divert water from the Colorado River Watershed into the Great Basin watershed (Powell, 1994).

In the 1890s farmers and civic leaders gathered to discuss the now antiquated laws and management of Utahôs water. It was during this time that the stateôs engineer was appointed who was charged with managing Utahôs water resources.

The twentieth century continued to see changes in the use and management in Utah water. Large reservoirs and dams were constructed, new canals built, as well as the desire to improve the quality of the stateôs water systems. Open dirt canals continue to be common in most parts of Utah, but there is an increasing conversion to concrete and piped canals in an effort to reduce water loss through infiltration and evaporation. There have also been new developments in irrigation technology that allows farmers to use less water to achieve the same effect;

new strains of plants are also being developed that require less water.

ñThe story of irrigation in Utah is the saga that began with the individual irrigator, shovel in hand, coaxing a trickle of water onto the dry land.ò (Powell, 1994) The history as well as the future of the state and the Great Salt Lake Watershed will continue to be linked to irrigation.


Weber River (Danny White)

Understanding Wetlands

The wetlands of the Great Salt Lake are a vast ecosystem consisting of approximately 400,000 acres of wetland habitat (See figure 3.1) (United States Environmental Protection Agency, 2010). These wetlands are an integral part of a larger system that provides habitat for migratory shorebirds, waterfowl, and waterbirds from both the Central and Pacific flyways of North America. This highly valued resource is currently at risk from encroaching urban development and from the development of its water resources to provide for the growing population within the watershed.

Functions Performed by Wetlands

Perhaps the richest habitat in terms of species diversity in the watershed are the wetlands of the Great Salt Lake. Within this small portion of the region hundreds of thousands of birds gather each year as they migrate to their summer and winter homes. In fact the wetlands of the Great Salt Lake are one of the most important migration stops in the western United Sates as it provides habitat for both the central and western flyways. Wetlands also perform vital functions of the human inhabitants of the watershed. Some of these benefits include storm abatement, flood control, water quality improvements, aquifer recharge, recreation, and aesthetics (Haslam, 2003; William J. Mitsch, 2007).

Introduction to Wetland Hydrology

Wetlands are transitional zones between the aquatic and terrestrial environment and throughout the year and from one year to another with respect to the volume of water they store (Mitsch & Gosselink, 2007). Hydrology is the ñsingle most important determinant of the establishment of wetlands and wetland processesò (Maltsby & Barker, 2009). Therefore it is vital that the role and character of wetland hydrology be thoroughly understood before any planning should take place regarding a wetlandôs water resources. The influence of wetland hydrology may be seen in many chemical and physical properties including: the availability of nutrients, water and soil salinity, sediment deposition, and characteristics of the soil such as pH and texture (Lewis, 1995; Mitsch & Gosselink, 2007). Wetland hydrology also has a tremendous influence on the biotic component of wetlands. For example, the depth and duration of inundation or saturation determines the specific vegetative types and their distribution on the landscape.

In order to fully understand the character and role of a wetlandôs hydrologic regime, one must have a firm understanding of the larger scale perspective (Maltsby & Barker, 2009). To gain this understanding one must look to the watershed that provides the wetland its water. For the wetlands of the Great Salt Lake it is essential to know how the hydrologic regime of the Great Salt Lake Watershed influences the wetlands, and what human uses within this watershed impact its hydrology.

The natural inflow and outflow of water from a wetland is known as its water balance. Each different type of wetland has its own distinct water balance

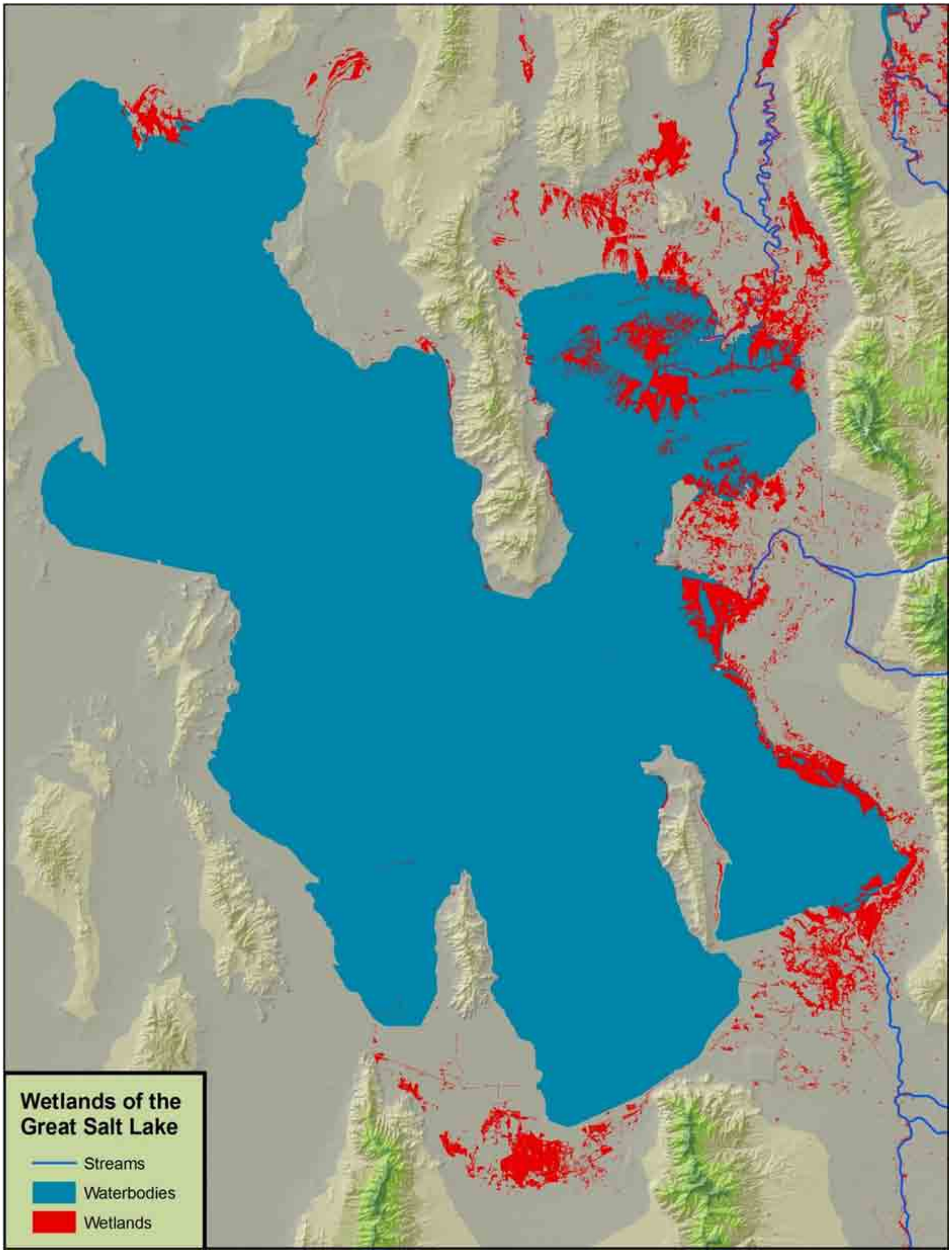


Figure 3.1 Distribution of wetlands along the Great Salt Lake based on the 2008 NWI data.

Component	Pattern	Wetlands Affected
Precipitation	Varies with climate although many regions exhibit distinct wet and dry seasons.	All
Evaporation	Seasonal in peaks in summer and low rates in winter. Controlled by meteorological, physical and biological conditions within specific wetlands.	All
Surface inflows and outflows	Seasonal, usually matches the precipitation pattern or spring thaw. Can be channeled as stream flow or non-channeled as overland flow from wetland contributory areas. Includes inundation with water from streams, rivers, and lakes.	Potentially all wetlands except ombrotrophic. Surface flows are particularly important for riparian wetlands.
Groundwater	Less seasonal than surface water flows and not always present.	Potentially all wetlands except ombrotrophic wetlands.

Table 3.1 The principle components of freshwater wetland water balances. Adapted from (Maltsby & Barker, 2009)

(Edward Maltsby, 2009). Table 3.1 describes the principle components of water balance along with the wetland type they affect. It is important to note that wetland vegetation plays a large part in the water balance; vegetation not only releases water from the wetland to the atmosphere through evapotranspiration, it also shades the water reducing the impact of evaporation. Plants can also cause a buildup of sediments and organic matter, which over time disrupts the flow of water through the wetland and can lead to a decrease in the duration and frequency in of inundated (William J. Mitsch, 2007).

As a result of the essential role hydrology plays in the function of wetlands, it also means that any modification to the hydrologic regime, whether at a site or watershed scale, will result in changes to a wetland (Maltsby & Barker, 2009). Some potential changes in hydrology can cause alterations in wetland vegetation, an overall decline of extent, or in some cases these changes can lead to the complete loss of a wetland community (Conly & van der Kamp, 2001; Rood, Pan, Franks, Samualson, & Shepard, 2008; Maltsby & Barker, 2009).

There are a multitude of different factors both natural and human induced, that can lead to a change in the hydrologic regime. Two major factors that are of primary concern in the Great Salt Lake Watershed are climate change and water development projects.

Potential for Climate Change

It is predicted that by the year 2060 the average air temperature in Utah will increase by 5.4° to 6.3° F (Utah Division of Water Resources, 2007). This will increase evapotranspiration rates by as much as 6.7 inches per year while precipitation may only increase as much as 1.2 inches per year (Utah Division of Water Resources, 2007). This will cause a decrease in the annual water budget of 30%, signifying a higher loss than recovery (Utah Division of Water Resources, 2007). Compounding this issue is the fact that the majority of this precipitation will come in the winter months and in the form of rain rather than snow, resulting in decreased streamflow in the late spring and summer months.

from a tributary does not result in a net loss of 100,000 acre-feet to the lake. Approximately 56% of water diverted

Affected Area	Proposed Withdrawals
Bear River - to remain in Box Elder and Cache County	120,000 acre-feet
Weber River	17,000 acre-feet
Utah Lake Watershed	10,000-50,000 acre-feet
West Desert groundwater - to be pumped to Las Vegas	50,000 acre-feet
Great Salt Lake - to be evaporated	353,000 acre-feet
Bear River - transported to Wasatch Front, only to be diverted during years of high flow	100,000 acre-feet
Total	**650,000-690,000**
Total amount staying in the watershed	**247,000-287,000 acre-feet**

Table 3.2 Proposed water withdrawals from within the Great Salt Lake Watershed. (Adapted from Utah Division of Water Resources Bear River, Utah Lake, and Weber River Basins, Planning for the Future)

Water Withdrawals from the Great Salt Lake and Its Tributaries

According to the Utah Division of Water Resources there are a number of potential withdrawals from tributaries of the Great Salt Lake to facilitate the projected population growth within the state of Utah (see table 3.2).

These water withdrawals have the potential to pose significant risks to the wetlands of the Great Salt Lake. Over the last several decades numerous studies have been undertaken to determine the effects of withdrawals from tributaries on the level of the Great Salt Lake. They indicate that every 100,000 acre-feet of diminished inflow results in the lowering of the lake by one foot (DeFault & and Carter, 2000). However the depletion of 100,000 acres-feet of water eventually flows to the lake once it has been used for municipal and industrial purposes (Utah Division of Water Resources, 2005). Nearly all of the water used for the irrigation of crops never arrives at the lake (Richter & Thomas, 2007).

Given the volumes of water listed in figure 3.2 and the 60% of return flow, up to 74,800 acre-feet would be prevented from reaching the Great Salt Lake for the purposes of municipal and industrial use within the watershed. This would result in a lowering of the lake level by approximately 9 inches. An additional 453,000 acre-feet of water would be either prevented from reaching the Great Salt Lake, or taken directly from the lake resulting in a decrease of approximately 4.5 feet in elevation. If all of this water is developed there is the potential for the lake to decrease in elevation by as much as 5.25 feet. A reduction of this magnitude will result in significant reductions in the wetlands of the Great Salt Lake.

Furthermore the 100,000 acre-feet that is proposed to be diverted to the Wasatch Front during high flow years would disrupt the natural flood cycle of wetlands by as much as 44,000 acre-feet, reducing potential lake level rises by as much as 5.28 inches during those high flow years.

Groundwater development within the watershed also poses a significant threat to wetlands even when the wetlands are located far from the groundwater wells. The majority of the wetlands in the Salt Lake Valley are down slope from the principle water users in the valley and are susceptible to the use of water upslope (Yidana, Lowe, & Emerson, 2010). As a result, any development of groundwater up slope from the wetlands of the Great Salt Lake will result in a decrease in flow for some of these wetlands.

Effects of Climate Change and Water Development on Wetlands

Both climate change and water development will result in less water for the wetlands of the Great Salt Lake. Each will most likely result in a decrease of the level of the lake and a decrease in available freshwater to flush the highly saline waters out of the wetlands. Since both climate change and increased water use are likely to occur concurrently, the affects will be magnified.

Effects of Decreased Water on Wetland Vegetation

One of the major issues regarding increased water production and climate change is the loss of wetland hydrology. With this, there will be less wetland habitat inundated during the late spring and summer months, the critical time that wetland vegetation needs the water to grow. As the water table begins to drop, there will be an initial phase where wetland biomass will increase (Kennedy, Murphy, & Gilvear, 2006). This increase in biomass will likely be short-lived (one growing season) and is most likely to occur during small disturbances in water availability resulting from the positive influence of short-duration drawdowns (Kennedy, Murphy, & Gilvear, 2006). Studies indicate that the greatest species composition change exists when wetland soils transition from inundated to saturated or to simply moist (Smith & Kadlec, 1983). This will be a critical stage for the wetlands of the Great Salt Lake, for this transition may welcome undesirable invasive species such as *Phragmites*. Over time, as the water recedes, wetland species will become confined to specific elevational ranges dependent upon their particular water requirements (Odland & del Moral, 2002).

If water development and climate change result in a long term reduction in water supply to the Great Salt Lake wetlands, then there will be major changes in the vegetative communities, especially the most dominant, water loving species (Kadlec & Adair, 1994). Existing seed banks will be a deciding factor in which species succeed once water levels decline (Odland & del

Moral, 2002). Some species such as cattail will not experience much trouble during this period of transition as a result of their height and method of seed distribution (Smith & Kadlec, 1983). Cattail are capable of distributing their seed over large open areas, so when the lake does recede there is a good chance that their seeds will be present in the newly exposed seed bank. Smaller species will have a harder time transitioning into the new wetland boundaries and may take much longer to become fully established.

Effects of Increased Salinity

Since the sediments of the Great Salt Lake are extremely saline, a reduction of freshwater inflows from the Bear, Weber, and Jordan Rivers will result in a reduction of many wetland plant species in the managed wetlands of the lake (Kadlec & Adair, 1994). As a result of the higher osmotic pressure found in highly saline solutions, such as those found in the Great Salt Lake, plants are unable to extract enough moisture from the soil. This results in a decrease in vegetative growth in many wetland species as well as an increase in mortality rate (Christiansen & Low, 1970). Table 3.3 illustrates the effects of increasing salinity on the growth and mortality of three of the dominant emergent aquatic plants found in the wetlands of the lake.

Increased salinity is also associated with a decrease in germination success (Christiansen & Low, 1970). The increased osmotic pressure which affected plant growth tends to reduce the uptake of moisture from seeds of several species as well. It also appears that an increase in temperature when combined with increased salinity resulted in the fewest number of seedling success (Christiansen & Low, 1970). For the wetlands of the Great Salt Lake, this result may be particularly damaging when the increased temperature of expected climate change is combined with future water development in the region.

Studies have also indicated that increased salinity decreases seed production. In experiments conducted in the Bear River Migratory Bird Refuge, it was determined that a salinity of 840 to 1,899 p.p.m. (normal range in the refuge) resulted in approximately 10 seed heads per square foot. However, an increase in salinity to 5,080 p.p.m. resulted in a decrease of seed heads to one half per square foot (Christiansen & Low, 1970). An increase in salinity to 2,311 p.p.m. is significant enough to drastically reduce seed head production, as was found in unit 4 of the Bear River Migratory Bird Refuge (Christiansen & Low, 1970).

Effects of Decreased Water and Phragmites australis

The invasive species *Phragmites australis* is a growing concern in the Great Salt Lake Watershed. Many of the wetland communities along the Great Salt Lake are already experiencing the invasion of this species. One of the major problems *Phragmites* will pose is its ability to survive a wide range of hydrologic regimes, from completely inundated soils, to soils of limited available moisture. Unlike Cattail, hardstem bulrush, and alkali bulrush, *Phragmites* is not as severely impacted by increased levels of salinity.

Species and Treatment Level (NaCl meq./l.)	Diameter of Plant (cm)	Total Length of Leaves (cm)	Dry Weight of Plant Top (g.)	Mortality %	Average Days to Death
Cattail (*Typha latifolia*)					
0	16.9	139.7	6.9	0.0	0.0
90	15.6	133.9	7.3	6.6	34.6
120	14.7	103.7	5.6	26.6	32.2
150	13.6	84.8	4.7	30.0	32.9
180	11.7	62.1	4.3	46.6	25.8
200	NA	NA	NA	87.4	8.9
220	NA	NA	NA	100.0	6.0
240	NA	NA	NA	100.0	3.3
Hardstem Bulrush (*Scirpus acutus*)					
0	13.9	153.3	5.2	0.0	0.0
90	12.7	146.0	5.9	6.6	0.0
120	11.5	130.1	6.5	23.3	23.6
150	9.4	112.1	5.7	40.0	23.2
180	8.2	79.0	4.9	6.6	23.8
200	NA	NA	NA	66.6	10.0
220	NA	NA	NA	83.3	6.7
240	NA	NA	NA	91.6	4.1
Alkali Bulrush (*Scirpus paludosus*)					
0	4.5	76.1	2.1	0.0	0.0
90	4.5	76.4	2.2	0.0	0.0
120	3.7	73.6	2.1	0.0	0.0
150	3.0	61.7	1.9	20.0	0.0
180	2.4	44.5	1.4	33.3	49.3
200	NA	NA	NA	33.3	13.0
220	NA	NA	NA	50.0	10.1
240	NA	NA	NA	66.6	8.3

Table 3.3 Comparative effects of salinity on vegetative growth and mortality of emergent aquatic plants. Adapted from (Christiansen & Low, 1970).

When exposed to a low increase in salinity (50 mM) *Phragmites* increased in productivity (Saleh & Saleh, 2006). While with each subsequent increase it began to decline in biomass but continued to survive at up to 300 mM which was the maximum salinity in the test (Saleh & Saleh, 2006). Studies have also shown that *Phragmites* is not as successful at reproduction from seed under levels of high salinity, however, given the aggressive nature of *Phragmites* rhizomes, it will easily be able to spread under conditions of increased salinity (Vasquez, Glenn, Brown, Guntenspergen, & Nelson, 2005).

This section of the report has focused on how the development of water will affect the wetlands of the Great Salt Lake. The following sections will identify how future growth and development will impact critical components of the watershed, including wetlands.

Evaluation Models

Models are simply caricatures of reality that synthesize information about the environment into a format that is easier to comprehend than the reality from which they are derived. These models are useful when trying to understand the complex processes that take place in large geographic extents. They are also helpful in determining the possible affects a future scenario will have on the different biophysical aspects of a region.

The creation of evaluation models is the fourth stage in the development of this study. The primary objective in developing these models is to provide a means of assessing the impacts of future development scenarios on the key issues identified in this study. The results of assessing the future scenarios with the evaluation models will provide key insight that will improve the decision-making process.

This process contains several important steps which include: list evaluations that were identified for the Great Salt Lake Watershed, evaluations are then researched to provide measurement criteria that can be modeled spatially, and synthesize the criteria for the evaluations to construct each model.

Selection of Evaluations

This phase began by selecting specific evaluations for the Great Salt Lake Watershed. Choosing evaluations that were appropriate for the study relied extensively on the issues identified in this study. Due to time, availability of data, and budget restraints the following four evaluations were selected for the study:

- Working Lands
- Public Health Welfare and Safety
- Critical Habitat
- Integrated Resources

Development of Evaluations

Once the evaluations were selected, the criterion for each model was outlined. It is important to note that all criteria contained in these models must be spatially defined. Case studies, background research, input from faculty and industry professionals, and personal knowledge plays an important part in this process. This knowledge is to select specific criteria such as soil type, slope, aspect, elevation, land use, or proximity to waterbodies and wetlands.

Modeling Process

Once these criteria were selected the process of model building began. The models for this study were created using ArcGIS which is a Geographic Information System (GIS) that provides a platform mapping and analyzing geospatial data. The overlay technique was used extensively in this study, allowing the user to analyze multiple components together or individually. Figure 4.1 and 4.2 illustrate the overlay process, displaying individual components and then combining them to create a composite image.

Tiering Evaluation Models

Three of the evaluation models incorporate a technique known as tiering. This technique adds a level of flexibility in criteria selection. Tiering also allows decision makers the opportunity to incorporate their constituentsô views in deciding conservation levels that best suit their needs.

This approach was advanced by planners at Utah State University, specifically (Toth, 2004) as well as multiple other bioregional planning reports, e.g., (Hurst, 2009), (Toth R. E., 2007), (Toth R. E., 2008).

The tiering method follows that of previous bioregional studies. For the Great Salt Lake Watershed, there will be a three-level hierarchy. The tier 1 models contain the most critical components of the watershed and are the minimal requirements for evaluation. Tier 2 includes all of the criteria from tier 1, plus additional, more conservative criteria. The resulting tier 2 model is more conservative and thus protective of the key issues. Tier 3 includes all of the criteria from the first two tiers and even more conservative criteria. The tier 3 model is the most protective of the key issues identified in this study.

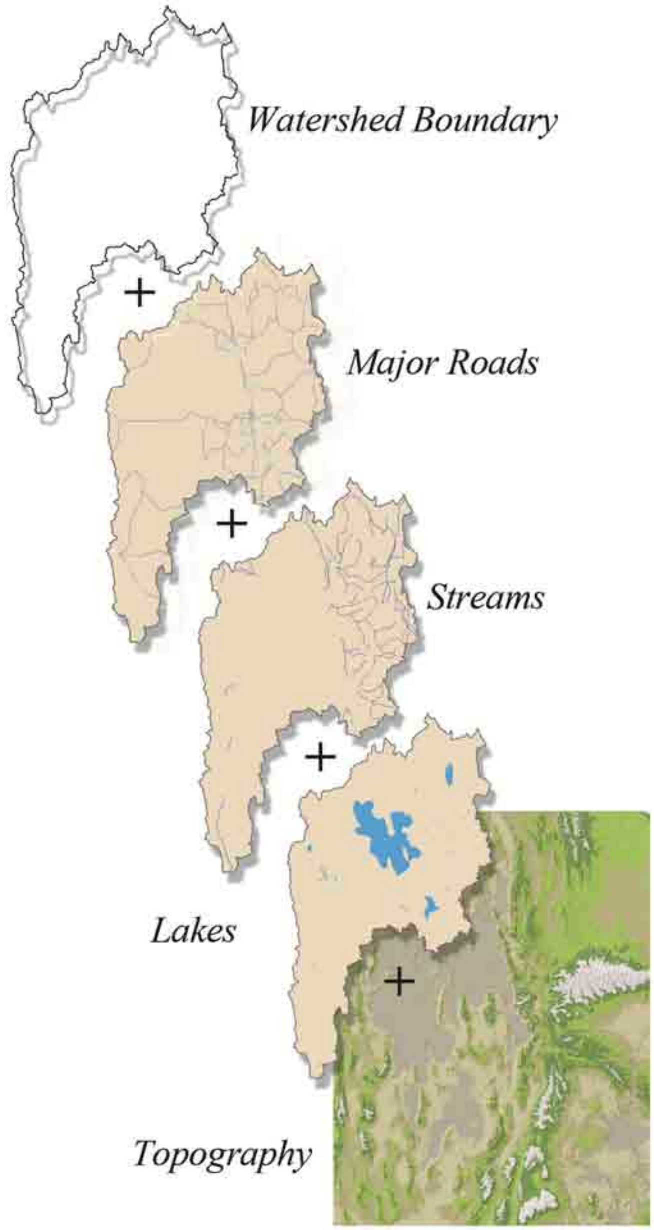


Figure 4.1 Individual components in the overlay process used to create the basic template

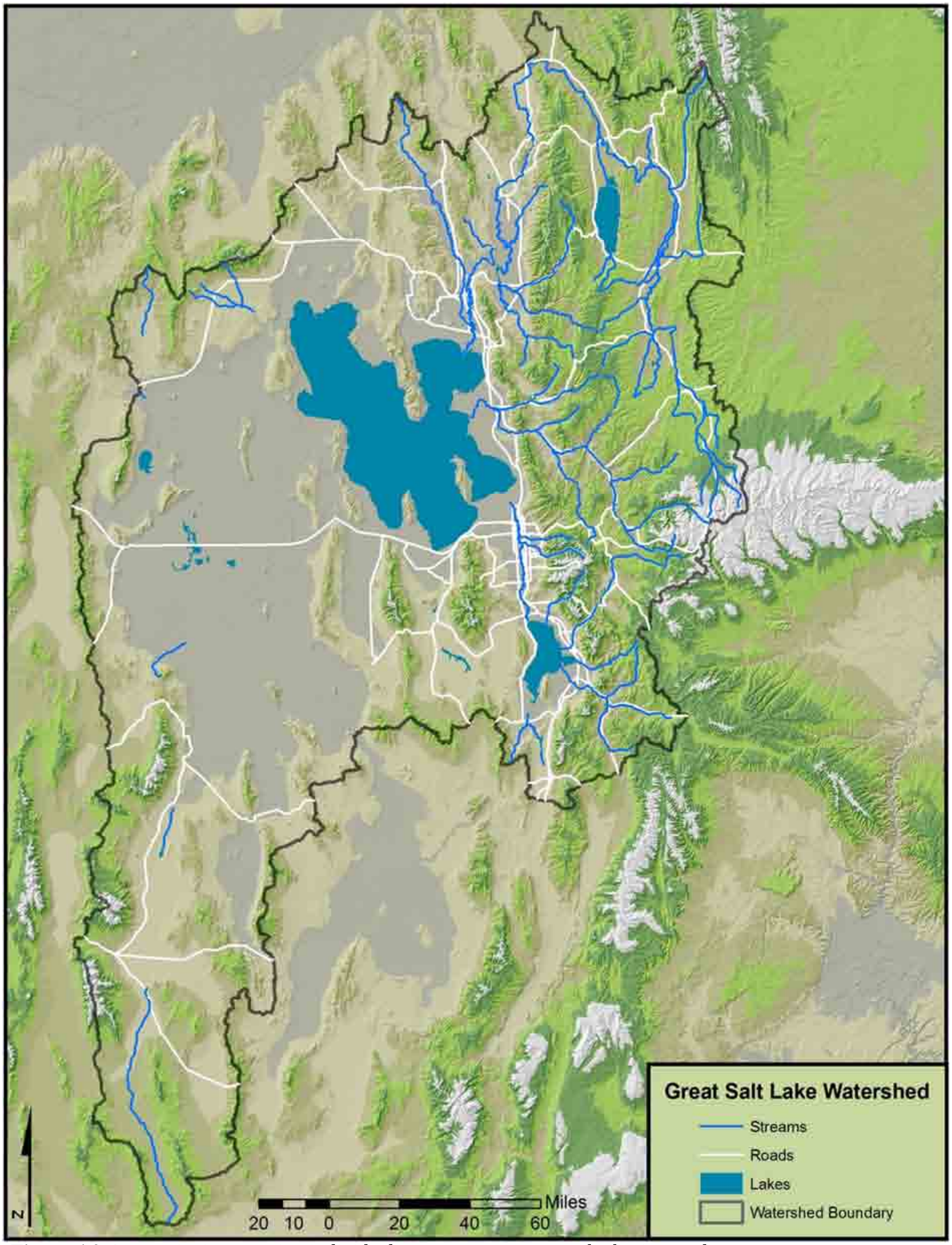


Figure 4.2 Composite image using individual components to create the basic template

Working Lands

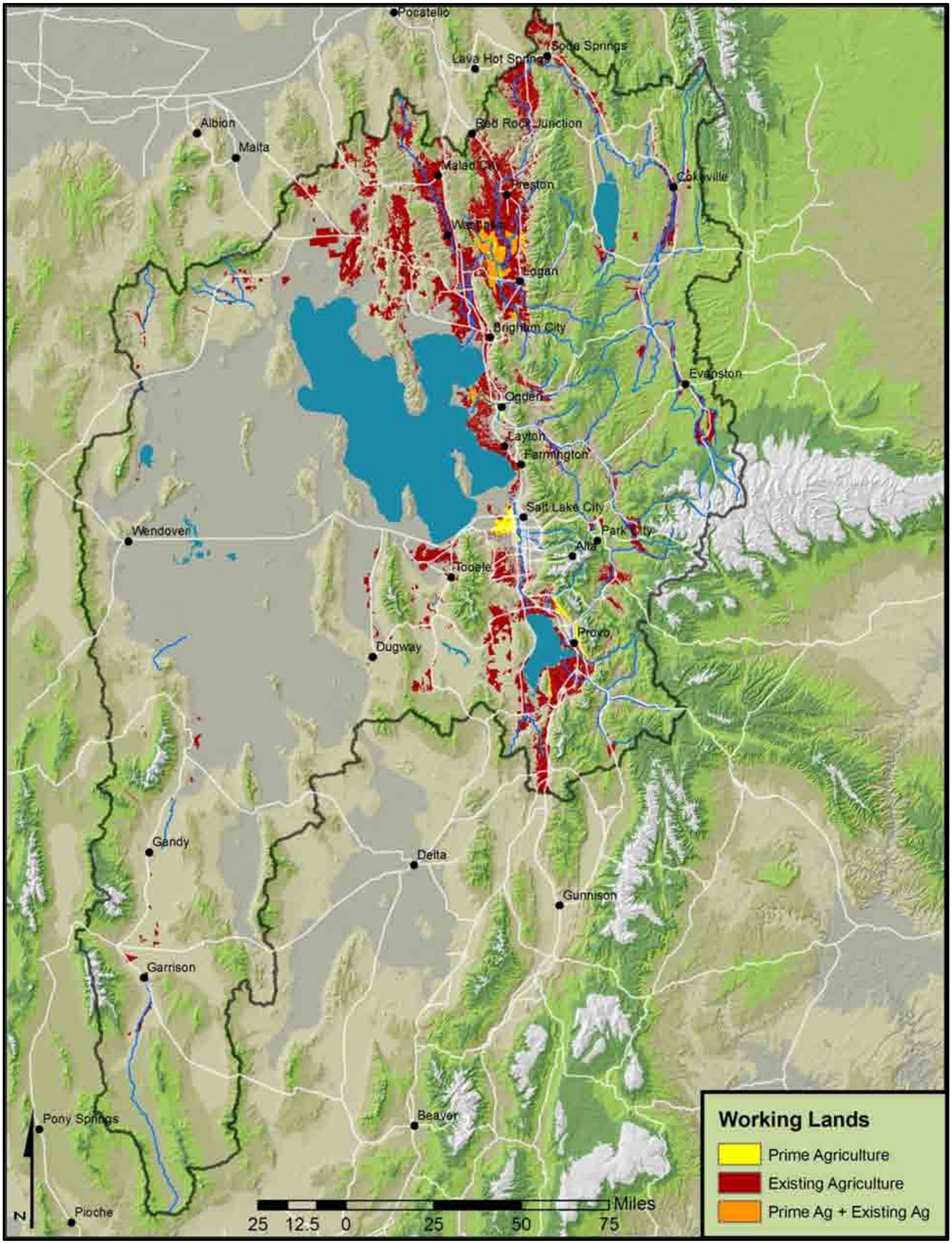
The working lands assessment model was developed to identify lands within the Great Salt Lake Watershed capable of producing sustenance for the inhabitants of the region. Working lands will quickly develop as the population of the watershed continues to increase due to their proximity to existing development and their relative ease of construction. During the five year period from 1997 to 2002, working lands within the Cache Valley were developed at a rate 5,000 acres per year, which resulted in a 9% total decrease (Toth, et al., 2006). The lands identified in this model should be protected from developmental encroachment and will be used to determine the impacts of each alternative future on the agricultural lands of the Great Salt Lake Watershed.

To determine the current extent of working lands in the watershed, several criteria are used to illustrate areas of prime agricultural soils and current agricultural lands. The U.S. Department of Agriculture defines prime agricultural lands as ñland that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these usesò (Staff, 1993).

Model Criteria

- Prime agricultural lands
- Existing agriculture

Grain Harvesting near Grace Idaho (Danny White)


Pocatello
Soda Springs
Lava Hot Springs
Red Rock Junction
Albion
Malta
Malad City
Preston
Cokeville
Logan
Brigham City
Evanston
Ogden
Layton
Farmington
Salt Lake City
Park City
Alta
Wendover
Tooele
Provo
Dugway
Gandy
Delta
Gunnison
Garrison
Beaver
Pony Springs
Pioche
N
25 12.5 0 25 50 75
Miles
Working Lands
Prime Agriculture
Existing Agriculture
Prime Ag + Existing Ag

Public Health, Welfare, and Safety

The Public Health, Welfare, and Safety (PHWS) model was developed to identify areas within the watershed that pose a threat to human residents and structures. The major threats identified within the watershed include floodplains, areas of landslide potential, and areas of seismic activity.

Floodplains

Flooding is among the most common natural disasters that occur in the United States (FEMA, 2010). Within the watershed flooding typically occurs along floodplains, which are low-lying areas that are in relatively close proximity to rivers and streams that are temporarily inundated with water during high flow events. Although the majority of the rivers and streams in the Great Salt Lake Watershed are highly manipulated by dams and reservoirs, there is still the possibility of flooding during periods of high precipitation or when the winter snowpack melts too quickly. If a flood occurred or a dam burst, there would be a potential for significant property damage and loss of life, especially in developed floodplains.

Landslide Potential

Landslides can occur on slopes of less than 5° and are typically the result of water buildup in the soil, which increases the pore pressure and reduces the bonds that hold the soil together (Shaw, 2007; Case). Since landslides can occur in almost any soil type with enough water, the PHWS model uses slope to determine landslide potential. The model contains three tiers including varying degrees of slope discussed later in this section.

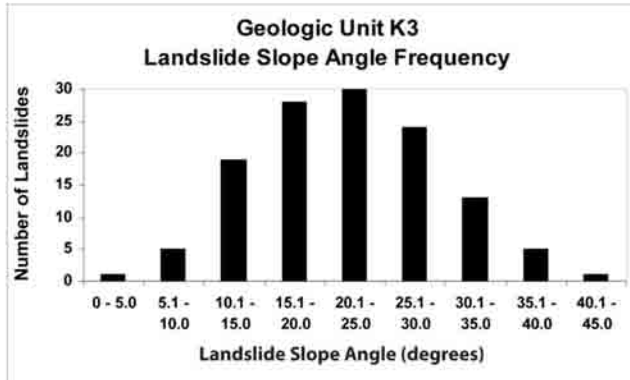


Figure 4.2 Landslide slope angle frequency in geologic unit K3 showing a normal distribution

Landslide Zones (based on figure 4.2)	
Zone 1	Slope 20° Ó25°
Zone 2	Slope 15° Ó30°
Zone 3	Slope 10° Ó35°

Seismic Activity

Earthquakes are the result of a sudden release of energy deep within the earthôs crust that creates seismic waves. The seismic activity of an area refers to the size and type of earthquake experienced over a period of time. For this model seismic activity has been broken into three separate levels as described in table 4.1. These zones pose threats to the public health welfare and safety and should be taken into consideration when planning for the future development of the watershed.

Seismic Activity Levels		
Seismic activity level	**Probability of exceedance in 50 years**	**Acceleration due to gravity (%g)**
Seismic zone 1	2%	120-60
Seismic zone 2	2%	40-60
Seismic zone 3	2%	30-40

Table 4.1 Levels of seismic activity

Oneida Narrows Dam (Danny White)

As the population continues to increase the need for clean water will be in even higher demand. With this in mind, wetlands, rivers and waterbodies were added to the PHSW model to protect this vital resource.

Protecting Welfare

Wetlands

Wetlands perform many functions for both wildlife and human needs. Wetlands act as natureĝs filters, removing excess sediments and pollutants from the water. They also perform the function of flood abatement. During periods of high flow, wetlands slow the flow of water, while its plants transpire some of the moisture back into the atmosphere. They have also been shown to be important recharge zones for aquifers. Wetlands are a vital resource and should be protected from the encroachment of development.

Rivers

Rivers act as the conduit to bring water from the mountains to the valleys where it can be utilized by society. Water is the most important resource in the arid west, and is vital to the success of future generations of inhabitants in the watershed. As such, the conduit through which it flows should be protected to ensure this resource is properly protected. The PHWS model provides a means for planners to identify where potential conflicts may exist with future development and river corridors. It will also be used to determine how the alternative futures in this study impact rivers.

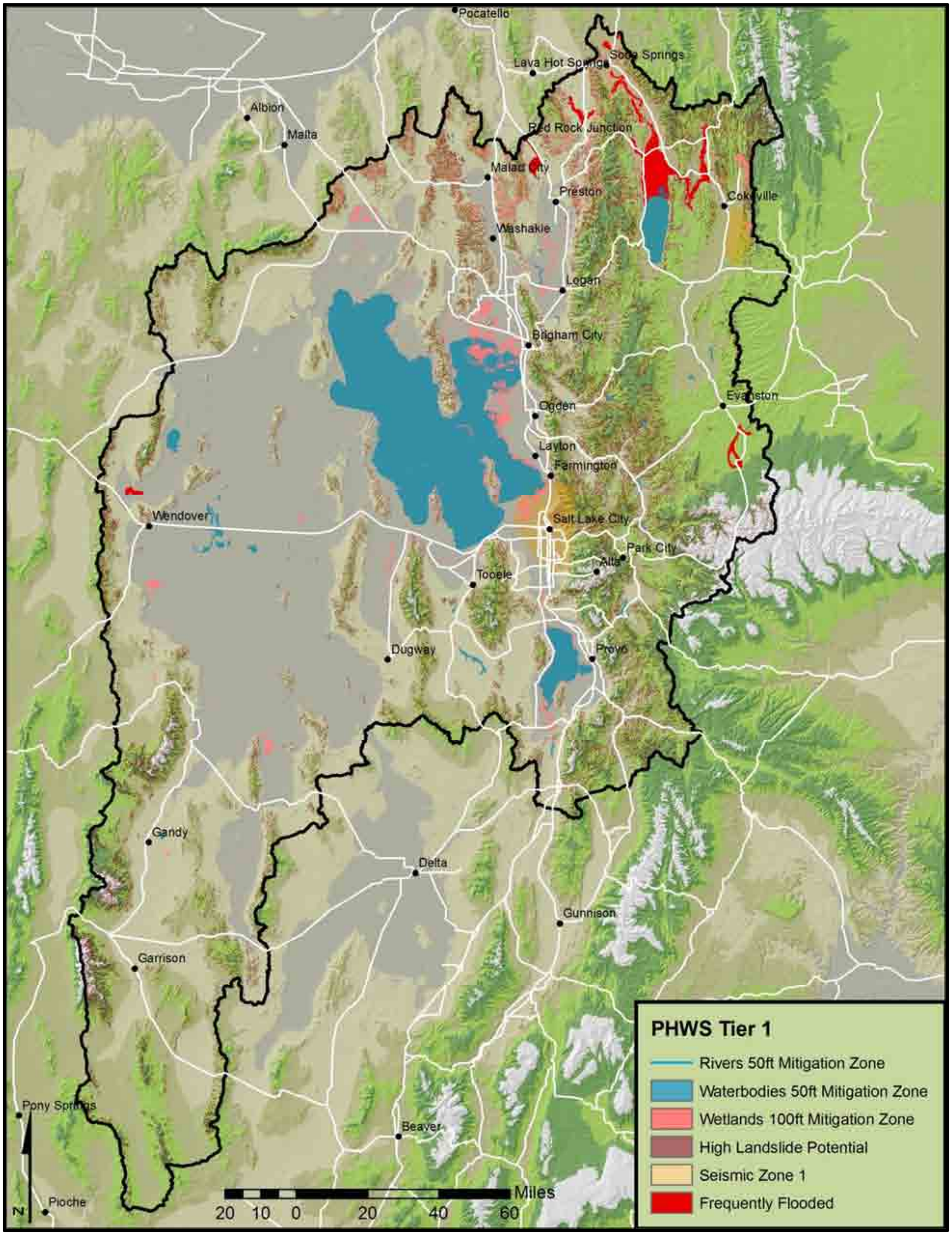
Waterbodies

Precipitation in the watershed occurs primarily in the form of snow, which melts in late spring and early summer. Much of this snowmelt occurs at a time when it is unusable for agricultural purposes. To control this excess flow in the spring, reservoirs have been constructed throughout the watershed to ensure adequate flows in late summer and early fall. Bear Lake acts not only as a hub for recreation, it also provides water storage from the Bear River. Both natural and manmade lakes should be protected from development pressures, to provide clean water for those that rely on it.

Model Criteria

- Mitigation Zones
  - Rivers
  - Wetlands
  - Waterbodies
- Floodplains
- Landslide potential
- Seismic activity

Public Health Welfare and Safety		
Tier 1: Identifies areas of the watershed with a high level of priority for protecting water availability and quality.	**Tier 2:** Identifies areas of the watershed with a medium level of priority for protecting water availability and quality.	**Tier 3:** Identifies areas of the watershed with a low level of priority for protecting water availability and quality.
Includes: • 100 ft. mitigation zone around wetlands • 50 ft. mitigation zone around waterbodies • 50ft. mitigation zone around streams • Frequently flooded areas • Seismic zone 1 • Landslide zone 1	**Includes:** • All tier 1 lands • Frequently + occasionally flooded areas • Seismic zone 2 • Landslide zone 2	**Includes:** • All lands in tiers 1 and 2 • Frequently + occasionally + rarely flooded areas • Seismic zone 3 • Landslide zone 3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Pony Springs
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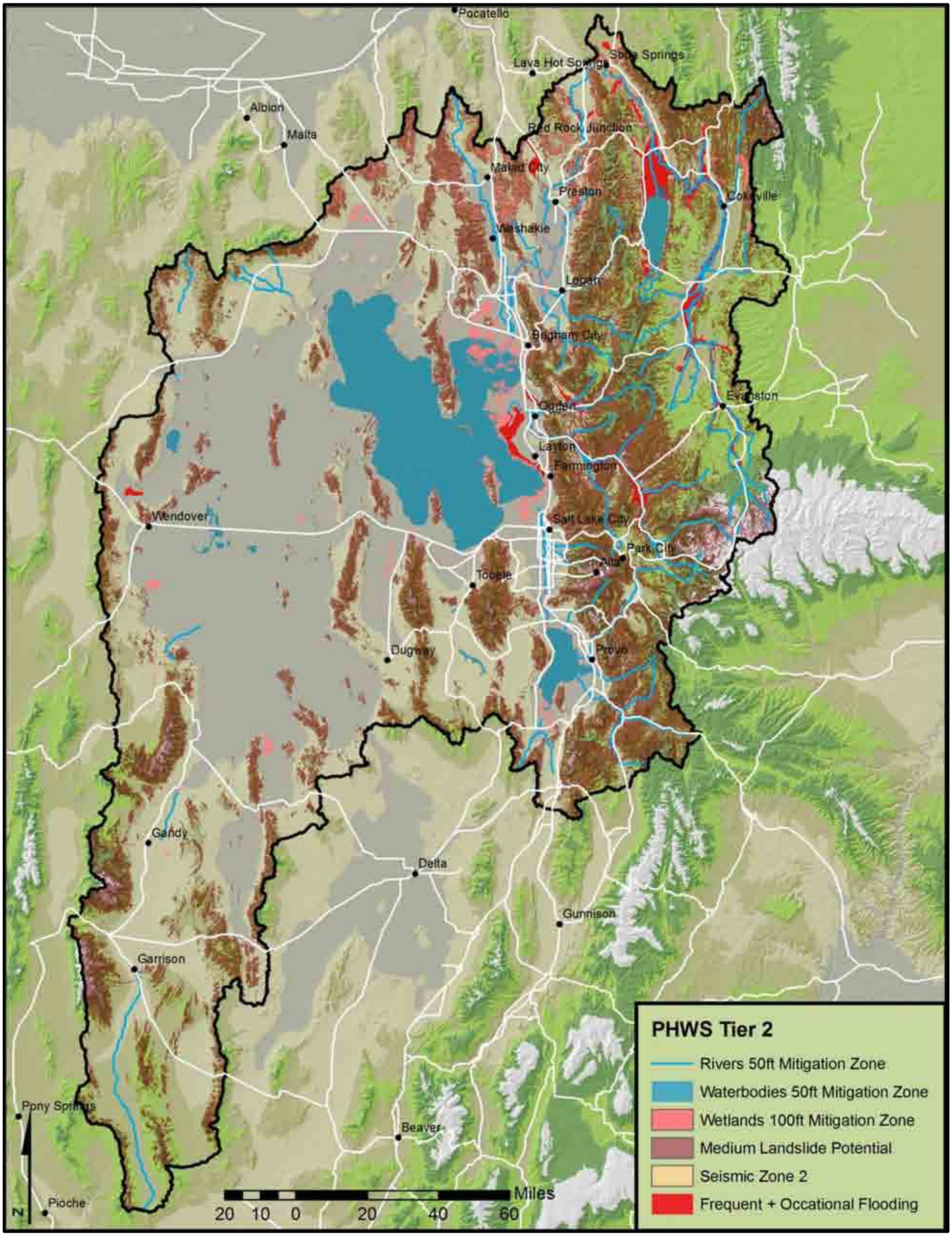
N
20 10 0 20 40 60
Miles
PHWS Tier 1
Rivers 50ft Mitigation Zone
Waterbodies 50ft Mitigation Zone
Wetlands 100ft Mitigation Zone
High Landslide Potential
Seismic Zone 1
Frequently Flooded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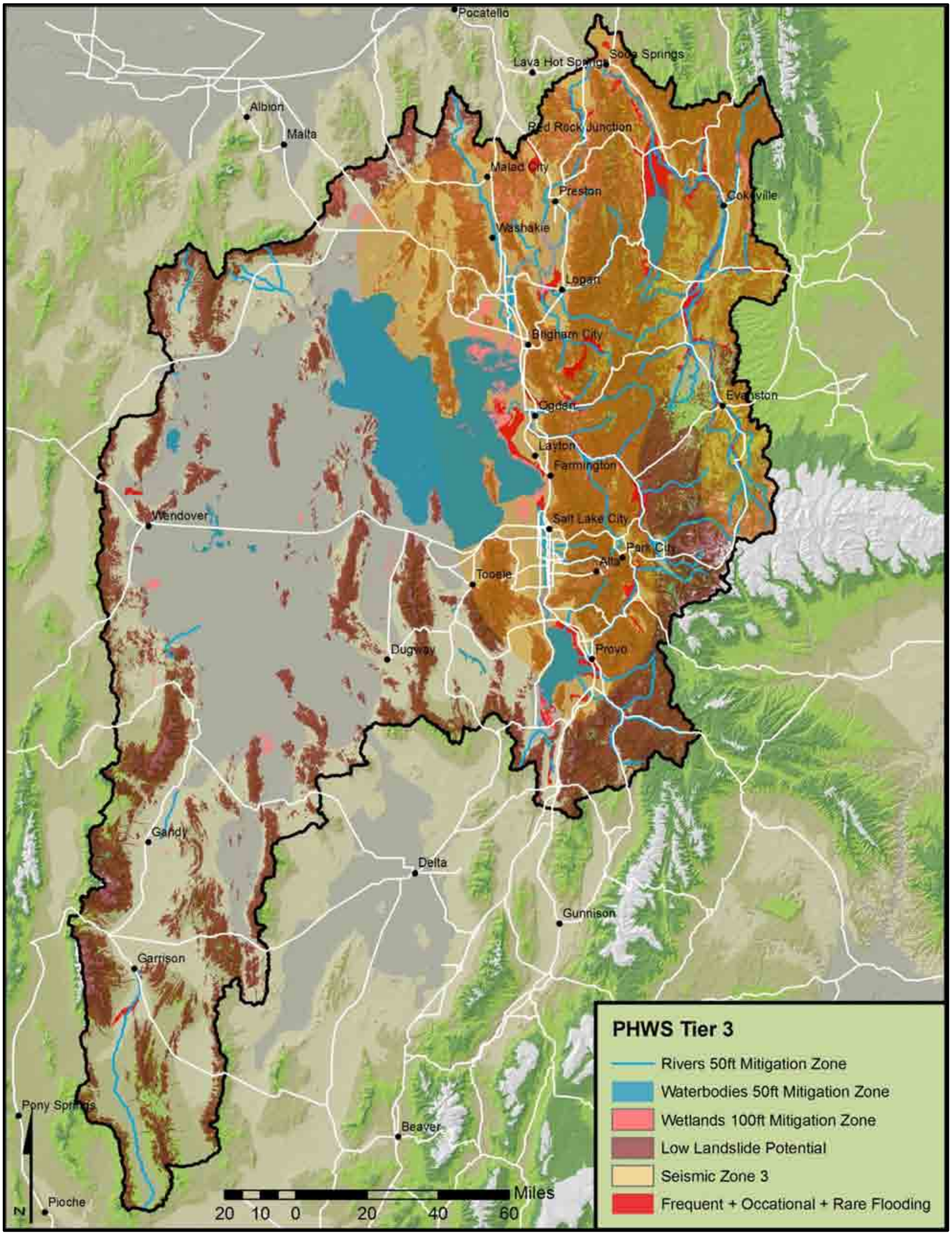
N
20 10 0 20 40 60
Miles
PHWS Tier 2
Rivers 50ft Mitigation Zone
Waterbodies 50ft Mitigation Zone
Wetlands 100ft Mitigation Zone
Medium Landslide Potential
Seismic Zone 2
Frequent + Occational Flooding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Beaver
Pioche
N
20 10 0 20 40 60
Miles
PHWS Tier 3
Rivers 50ft Mitigation Zone
Waterbodies 50ft Mitigation Zone
Wetlands 100ft Mitigation Zone
Low Landslide Potential
Seismic Zone 3
Frequent + Occational + Rare Flooding

Critical Habitat

Wildlife are an important part of the watershed and play a critical role in the economics and aesthetics of the region. The Critical Habitat model identifies portions of the watershed that provide habitat for the greatest number of wildlife species. Its purpose is to determine how various future scenarios will affect the wildlife habitat of the watershed and can be used as a predictor of how wildlife will thrive under the various scenarios.

The Utah Division of Wildlife Resources developed a three-tiered system to assemble native species in order of conservation needs (Gorrell, et al., 2005). This tiered ranking system is based upon several factors including state and federal status, conservation need, life history, distribution, abundance, and threat.

Since no wildlife population data exists for the Great Salt Lake Watershed, the state tiering system is used as a proxy. Data for this model was derived from the Southwest Regional Gap Analysis Project and the Northwest Regional Gap Analysis Project. The Critical Habitat model utilizes the tiering methodology of the Utah Division of Wildlife Resources (Gorrell, et al., 2005) to create a hybrid model, depicting both individual species and species richness.

Tier 1
As per Utah Division of Wildlife Resources, tier 1 consists of federally endangered and threatened species, federal candidate species, and species with conservation agreements. The Great Salt Lake Watershed contains habitat for 15 tier 1 species (see table 4.2).

Tier 1 Wildlife Species		
Group	**Common Name**	**Primary Habitat**
Amphibians	Columbia Spotted Frog	Wetland
	Leopard Frog	Wetland
Birds	Bald Eagle	Lowland Riparian
	Gunnison Sage-grouse	Shrubsteppe
	California Condor	Cliff
	Mexican Spotted Owl	Cliff
	Northern Goshawk	Mixed Conifer
	Southwestern Willow Flycatcher	Lowland Riparian
	Whooping Crane (extirpated)	Wetland
	Yellow-billed Cuckoo	Lowland Riparian
Mammals	Black-footed Ferret	Grassland
	Brown Bear	Mixed Conifer
	Canada Lynx	Sub-alpine Conifer
	Gray Wolf	Mountain Shrub
	Utah Prairie Dog	Grassland

Table 4.2 Tier 1 wildlife species from the Utah Comprehensive Wildlife Conservation Strategy

Tier 2
The tier 2 species are generally equivalent to the Utah Species of Concern List. To generate the list the Utah Division of Wildlife Resources utilized a panel of expert biologists. The species for tier 2 were selected based on species biology, life history, population ï abundance, population

conditions, distribution, and threats (Gorrell, et al., 2005). The Great Salt Lake Watershed contains habitat for 26 tier 2 species (see table 4.3).

Tier 2 Wildlife Species

Group	Common Name	Primary Habitat
Amphibians	Arizona Toad	Lowland Riparian
	Western Toad	Wetland
Birds	American White Pelican	Water ï Lentic
	Black Swift	Lowland Riparian
	Bobolink	Wet Meadow
	Burrowing Owl	High Dessert Scrub
	Ferruginous Hawk	Pinyon-Juniper
	Grasshopper Sparrow	Grassland
	Greater Sage-grouse	Shrubsteppe
	Lewisôs Woodpecker	Ponderosa Pine
	Long-billed Curlew	Grassland
	Sharp-tailed Grouse	Shrubsteppe
	Short-eared Owl	Wetland
	Three-toed Woodpecker	Sub-alpine Conifer
Mammals	Allenôs Big-eared Bat	Lowland Riparian
	Big Free-tailed Bat	Lowland Riparian
	Dark Kangaroo Mouse	High Dessert Scrub
	Fringed Myotis	Northern Oak
	Gunnisonôs Prairie-dog	Northern Oak
	Kit Fox	High Dessert Scrub
	Mexican Vole	Ponderosa Pine
	Prebleôs Shrew	Wetland
	Pygmy Rabbit	Shrubsteppe

Tier 2 Wildlife Species (*continued)*

Group	Common Name	Primary Habitat
Mammals	Silky Pocket Mouse	Grassland
	Townsendôs Big-eared Bat	Pinyon-Juniper
	Western Red Bat	Lowland Riparian
	White-tailed Prairie-dog	Grassland

Table 4.3 Tier 2 wildlife species from the Utah Comprehensive Wildlife Conservation Strategy

Tier 3

Species for tier 3 were generated using the same process as for tier 2, but Tier 3 includes species of conservation concern because they are tied to threatened habitat, experience a significant population decrease, or little information about the species exists. The Great Salt Lake Watershed contains habitat for 43 tier 3 species (see table 4.4).

Tier 3 Wildlife Species

Group	Common Name	Primary Habitat
Amphibians	Canyon Treefrog	Lowland Riparian
	Great Plains Toad	High Desert Scrub
	Mexican Spadefoot	Pinyon-Juniper
	Northern Leopard Frog	Wetland
	Pacific Treefrog	Lowland Riparian
	Plains Spadefoot	Pinyon-Juniper
	Canyon Treefrog	Lowland Riparian
	Great Plains Toad	High Desert Scrub
	Mexican Spadefoot	Pinyon-Juniper

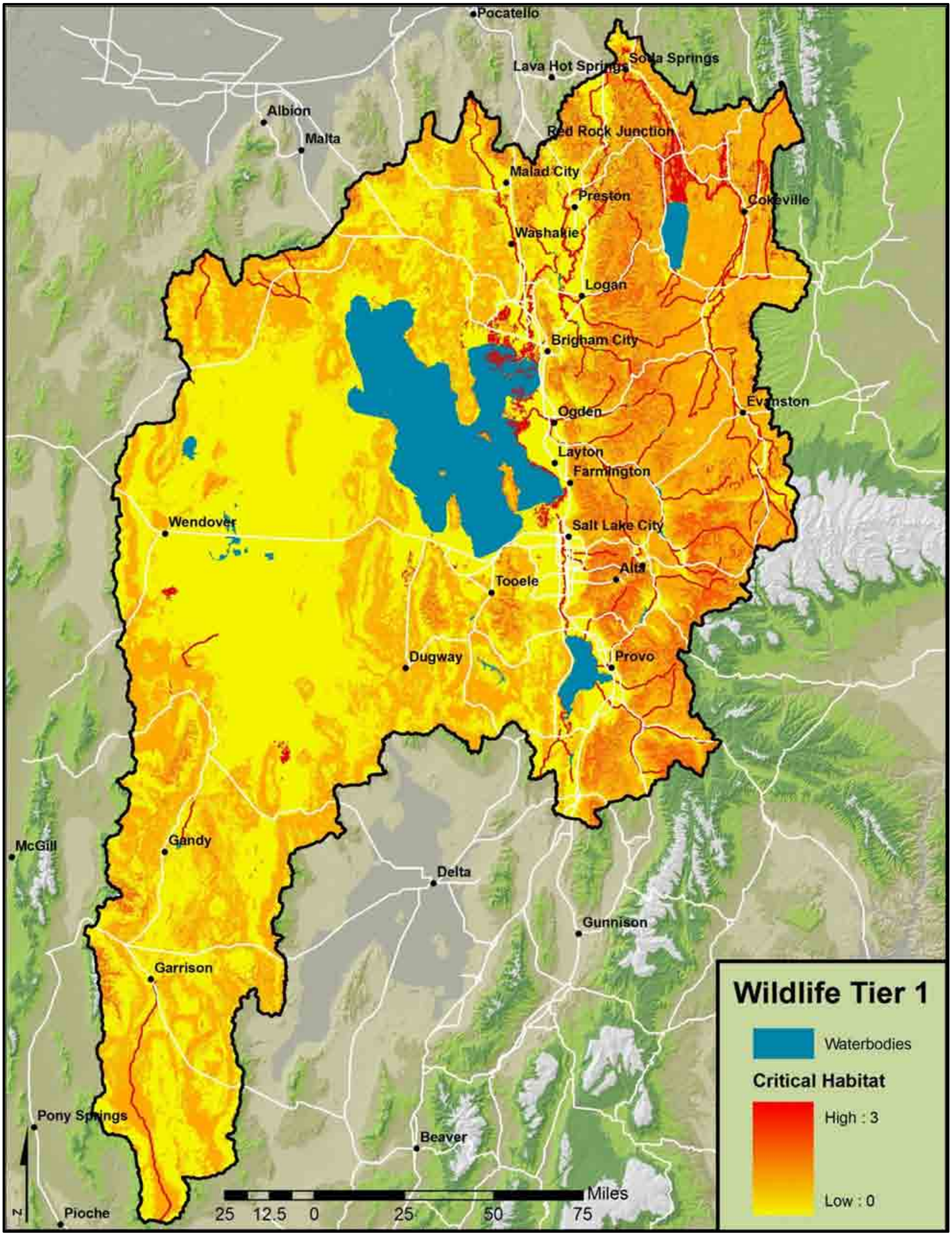
Tier 3 Wildlife Species (*continued*)

Group	Common Name	Primary Habitat
Amphibians	Northern Leopard Frog	Wetland
	Pacific Treefrog	Lowland Riparian
	Plains Spadefoot	Pinyon-Juniper
Birds	Abertôs Towhee	Lowland Riparian
	American Avocet	Wetland
	Band-tailed Pigeon	Ponderosa Pine
	Bellôs Vireo	Lowland Riparian
	Black Rosy-finch	Alpine
	Black-necked Stilt	Wetland
	Black-throated Gray Warbler	Pinyon-Juniper
	Boreal Owl	Sub-alpine Conifer
	Brewerôs Sparrow	Shrubsteppe
	Caspian Tern	Playa
	Gray Vireo	Pinyon-Juniper
	Lucyôs Warbler	Lowland Riparian
	Mountain Plover	High Desert Scrub
	Osprey	Water ï Lentic
	Peregrine Falcon	Cliff
	Sage Sparrow	Shrubsteppe
	Sage Thrasher	Shrubsteppe
	Snowy Plover	Playa
	Virginiaôs Warbler	Northern Oak
	Williamsonôs Sapsucker	Sub-alpine Conifer
Mammals	American Marten	Sub-alpine Conifer
	American Pika	Alpine
	Bighorn Sheep	High Desert Scrub
	Dwarf Shrew	Sub-alpine Conifer
	Idaho Pocket Gopher	Grassland
	Merriamôs Shrew	Shrubsteppe

Tier 3 Wildlife Species (*continued*)

Group	Common Name	Primary Habitat
Mammals	Mule Deer	Shrubsteppe
	Northern Flying Squirrel	Sub-alpine Conifer
	Northern River Otter	Mountain Riparian
	Northern Rock Mouse	Rock
	Olive-backed Pocket Mouse	Shrubsteppe
	Stephenôs Woodrat	Pinyon-Juniper
	Spotted Ground Squirrel	Grassland
	Thirteen-lined Ground Squirrel	Grassland
	Wolverine	Sub-alpine Conifer
	Wyoming Ground Squirrel	Shrubsteppe
	Yuma Myotis	Lowland Riparian

Table 4.4 Tier 3 wildlife species from the Utah Comprehensive Wildlife Conservation Strategy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25 12.5 0 25 50 75
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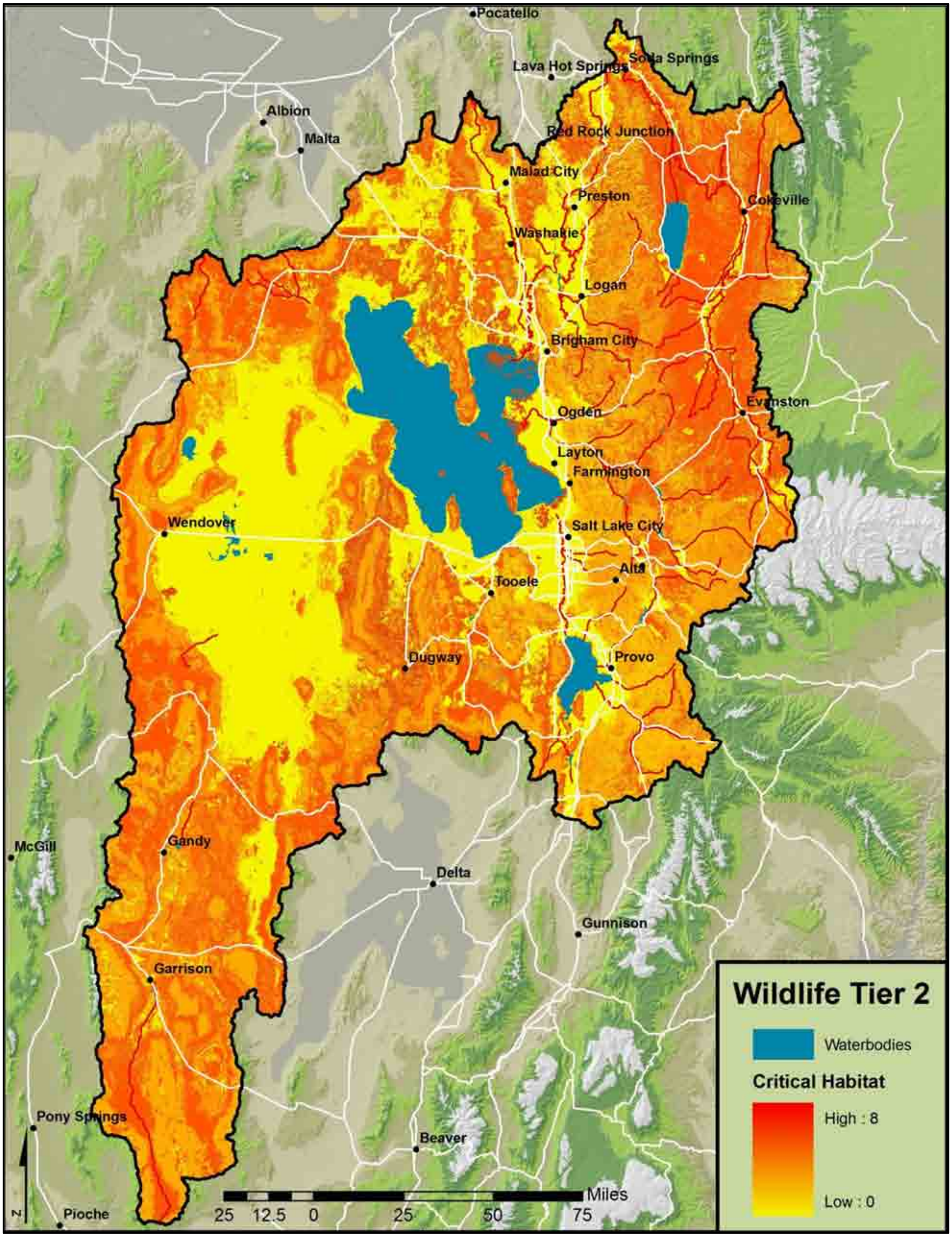
Wildlife Tier 1
Waterbodies
Critical Habitat
High : 3
Low : 0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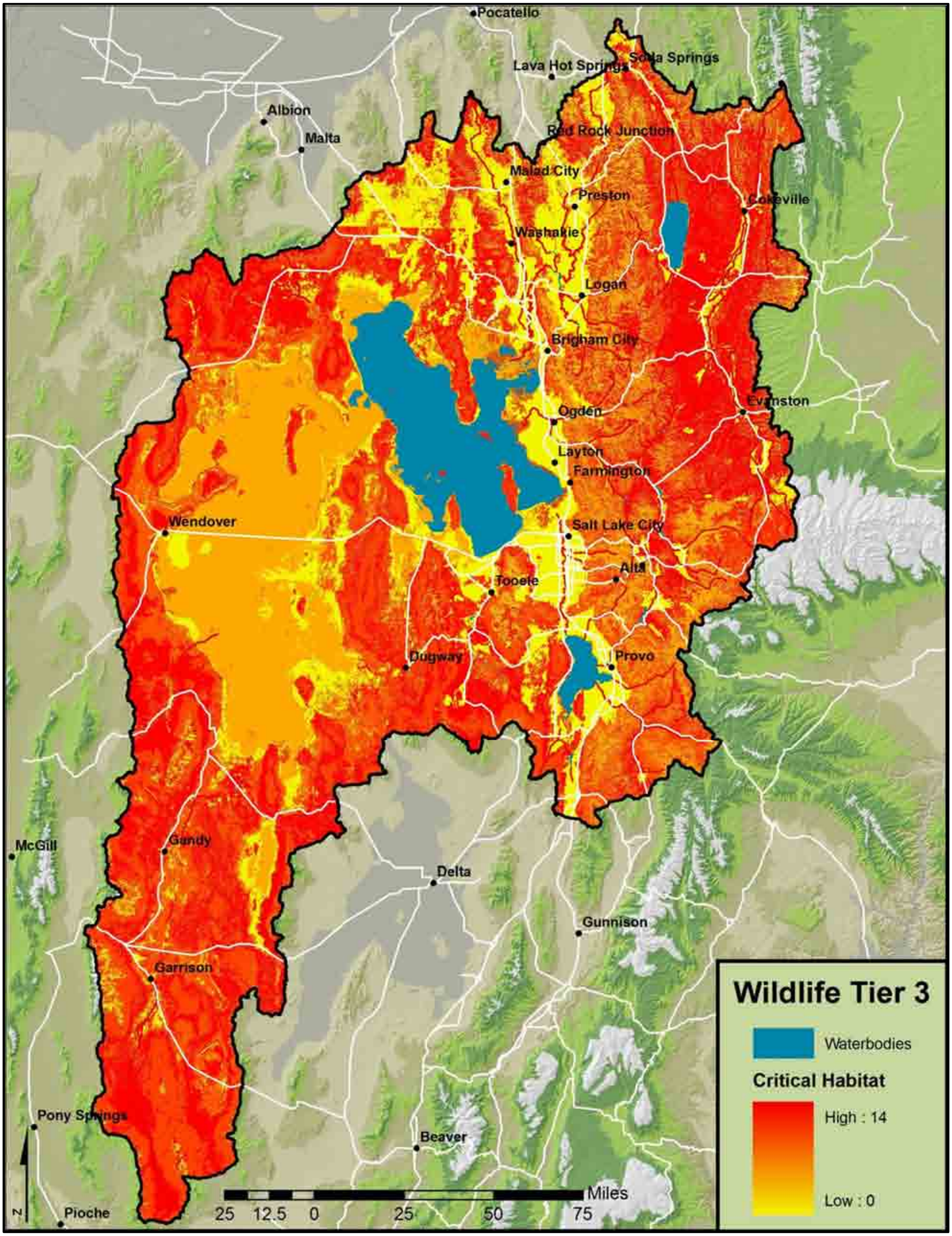
N
25 12.5 0 25 50 75 Miles
Wildlife Tier 2
Waterbodies
Critical Habitat
High : 8
Low : 0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Beaver
Pioche
N
25 12.5 0 25 50 75
Miles
Wildlife Tier 3
Waterbodies
Critical Habitat
High : 14
Low : 0

Integrated Resources

The Integrated Resources assessment model was developed to determine the impacts the alternative futures will have on the availability and quality of water throughout the watershed. Although this model does not provide a quantitative view of the impacts alternative futures will have on the watershed, it does illustrate the areas within the watershed that if impacted will result in a loss of water quality or quantity. The criteria for this model was developed through numerous case studies as well as input from faculty from Utah State University and the University of Utah.

Water is the most important resource in the arid west, and should be protected to provide a high quality of life for the residents of the watershed for years to come. For this reason, the Integrated Resources model identifies various mitigation zones in the watershed for precipitation zones, river, wetlands, waterbodies, floodplains, and groundwater recharge zones.

Mitigation Zones

A mitigation zone represents a portion of the landscape that is to remain under the ownership of the landholder but provides certain restrictions to the activities on the land that pose a threat to water quality and quantity. Any proposed use that takes place inside a mitigation zone must first be brought before the county planning commission to determine if the use would impact water. If the proposed use is granted, the planning commission would determine the level of mitigation required to protect the water. As an incentive to the landowner for agreeing to these initiatives, the landowner would be granted the right to exclude public access to the mitigation zone on their property.

Precipitation zones were developed to maintain and enhance the quality and quantity of water in the watershed. The precipitation zones consist of seven separate zones based on amount of precipitation (See table 4.5). Land use within designated precipitation zones should exclude development, recreation, logging, grazing, and other practices that would degrade water quality and impede water quantity.

Precipitation Zones	
Zone one	Areas of precipitation Ó45
Zone two	Areas of precipitation Ó40
Zone three	Areas of precipitation Ó35
Zone four	Areas of precipitation Ó30
Zone five	Areas of precipitation Ó25
Zone six	Areas of precipitation Ó20
Zone seven	Areas of precipitation Ò20

Table 4.5 Precipitation Zones

The **river mitigation zones** were developed to help reduce the impact potential development activities will have on the availability and quality of water in the rivers of the watershed. Three separate mitigation zones were developed for the rivers of the Great Salt Lake Watershed based on the above listed precipitation zones. These mitigation zones were created to protect the most productive portions of the rivers and streams within the watershed while providing the least amount of impact to landowners. The river mitigation zones include:

- 300 ft mitigation zone around all rivers and streams within mitigation zone four.
- 200 ft mitigation zone around all rivers and streams within precipitation zone six.
- 100 ft mitigation zone around all rivers located within mitigation zone seven.

Wetland mitigation zones were included to protect and enhance the function wetlands provide for the watershed. The wetlands contain three separate mitigation zones based on slope and include:

- 100 ft mitigation zone around all wetlands within the watershed regardless of slope.

A mitigation zone around **waterbodies** was included to maintain and enhance the quality of water held in the natural and manmade reservoirs of the watershed. According to the code of federal regulations all waterbodies should have a minimum buffer width of 50 ft, where there is no developmental impact, unless a proper permit is attained. This model contains three successively larger mitigation zones around waterbodies.

- 50 ft mitigation zone around all waterbodies.

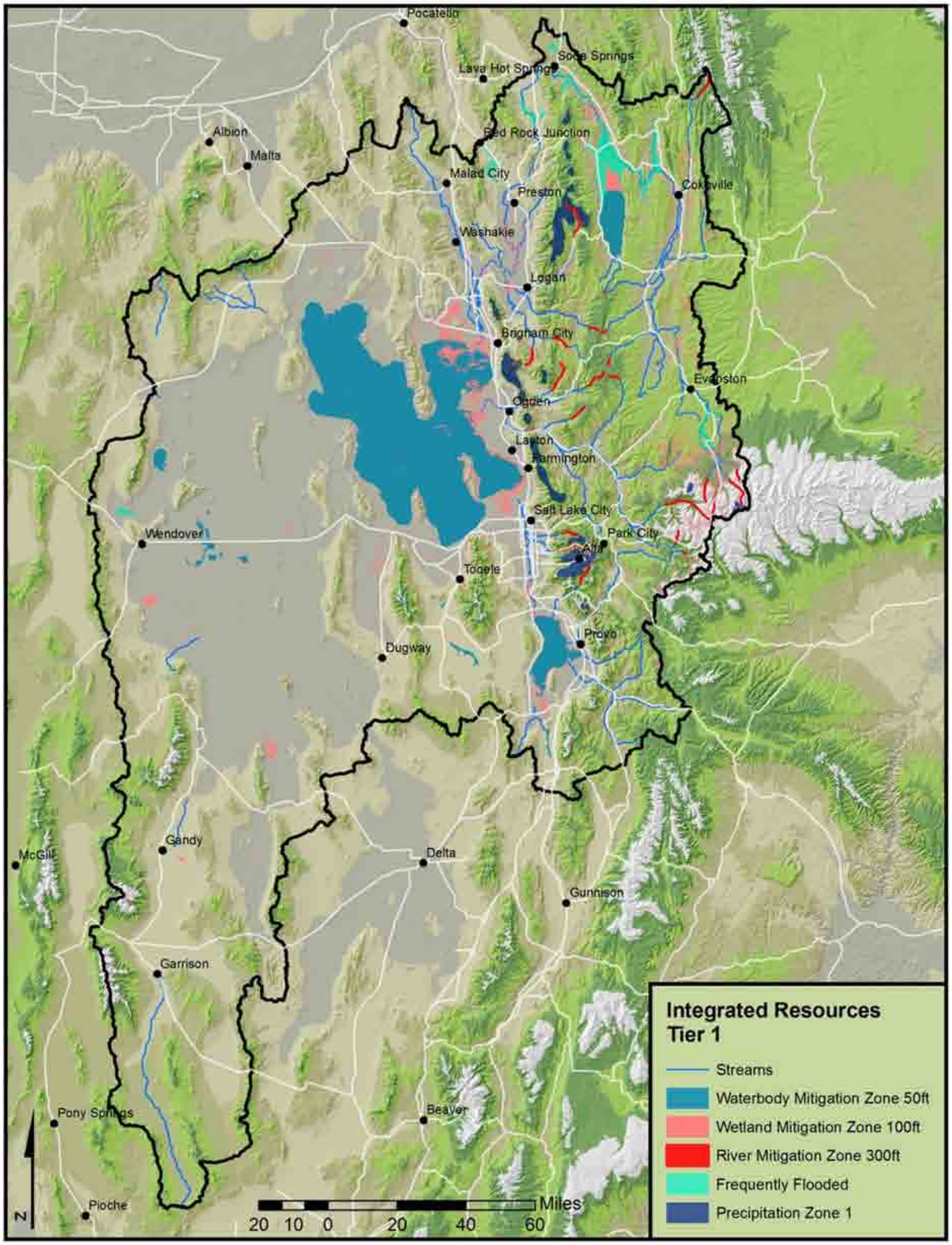
The mitigation zones around floodplains serve a twofold agenda. First, this mitigation zone reduces the impact to human life and property during flood events. Second it protects the river water from being degraded by development along floodplains during a flood event. Using soil data from NRCS, this model identifies areas that have a history of flooding.

This model also identifies areas of groundwater recharge and includes mitigation zones to protect that recharge. These groundwater recharge areas should be protected from future development that involves increasing the amount of impermeable surfaces or diverts water from the recharge zone. Other restrictions include agricultural practices that might allow contaminated water to pollute the groundwater.

Model Criteria

- **Mitigation Zones**
  - Precipitation zones
  - Rivers
  - Wetlands
  - Waterbodies
  - Floodplains
  - Groundwater recharge zones

Integrated Resources		
Tier 1: Identifies areas of the watershed with a high level of priority for protecting water availability and quality.	**Tier 2:** Identifies areas of the watershed with a medium level of priority for protecting water availability and quality.	**Tier 3:** Identifies areas of the watershed with a low level of priority for protecting water availability and quality.
Includes: • 300ô mitigation zone around all streams in precipitation zone 1 • 100ô mitigation zone around all wetlands • 50 mitigation zone around all waterbodies • Mitigation zone around floodplains with frequent occurrence • Precipitation Zone 1	**Includes:** • All tier 1 lands • 200ô mitigation zone around all streams in precipitation zone 2 • Mitigation zone around all groundwater recharge zones within precipitation zone 5 • Precipitation zone 3	**Includes:** • All lands in tiers 1 and 2 • 100ô mitigation zone around all streams in precipitation zone 3 • Mitigation zone around floodplains with frequent and occasional occurrence • Mitigation zone around all groundwater recharge zones within precipitation zone 6 • Precipitation zone 4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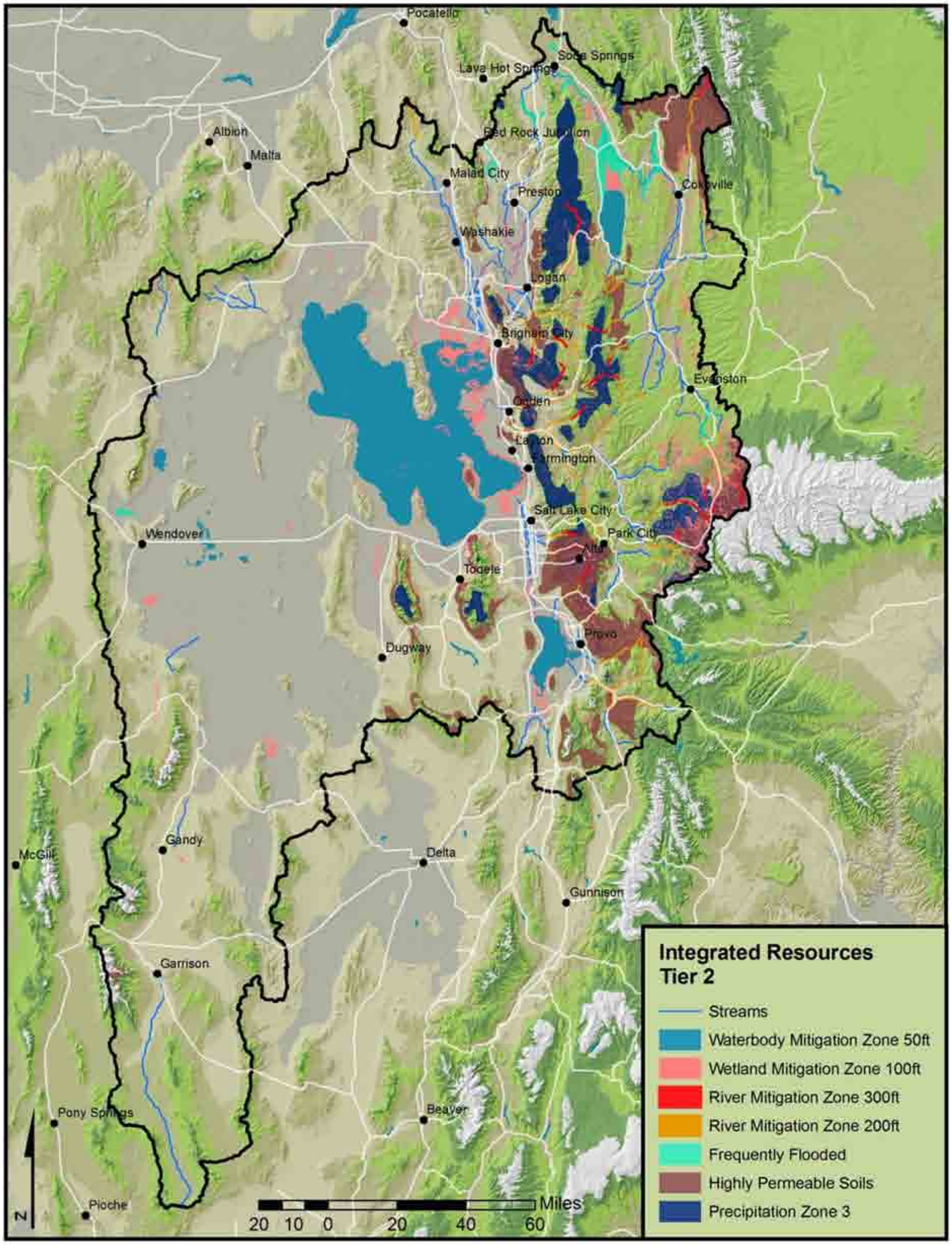
N
20 10 0 20 40 60
Miles
Integrated Resources
Tier 1
Streams
Waterbody Mitigation Zone 50ft
Wetland Mitigation Zone 100ft
River Mitigation Zone 300ft
Frequently Flooded
Precipitation Zone 1


Integrated Resources
Tier 2
Streams
Waterbody Mitigation Zone 50ft
Wetland Mitigation Zone 100ft
River Mitigation Zone 300ft
River Mitigation Zone 200ft
Frequently Flooded
Highly Permeable Soils
Precipitation Zone 3
Miles
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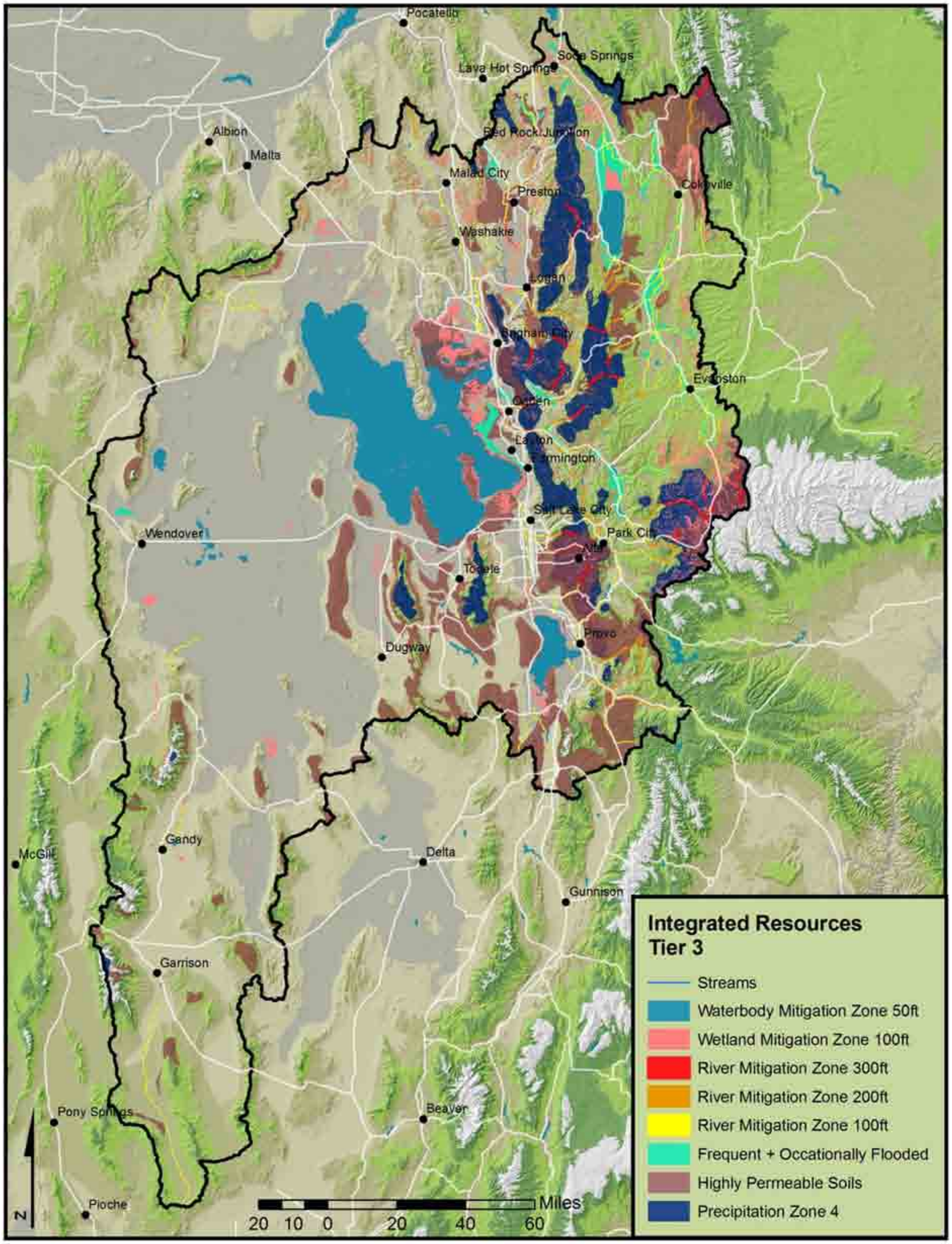
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Pony Springs
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Pioche
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20 10 0 20 40 60 Miles
Integrated Resources
Tier 3
Streams
Waterbody Mitigation Zone 50ft
Wetland Mitigation Zone 100ft
River Mitigation Zone 300ft
River Mitigation Zone 200ft
River Mitigation Zone 100ft
Frequent + Occationally Flooded
Highly Permeable Soils
Precipitation Zone 4

Plan Trend

The Plan Trend future identifies areas of the Great Salt Lake Watershed where the greatest potential for development exists, given current trends. This model representing the ñstatus quoò, emphasizes low-density urban sprawl, commuter-based infrastructure, and few considerations for the protection of critical lands (i.e. wetlands, riparian corridors, prime agricultural lands, and floodplains).

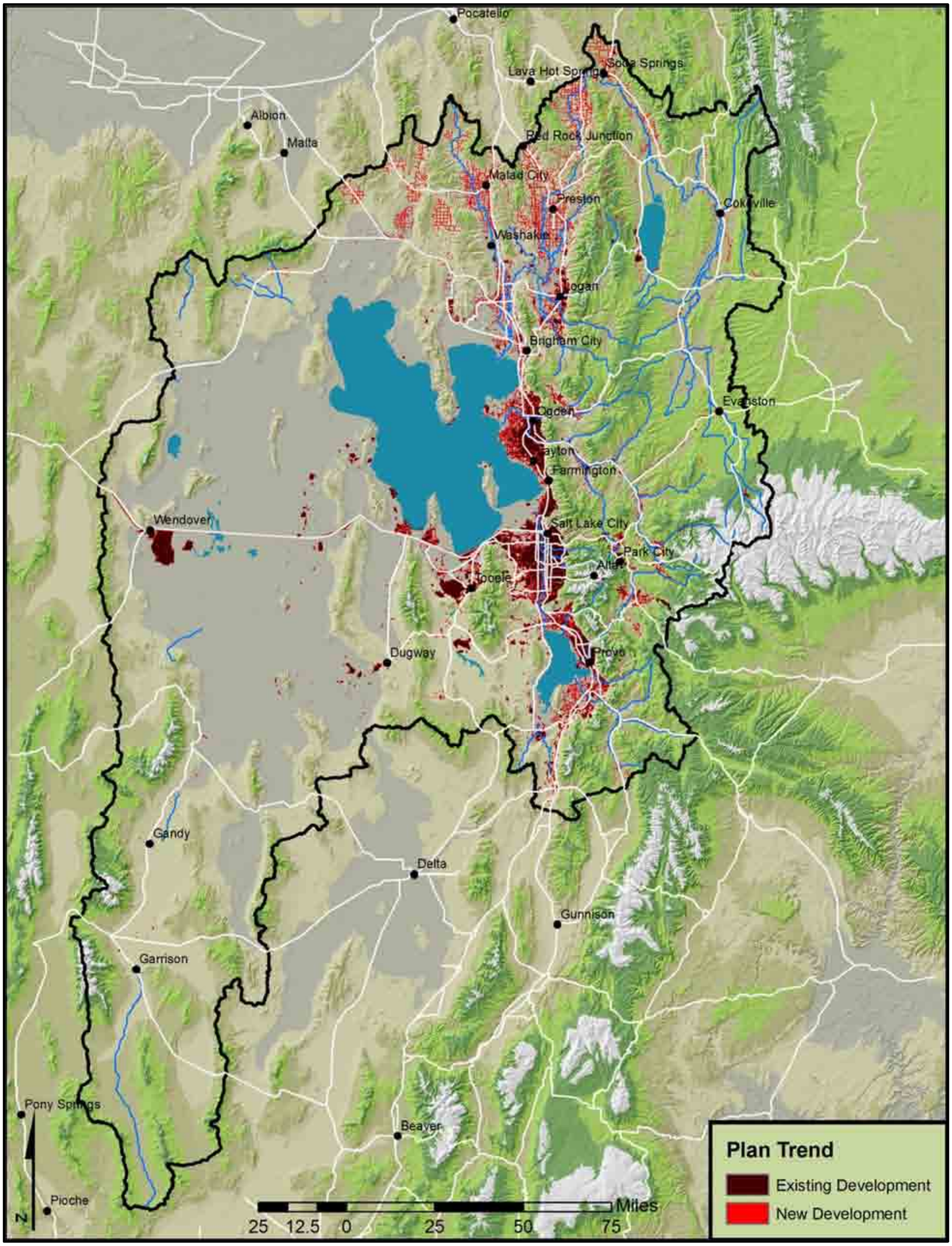
Model criteria for plan trend were adapted from previous bioregional reports on the Bear River Watershed (Toth, Edwards, Lilieholm, Bell, & Buteau, 2002; Toth, Edwards, Perschon, & White, 2010). The lands identified in this model are those within close proximity to existing development and major roads, and within a slope of 15%. These lands reflect those that are most affordable and efficient for development.

Public lands were excluded from this model, except in areas where development currently exists on public lands. The future development impacts to public lands will be minimal in the near future, however, it is impossible to predict the changes that may occur in the management of these lands. As population continues to increase in the watershed, development pressures on public land will continue to rise (Toth, Edwards, Perschon, & White, 2010). Areas of slope greater than 15% were also excluded from Plan Trend based on the assumption that development on land with slope less than 15% is cheaper and more efficient. Evidence of this assumption exists throughout the region, especially along the Wasatch Front and the Cache Valley, where the heaviest development has been focused in areas of relatively low slope.

The resulting map depicts how the spatial arrangement of development may appear in the future if current development practices continue.

Model Criteria

- Existing development
- Development zone within 400 feet of existing development
- Development zone within 400 feet of existing major roads
- Slope less than 15%
- Exclude public land (except where current development exists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25 12.5 0 25 50 75 Miles
Plan Trend
Existing Development
New Development

Build Out

Build Out is characterized by an aggressive growth pattern with few considerations for impacts to the environment. Similar to plan trend, build out emphasizes low-density urban sprawl and commuter-based infrastructure. This model demonstrates where future development may occur, if growth were to occur faster than current trends indicate. One of the primary assumptions of this model is that future development will occur on lands that are most feasible to build, maintaining a relatively close proximity to existing development.

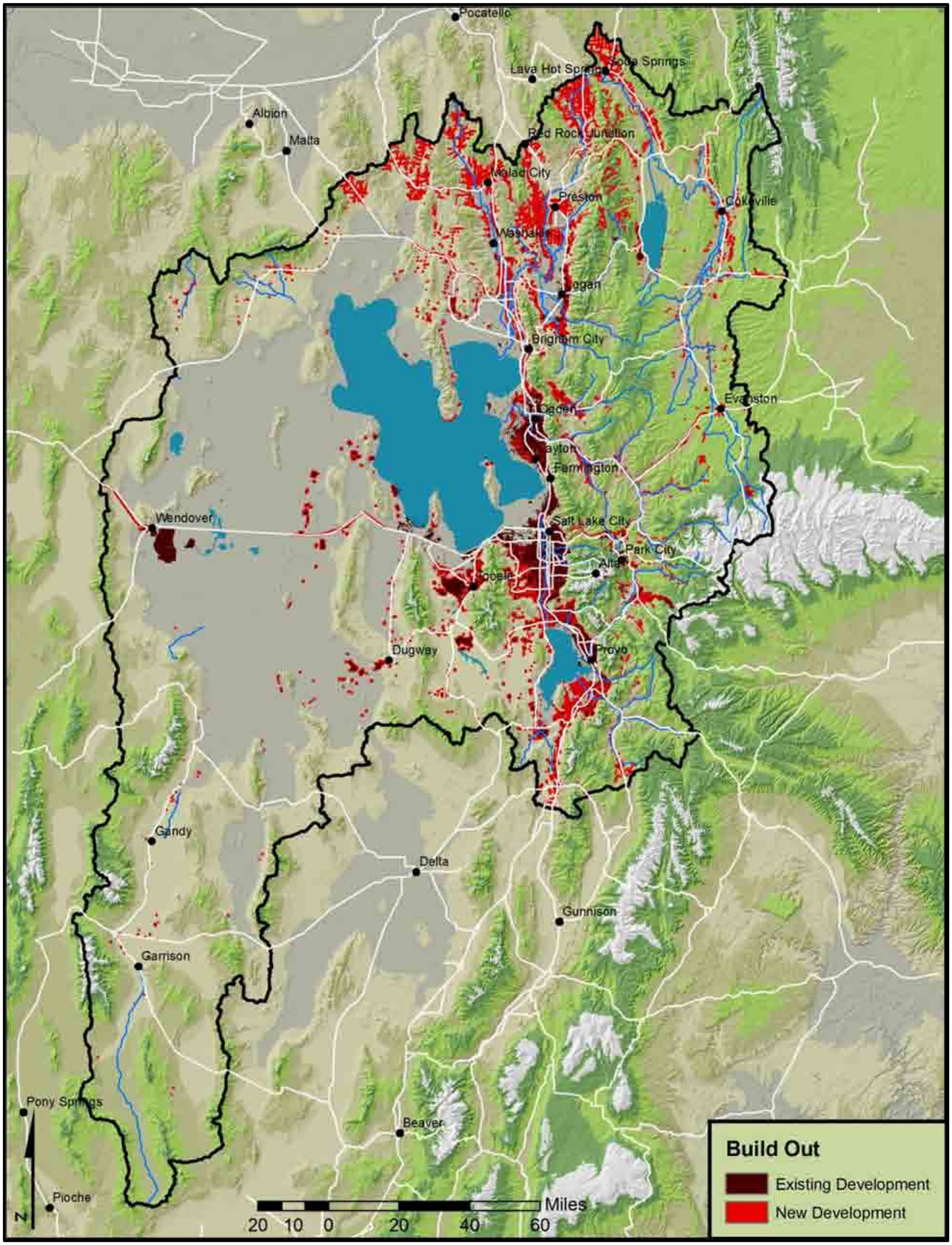
Criteria for Build Out are similar to Plan Trend with modifications to simulate faster rates of development and locating lands that are cheaper to build on. Build Out continues to focus on lands relatively close to existing development; however, new development has been extended nearly three times further than in Plan Trend. The allowable slope gradient is also increased with developable land now occurring on a maximum slope of 25%. Also included in this model is the requirement that all new development occurs on soils with good drainage. Soil drainage class was determined using STATSGO data from NRCS to identify lands with well drained or better soils. This was based on the fact that building on well drained soils is cheaper and reduces the cost of potential mitigation due to building on wetlands or other sensitive areas.

Like Plan Trend, Build Out continues to exclude development from land that belongs to the public, based on the assumption that the majority of public land will continue to be free from development pressure into the near future. Although it is unlikely for future development to occur on public land due to the higher slope allowance in Build Out, it is likely public land will be indirectly affected by development through pollution and debris from construction activities and pollution from storm water runoff.

This map depicts how the spatial arrangement of development may appear in the future given more aggressive development than Plan Trend.

Model Criteria

- Existing development
- Development zone within ¼ mile of existing development
- Development zone within ¼ mile of existing major roads
- Slope less than 25%
- Well drained soils or better
- Exclude public land (except where current development exists)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Beaver
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Miles
Build Out
Existing Development
New Development

Focused Development

Both Plan Trend and Build Out are commuter-oriented developments and follow current trends in urban sprawl. However, there are some within the region that recognize the damaging effects of this type of development and may cause a shift to development practiced that are more community oriented, focusing more on the proximity to existing development.

The Focused Development models retain the same proximity to existing development parameters as Plan Trend and Build Out. These models do not allow new development to occur along major roads, except where they are within the defined proximity to existing development as indicated in the model criteria to the right.

The resulting maps indicate how the spatial arrangement of development may appear in the future if restrictions are placed on urban sprawl.

Focused Development (Plan Trend)

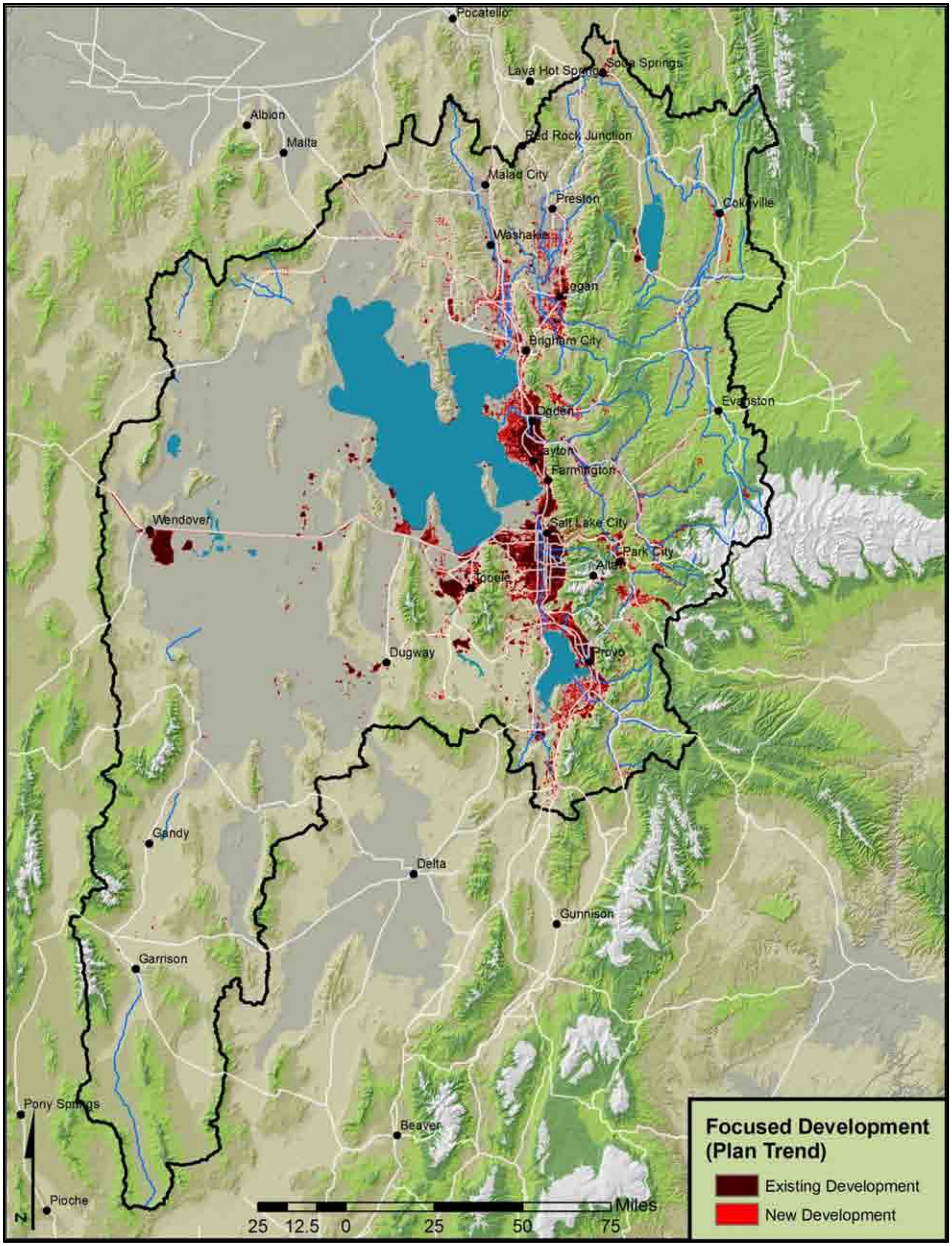
Model Criteria

- Existing development
- Development zone within 400 feet of existing development
- Slope less than 15%
- Exclude public land (except where current development exists)

Focused Development (Build Out)

Model Criteria

- Existing development
- Development zone within ¼ mile of existing development
- Slope less than 25%
- Well drained soils or better
- Exclude public land (except where current development exists)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Ogden
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(Plan Trend)
Existing Development
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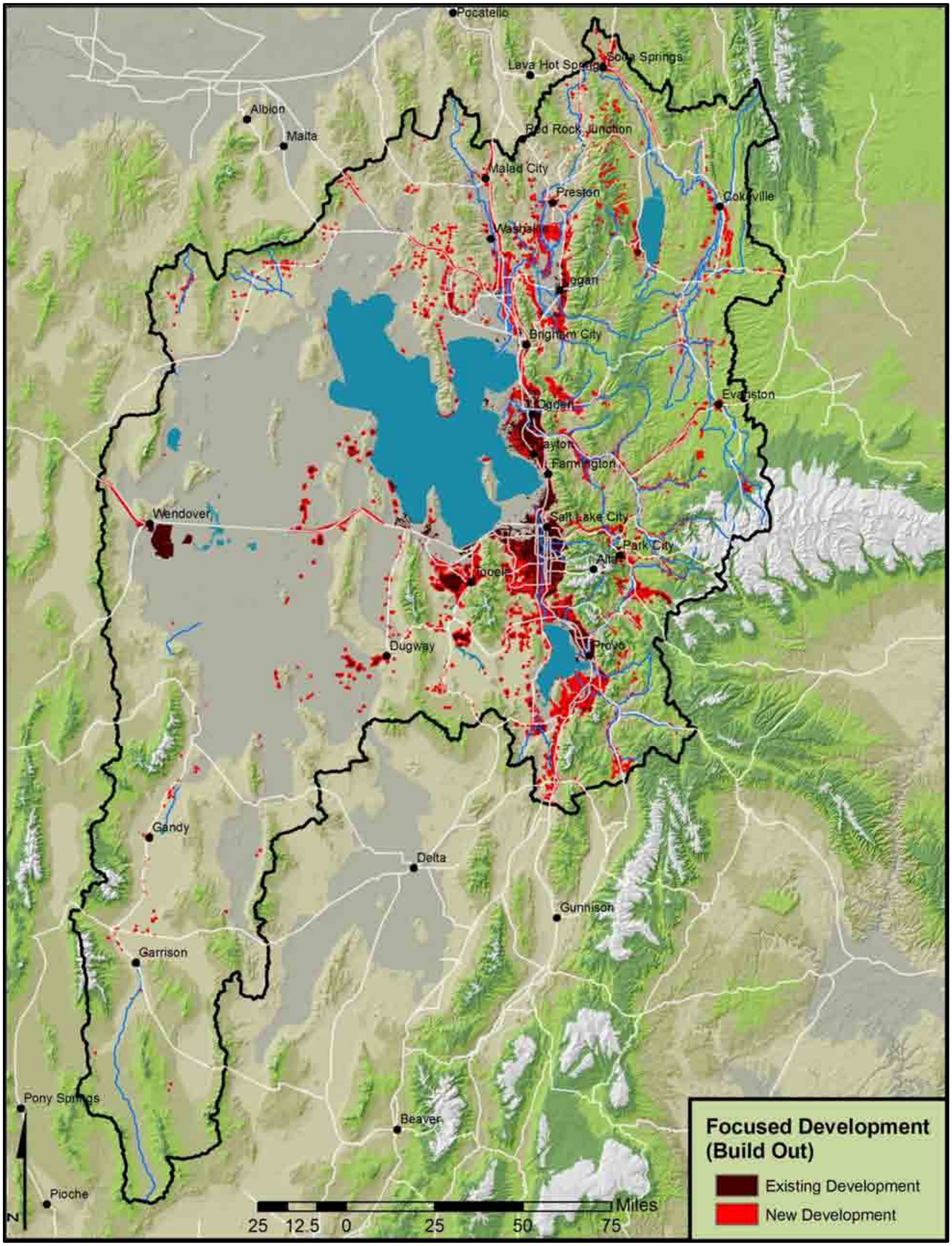
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Focused Development (Build Out)
Existing Development
New Development

LEED

The Leadership in Energy and Environmental Design (LEED) future model was developed to identify the potential strengths and weaknesses of a relatively well-known sustainable development model. LEED is an internationally recognized sustainable design rating system that provides third-party verification that a building or community was designed and constructed based upon strategies intended to increase energy savings, water efficiency, indoor and outdoor environmental quality, and decrease CO2 emissions and decrease the impact of development on critical habitat. Although multiple LEED rating systems exist, the Neighborhood Development rating system was used in the design of the LEED future model.

The following criteria are prerequisites under the LEED for Neighborhood Development rating system and were modified slightly in order to apply and represent them graphically at a large spatial extent.

Smart Location

The intent of this prerequisite is to encourage development within existing communities and near existing public transit infrastructure (U.S. Green Building Council, 2009). In order to extrapolate this to a large spatial extent the LEED model restricts future development to within 400 feet of existing development.

Imperiled Species and Ecological Communities Conservation

This prerequisite was created to conserve endangered or imperiled species and critical ecological communities (U.S. Green Building Council, 2009). The LEED model utilized information from the Critical Habitat assessment model to restrict development from occurring within areas that contain habitat considered critical to the conservation of threatened or endangered species.

Wetland and Waterbody Conservation

This intent is to preserve or enhance the quality of water, natural hydrology, and biodiversity by protecting wetlands and waterbodies (U.S. Green Building Council, 2009). To satisfy the criteria for the wetland and waterbody conservation prerequisite, the LEED future model restricts any new development from occurring within 100 feet of a wetland and within 50 feet from the shoreline of a waterbody. Due to the resolution of this model (30 meter) some wetlands may not have been identified or properly represented. For this reason it is important that a proper wetland delineation take place before the development of new land takes place.

Agricultural Land Conservation

This prerequisite protects irreplaceable agricultural resources by preserving prime agricultural soils from future development (U.S. Green Building Council, 2009). To ensure the protection of prime soils the LEED future model restricts development from occurring on soils that are considered prime by the United States Department of

Agriculture. It is important to note that within the Great Salt Lake Watershed soils must be irrigated to be considered prime.

Floodplain Avoidance

Under the LEED for Neighborhood Development rating system development within floodplains is avoided to protect life and property, provide open space, and improve the quality of water and natural hydrology (U.S. Green Building Council, 2009). This criteria was met by excluding future development from all areas prone to flooding as determined by STATSGO soil data from the Natural Resources Conservation Service (NRCS).

Steep Slope Protection

The steep slope protection is used to minimize erosion of soil, reduce impacts to natural hydrology, and preserve habitat (U.S. Green Building Council, 2009). To satisfy this criterion, areas with a slope greater than 15% were excluded from the model.

Although there are a multitude of criteria in the LEED future model that cannot be represented spatially, they are important to the effectiveness of this model. The following are additional criteria that facilitate a reduction in the use of water resources.

Building Water Efficiency

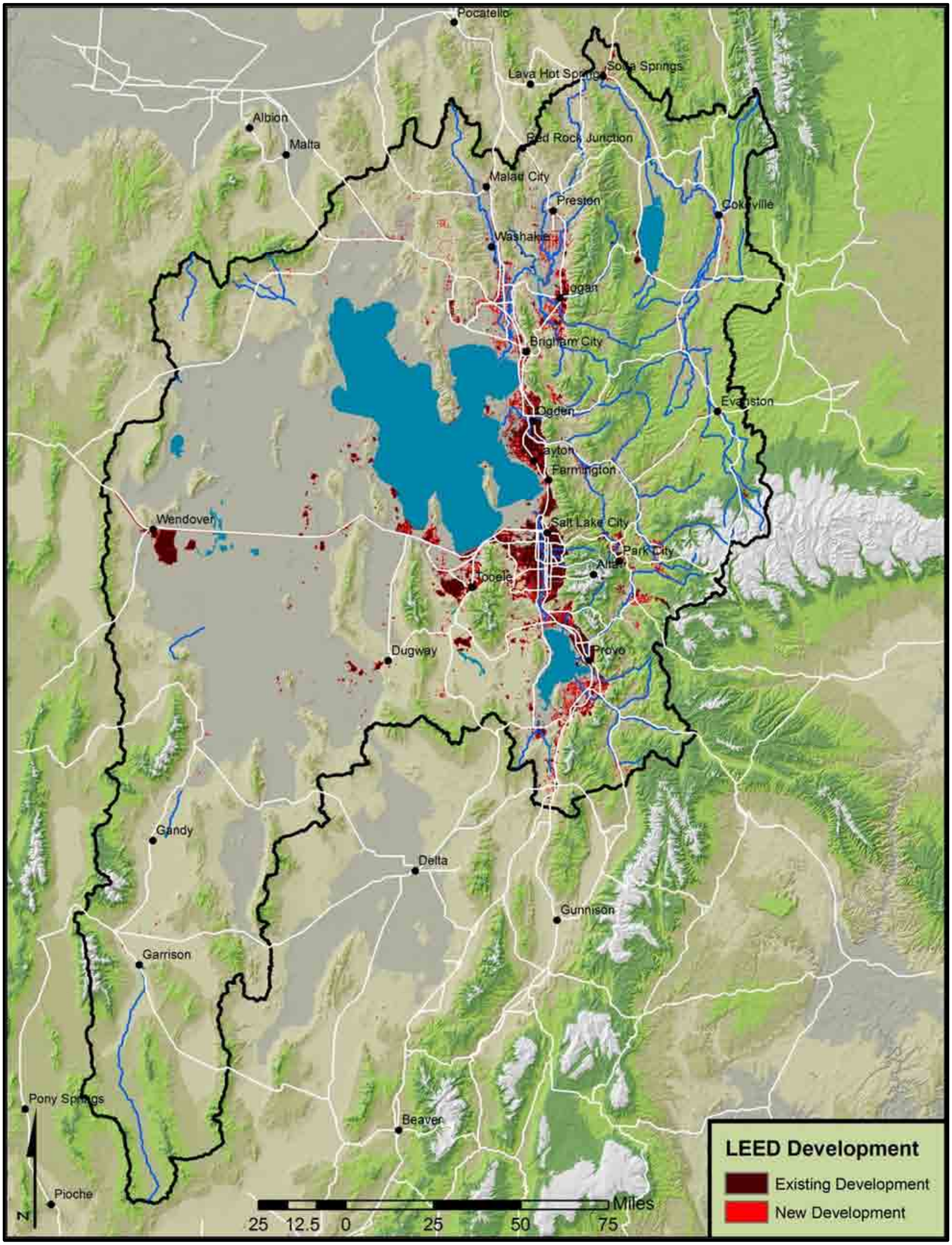
This requirement reduces the impacts of development on natural water resources and reduces the burdens placed on the community water supply (U.S. Green Building Council, 2009). To meet this objective all new development must reduce the use of water inside buildings to 40% less than in baseline buildings. For additional information regarding this requirement see appendix D.

Water Efficient Landscaping

This requirement eliminates the use of potable (or drinking water) and other naturally occurring surface or subsurface water for landscape irrigation (U.S. Green Building Council, 2009). Water efficient landscaping requires that the consumption of water be reduced by 50% from a mid-summer baseline. This can be determined by calculating the average amount of water used for landscape irrigation for the area where new development is to occur. These reductions may be attributed to any of the flowing strategies:

- Plant species, plant density, and microclimate
- Efficient irrigation
- Use of captured rainwater
- Use of recycled gray-water

According to the U.S. Green Building Council by implementing water efficiency principles discussed here and advocated by LEED, water use can be reduced by as much as 50%. In addition to water savings LEED for Neighborhood Development can also help reduce the dependency of carbon-based energy sources, which has the added benefit of reducing air pollution. For more information about some of the requirements for these benefits see appendix E.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Evaluation of Future Models

An integral step in the planning process is an evaluation of how alternative futures perform on the landscape and what their impacts might be on the key issues identified in this study. This step helps policy makers and planners gain a better understanding of the possible outcomes of future actions prior to the implementation of these actions.

Using ArcGIS the alternative future models were placed over the assessment models to identify where overlap occurred. This process determined where the alternative future models were in conflict with the assessment models and identified the total area in acres of these conflicts. These areas of conflict were then compared to the futures within each assessment model and an average conflict size was produced for each assessment model.

Once all futures were compared, a designation of: favorable, somewhat favorable, or undesirable was given, which was based upon the severity of conflict.
A designation of undesirable was given to futures whose conflict with the assessment model was greater than the average impact. Somewhat favorable designations were given to futures whose conflict was less than average but within one standard deviation of the average impact for the assessment model. A designation of favorable was given to futures whose impact was greater than one standard deviation from the average impact for the assessment model. Figure 6.1 illustrates the results of this evaluation of future models.

The assessment models utilized in the evaluation of futures were discussed in previous sections of this report.

Provo River in the Uinta Mountains (Danny White)

Evaluation of Future Scenarios						
Evaluation Models	**Tiers**	**Plan Trend**	**Build Out**	**Focused Development (Plan Trend)**	**Focused Development (Build Out)**	**LEED**
Working Lands	NA	Somewhat Favorable	Unfavorable	Somewhat Favorable	Unfavorable	Favorable
Public Health, Welfare, and Safety	Tier 1	Unfavorable	Somewhat Favorable	Unfavorable	Somewhat Favorable	Favorable
	Tier 2	Unfavorable	Unfavorable	Somewhat Favorable	Unfavorable	Favorable
	Tier 3	Unfavorable	Unfavorable	Somewhat Favorable	Unfavorable	Favorable
Critical Habitat	Tier 1	Somewhat Favorable	Unfavorable	Somewhat Favorable	Unfavorable	Favorable
	Tier 2	Somewhat Favorable	Unfavorable	Somewhat Favorable	Unfavorable	Somewhat Favorable
	Tier 3	Somewhat Favorable	Unfavorable	Somewhat Favorable	Unfavorable	Somewhat Favorable
Integrated Resources	Tier 1	Unfavorable	Unfavorable	Unfavorable	Somewhat Favorable	Favorable
	Tier 2	Unfavorable	Unfavorable	Somewhat Favorable	Unfavorable	Favorable
	Tier 3	Somewhat Favorable	Unfavorable	Somewhat Favorable	Unfavorable	Favorable

Favorable — Somewhat Favorable — Unfavorable

Figure 6.1 Evaluation of Futures against assessment models

Plan Trend

The Plan Trend future was created to demonstrate how current land use practices and policies may affect the future growth and development of the Great Salt Lake Watershed. This provides a baseline by which the other future models can be judged. Through the evaluation process it was determined that plan trend would have an unfavorable impact on all three of the Public Health, Welfare, and Safety tiers, as well as the first two tiers of the Integrated Resources model. Both of these assessment models contain wetland, riparian, and floodplain mitigation zones as part of their criteria and since a great deal of current development exists near these areas, they will be impacted relatively heavily by Plan Trend.

If implemented, Plan Trend will have a somewhat favorable impact to both Working Lands and all three tiers of Critical Habitat. This is most likely due to the relatively small footprint Plan Trend imposes on the landscape by being restricted to areas within 400 feet of existing development and excluding areas with a slope greater than 15%. According to the data, Plan Trend will have a somewhat favorable impact to tier three of the Integrated Resources model. This is most likely due to the extremely large impact Build Out has on tier three of the Integrated Resources model, which raises the average, allowing Plan Trend to just barely receive this designation.

It is clear that Plan Trend will have significant impacts to water resources as indicated by its impact to the Integrated Resources assessment model. In tier one alone, Plan Trend will impact 1,637 acres of land identified as important to maintaining and enhancing the quality of water in the Great Salt Lake Watershed.

Plan trend also retains the same water use practices as seen today. The Utah Department of Water Resources predicts that unless additional water is developed or there is a significant increase in water conservation, the watershed will have a shortfall of 800,000 acre-feet per year deficit by the 2050 (Utah State, 2010).

Build Out

The Build Out future represents a more intense development model than Plan Trend and was designed to illustrate how a more aggressive growth pattern might affect the key issues of the watershed as described in this report. As expected Build Out has an unfavorable impact to the majority of the assessment models. The only model to receive a somewhat favorable impact was tier one of the Public Health, Welfare, and Safety model. The most likely reason for this designation is the restriction Build Out places on the development of soils that are less than well drained. By so doing, Build Out does avoid some wetlands and avoids some of the development within seismic zone one.

Build out has a much higher impact to Working Lands and Critical Habitat than Plan Trend. Under this development scenario 22,000 acres of Working Land will be impacted and 6,836 acres of tier one Critical Habitat will be lost. With fewer homes per developed acre and no new conservation efforts, Build Out will require much more water than Plan Trend just for landscape irrigation. It is clear that the aggressive growth offered by Build Out will not result in a sustainable use of resources and will result in a significant loss to habitat to threatened and endangered species.

Focused Development

The Focused Development future models were created to reflect a more compact growth alternative to Plan Trend and Build Out. The evaluation results of Focused Development were somewhat surprising, with Focused Development (Plan Trend) creating greater impacts to the first tiers of Public Health, Welfare, and Safety and Integrated Resources. The cause of this impact is most likely due to the restriction Build Out provides against developing on poorly drained soils, allowing it to avoid wetlands impacted by Plan Trend.

Focused Development (Build Out) had a significantly higher impact on Working Lands and Critical Habitat, with Working Lands losing 13,878 acres and tier one of Critical Habitat losing 6,710 acres. One benefit provided by this model is a decreased need for landscape irrigation by reducing urban sprawl and creating higher density housing. However, even with the added benefits these models provide, Focused Development (Build Out) will still result in a significant impact to many of the key issues identified in this report. Of the Focused Development models Focused Development (Plan Trend) comes closest to providing a suitable outcome.

LEED

The LEED future model was developed to illustrate how implementing a few principles of smart growth can protect the vital resources of the watershed, while maintaining the health, welfare, and safety of its human inhabitants. The LEED future received a favorable designation for all assessments with the exception of Critical Habitat tiers two and three. This resulted from providing protection only for federally threatened and endangered species and not for those species of state concern. Some of the habitat for species of state concern is located adjacent to existing development, so even extending new development a few feet could potentially impact these species. However, the LEED future has a lower impact to these areas than all other future scenarios; for tier one of Critical Habitat, LEED impacts 3,518 acres and only 6,572 acres for tier two. The future with the next lowest impact to tiers two and three of Critical Habitat is Focused Development (Plan Trend) with only 3,869 acres and 7,229 acres respectively.

The LEED future had the lowest amount of impact to the assessment models out of all the futures tested in this study. Through this analysis it is clear that adopting the principles of LEED for Neighborhood Development as discussed in this report, can significantly reduce the impact future development will have on the water quality and quantity of the watershed. It will also result in the protection of human health, welfare, and safety, while preserving critical habitat for wildlife and the limited resources of prime agricultural land.

Wetland Protection
Although the LEED model was the only future developed with the protection of wetlands as a primary criterion, the other futures discussed in this report could easily be adjusted to provide that same protection. Figure 6.2 illustrates how excluding development from occurring in wetlands changes the results from figure 6.1.

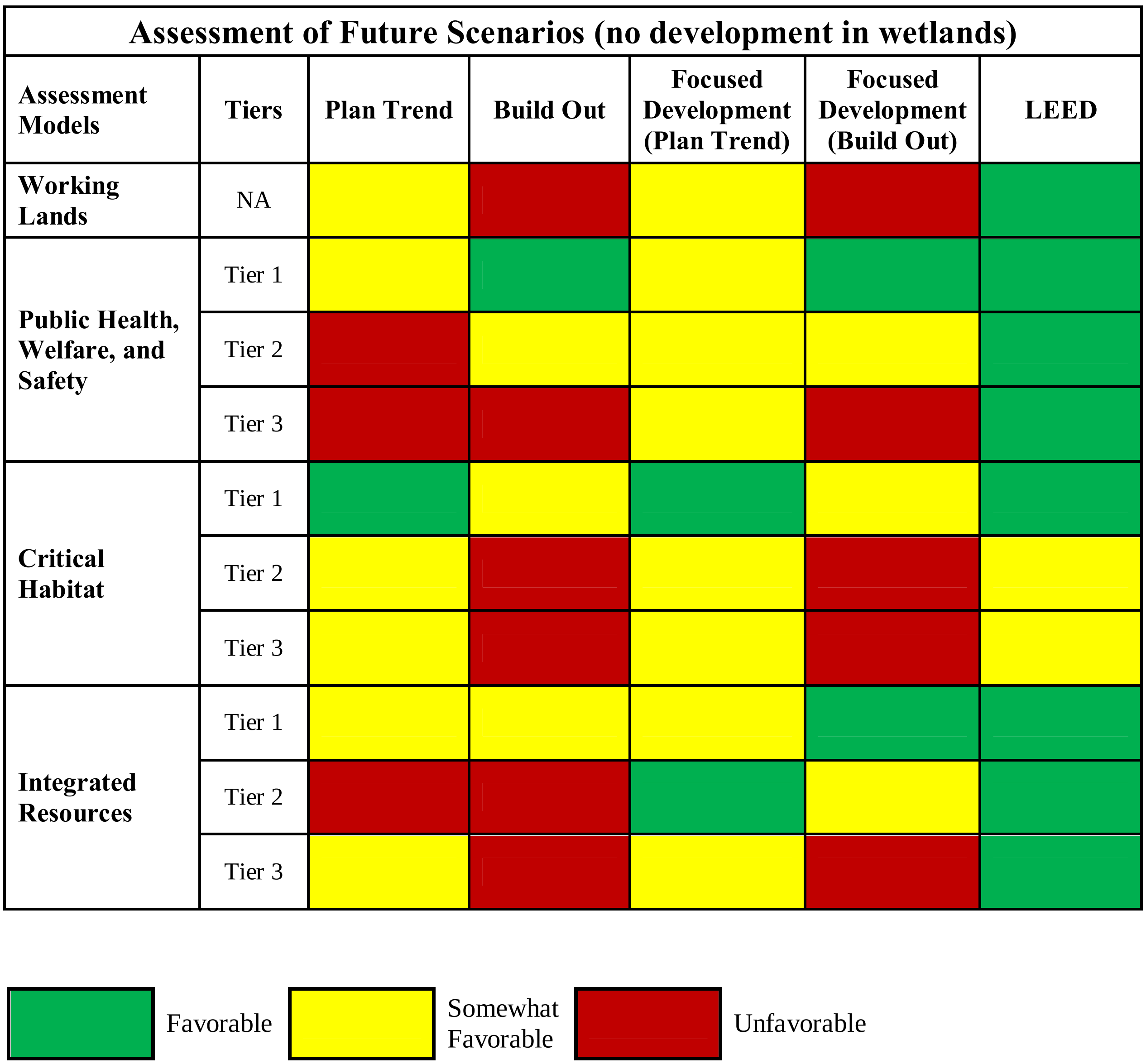

Figure 6.2 Evaluation of Futures against assessment models

Effects of Alternative Futures on Great Salt Lake Wetlands

Current land use practices in the Great Salt Lake Watershed have little regard for the protection of wetlands. Often, wetlands are drained or filled with soil to provide land for expanding development. Usually the removal of wetlands is mitigated by creating new wetlands; however, constructed wetlands are often incapable of fully replicating the functions performed by the wetlands they replace (Hunt, 1996; Sutula & Stein, 2003).

Many of the future scenarios examined in this report will result in a significant loss of wetlands bordering the Great Salt Lake, as well as throughout the watershed. Using the same overlay process discussed earlier, each alternative future was evaluated against the wetlands of the watershed. Figure 6.3 below describes the impact incurred on wetlands by each future scenario.

Although Build Out will result in a greater area of wetland loss throughout the watershed, it actually has less of an impact than Plan Trend on the wetlands of the Great Salt Lake. This result is due to the restrictions Build Out places on developing on poorly drained soil. The same holds true for the relationship between Focused Development (Build Out) and Focused Development (Plan Trend).

All of the alternative futures discussed in this report will require some increase in water usage, although the LEED future will require up to 50% less water than Plan Trend. As discussed previously in this report water is the most important factor in the establishment and maintenance of wetlands and wetland processes (William J. Mitsch, 2007). A long-term reduction of water to the wetlands of the Great Salt Lake will result in a shift in the elevational range of wetland species found along the lakeôs

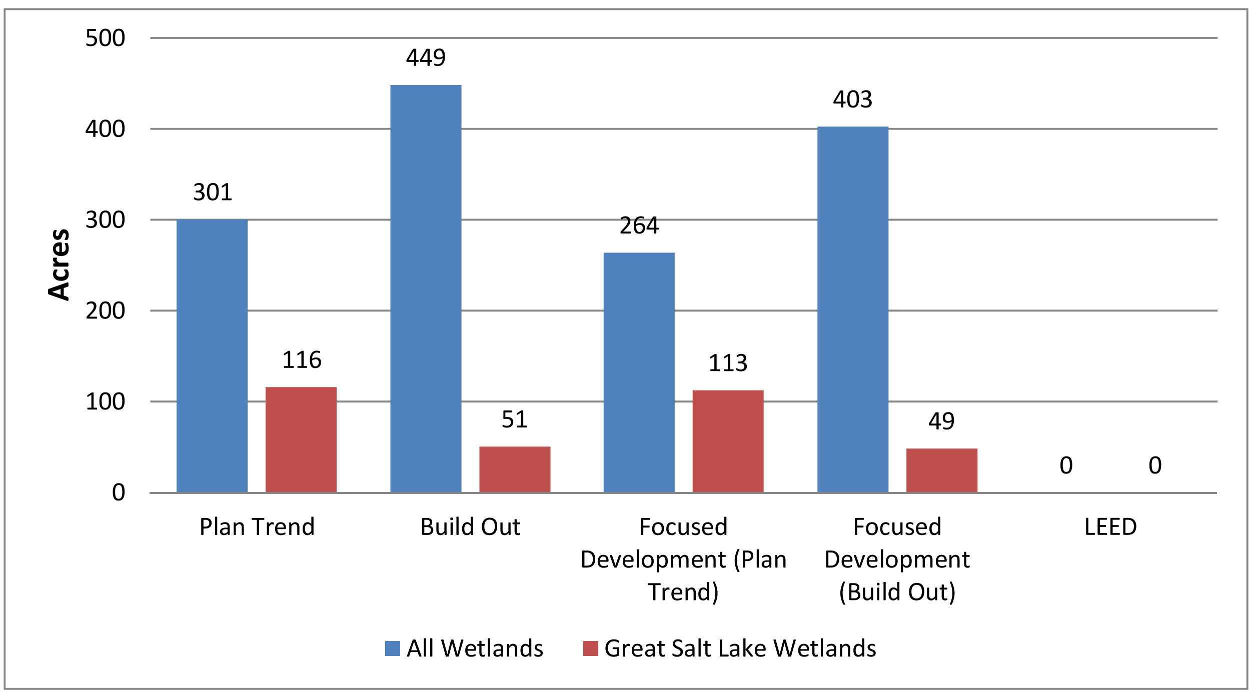

Figure 6.3 Impacts of alternative futures on wetlands

edge (Odland & del Moral, 2002). This period of transition will be critical in the success of these wetlands, for a disturbance of this proportion will likely invite invasive species such as *Phragmites*. A determining factor of how the lake level changes will impact the bordering wetlands will depend on the magnitude of lake level drawdown and the existing seed banks of wetland species.

Compounding the issue of decreased water from development is the possibility of increased salinity in the managed wetlands of the Great Salt Lake. As discussed previously in this report (page 47) by reducing the freshwater flow of the Bear, Weber, and Jordan Rivers, there will be a significant decrease in wetland species (Kadlec & Adair, 1994).

The predicted change in climate for the Great Salt Lake Watershed will magnify the effects of increased water development on Great Salt Lake wetlands. By the year 2060 it is expected that the annual water balance will decrease by 30% as a consequence of increased evapotranspiration (Utah Division of Water Resources, 2007). This will require more water to maintain the same lifestyle the inhabitants of the region now enjoy. Furthermore, it is estimated that a warming climate will result in an increase in winter precipitation falling in the form of rain. This will lead to a reduction in the winter snowpack allowing water to flow to the Great Salt Lake too early for it to be utilized by the wetlands. Much of this water will also be unusable to farmers for irrigation since it will likely exceed the capacity of the current infrastructure of reservoirs to contain it.

If the policies that shape the growth and development of the Great Salt Lake Watershed are not changed, the result will be a loss of wetlands throughout the region. The wetlands of the Great Salt Lake will be especially hard hit due to their location at the bottom of the basin, which means that any impact to water upstream from the lake will impact its wetlands. This report has identified many of the likely problems these wetlands will face due to development; however, further research will be necessary to determine exactly how much the Great Salt Lake will recede and how this recession will affect the function and structure of its bordering wetlands. This will be discussed in the Conclusion of this report.

Conclusions

The Great Salt Lake Watershed is composed of a diverse landscape that has attracted settlers for hundreds of years. This same landscape also provides essential habitat for a wide range of wildlife species. In the arid west, water has always been a limited resource; given the propensity of population growth and the likely outcome of climate change, this resource will become even more limited in the future. Without proper management, the ability of the region to sustain itself will deteriorate.

While there are a great variety of habitats contained within the Great Salt Lake Watershed, wetlands are perhaps the most important. Wetlands provide critical habitat for a number of threatened and endangered species and perform vital functions for the human inhabitants of the watershed as well. By protecting wetlands, planners not only protect wildlife, but also enhance the health, welfare, and safety of the people that call this region home.

It is unrealistic to expect that we can continue to increase the human population and the development that follows in the watershed without incurring some impacts to wetlands. Any type of development, no matter how little water it uses, will degrade the natural hydrology in some way. However, there are some forms of development that can significantly reduce these impacts. In order to protect the wetlands of the region and those that border the Great Salt Lake, planners must eliminate the intrusion of development onto wetlands. Furthermore, a more sustainable water use strategy must be implemented throughout the watershed. Without an adequate supply of water, the wetlands and the inhabitants of the Great Salt Lake Watershed will suffer significantly.

Recommendations

Utah has already adopted a water conservation strategy by which they plan to reduce water consumption by 25% by the year 2020 (Utah Division of Water Resources, 2001). In order to meet the future demands of population growth and climate change, a greater reduction in water use is needed.

To significantly reduce the amount of water used for municipal and industrial supply a major change in planning policy will be required. The LEED alternative future presented in this study would significantly reduce the amount of water used in the urban environment. According to the U.S. Green Building Council implementing the water saving initiatives promoted by LEED can reduce water demand by up to 50%. In addition to water savings, this report has shown that by utilizing the development principles of LEED, planners can significantly reduce the impact of development on the components of the watershed critical to the success of humans and wildlife. The following process can be used by planners as steps to adjust both existing and new development to take advantage of these benefits.

1. All new development adopts the principles of LEED discussed in the alternative futures section of this

report and as found in appendices D and E.

2. Begin applying step one to previously developed land within the watershed.
3. Restore the components identified in the Integrated Resources model that were impacted by previous development to enhance the quality of water in the region. This step should occur concurrently with steps one and two.

As evapotranspiration rates increase it may become necessary to implement greater conservation of water. Throughout the watershed a disproportionately large amount of water is used for irrigation of crops. This could be significantly reduced if recycled water were used for irrigation purposes. Much of the irrigated agricultural land in the watershed is located near developed areas. Technology currently exists that would allow gray water to be recycled and used for irrigation. By implementing this technology along with low water use vegetation, a large amount of water can be saved for municipal and industrial uses.

The transfer of water between basins is a common practice in the U.S. and the Great Salt Lake Watershed is no exception. This practice can have detrimental effects on the sub-basins losing water. It is recommended that the sub-basins within the Great Salt Lake Watershed adopt the policy of no transfer of water between basins. The habitat within each sub-basin is uniquely adapted to the hydrologic characteristics found within that basin. Removing large volumes of water from these basins and transferring them elsewhere, will result in changes to habitat.

This report has identified many of the potential impacts future development is likely to have on the wetlands of the Great Salt Lake Watershed. However, due to the lack of available data it is difficult to provide an accurate prediction of what the wetlands of the Great Salt Lake will look like once additional water is developed. There is a great need for future research to determine the consequences of water withdrawals on the Great Salt Lake wetlands.

Suggested Future Research

- An analysis of existing seed banks along the Great Salt Lake shoreline must be performed to accurately predict what the future species composition of wetlands will be post water development.
- Existing data on the bathymetry of the Great Salt Lake excludes the Bear River Bay, which contains some of the most important wetlands in the watershed, the Bear River Migratory Bird Refuge. Accurate bathymetry of Bear River Bay is needed to predict what reduced inflow will do the Great Salt Lake shoreline.
- Identify and map the location of potentially threatening invasive weeds that will thrive after water development and climate change.
- Mitigation plan for preserving wetland habitat along the Great Salt Lake.

- Perform an economic impact analysis to determine what affect a loss of Great Salt Lake wetlands will have on the region.

Beneficial Data Available in the Near Future

- Great Salt Lake Management Plan which should be available later this year www.gslplanning.utah.gov.

Useful Existing Data for Future Research

- Great Salt Lake Volume Calculations
  - Calculation of Area and Volume for the South Part of Great Salt Lake, Utah, excludes Bear River Bay (Baskin & L, 2005)
  - Calculation of Area and Volume for the North Part of Great Salt Lake, Utah (Baskin R. L., 2006)

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Ecoregions of the Great Salt Lake Watershed

The Central Basin and Range
The Central Basin and Range ecoregion is made up of north-south oriented fault-block ranges and, intermittent drier basins. Valleys, mountain slopes, and alluvial fans are composed of grass, shrub, or barren. Within higher elevation mountain slopes, mountain brush, woodlands, and open forests can be found. ñThe potential natural vegetation is, in order of increasing elevation and ruggedness, saltbush-greasewood, Great Basin sagebrush, juniper-pinyon woodland, and scattered western spruce-fir forest. In addition, tule marshes occur locally, especially along the Great Salt Lake shorelineò (Woods, et al., 2001).

Drainage within the Central Basin and Range is performed by ephemeral streams. More than 14,500 years ago, most of this ecoregion below 5,200 feet in elevation was inundated by the Pleistocene Lake Bonneville (Baskin, Waddell, Thiros, & Giddings, 2002).

Livestock grazing is the primary land use in this ecoregion and occurs at a much higher percentage than in The Mojave Basin and Range. Irrigated crops can also be found, especially near water sources from the mountains. Multiple military bases are found within this ecoregion and are of special environmental concern as a result of their size and management practices (Toth, Edwards, & Lilieholm, 2004).

The Salt Deserts ecoregion is drained internally, and is almost completely level, barren, arid and nonarable (Toth, Edwards, & Lilieholm, 2004). This ecoregion is composed of playas, mud flats, salt flats and highly saline lakes. Levels of salinity and water fluctuate throughout the season and from year to year. Many of these saline lakes, including the Great Salt Lake are too salty for most aquatic life to survive. Soils within this region are poorly drained and composed mostly of clay. Vegetation, where present, is sparse and composed of salt-tolerant plants such as salicornia and saltgrass (Woods, et al., 2001).

The Salt Deserts are primarily used for military facilities, transportation, recreation, and a number of industries that include the production of salt.

The Shadscale-Dominated Saline Basins ecoregion is dry, nearly flat, and drained internally. ñVegetation is salt and drought-tolerant. It is dominated by shadscale, winterfat, and greasewood and is distinct from the Wyoming big sagebrush of the less saline Sagebrush Basins and Slopes ecoregion and the mostly barren Salt Desertsò (Woods, et al., 2001).

The Shadscale-Dominated Saline Basins ecoregion is dominated by rangeland, however there are scattered livestock and poultry farms found at a local level. The use of irrigation is not a common farming practice in this ecoregion.

The **Sagebrush Basins and Slopes** is a semiarid ecoregion, with potential natural vegetation of Great Basin sagebrush (Woods, et al., 2001). This region is dominated by Wyoming big sagebrush although perennial bunchgrasses start to become common to the north where moisture is more abundant.

The primary land use in this region is grazing; however feedlots, dairies, and irrigated crops are common at a local level.

The rocky **Woodland- and Shrub-Covered Low Mountains** ecoregion is dominated by woodlands at lower elevations, and by mountain brush at higher elevations (Woods, et al., 2001).Juniper (*Juniperus osteosperma*) is frequently found at lower elevations,while piñon (*Pinus edulis*) is found at higher elevations, there are also many locations where the two are intermixed (Toth, Edwards, & Lilieholm, 2004).

Livestock grazing is a common land use and trees in this region have been cleared to facilitate the growth of forage. Both Bitterbrush and Western serviceberry are essential forage for mule deer in this area.

The disjunct **High Elevation Carbonate Mountains** ecoregion ñis higher, wetter, and more rugged than nearby ecoregions and is largely underlain by limestone, dolomite, or quartziteò (Woods, et al., 2001). There are a minimal number of streams that originate in the mountains of this region and supply water to the dryer surrounding ecoregions.

Dominate vegetation includes subalpine fir, Engelmann spruce, bristlecone pine, limber pine, Douglas-fir, mountain big sagebrush, and aspen (Woods, et al., 2001). These forest stands occur most frequently on higher elevation north facing slopes. Floristic diversity in this region is driven by carbonates, which extends the tree line, decreases the density of vegetation, and impacts both the quality and quantity of water (Woods, et al., 2001).

The **Moist Wasatch Front Footslopes** ecoregion supports the majority of the state of Utahõs population as well as its commercial activity. Perennial streams from the adjacent Wasatch Mountains provide water to this population. Outside the urban environment irrigated crops support the growth of alfalfa, vegetables, small grains, and orchards. Land use practices, including irrigation diversions, has affected the quality and quantity of stream flow.

The **Wetlands** ecoregion is composed of a variety of rushes, reed grasses, and open water. This region is critical wildlife habitat for millions of migratory birds and contains a multitude of state and federal wildlife refuges. Water levels within these wetlands are often managed, however marshes can be temporarily inundated by rising Great Salt Lake water, or impacted by seasonal drought. Potential vegetation consists of tule marshes (Woods, et al., 2001), however for agricultural purposes, most of these marshes have been diked and drained (Toth, Edwards, & Lilieholm, 2004). As a result of the dikes, the system is now static, making it susceptible to flooding, causing damage to the vegetation. ñIn past times this was not a problem because adjacent areas could absorb some of the floodwater as well as provide marsh habitat for wildlife dependent on marsh ecosystemsò (Toth, Edwards, & Lilieholm, 2004).

> *"With increasing municipal water needs, fresh water that reaches the lake is likely to decrease, which will result in an increase in the salinity of the lake. Also, with increased municipal areas being built, the amount of polluted runoff reaching the lake will increase. The trigger point is not known, but at some increased level of salinity, brine shrimp will not survive. The consequences of such a loss could be enormous. First of all, the brine shrimp and their eggs comprise the majority of the diet for the birds which flock to the region annually. Lack of food, combined with decreased habitat, might cause the displaced birds to seek new habitat already occupied by other birds. Or, as has happened in the past, they might try to inhabit lower quality habitats like local golf courses or parks, creating a nuisance for area residents and*

> *ultimately not sustaining the birds' dietary needs. In short, numbers of shorebirds will be drastically reduced. Another consequence of loss of brine shrimp could be a drastic increase in algae, their food supply. Without the shrimp to control algae levels, huge amounts will wash up on the shores of the Great Salt Lake and start to decay, resulting in odor and water quality problems that could affect the quality of life of area residents"* (Toth, Edwards, & Lilieholm, 2004).

The **Malad and Cache Valleys** ecoregion is composed of narrow floodplains, wide terraces, and alluvial fans. Perennial streams and canals provide mountain water to crops and municipalities. Potential vegetation along the Bear River Range resembles that of the Upper Sagebrush-Grass ecoregion, with occasional mountain mahogany woodlands. Across the valley the Wellsville Mountains are dominated by big-tooth maple, interspersed with quaking aspen and limber pine at higher elevations and on north facing slopes.

This region has a shorter growing season but is extensively farmed as a result of the increased availability of water from regions to the south.

> *"According to Utah State University Professor Mike Wolfe, deer populations have been on the downward slide since the mid 1960's. He also attributes the decreasing population to habitat loss. There has been a quantitative loss of winter range, as well as a qualitative loss as shrub lands, which serve as deer browse, have been converted to grasses. This conversion to grassland has been in some cases deliberate, in order to increase cattle grazing land. Such conversion has resulted in an increase in elk population as they graze on the same types of grasses as cattle. Along with decreased deer populations, hunter participation in Utah is down. There are currently half as many hunters as in the 1960's. Wolfe attributes this to the rapidly urbanizing population in northern Utah. As people move off the land, they lose interest in hunting recreation. The Division of Wildlife Resources (DWR) earns most of its money for habitat conservation through the sale of hunting licenses and, as fewer and fewer people buy these licenses, the DWR will need to devise new ways to fund its efforts*ò (Toth, Edwards, & Lilieholm, 2004).

The semi-arid uplands and basins of the **Carbonate Sagebrush Valleys** encompass the carbonate ranges along eastern Nevada. This ecoregion is almost completely underlain by dolomite and limestone. The dominance and elevation distribution of the vegetation in the region is effected primarily by the combination of precipitation and the dolomite/limestone underlayment (Bryce, et al., 2003). Dominant vegetation includes sagebrush and winterfat and is relatively sparse when compared to other neighboring sagebrush ecoregions (Bryce, et al., 2003).

Pinyon-juniper woodland canopies within the **Carbonate Woodland Zone** overtop the mountain brush and sagebrush communities that lie below. The pinyon-juniper woodlands tend to have a larger elevatoional range within the carbonate areas of Nevada than any other region; in some cases extending to the floors of higher basins, due to higher amounts of precipitation in the summer months (Bryce, et al., 2003).

Pinyon-juniper woodlands in this ecoregion were historically used for timber in the mining industry. As a result of fire suppression, these woodlands made a comeback early in the last century and has increased in density and its range has expanded into lower sagebrush zones (Bryce, et al., 2003). In recent times large portions of these woodlands have been cleared to increase forage for cattle grazing.

Middle Rockies

Southeast of Yellowstone National Park lies the **Sedimentary Subalpine Zone** located in the overthrust belt, where the underlain material has been faulted and folded. The elevation ranges from 8,500 to 10,000 feet. The region receives relatively high amounts of precipitation which allows it to support spruce-fir forests. Potential vegetation includes Engelmann spruce, subalpine fir, and lodgepole pine (Chapman, Bryce, Omernik, Despain, ZumBerge, & Conrad, 2004). However the forests of this ecoregion are confined to fine-grained soils derived from shale, resulting in a landscape that alternates from forests to grassy slopes (Chapman, Bryce, Omernik, Despain, ZumBerge, & Conrad, 2004).

Northern Basin and Range

The **Partly Forested Mountains** of the Northern Basin and Range vary in elevation from 6,000 to over 9,000 feet. Typical vegetation includes lodgepole pine, Douglas fir, and aspen along the north-facing slopes, with mountain brush and mountain big sagebrush dominate the warmer dryer, south-facing slopes. This ecoregion is utilized as summer range as well as timber production (McGrath, et al., 2002).

The **Dissected High Lava Plateau** ecoregion is composed of rolling plains, alluvial fans and shear-walled canyons. Common vegetative communities include scattered woodlands and grasslands (McGrath, et al., 2002). The primary land use is grazing with agricultural land found only intermittently. Native fish can be found in a few isolated canyons where water quality is high.

The **Semiarid Hills and Low Mountains** ecoregion can be found in the low elevation range between the Sagebrush Steppe Valleys and the Dissected High Lava Plateau ecoregions. Natural vegetation consists primarily of sagebrush steppe communities. Forest components, although much less common, consist of juniper woodland and are found primarily on rock outcrops (McGrath, et al., 2002). The primary land use is grazing.

The High Elevation Forests and Shrublands ecoregion is located in the higher elevational band above the Semiarid Hills and Low Mountains ecoregion. Typical vegetative communities include a mixture of sagebrush grassland, mountain brush, and conifers (McGrath, et al., 2002). Found along north-facing slopes are lodgepole pine, Douglas fir, and aspen. Winters in this ecoregion are cold and average annual precipitation is much greater than ecoregions found at lower elevations.

The **Saltbush-Dominated Valleys** ecoregion is dominated by greasewood and shadscale and consists of a gently sloping, arid landscape (McGrath, et al., 2002). The dominant land use is grazing, with some irrigated cropland (McGrath, et al., 2002).

The Sagebrush Steppe Valleys ecoregion is surrounded by the hills and mountains of the Semiarid Hills and Low Mountains and the High Elevation and Shrubland ecoregions. The dominant vegetative community is sagebrush grasslands (McGrath, et al., 2002). The primary land use is grazing with some non-irrigated cropland, much of this ecoregion is not suitable for cropland as a result of low water availability (McGrath, et al., 2002).

The Wyoming Basin
The Wyoming Basin ecoregion is an expansive intermontane basin composed of mesas, rolling plains, high hills, and low mountains; grass and shrublands dominate the region. This ecoregion does not contain the large forests of the Wasatch and Uinta Mountains.

Livestock grazing is a common land use, however, many areas in the region lack adequate forage to support grazing for extended periods. Another common activity is the extraction of natural gas and oil.

The **Rolling Sagebrush Steppe** is made up of ridges, hills, rolling plains, mesas, and outwash fans. Dominant vegetation includes big sagebrush and bluebunch wheatgrass, and dissimilar to the vegetation of neighboring ecoregions.

Rangeland is the primary land use in the ecoregion. Introduction of annual grasses is common due to repeated fires and grazing pressure.

The **Wet Valleys** ecoregion ñconsists of very poorly-drained, nearly flat floodplains, low terraces, and alluvial fans along the Bear Riverò (Woods, et al., 2001). frigid winters, with cold soils, and short growing seasons typify this region. Wetlands are frequent and consist of sedges, rushes, cattails, and marsh grasses.

The **Semiarid Bear Hills** ecoregion consists of dry terrain resulting from the presence of the rain shadow from high mountains located to the west. Terrain is hilly and is unique to the surrounding ecoregions. ñBunchgrasses and big sagebrush are common and contrast with the forests of neighboring, mountainous ecoregionsò (Woods, et al., 2001).

Rangeland is the primary land use in this ecoregion.

Wasatch and Uinta Mountains
The Wasatch and Uinta Mountains ecoregion is derived from tall glaciated mountains, foothills, plateaus, and interspersed valleys. This region includes the uniquely east-west oriented Uinta Mountains, the Wasatch Mountains, and the Wasatch Plateau. ñAgricultural valleys occur especially in the eastern part of the Wasatch Rangeò (Toth, Edwards, & Lilieholm, 2004). The Wasatch Front is wetter, steeper, and more rugged than other parts of the Wasatch Mountain Range. Alpine meadows, talus slopes, and rocklands occur above an elevation of around 11,000 feet, and are especially prevalent in the Uinta Mountains. At an elevation range between 8,000 to 11,000 feet, Douglas fir forests, aspen parklands, and subalpine forests are most prevalent, with limber and ponderosa pine occurring on high volcanic plateaus (Woods, et al., 2001). Between the elevation range of 5,000 to 8,000 feet, mahogany-oak scrub and juniper-pinyon woodland communities occur, with mahogany-oak scrub more common in the north extent than in the south.

Dominant land uses include summer grazing, recreation, homes, and logging.

The **Alpine Zone** is found above the timberline which is around 11,000 feet and is especially common in the high Uinta Mountains. This landscape is dominated by features formed by glacial processes. ñMeadows and rockland are common and contrast with the dense forests of neighboring, lower ecoregionsò (Woods, et al., 2001). However, in the Uintaôs, the landscape is dominated by gently undulating terrain which provides an environment that is more similar to those found in the arctic. ñHayward (1945) lists 127 of the common plants found in this zone. Of these, 33 percent are also found in the Arctic regionsò (Toth, Edwards, & Lilieholm, 2004). The conditions in this region can be just as severe as in the arctic. At these high elevations incoming solar radiation has less of the atmosphere to pass through, so temperatures at the surface can easily reach 90° F and then as a cloud passes overhead, drop to near freezing temperatures in a matter of minutes. Strong winds also shape the vegetation, which can be seen in the krummholz growth form of trees found near the tree line, herbaceous species often exhibit short flowering stalks (Toth, Edwards, & Lilieholm, 2004).

The Alpine ecoregion receives a greater abundance of precipitation resulting from its altitude than other ecoregions within the Wasatch and Uinta Mountains. A major source of spring and summer runoff for lower ecoregions is the deep snowpack that accumulates in the Alpine Zone. The Alpine Zone is primarily used for recreation and seasonal recreation.

Uinta Subalpine Forests ecoregion is composed of a multitude of lakes, glaciated basins, deep canyons, and high mountains. This ecoregion is higher, with elevations from 10,000 to 11,000 feet, more moisture, and less rugged terrain than the Mid-elevation Uinta Mountains ecoregion, but not does not receive as much precipitation as the Alpine Zone. Its soils ñsupport Engelmann spruce, lodgepole pine, and subalpine fir. Such subalpine forests are far more extensive in the Uinta Mountains than in the less massive Wasatch Rangeò (Woods, et al., 2001).

Land use activities include recreation, logging, and seasonal grazing. Snow melt from this region provides water to the more arid, lower ecoregions.

The **Mid-elevation Uinta Mountains** ecoregion is forested and highly glaciated. Elevations range from 8,000 to 10,000 feet, where ponderosa pine douglas fir, aspen parkland, and lodgpole pine (found in the northern extent).

Of particular interest is the loss of aspen stands, for according to Utah State professor Ron Ryel:

> *"the prevention of coniferous trees moving into aspen habitat through succession is of particular interest to municipalities within the same watershed. Aspen stands have a much higher water storage capacity when compared with conifer stands. Aspen defoliates in the autumn. The bare canopies of winter aspen stands allow snow to fall to the forest floor. In conifer stands, snow gets caught on the needles and branches. A significant amount of this precipitation is lost directly to the atmosphere through evaporation and sublimation. This, combined with transpiration, results in a much lower amount of water that actually reaches the forest floor and enters the watershed"* (Toth, Edwards, & Lilieholm, 2004).

The Mid-elevation Uinta Mountains terrain is much more rugged than the Uinta Subalpine Forests, and its deep canyons provide numerous good quality, ephemeral streams that receive meltwater from the Uinta Mountains. This ecoregion also provides water to the more arid, lower ecoregions.
The partially glaciated **Wasatch Montane Zone** is composed of "forested mountains and plateaus underlain by sedimentary and

metamorphic rocksò (Woods, et al., 2001). Common in this region are aspen parkland and Douglas-fir, while on the steep north facing slopes grow subalpine fir and Engelmann spruce. Snow melt from this region provides water to the more arid, lower ecoregions.

The **Semiarid Foothills** ecoregion is located between the elevation range of 5,000 to 8,000 feet. ñWidely spaced juniper and pinyon typically occur in a matrix of sagebrush, grama grass, mountain mahogany, and Gambel oak. Maple-oak scrub is common in the north but, southward, it is gradually replaced by pinyon-juniper woodland at lower elevations and ponderosa pine at upper elevationsò (Woods, et al., 2001)

Grazing is a common occurrence in this region, with some trees being cleared to provide more land for forage.

The unforested **Mountain Valleys** ecoregion is composed of hills, terraces, alluvial fans, and flood plains. This region is highly impacted by a cold climate and has a relatively short growing season. Natural vegetation consists primarily of Great Basin sagebrush.

Primary land use includes irrigated pastures and crops, as well as rangeland. At a local level dairies, feedlots, and turkey farms are common.

Ecoregions	Existing Development (acres)	Potential for New Development (acres)	After New Development (acres)
Moist Wasatch Front Footslopes	9,249	4,348	13,596
Malad and Cache Valleys	1,786	7,422	9,208
Semiarid Foothills	1,005	6,964	7,969
Semiarid Hills and Low Mountains	261	4,783	5,045
High Elevation Forests and Shrublands	2,380	1,310	3,690
Wetlands	231	2,313	2,545
Wasatch Montane Zone	93	1,651	1,745
Partly Forested Mountains	180	267	447
Mountain Valleys	80	302	381
Mid-Elevation Uinta Mountains	5	157	161

Wildlife

The great diversity of species within the Great Salt Lake Watershed is directly related to the variability of ecosystems. With high elevation forests to desert wetlands, the region is composed of a wide variety of landscapes and a great wealth of habitats for both aquatic and terrestrial species. Throughout the region, the maintenance of healthy and abundant wildlife has been a historic role of land management and continues to be very important today. Many of the wildlife species found in the watershed play an important role to the economics of the region, as well as provide an aesthetic quality that people associate with the area.

Habitat is the suitable environment for a particular species and typically consists of the appropriate topography, food, climate, water, and shelter (Benyus, 1989; Lindenmayer & Fischer, 2006). In order to provide details about the habitat of the Great Salt Lake Watershed *Utah's Comprehensive Wildlife Strategy* was utilized. Utah classifies habitat into 5 categories with 25 distinct subcategories, 19 of which will be used in the description of the watershed.

Shrubland

Shrubsteppe is a vast habitat that occurs within an elevation range between 2,500 to 11,500 feet and has the highest frequency of occurrence than any other habitat in Utah (Gorrell, et al., 2005). A wide variety of vegetation is found in this community and includes several species of sagebrush, rabbit brush, needle grass, bluebunch wheatgrass, cheatgrass, juniper, pinyon, and mountain mahogany (Gorrell, et al., 2005). This habitat forms a diverse ecological system that is vital winter habitat to a variety of animal species such as moose, elk, and mule deer. For the past couple of decades the health of this vital habitat has been on the decline and several causes have been identified. These include changes in the disturbance regime, improper grazing practices, improper use of all-terrain vehicles, urban development, and invasive plant species. Shrubsteppe habitat is important for a variety of species which include: Gunnison sage-grouse, greater sage-grouse, sharp-tailed grouse, sage sparrow, brewerôs sparrow, pygmy rabbit, Merriamôs shrew, mule deer, and Wyoming ground squirrel (Gorrell, et al., 2005).

The **Mountain Shrub** habitat is a deciduous zone that occurs between 3,300 to 9,800 feet in elevation and serves as a transition between lowlands and higher forested mountains (Gorrell, et al., 2005). This habitat is rare within the context of the watershed but serves an important ecological function to a variety of wildlife.

There are a variety of plants and berries that comprise this habitat. Some of the dominate species include mountain mahogany, cliff rose, bitter brush, serviceberry, chokecherry, snowberry, and bigtooth maple. Wildlife species in this habitat would include: mule deer, elk, shrews, black-throated gray warbler, rubber boa, Townsendôs big-eared Bat, Merriamôs shrew, American pika, gray wolf (extirpated), and brown bear (extirpated) (Gorrell, et al., 2005; Benyus, 1989; Bosworth, 2003). This habitat type is facing threat from energy development, alterations to disturbance regimes, improper grazing practices, and invasive vegetation.

High Desert Scrub consists of shrublands typically found between 2,200 to 10,300 feet in elevation. Dominate vegetation includes: greasewood, shadscale, atriplex, winterfat, Mormon tea, and rabbit brush.

Wildlife species that thrive in this habitat include: burrowing owl, dark kangaroo mouse, common chuckwalla, Great Plains toad, mountain plover, and bighorn sheep,

The **Low Desert Scrub** habitat is found at an elevation range between 2,200 to 6,000 feet. Primary vegetation can include: creosote, Mormon tea, shadscale, turpentine bush, honey mesquite, and brittlebrush (Gorrell, et al., 2005).

Despite the low amounts of precipitation a variety of wildlife species have adapted to this inhospitable habitat. Common species include: spotted bat, Mojave rattlesnake, sidewinder, common kingsnake, desert night lizard, western banded gecko, zebra-tailed lizard, lesser earless lizard, Bendireȏs thrasher, crissal thrasher, Gambelȏs quail, desert shrew, desert kangaroo rat along with several other reptilian and mammalian species (Gorrell, et al., 2005).

Northern Oak is dominated by Gambelȏs oak and occurs between 3,700 to 9,000 feet in elevation. Common wildlife include: fringed myotis and gray vireo (Gorrell, et al., 2005).

The **Desert Oak** habitat occurs at an elevation range of 2,700 to 7,000 feet and is dominated by wavyleaf oak. This habitat type is not a primary indicator for any wildlife species; however, it is a secondary habitat for the plateau striped tail (Gorrell, et al., 2005).

Grassland

Grasslands are similar to Wet Meadows with the exception of the lack of saturated soils. This habitat is dominated by mostly forbs and grasses and occurs between 2,200 to 9,000 feet in elevation (Gorrell, et al., 2005).

In order to thrive Grasslands need a specific combination of topography, precipitation, and temperature (Benyus, 1989). Grasslands also require a delicate balance between disturbance events and productivity. Naturally occurring vegetation in this habitat has adapted to fire regimes and improper management of these regimes is threatening this habitat. Wide varieties of wildlife thrive in these areas and include: short-eared owl, burrowing owl, long-billed curlew, sharp-tailed grouse, grasshopper sparrow, black-footed ferret, Merriamȏs shrew, Idaho pocket gopher, and spotted ground squirrel as well as a multitude of other animal species (Gorrell, et al., 2005; Hurst, 2009).

The **Alpine** habitat occurs at an elevation range that is above timberline and is between 6,500 to 11,500 feet. As a result of the high winds and cold temperatures experienced in this habitat, there are no tree species that can grow higher than a few feet. In fact this habitat more closely resembles those found in the arctic than any other found in the watershed. This region also experiences some of the highest amounts of precipitation in the watershed at over 40 inches annually. Dominant plant species include: alpine avens, tufted hair grass, sedges, moss campion, and willow (Gorrell, et al., 2005).

A variety of wildlife species can be found in the Alpine zone and include: black rosy-finch and American pika with species such as the dwarf shrew using this as secondary habitat (Gorrell, et al., 2005).

Forest

Sub-Alpine Conifer habitats occur between 6,000 to 11,200 feet in elevation and are dominated by conifers such as sub-alpine fir, blue spruce, and Engelmann spruce (Gorrell, et al., 2005).

Common wildlife may include: Canada lynx, boreal owl, Williamsonôs sapsucker, American marten, dwarf shrew, and wolverine (Gorrell, et al., 2005).

Mixed Conifer forests are dominated by Douglas and white fir and occur at an elevation range of 5,000 to 10,000 feet (Gorrell, et al., 2005). Additional tree species may include blue spruce, sub-alpine fir, and Engelmann spruce.

Potential wildlife in this habitat type may include: northern goshawk and brown bear (extirpated), secondary users would include: gray wolf (extirpated), banded-tailed pigeon, and rubber boa (Gorrell, et al., 2005).

The **Ponderosa Pine** habitat consists of coniferous forests that are dominated by Ponderosa pine and mountain shrubs with an elevation range between 5,200 to 8,700 feet (Gorrell, et al., 2005).

Although many species may use this habitat to migrate between their primary and secondary habitats; only the Mexican vole, banded-tailed pigeon, Abertôs squirrel, and many-lined skink use this as primary habitat (Gorrell, et al., 2005).

Lodgepole Pine forests range in elevation from 8,000 to 11,000 feet and are dominated by lodgepole pines (Gorrell, et al., 2005).

This habitat type is was not a significant indicator for primary habitat for any animal species however, it provides secondary habitat for the following species: American marten, three-toed woodpecker, and Canada lynx (Gorrell, et al., 2005).

The **Pinyon-Juniper** habitat is composed of coniferous forests that have a wide elevation range between 2,700 to 11,000 feet. Dominant vegetation in this habitat include: Rocky Mountain juniper, Utah juniper, and one-seed juniper or coniferous forests containing singleleaf pinyon or two-needle pinyon (Gorrell, et al., 2005).

A variety of wildlife species utilize this habitat and include: Ferruginous hawk, Townsendôs big-earded bat, plains spadefoot, black-throat gray warbler, gray vireo, Stephenôs woodrat, nightsnake, and western skink (Gorrell, et al., 2005).

Aspen habitat typically occurs at an elevation range between 5,600 to 10,500 feet. The dominant plant species occurring here is quaking aspen, and can include coniferous species such as blue spruce, Engelmann spruce, sub-alpine fir, Douglas fir, white fir, ponderosa pine and lodgepole pine (Gorrell, et al., 2005). With its combination of plant species and thick cover, this habitat supports a wide variety of wildlife who seek the cool temperatures found beneath this vegetative cover (Hurst, 2009).

Wildlife species that utilize this habitat include: northern goshawks, Williamsonôs sapsucker, western toad, woodpecker, vole, weasel, mule deer, moose, elk, and a variety of other bird species (Gorrell, et al., 2005; Hurst, 2009).

This habitat is beginning to decrease in growth and productivity due to a change in disturbance regimes and changes in climate are impacting their growth and productivity.

Riparian/ Wetland

As rivers and streams depart mountain slopes and reach the valleys their water begins to slow and form **Lowland Riparian habitat**. These riparian communities are typically found at an elevation of less than 5,500 feet and are composed of Fremont cottonwood, salt cedar, tamarisk, netleaf hackberry, velvet ash, desert willow, and other willow species (Gorrell, et al., 2005).

Riparian communities are transitional zones between terrestrial and aquatic habitat and are frequently areas of concentrated biodiversity at both regional and continental scales (Naiman, 2005). Wildlife species that utilize this habitat include: bald eagle, southwestern willow flycatcher, black swift, broad-tailed hummingbird, and western threadsnake (Gorrell, et al., 2005).

Mountain Riparian habitat refers to the rivers and streams that are above 5,500 feet and are composed of steep slopes and swift water. Vegetation in this habitat consists of primarily woody species such as willow, narrowleaf cottonwood, thinleaf alder, black hawthorn, water birch, rocky mountain maple, wild rose, and redosier dogwood (Gorrell, et al., 2005).

The steams that create this habitat are cold and consist of rocky bottoms; they are however, highly productive and biologically diverse areas (Benyus, 1989). Mountain riparian wildlife may include: rubber boa, smooth greensnake, northern river otter, black gloss, and Montane snaggletooth (Gorrell, et al., 2005).

Wet Meadow habitats can be found at an elevation range from 3,000 to 9,000 feet and are composed of grasses, sedges, forbs, and rushes. Dominant plant species include: sedges, reedgrass, haigrass, rushes, willowherb, cinquefoil, saxifrage, willow, water birch, and honeysuckle (Gorrell, et al., 2005)

Common wildlife to this habitat include smooth greensnake, gartersnake, bobolink, Columbia spotted frog, and several other amphibians and birds (Benyus, 1989) (Gorrell, et al., 2005). This habitat is highly sensitive to a variety of disturbances in the watershed which include human disturbance, improper grazing practices, and water development projects.

Wetland habitat is typically found at an elevation lower than 5,500 feet and consists of vegetation such as bulrush, cattail, and sedges.

Perhaps the richest habitat in terms of species diversity in the watershed is the wetlands of the Great Salt Lake. Within this small portion of the region hundreds of thousands of birds gather each year as they migrate to their summer and winter homes. In fact the wetlands of the Great Salt Lake are one of the most important migration stops in the western United Sates as it provides habitat for both the central and western flyways.

An account from Jim Bridger in the fall of 1824 describes the volume of wildlife that once relied on the Great Salt Lake wetlands; as he drifted toward the mouth of the Bear River ñEverywhere he looked ï in the sky, on the open water, over the marshy borders of the lake ï there were birdsò (Wilson & Carson, 1950). When he reported his experience it is said that on that day he saw millions of ducks and geese.

Although the population of birds may no longer be as large as reported by the late Jim Bridger, the wetlands still provide essential habitat for a staggering population of bird species. See figure 2.14 for information regarding the most populous species found in Great Salt Lake wetlands.

Playas occur at an elevation range between 4,200 to 5,300 feet and are primarily composed of sapphire, greasewood, mound saltbrush, saltgrass, and seepwood (Gorrell, et al., 2005). This habitat community tends to form in sub-basins that are internally drained and fill with water periodically to form a temporary lake.

Common animal species in this habitat may include: Caspian tern and snowy plover with both black-necked stilt and the American avocet using playas as secondary habitat (Gorrell, et al., 2005).

Requirements
For nonresidential buildings, mixed-use buildings, and multifamily residential buildings four stories or more:

Indoor water usage in new buildings and buildings undergoing major renovations as part of the *project* must be an average 40% less than in baseline buildings. The baseline usage is based on the requirements of the Energy Policy Act of 1992 and subsequent rulings by the Department of Energy, the requirements of the Energy Policy Act of 2005, and the fixture performance standards in the 2006 editions of the Uniform Plumbing Code or International Plumbing Code as to fixture performance. Calculations are based on estimated occupant usage and include only the following fixtures and fixture fittings (as applicable to the project scope): water closets (toilets), urinals, lavatory faucets, showers, kitchen sink faucets, and prerinse spray valves.

The water efficiency threshold is calculated as a weighted average of water usage for the buildings constructed as part of the project based on their conditioned square footage. Projects may also follow the LEED for Multiple Buildings and On-Campus Building Application Guide alternative calculation methodology to show compliance with this prerequisite.

National efficiency baselines

Commercial fixtures, fittings, or appliances	**Baseline water usage**
Commercial toilet	1.6 gpf1 Except blow-out fixtures, 3.5 gpf
Commercial urinal	1.0 gpf
Commercial lavatory (restroom) faucet	2.2 gpm at 60 psi, private applications only (hotel-motel guest rooms, hospital patient rooms) 0.5 gpm at 60 psi2 all others except private applications 0.25 gallons per cycle for metering faucets
Commercial pre-rinse spray valve (for food service applications)	Flow rate Ò1.6 gpm (no pressure specified; no performance requirement)

1 EPAct 1992 standard for toilets applies to both commercial and residential models.
2 In addition to EPAct requirements, the American Society of Mechanical Engineers standard for public lavatory faucets is 0.5 gpm at 60 psi (ASME
A112.18.1-2005). This maximum has been incorporated into the national Uniform Plumbing Code and the International Plumbing Code.

Residential Fixtures, Fittings, and Appliances	**Baseline water usage**
Residential toilet	1.6 gpf3
Residential lavatory (bathroom) faucet	2.2 gpm at 60 psi
Residential kitchen faucet	
Residential showerhead	2.5 gpm at 80 psi per shower stall4

gpf = gallons per flush; psi = pounds per square inch.
Source: Adapted from information developed and summarized by the U.S. EPA Office of Water.
3 EPAct 1992 standard for toilets applies to both commercial and residential models.
4 Residential shower compartment (stall) in dwelling units: The total allowable flow rate from all flowing showerheads at any given time, including rain systems, waterfalls, bodysprays, bodyspas, and jets, shall be limited to the allowable showerhead flow rate as specified above (2.5-gpm) per shower compartment, where the floor area

of the shower compartment is less than 2,500 sq.in. For each increment of 2,500 sq.in. of floor area thereafter or part thereof, an additional showerhead with total allowable flow rate from all flowing devices equal to or less than the allowable flow rate as specified above shall be allowed. Exception: Showers that emit recirculated non-potable water originating from within the shower compartment while operating are allowed to exceed the maximum as long as the total potable water flow does not exceed the flow rate as specified above.

SLL Credit 3: Locations with Reduced Automobile Dependence

Intent

To encourage development in locations shown to have multimodal transportation choices or otherwise reduced motor vehicle use, thereby reducing greenhouse gas emissions, air pollution, and other adverse environmental and public health effects associated with motor vehicle use.

Requirements

OPTION 1. Transit-Served Location

Locate the *project* on a site with *existing* transit service such that at least 50% of *dwelling units* and nonresidential building entrances (inclusive of existing buildings) are within a 1/4-mile *walk distance* of bus or streetcar stops, or within a 1/2-mile walk distance of *bus rapid transit* stops, light or heavy rail stations, or ferry terminals, and the transit service at those stops in aggregate meets the minimums listed in Tables 1 and 2. Both weekday and weekend trip minimums must be met to earn points at a particular threshold.

Projects larger than 125 acres can meet the requirements by locating on a site with existing transit service such that at least 40% of dwelling units and nonresidential building entrances (inclusive of existing buildings) are within a 1/4-mile walk distance of bus or streetcar stops, or within a 1/2-mile walk distance of bus rapid transit stops, lightor heavy rail stations, or ferry terminals, and the transit service at those stops in aggregate meets the minimums listed in Tables 1 and 2 (both weekday and weekend trip minimums must be met to earn points at a particular threshold), as long as the 40% complies with NPD Prerequisite 2 and any portion of the project beyond the 1/4-mile and/or 1/2-mile walk distances meets SLL Prerequisite 1, Option 3-compliant planned transit service.

Projects greater than 500 acres can meet the requirements by locating on a site with existing transit service such that at least 30% of dwelling units and nonresidential building entrances (inclusive of existing buildings) are within a 1/4-mile walk distance of bus or streetcar stops, or within a 1/2-mile walk distance of bus rapid transit stops, light or heavy rail stations, or ferry terminals, and the transit service at those stops in aggregate meets the minimums listed in Tables 1 and 2 (both weekday and weekend trip minimums must be met to earn points at a particular threshold), as long as the 30% complies with NPD Prerequisite 2 and any portion of the project beyond the 1/4-mile and/or 1/2-mile walk distances meets SLL Prerequisite 1, Option 3-compliant planned transit service.

For all projects, weekend daily trips must include service on both Saturday and Sunday. Commuter rail must serve more than one *metropolitan statistical area* (MSA) and/or the area surrounding the core of an MSA.

Table 1. Minimum daily transit service for projects with multiple transit types (bus, streetcar, rail, or ferry)

Weekday trips	Weekend trips	Points
60	40	1
7j	50	2
100	j 0	y
132	x0	F
180	130	0
246	150	j
320	200	7

Table 2. Minimum daily transit service for projects with commuter rail or ferry service only

Weekday trips	Weekend trips	Points
24	j	1
40	x	2
60	12	y

Projects served by two or more transit routes such that no one route provides more than 60% of the prescribed levels may earn 1 bonus point, up to the maximum 7 points.

Projects where existing transit service is temporarily rerouted outside the required distances for less than 2 years may meet the requirements if the local transit agency has committed to restoring the compliant routes with service at or above the prior level.

OR

OPTION 2. Metropolitan Planning Organization Location with Low VMT

Locate the project within a region served by a metropolitan planning organization (MPO) and within a transportation analysis zone where the current annual home-based *vehicle miles traveled* (VMT) per capita does not exceed 90% of the average of the metropolitan region. The research must be derived from household transportation surveys conducted by the MPO within ten years of the date of submission for LEED for Neighborhood Development certification. Additional credit may be awarded for increasing levels of performance, as indicated in Table 3.

Table 3. Points for low-VMT location

Percentage of average regional VMT per capita	Points
81–90%	1
71–80%	2
61–70%	y
51–60%	F
41–50%	0
31–40%	j
30 or less	7

VMT = vehicle miles traveled.

Points earned under Options 1 and 2 may not be combined.

SLL Credit 4: Bicycle Network and Storage

Intent

To promote bicycling and transportation efficiency, including reduced *vehicle miles traveled* (VMT)ſTo support public health by encouraging utilitarian and recreational physical activity.

Requirements

BICYCLE NETp OR

Design and/or locate the *project* to meet at least one of the three requirements below:

a. An *existing bicycle network* of at least 5 continuous miles in length is within 1/4-mile bicycling distance of the *project boundary*.

b. If the project is 100% residential, an existing bicycle network begins within 1/4-mile bicycling distance of the project boundary and connects to a *school* or *employment center* within 3 miles' bicycling distance.

c. An existing bicycle network within 1/4-mile bicycling distance of the project boundary connects to at least ten diverse uses (see Appendix) within 3 miles' bicycling distance from the project boundary.

AND

BICYCLE STOR2GE

Provide bicycle parking and storage capacity to new buildings as follows:

a. **Multiunit residential.** Provide at least one secure, enclosed bicycle storage space per occupant for 30% of the *planned occupancy* but no fewer than one per unit. Provide secure visitor bicycle racks on-site, with at least one bicycle space per ten *dwelling units* but no fewer than four spaces per project site.

b. **Retail.** Provide at least one secure, enclosed bicycle storage space per new retail worker for 10% of retail worker planned occupancy. Provide visitor or customer bicycle racks on-site, with at least one bicycle space per 5,000 square feet of retail space, but no fewer than one bicycle space per business or four bicycle spaces per project site, whichever is greater. Provide at least one on-site shower with changing facility for any development with 100 or more new workers and at least one additional on-site shower with changing facility for every 150 new workers thereafter.

c. **Nonresidential other than retail.** Provide at least one secure, enclosed bicycle storage space per new occupant for 10% of planned occupancy. Provide visitor bicycle racks on-site with at least one bicycle space per 10,000 square feet of new commercial nonretail space but not fewer than four bicycle spaces per building. Provide at least one on-site shower with changing facility for any development with 100 or more new workers and at least one additional on-site shower with changing facility for every 150 new workers thereafter.

Secure, enclosed bicycle storage areas must be locked and easily accessible to residents and/or workers. Provide informational signage on using the storage facilities.

Visitors' and customers' bicycle racks must be clearly visible from a main entry, located within 100 feet of the door, served with night lighting, and protected from damage from nearby vehicles. If the building has multiple main entries, bicycle racks must be proportionally dispersed within 100 feet of each.

Shower and changing facility requirements may be met by providing the equivalent of free access to on-site health club shower facilities, if the health club can be accessed without going outside. Provide informational signage on using the shower facilities.

SLL Credit 5: Housing and Jobs Proximity

Intent

To encourage balanced communities with a diversity of uses and employment opportunities.

Requirements

OPTION 1. Project with Affordable Residential Component (3 points)

Include a residential component equaling at least 30% of the *project*'s total building square footage (exclusive of parking structures), and locate and/or design the project such that the geographic center (or boundary if the project exceeds 500 acres) is within 1/2-mile *walk distance* of *existing* full-time-equivalent jobs whose number is equal to or greater than the number of *dwelling units* in the project; and satisfy the requirements necessary to earn at least one point under NPD Credit 4, Mixed-Income Diverse Communities, Option 2, Affordable Housing.

OR

OPTION 2. Project With Residential Component (2 points)

Include a residential component equaling at least 30% of the project's total building square footage (exclusive of parking structures), and locate and/or design the project such that the geographic center (or boundary if the project exceeds 500 acres) is within 1/2-mile walk distance of existing full-time-equivalent jobs whose number is equal to or greater than the number of dwelling units in the project.

OR

OPTION 3. Infill Project with Nonresidential Component (1 point)

Include a nonresidential component equaling at least 30% of the project's total building square footage (exclusive of parking structures), and locate on an *infill site* whose geographic center (or boundary if the project exceeds 500 acres) is within 1/2-mile walk distance of an existing rail transit, ferry, or tram stop and within 1/2-mile walk distance of existing dwelling units whose number is equal to or greater than 50% of the number of new full-time-equivalent jobs created as part of the project.

Key Definitions

infill site a site that meets any of the following four conditions:

a. At least 75% of its boundary borders parcels that individually are at least 50% *previously developed,* and that in aggregate are at least 75% previously developed.

b. The site, in combination with bordering parcels, forms an aggregate parcel whose boundary is 75% bounded by parcels that individually are at least 50% previously developed, and that in aggregate are at least 75% previously developed.

c. At least 75% of the land area, exclusive of rights-of-way, within a 1/2 mile distance from the *project boundary* is previously developed.

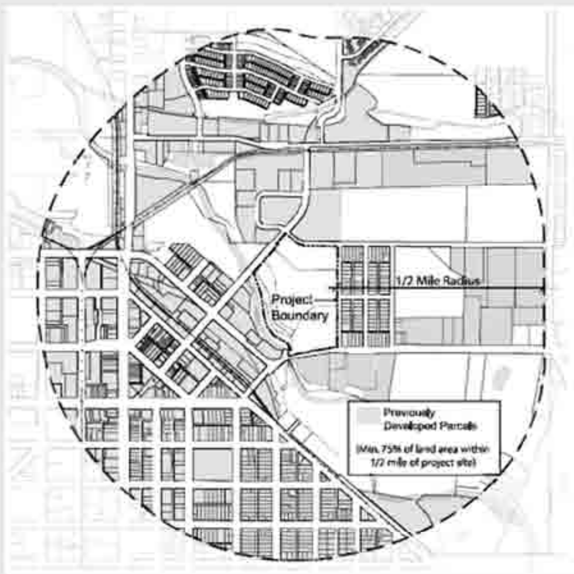
d. The lands within a 1/2 mile distance from the project boundary have a *preproject connectivity* of at least 140 intersections per square mile.

A *street* or other right-of-way does not constitute previously developed land; it is the status of property on the other side or right-of-way of the street that matters. For conditions (a) and (b) above, any fraction of the perimeter that borders waterfront other than a stream is excluded from the calculation.

(a). Infill project site based on minimum 75% of perimeter adjacent to previously developed parcels

(b). Infill project site based on minimum 75% adjacent to previously developed parcels using project boundary and selected bordering parcels

(c). Infill project site based on minimum 75% of land area within 1/2 mile of project boundary being previously developed



(d). Infill project site based on minimum 140 intersections/sq.mi. within 1/2 mile of project boundary

NPD Credit 2: Compact Development

Intent

To encourage development in *existing* areas to conserve land and protect farmland and wildlife habitat. To promote livability, walkability, and transportation efficiency, including reduced *vehicle miles traveled* (VMT). To improve public health encouraging daily physical activity associated with alternative modes of transportation and compact development.

Requirements

Design and build the *project* such that residential and nonresidential components achieve the *densities* per acre of *buildable land* listed in Table 1 (excluding those portions of parking structures devoted to parking).

Table 1. Points for density per acre of buildable land

Residential density (DU/acre)	Nonresidential density (FAR)	Points
> 10 and ≤ 13	> 0.75 and ≤ 1.0	1
> 13 and ≤ 18	> 1.0 and ≤ 1.25	2
> 18 and ≤ 25	> 1.25 and ≤ 1.75	3
> 25 and ≤ 38	> 1.75 and ≤ 2.25	4
> 38 and ≤ 63	> 2.25 and ≤ 3.0	5
> 63	> 3.0	6
DU = dwelling unit; FAR = floor-area ratio.		

The specified densities must be achieved within five years of the date that the first building of any type is occupied.

The scoring of a mixed-use project is calculated with a weighted average, according to the following steps.

1. Determine the total square footage of all residential and nonresidential uses.
2. Calculate the percentage residential and percentage nonresidential of the total square footage.
3. Determine the density of each component as measured in *dwelling units* per acre and *floor-area ratio*, respectively.
4. Referring to Table 1, find the appropriate points for the densities of the residential and nonresidential components.
5. If the points are different, multiply the point value of the residential component by its percentage of the total square footage and multiply the point value of the nonresidential component by its percentage.
6. Add the two scores.

Key Definitions

For the meanings of other terms used in the requirements, refer to the Glossary.

buildable land the portion of the site where construction can occur, including land voluntarily set aside and not constructed upon. When used in *density* calculations, buildable land excludes public rights-of-way and land excluded from development by codified law or LEED for Neighborhood Development prerequisites. An *applicant* may exclude additional land not exceeding 15% of the buildable land base defined above, provided the following conditions are present:

a. The land is protected from residential and nonresidential construction by easement, deed restriction, or other enforceable legal instrument.

AND

b. Either 25% or more of the boundary of each contiguous parcel proposed for exclusion borders a *water body* or areas outside the *project boundary* that are protected by codified law; or ownership of, or management authority over, the exclusion area is transferred to a public entity.

NPD Credit 3: Mixed-Use Neighborhood Centers

Intent

To cluster diverse land uses in accessible neighborhood and regional centers to encourage daily walking, biking, and transit use, reduce *vehicle miles traveled* (VMT) and automobile dependence, and support car-free living.

Requirements

FOR ALL PROJECTS

Locate and/or design the *project* such that 50% of its *dwelling units* are within a 1/4-mile *walk distance* of the number of diverse uses (see Appendix) in Table 1, including at least one use from each of the four categories. For projects with no dwellings, 50% of dwelling units within 1/4 mile of the *project boundary* must be within a 1/4-mile walk distance of the number of diverse uses specified in Table 1, including at least one food retail store and at least one establishment from each of two other categories. Establishments may be inside or outside the project and may be *existing* or *planned diverse uses*.

The specified number of diverse uses must be in place by the time of occupancy according to the percentages indicated in Table 1 (exclusive of portions of parking structures devoted to parking):

Table 1. Points for diverse uses within 1/4-mile walk distance, by time of occupancy

Diverse uses	Percentage occupancy of total square footage	Points
4–6	20%	1
7–10	30%	2
11–18	40%	3
≥ 19	50%	4

Per neighborhood center, the following restrictions apply:

a. A single establishment may not be counted in two categories (e.g., a place of worship may be counted only once even if it also contains a daycare facility, and a retail store may be counted only once even if it sells products in several categories).

b. Establishments in a mixed-use building may each count if they are distinctly operated enterprises with separate exterior entrances, but no more than half of the minimum number of diverse uses can be situated in a single building or under a common roof.

c. Only two establishments in a single category may be counted (e.g., if five restaurants are within the required distance, only two may be counted).

FOR PROJECTS 40 ACRES OR GREATER

Cluster diverse uses into neighborhood centers as follows:

Table 2. Points for clustering of diverse uses

Diverse uses	Minimum uses per neighborhood center	Points
4–6	3	1
7–10	5	2
11–18	7	3
≥ 19	9	4

Within each neighborhood center, the principal entries of the establishments must be within a 300-foot walk distance from a single common point that represents the center of the cluster (1 or 2 points) or within a 400-foot walk distance (3 or 4 points).

Also, projects with multiple centers must determine points earned based on the number of uses in the centers weighted by the percentage of total dwelling units within a 1/4-mile walk distance from each center's common point.

AND

FOR PROJECTS WITH REGIONAL-SERVING RETAIL OF 150,000 OR MORE SQUARE FEET

Projects with retail uses totaling 150,000 or more square feet, if they have at least one retail establishment totaling 75,000 or more square feet, must also earn a minimum of 1 point under SLL Credit 3, Reduced Automobile Dependence, Option 1, Transit-Served Location (planned transit service can be counted), and for every additional 50,000 square feet of retail above 150,000 square feet, must earn 1 additional point under SLL Credit 3.

If transit service is planned but not yet operational, the project must demonstrate one of the following:

a. The relevant transit agency has a signed full funding grant agreement with the Federal Transit Administration that includes a revenue operations date for the start of transit service. The revenue operations date must be no later than the occupancy date of 50% of the project's total building square footage.

b. For bus, streetcar, *bus rapid transit*, or ferry service, the transit agency must certify that it has an approved budget that includes specifically allocated funds sufficient to provide the planned service at the levels listed above and that service at these levels will commence no later than occupancy of 50% of the project's total building square footage.

c. For rail service other than streetcars, the transit agency must certify that preliminary engineering for a rail line has commenced. In addition, the service must meet either of these two requirements:

- A state legislature or local subdivision of the state has authorized the transit agency to expend funds to establish rail transit service that will commence no later than occupancy of 50% of the project's total building square footage.

OR

- A municipality has dedicated funding or reimbursement commitments from future tax revenue for the development of stations, platforms, or other rail transit infrastructure that will service the project no later than occupancy of 50% of the project's total building square footage.

NPD Credit 4: Mixed-Income Diverse Communities

Intent

To promote socially equitable and engaging communities by enabling residents from a wide range of economic levels, household sizes, and age groups to live in a community.

Requirements

Meet the requirements of one or more options below.

OPTION 1. Diversity of Housing Types

Include a sufficient variety of housing sizes and types in the *project* such that the total variety of planned and *existing* housing within the project achieves a Simpson Diversity Index score greater than 0.5, using the housing categories below. Projects of less than 125 acres may calculate the Simpson Diversity Index for the area within 1/4 mile of the project's geographic center. The Simpson Diversity Index calculates the probability that any two randomly selected *dwelling units* in a project will be of a different type.

Score = $1 - \sum (n/N)^2$

where n = the total number of dwelling units in a single category, and N = the total number of dwelling units in all categories.

Table 1. Points for housing diversity

Simpson Diversity Index score	Points
> 0.5 to < 0.6	1
≥ 0.6 to < 0.7	2
≥ 0.7	3

Housing categories are defined according to the dwelling unit's net square footage, exclusive of any garage, as listed in Table 2.

Table 2. Housing categories

Type	Square feet
Detached residential, large	> 1,250
Detached residential, small	≤ 1,250
Duplex or townhouse, large	> 1,250
Duplex or townhouse, small	≤ 1,250
Dwelling unit in multiunit building with no elevator, large	> 1,250
Dwelling unit in multiunit building with no elevator, medium	> 750 to ≤ 1,250
Dwelling unit in multiunit building with no elevator, small	≤ 750
Dwelling unit in multiunit building with elevator, 4 stories or fewer, large	> 1,250
Dwelling unit in multiunit building with elevator, 4 stories or fewer, medium	> 750 to ≤ 1,250
Dwelling unit in multiunit building with elevator, 4 stories or fewer, small	≤ 750
Dwelling unit in multiunit building with elevator, 5 to 8 stories, large	> 1,250
Dwelling unit in multiunit building with elevator, 5 to 8 stories, medium	> 750 to ≤ 1,250
Dwelling unit in multiunit building with elevator, 5 to 8 stories, small	≤ 750
Dwelling unit in multiunit building with elevator, 9 stories or more, large	> 1,250
Dwelling unit in multiunit building with elevator, 9 stories or more, medium	> 750 to ≤ 1,250
Dwelling unit in multiunit building with elevator, 9 stories or more, small	≤ 750
Live-work space, large	> 1,250
Live-work space, small	≤ 1,250
Accessory dwelling unit, large	> 1,250
Accessory dwelling unit, small	≤ 1,250

For the purposes of this credit, townhouse and live-work units may have individual ground-level entrances and/or be within a multiunit or mixed-use building. Double counting is prohibited; each dwelling may be classified in only one category. The number of stories in a building is inclusive of the ground floor regardless of its use.

AND/OR

OPTION 2. Affordable Housing

Include a proportion of new rental and/or for-sale dwelling units priced for households earning below the *area median income* (AMI). Rental units must be maintained at affordable levels for a minimum of 15 years. Existing dwelling units are exempt from requirement calculations. A maximum of 3 points may be earned by meeting any combination of thresholds in Table 3.

Table 3. Points for affordable housing

Rental dwelling units				For-sale dwelling units			
Priced up to 60% AMI		Priced up to 80% AMI		Priced up to 100% AMI		Priced up to 120% AMI	
Percentage of total rental units	**Points**	Percentage of total rental units	**Points**	Percentage of total for-sale units	**Points**	Percentage of total for-sale units	**Points**
5	**1**	10	**1**	5	**1**	8	**1**
10	**2**	15	**2**	10	**2**	12	**2**
15	**3**	25	**3**	15	**3**	--	--

AMI = area median income.

AND/OR

OPTION 3. Mixed-Income Diverse Communities

A project may earn 1 additional point by earning at least 2 points in Option 1 and at least 2 points in Option 2 (at least one of which must be for providing housing at or below 100% AMI).

NPD Credit 6: Street Network

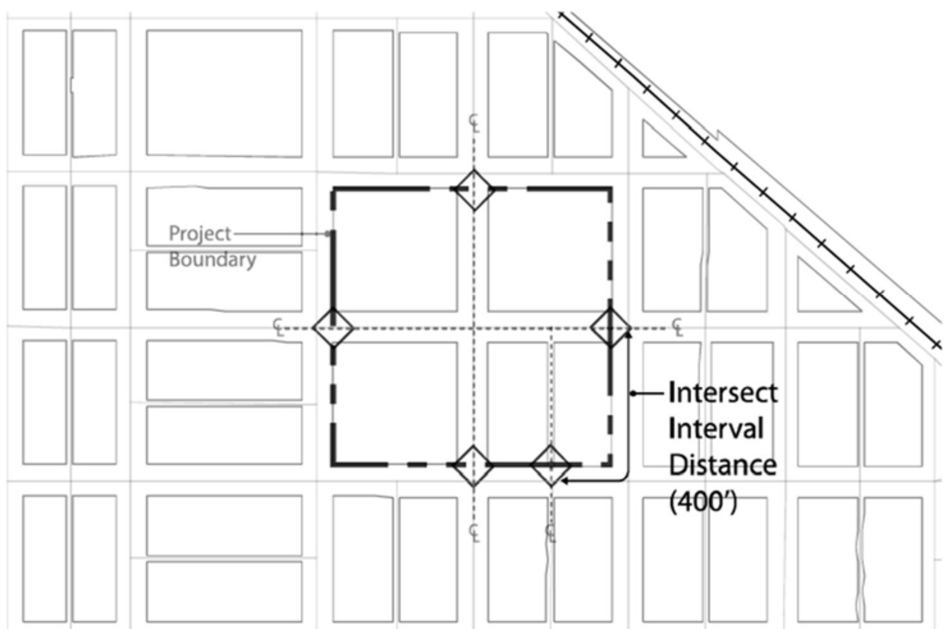
Intent

To promote *projects* that have high levels of internal connectivity and are well connected to the community at large. To encourage development within *existing* communities, thereby conserving land and promoting multimodal transportation. To improve public health by encouraging daily physical activity and reducing the negative effects of motor vehicle emissions.

Requirements

Design and/or locate the project such that a through-street and/or nonmotorized right-of-way intersects or terminates at the *project boundary* at least every 400 feet or at existing abutting street intervals and intersections, whichever is the shorter distance. Include a pedestrian or bicycle through-connection in at least 90% of any new *culs-de-sac*. This does not apply to portions of the boundary where connections cannot be made because of physical obstacles, such as prior platting of property, construction of existing buildings or other barriers, slopes over 15%, *wetlands* and *water bodies*, railroad and utility rights-of-way, existing limited-access motor vehicle rights-of-way, and parks and dedicated open space.

Figure 1. Project site with right-of-way intersects on project boundary at least every 400 feet



AND

Locate and/or design the project such that its internal *connectivity* and/or the connectivity within a 1/4-mile distance of the project boundary falls within one of the ranges listed in Table 1.

Table 1. Points for connectivity

Street intersections per square mile	Points
> 300 and ≤ 400	1
> 400	2

All streets and sidewalks that are counted toward the connectivity requirement must be available for general public use and not gated. Gated areas are not considered available for public use, with the exception of education and health care campuses, and military bases where gates are used for security purposes.

Key Definitions

For the meanings of other terms used in the requirements, refer to the Glossary.

connectivity the number of publicly accessible *street* intersections per square mile, including intersections of streets with dedicated *alleys* and transit rights-of-way, and intersections of streets with nonmotorized rights-of-way (up to 20% of total intersections). If one must both enter and exit an area through the same intersection, such an intersection and any intersections beyond that point are not counted; intersections leading only to *culs-de-sac* are also not counted. The calculation of square mileage excludes *water bodies*, *parks* larger than 1/2 acre, public facility campuses, airports, rail yards, slopes over 15%, and areas nonbuildable under codified law or the rating system. Street rights-of-way may not be excluded.

NPD Credit 7: Transit Facilities

Intent

To encourage transit use and reduce driving by providing safe, convenient, and comfortable transit waiting areas and safe and secure bicycle storage facilities for transit users.

Requirements

Work with the transit agency or agencies serving the *project* to identify transit stop locations within and/or bordering the *project boundary* where transit agency-approved shelters and any other agency-required improvements, including bicycle racks, will be installed no later than construction of 50% of total project square footage. At those locations, install approved shelters and any required improvements, or provide funding to the transit agency for their installation. Shelters must be covered, be at least partially enclosed to buffer wind and rain, and have seating and illumination. Any required bicycle racks must have a two-point support system for locking the frame and wheels and be securely affixed to the ground or a building.

AND

Work with the transit agency or agencies serving the project to identify locations within and bordering the project boundary where the agency determines that transit stops will be warranted within two years of project completion, either because of increased ridership on *existing* service resulting from the project or because of planned future transit. At those locations, reserve space for transit shelters and any required improvements, including bicycle racks. In lieu of or in addition to new stops, this requirement can be satisfied with a commitment from the transit agency to provide increased service to the transit stops that will have been installed at the time of 50% *build-out*.

AND

Work with the transit agency or agencies serving the project to provide kiosks, bulletin boards, and/or signs that display transit schedules and route information at each public transit stop within and bordering the project.

NPD Credit 8: Transportation Demand Management

Intent

To reduce energy consumption, pollution from motor vehicles, and adverse public health effects by encouraging multimodal travel.

Requirements

FOR ALL PROJECTS

Earn one point for every two options achieved below, for a maximum of two points. For the purposes of this credit, *existing* buildings and their occupants are exempt from the requirements.

OPTION 1. TDM Program

Create and implement a comprehensive transportation demand management (TDM) program for the *project* that reduces weekday peak-period motor vehicle trips by at least 20% compared with a baseline case, and fund the program for a minimum of three years following *build-out* of the project. The TDM program must be prepared by a qualified transportation professional. Any trip reduction effects of Options 2, 3, 4, or 5 may not be included in calculating the 20% threshold.

OR

OPTION 2. Transit Passes

Provide transit passes valid for at least one year, subsidized to be half of regular price or cheaper, to each occupant locating within the project during the first three years of project occupancy (or longer). Publicize the availability of subsidized transit passes are available to project occupants;

OR

OPTION 3. Developer-Sponsored Transit

Provide year-round, *developer*-sponsored private transit service (with vans, shuttles, buses) from at least one central point in the project to other major transit facilities, and/or other destinations such as a retail or *employment center*, with service no less frequent than 45 daily weekday trips and 30 daily weekend trips. The service must begin by the time the project total square footage is 20% occupied and must be guaranteed for at least three years beyond project build-out. Twenty percent occupancy is defined as residents living in 20% of the *dwelling units* and/or employees working in 20% of the total nonresidential square footage.

Provide transit stop shelters and bicycle racks adequate to meet projected demand but no less than one shelter and one bicycle rack at each transit stop. Shelters must be covered, be at least partially enclosed to buffer wind and rain, and have seating and illumination. Bicycle racks must have a two-point support system for locking the frame and wheels and must be securely affixed to the ground or a building.

OR

OPTION 4. Vehicle Sharing

Locate the project such that 50% of the dwelling units and nonresidential building entrances are within a 1/4 mile *walk distance* of at least one vehicle in a vehicle-sharing program. For each vehicle, dedicate one parking space accessible to vehicle-sharing members. Through signage and other means, publicize to project occupants the availability and benefits of the vehicle-sharing program. If the project has more than 100 dwelling units and/or employees and has a minimum transit service of 60 daily weekday trips and 40 daily weekend trips, at least one additional vehicle and parking space for every 100 dwelling units and/or employees must be available. If the project has more than 100 dwelling units and/or employees but does not have transit service at the frequencies specified above, at least one additional vehicle and parking space for every 200 dwelling units and/or employees must be available. Where new vehicle locations are created, a vehicle sharing program must begin by the time the project total square footage is 20% occupied; commit to providing vehicles to the locations for at least two years. Twenty percent occupancy is defined as residents living in 20% of the project dwelling units and/or employees working in 20% of the total nonresidential square footage of the project.

OR

OPTION 5. Unbundling of Parking

For 90% of *multiunit residential* units and/or nonresidential square footage, the associated parking spaces are sold or rented separately from the dwelling units and/or nonresidential square footage.

Acres of Land Impacted by Alternative Futures						
Assessment Models	**Tiers**	**Plan Trend**	**Build Out**	**Focused Development (Plan Trend)**	**Focused Development (Build Out)**	**LEED**
Working Lands	NA	13,783	22,074	11,440	13,878	8,224
Public Health, Welfare, and Safety	Tier 1	5,098	3,936	4,232	3,805	3,151
	Tier 2	17,624	18,568	14,628	16,983	13,488
	Tier 3	31,163	40,302	25,866	31,042	21,350
Critical Habitat	Tier 1	2,158	6,836	1,973	6,710	1,794
	Tier 2	3,884	13,156	3,869	13,127	3,518
	Tier 3	7,210	20,851	7,229	16,091	6,572
Integrated Resources	Tier 1	1,637	1,443	1,580	987	145
	Tier 2	3,071	4,555	2,539	3,381	1,413
	Tier 3	8,179	13,110	6,506	8,719	5,475

GIS Data Sources

Computer Software
Data analyses performed using Environmental Systems Research Instituteôs (ESRI) ArcGIS, version 9.3.

Map Projection Data
Projection: UTM Zone 12 North
Datum: North American Datum 1983
Grid Resolution: 30 meters

Primary Data Sources
Data.gov
http://www.data.gov

Natural Resources Conservation Service (NRCS) Geospatial Data Gateway
http://datagateway.nrcs.usda.gov/

Northwest Gap Analysis Project
http://gap.uidaho.edu/index.php/gap-home/Northwest-GAP/

Southwest Regional Gap Analysis Project
http://fws-nmcfwru.nmsu.edu/swregap/

United States Geological Survey (USGS) National Map Seamless Server
http://seamless.usgs.gov/