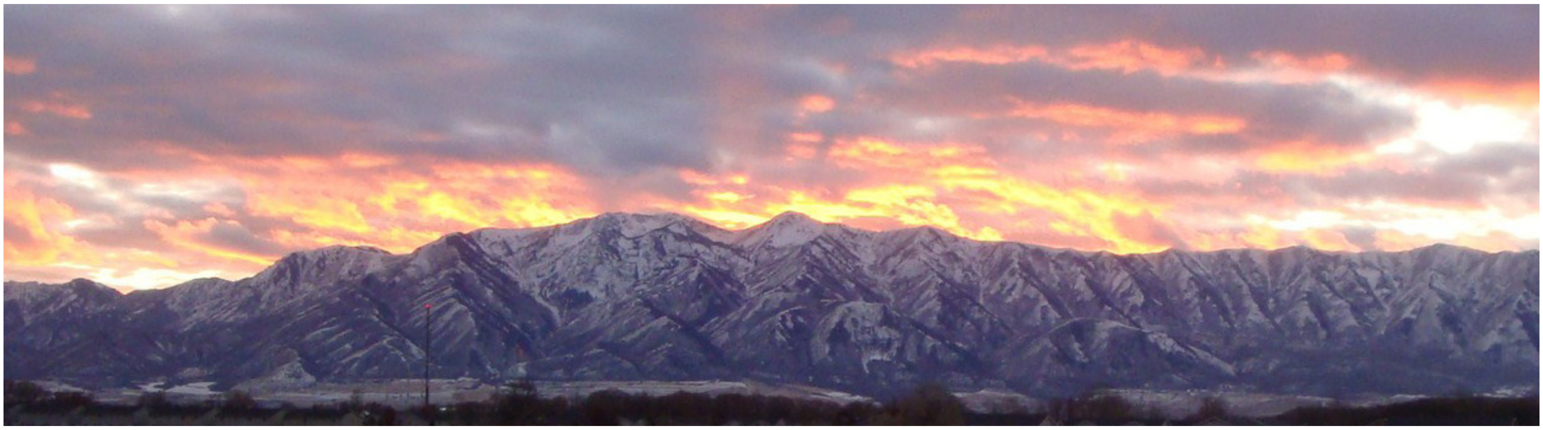
> A river is “an elusive thing that exists as much in the imagination as on the ground”
>
> *Craig Denton*



# BEAR RIVER WATERSHED

## Its role in maintaining the Bear River Migratory Bird Refuge

Adam Perschon, Danny White
Professor Richard E. Toth

Utah State University
College of Natural Resources
Department of Environment and Society
Bioregional Planning Studio 2009-2010

**College of Natural Resources**
**Department of Environment and Society**

# Bear River Watershed

Remote Sensing/GIS Laboratory
College of Natural Resources
Utah State University
5275 Old Main Hill
Logan, Utah 84322-5275

Scale 1:250 000

0 5 10 15 20 25 Miles

0 10 20 30 40 Kilometers

Universal Transverse Mercator projection, zone 12
North American Datum of 1983

| | |
|---|---|
| 🟥 | Interstate highways |
| 🟥 | Federal highways |
| ▨ | State highways |
| ▨ | State boundaries |
| 🟩 | U.S. forest boundaries |
| 🟨 | Bear River watershed boundary |

Image generated from 10 meter Digital Elevation Model (DEM) and 30 meter NDVI

30 meter NDVI derived from fall season 1999 and 2000 Enhanced Thematic Mapper Plus (ETM+) image mosaic, bands 4 and 3

10 meter seamless DEMs available from U.S. Geological Survey, EROS Data Center, Sioux Falls, SD

1:100,000 scale hydrography, boundary, and transportation layers available from Utah Automated Geographic Reference Center and U.S. Geological Survey, EROS Data Center, Sioux Falls, SD

# BEAR RIVER WATERSHED:
# ITS ROLE IN MAINTAINING THE BEAR RIVER MIGRATORY BIRD REFUGE

**Final Project Report**
**May 2010**

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Study team from left to right: Danny White, Temis Taylor, and Adam Perschon

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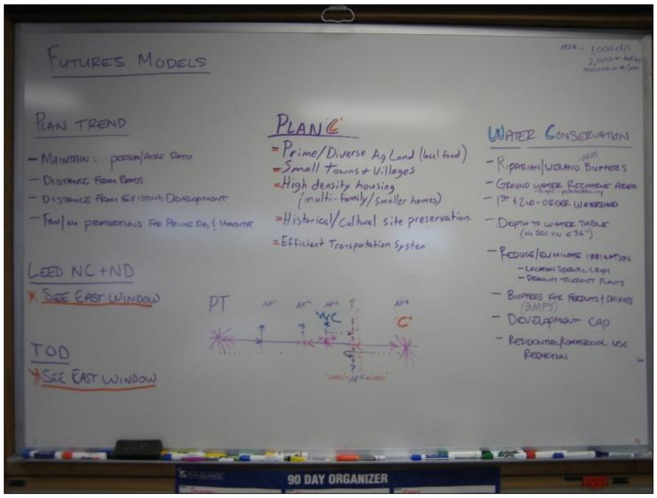


Developing futures models (Richard Toth)

Process model on the studio wall (Richard Toth)

Presenting ideas to USU faculty (Richard Toth)

Field trip to the Bear River Migratory Bird Refuge (Richard Toth)

USU faculty attending a studio presentation (Richard Toth)

Interactions network in the process model (Richard Toth)

# Introduction

Portions of this introduction are abstracted from the Phase I Report on the Upper Colorado River Ecosystem, September, 2008.

“The origins of this study were initiated in the summer of 2004, with the U.S. Fish & Wildlife Service (FWS) Region 6. Several individuals from the Region 6 office inquired to Utah State University about our willingness to assist them in the identification of appropriate data to be used in wildlife habitat analysis and management at the landscape scale. The study was to demonstrate GIS applications at the ecosystem-level planning scale. At the end of the summer, 2004, results of the study were presented to FWS Region 6 staff. There were 6 elements to the work: 1) Develop criteria for choosing which data is needed for these analysis; 2) Initiate a data search to find out which data are available; 3) Collect data and assemble data files; 4) Process, merge, and clip data to projected boundary; 5) Produce descriptive maps; 6) Define and display sample models using various criteria (data).

“This work was presented to the FWS staff on October 27, 2004. Given various FWS budget constraints, continuation of the work was not proposed at that time. However, in early 2006, FWS Region 6 inquired as to the USU research team’s interest in applying several of the planning concepts to the Upper-Colorado River Ecosystem. A “prospectus” was submitted to FWS Region 6, which outlined an approach for this project over a two-year period. The following is abstracted from portions of that prospectus:

“Management agencies such as the Fish and Wildlife Service have traditionally focused on point-level processes, working to conserve and maintain ecological functions, and plant and animal species of small spatial extents. Many of these efforts have been successful. However, management of systems and species of concern at the point level also requires an understanding of the landscape context in which the system or species resides. As part of the growing awareness, FWS Region 6 has embarked on a process of

The Bear River plain northwest of Preston, Idaho (Adam Perschon) landscape- and ecosystem-level planning and management seeking to identify key resources (elements), within identified ecosystems and how they are likely to be affected by anthropogenic stressors.

“The anthropocentric perspectives are emphasized in this work, in that it hopes to better understand the ecological constraints extending beyond those typically analyzed under traditional, multiple-use philosophies. This view defines the context for this study. This work seeks to formulate a process by which a range of potential stressors can be identified and extended to landscapes, offering a framework in which stressor impacts can be analyzed.

“Objectives:

We propose to evaluate the utility of a process for assessing stressor effects on the landscape. Our proposed ecosystem for development of this process is the Upper-Colorado River Ecosystem (UCRE), as defined by FWS Region 6. We will identify likely stressors in the UCRE, and prioritize possible relationships (both negative and positive) of each stressor with a set of landscape elements and selective plant and animal species (multiple species were also to be explored).

“The proposed process focused on the completion of four major elements over a two-year period:

- Characterize landscape-level biological and physical elements of the Upper Colorado River Ecosystem.
- Organize existing data on selective plant and animal species, including but not limited to migratory birds, listed and sensitive species, fisheries, and important habitats.
- Identify current and potential stressors potentially affecting the identified landscape-level elements and the plant and animal species of interest.
- Determine and assess possible relationships among stressors – how each is manifest and consequently measureable, and the identified landscape-level elements and the animal and plant species of interest.

“No primary data collection is proposed in this work; instead, data will come from existing geo-spatial databases, including state and federal management agencies. The types of data collected will follow closely but not be limited to that which was outlined in the October 2004 project.

“For this phase of work, the identification of landscape stressors will, by necessity, be broad-based and include those commonly identified with expanding oil and gas explorations, areas of potential urbanization, and recreation. Stressor impacts will be evaluated via literature review.”

Black Canyon, near Grace, Idaho (Adam Perschon)

# Introduction

Portions abstracted from the second-year final phase of work in progress:

"Because of the challenges presented by the large scale of the landscape in Phase I of the project, it was deemed appropriate to move down in scale in order to perform more specific landscape and land use analyses. Three sub-watersheds were selected for closer study. The White-Yampa, Colorado Headwaters, and Gunnison basins were chosen for several advantages they present.

"The three watersheds are largely within the state of Colorado. Although there are small sections in Wyoming and Utah, the majority of the area and populations remain within one state. The three regions are contiguous and therefore represent a larger-scale whole to assess the functions and hierarchy and scale dependence as well. The subregions also represent a variety of different geophysical and biological characteristics similar to those of the entire UCRE.

"Human uses in the subregions vary, ranging from high mountain ranches near the continental divide in the northwest to the increasingly urbanized area of Grand Junction, Colorado. Although the overall objective of the original prospectus was to evaluate and specify hotspots for wildlife, the intense human pressures on the region cannot be ignored. Low population density, availability of natural resources, and scenic quality make further growth of settlement and exploration of resources inevitable activities in the future of this region. For this reason, three primary drivers of change were identified at the end of the first year for further study: energy, recreation and working lands."

As portions of the second-year study were coming to a conclusion, the researchers at USU were contacted by staff in Region 6 to address a new, more detailed question within the region. For various reasons, individuals in Region 6 were interested in the future growth and development in the Bear River Watershed and their impacts on the Bear River Migratory Bird Refuge (BRMBR). Region 6 requested that a similar methodology of alternative growth scenarios utilized in Phase I be used to address several critical concerns related to BRMBR. This report documents the recommendations and policies needed to address future concerns of maintaining and/or enhancing the water quantity and quality entering the Bear River Migratory Bird Refuge.

Richard E. Toth
21 April, 2010

The Bear River in Box Elder County, Utah (Adam Perschon)

## Methodology

Developing a suitable methodology is a critical element in the regional planning process, one that provides a framework to guide research and analysis in a logical, yet flexible fashion. The complexity of systems and issues across a large landscape create the need for iterative approaches which allow the research team to adapt to newly-acquired information and feedback obtained from analyses throughout the research process. It is also imperative that the methodology facilitate research processes that take into consideration the unique features and challenges within each landscape.

The methodology used for the 2009-2010 Bioregional Planning Studio was adapted from the methodological work of Richard Toth (1972). It is a logical, flexible, and iterative model that carefully probes the watershed's complex issues, compares the potential outcomes of alternative futures, and evaluates the viability of those alternative futures against assessment metrics (see Figure 2.1) While the process diagram for the studio methodology can appear linear, it is important to note that many of the processes occurred concurrently, and many steps were revisited to ensure all salient information was thoughtfully integrated into the project.

The main portions of the research include site selection, pre-analysis, research and analysis, development of models, evaluation of models, and implementation strategies. Each of these sections is summarized here and is covered in more detail through the report.

**Site Selection:** The extent of the 2009-2010 studio project is the Bear River Watershed, taking into consideration surrounding areas for greater context. At the request of the U.S. Fish and Wildlife Service, the project focused on the watershed's role in maintaining the Bear River Migratory Bird Refuge.

**Pre-analysis:** Pre-analysis of the project area included several field trips, including a flight over the watershed in a light aircraft, the review of case studies pertinent to regional planning and analysis, lectures from and discussions with professionals from a wide variety of disciplines, and project opinion papers that prompted overall impressions of the study area before issues were identified.

**Research and Analysis:** A main element of the studio project was indentifying key issues impacting the watershed. Studio members examined the function and structure of the study area which involved an analysis of the interactions between the region's biological and physical components. From this analysis, issues were identified, as well as the driving factors behind those issues.

**Development of Models:** The project team used GIS data to develop assessment and alternative futures models based upon and designed to address the key issues identified for the watershed. The assessment models are visual representations of the study area's physical and/or biological attributes and are used to develop and assess alternative future models. Alternative futures models spatially describe what the study area might look like based on various scenarios, including baseline trends.

**Evaluation of Models:** The viability of alternative future models was determined by gauging their impact upon the assessment models. From this evaluation, the project team identified which alternative futures have the greatest potential to maintain or improve conditions within the watershed.

**Implementation Strategies:** Based on the research process and model evaluations, the project team developed implementation strategies aimed at balancing growth and ecological conditions in the region.

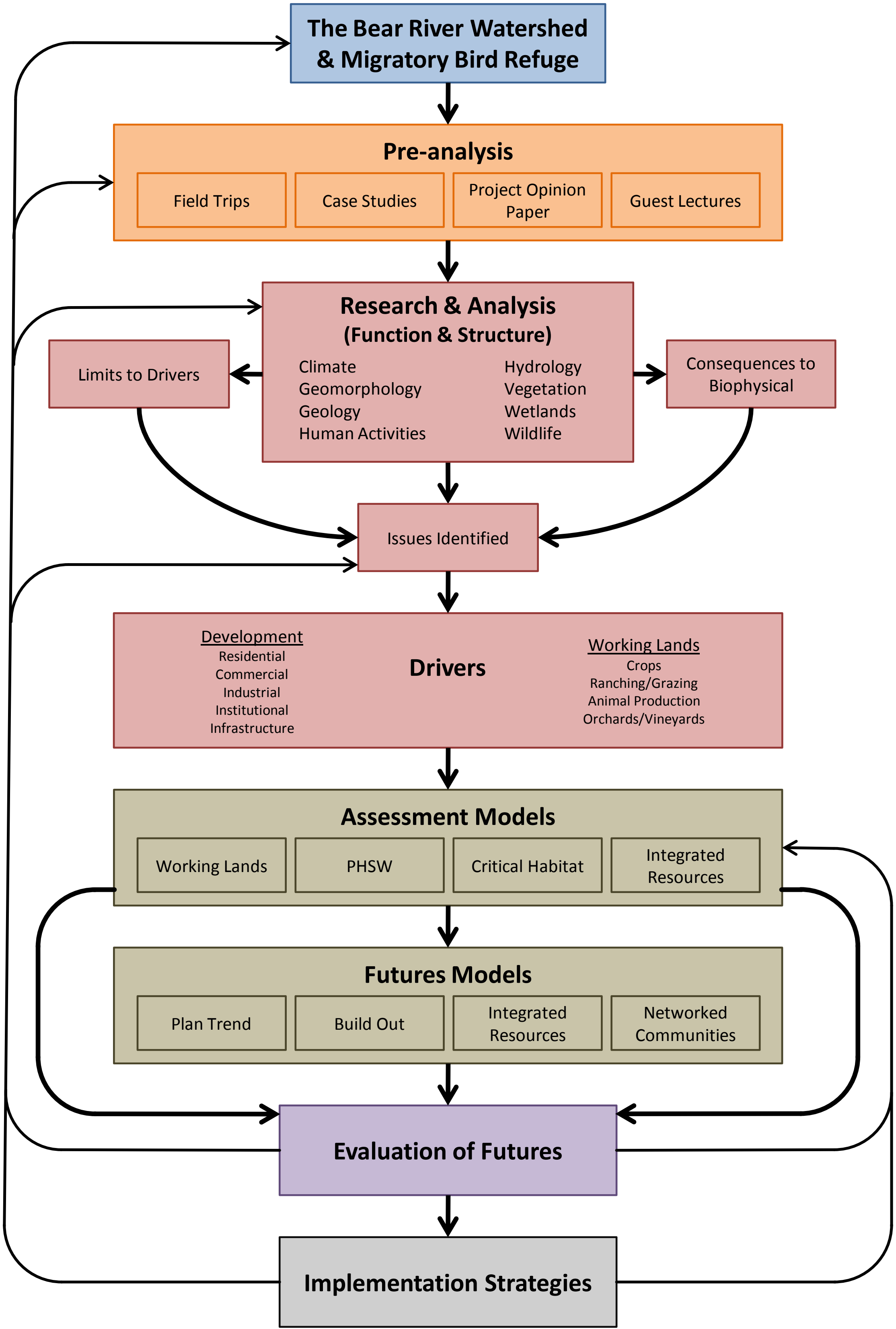


**Figure 2.1** Process Diagram

## Pre-analysis

At the commencement of this research project, the study team engaged in a series of pre-analysis activities to gain a better understanding of the attributes that contribute to the Bear River Watershed's complexity and uniqueness. This phase of the research was critical in providing a foundation for understanding the issues facing the region, especially those that impact the Bear River Migratory Bird Refuge.

Pre-analysis of the study area consisted of four primary activities: field trips, project opinion papers, case studies, and guest lectures. It is important to note that many of these activities occurred concurrently, and some were revisited throughout the research to ensure that the planning and modeling processes remained connected to the appropriate issues.

### Field Trips

The study team took five field trips to different portions of the Watershed, including an overflight in a light aircraft. The field trips were instrumental in exposing the study team to physical and biological aspects of the study area and provided insight to the region's history and culture.

Salt Creek Wildlife Management Area (Adam Perschon)

The first field trip focused on the Bear River Migratory Bird Refuge, as well as some of the surrounding wetlands and sites along the Bear River in Box Elder County. This field trip was helpful in understanding the vastness of the Refuge, the types of wildlife it supports, and the types of land use patterns immediately around the Refuge and the Bear River.

The second field trip followed closely along the Bear River, looping from Logan, Utah to Soda Springs, Idaho, to Bear Lake, and back to Logan. This route yielded insights to various agricultural practices in the region, as well as the myriad of recreational activities occurring on the Bear River, at Bear Lake, and in the mountainous areas. This field trip also introduced the study team to the Bear Lake Wildlife Refuge, another important wetland area operated by the U.S. Fish and Wildlife Service. As rural as some of the areas along this route were, development pressures were still apparent, especially seasonal homes near Bear Lake.

The destination of the third field trip was the eastern portion of the watershed, with a particular focus on the headwaters of the Bear River in the Uinta Mountains. During this trip, the study team experienced significant changes in elevation and topography, and viewed a wide variety of vegetative communities.

The fourth field trip was an overflight of the Bear River Migratory Bird Refuge and the Idaho and Utah portions of Cache Valley. The flight provided a unique opportunity to see the landscape at a very different scale than one would find on the ground and underscored both natural and human-based landscape patterns.

The fifth field trip took the study team to the Oneida Narrows in Idaho. This field trip was taken later in the research process than the other field trips due to the need for a better understanding of the potential effects of one of the proposed dam sites along the Bear River.

Geyser in Soda Springs, Idaho (Adam Perschon)

## Case Studies

Several case studies were reviewed to obtain a better understanding of general planning principles and methods. The cases reviewed consisted of a mixture of seminal planning works and more recent planning projects, all of which used different planning approaches to the issues they addressed. The process of reviewing these planning works introduced the study team to a variety of methodologies that could be used to address the issues affecting the Bear River Watershed and the Bear River Migratory Bird Refuge. The case studies reviewed were:

<u>Early Seminal Works</u>

- *The Plan and Program for the Brandywine* (Keene & Strong, 1968)
- *Design with Nature* (McHarg, 1969)
- *Regional Design for Human Impact: Upper Mississippi River Comprehensive Basin Study* (Lewis, 1969)
- *Honeyhill: A Systems Analysis for Planning the Multiple Use of Controlled Water Areas for U.S. Army Engineer* (Murray, et al., 1971)

<u>Recent Planning Projects</u>

- *Biodiversity and Landscape Planning: Alternative Futures for the Region for Camp Pendleton, California* (Steinitz, et al., 1995)
- *Guidelines for Ecological Risk Assessment* (EPA, 1998)
- *The Willamette River Basin Planning Atlas: Trajectories of Environmental and Ecological Change* (Hulse, et al., 2002)
- *Alternative Futures for Utah's Wasatch Front: Conservation of Open Space* (Toth, et al., 2002)

## Project Opinion Papers

After the first four field trips were concluded, each of the study team members wrote a project opinion paper based on their first impressions and observations of the watershed. This was a subjective interpretation of the watershed, set in the context of Lynch's framework for interpreting a particular area by identifying its paths, edges, districts, nodes, and landmarks (Lynch, 1961). This proved to be a useful tool in locating the region's movement corridors, transition zones, distinct sub-regions, areas of focused activity, and objects which bring a sense of identity to a particular area. This was a critical exercise that helped the study team better understand differing perceptions and ways of seeing the same landscape. Further, the project opinion paper helped prepare a foundation for the identification of the issues that affect the watershed and the Refuge.

## Guest Lectures

Planning at the regional level requires an interdisciplinary approach that utilizes specialists in a variety of fields to help guide the project's work. This study incorporated the use of experts the entire duration of the study in several ways. First, faculty from Utah State University (USU) met with the project team individually to discuss particular issues pertaining to their field of study. These were interactive meetings that provided greater context to the issues examined, as well as new ways at looking those issues. Second, team members also met with stakeholders within the region, most notably the management staff of the Bear River Migratory Bird Refuge. This provided additional viewpoints from a professional vantage point and helped identify some of the single most important issues facing the Refuge. Lastly, the study team presented its methodology and initial planning work halfway through the project to the USU faculty previously mentioned, but in a large group setting. This allowed the study team to receive critical feedback concerning the processes used and issues identified in the project. The large group setting generated a fruitful dialogue from those with differing opinions, highlighting new issues and approaches.

Uinta Mountain Range, the headwaters of the Bear River (Adam Perschon)

## Regional Inventory and Analysis

The Bear River Watershed is a vast basin that covers nearly 7,500 square miles of land, from mountains 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 Watershed is nestled in the northeastern portion of the Great Basin, which is unique because it is surrounded on all sides by mountains forming a large bowl which has no outlet for its water. 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 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.

Prior to entering the Great Salt Lake, the waters of the Bear River pass through the Bear River Migratory Bird Refuge. This refuge covers 74,000 acres of marsh, open water, uplands, and alkali mud flats. Established in 1928, the refuge provides critical resting points and nesting sites for hundreds of thousands of migratory birds each year - an oasis amidst a largely arid region (U.S. Fish and Wildlife Service). The livelihood of this refuge is reliant upon its primary source of water: the Bear River. Injecting its life-giving flows into the refuge, the Bear River and its tributaries directly impact the refuge’s overall ecological health and well-being. Thus, it is difficult, if not impossible, to consider any element within the refuge without considering the entire Bear River Watershed system. In order to understand how various land uses and policies implemented within the Bear River Watershed may impact the Bear River Migratory Bird Refuge, the regional inventory and analysis portion of the project analyzed the region’s biophysical elements in order to identify the driving issues for the watershed and the Refuge.

The Bear River Migratory Refuge (Danny White)

## Geology

Long before any human set eyes upon the Bear River Basin, geologic forces molded and shaped the basin in ways that made the region rich in resources and attractive for settlement. At the headwaters of the Bear, high in the Uinta Mountains, the rocks are Precambrian, dating from 570 million years ago or earlier. The Precambrian bedrock was exposed by glacial activity during the Pleistocene, creating smooth bowls that act to collect and funnel water down the Bear River (Denton, 2007).

As the river flows northward in the basin's eastern half, it follows the western edge of a Mesozoic region, which is characterized by solid structures that have little ability to absorb water. Upon entering the Bear Lake Valley and prior to turning south, the river enters the western half of the basin which is primarily composed of Paleozoic rock in the mountains and Cenozoic rock in the valleys. The Cenozoic group contains quaternary alluvial and glacial deposits which are very absorptive and lend very well to agricultural use (Haws & Hughes, 1973). Dividing the eastern Mesozoic and western Cenozoic zones in the basin is the Bear River Range, mountains that uplifted 50 million years ago. This range is an important catch basin for precipitation. The height of the range also creates somewhat of a rain shadow, decreasing precipitation on the eastern half of the basin to a degree (Denton, 2007).

The Bear River Basin sits in the northeastern portion of the Great Basin which is characterized as a huge bowl with no external outlets to the ocean (Utah Board of Water Resources, 1992). Anciently, much of this basin was covered by Lake Bonneville, a massive inland lake. Initially, the Bear River did not connect to Lake Bonneville but flowed into the Snake River further north. About 34,000 years ago, near present-day Soda Springs, lava extrusions created obstacles for the Bear, turning it south into Lake Bonneville. Experts estimate that the Bear accounted for up to one-half of the water flow into Lake Bonneville at one point. The Bear deposited great amounts of sediments in the lake each day. Much of these sediments settled in the Cache and Gem Valleys, resulting in fertile farmland (Denton, 2007).

Due to inflows from the Bear River, Lake Bonneville had begun to exceed its capacity and broke through an ice dam 14,500 years ago near what is now Downey, Idaho at Red Rock Pass. Much of Lake Bonneville drained north into the Snake River drainage system. This marked the beginning of Lake Bonneville's retreat. The Bear followed the lake southward and now flows into the lake's remnants, known today as the Great Salt Lake (Denton, 2007).

Interpretive sign at Red Rock Pass (Adam Perschon)

## Climate

According to the Koppen climate classification system, much of the Bear River Watershed is classified as Humid Continental, Mild Summer, while portions near the Great Salt Lake are classified as Mediterranean (see Figure 4.1). The variance in temperature experienced in the watershed is caused by the mountains that surround the basin. The upper valleys of the watershed experience long, cold winters and

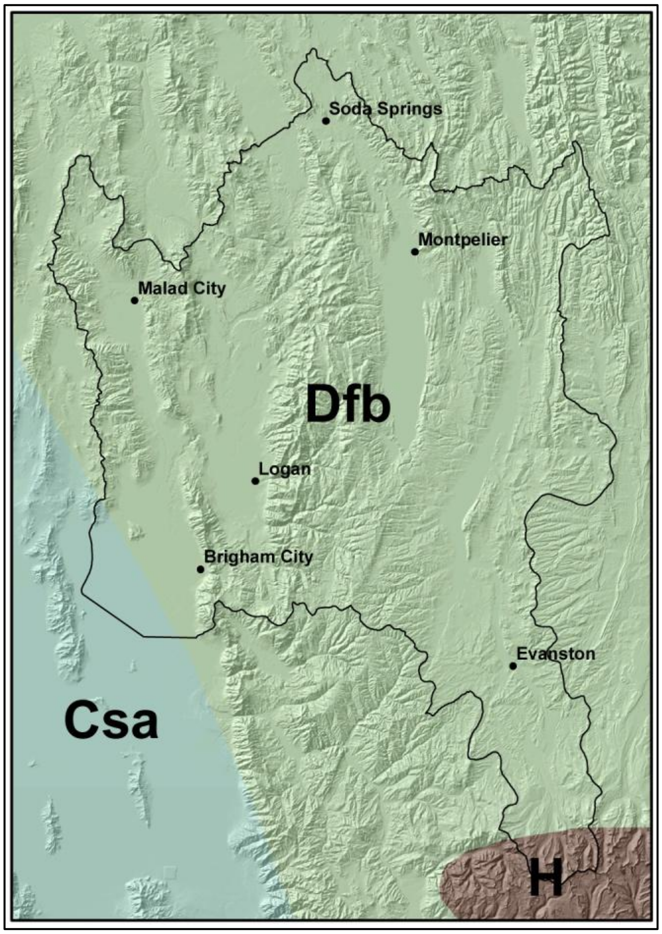


**Figure 4.1** Climate types (Gabler et al., 1997)

short, cool summers, while the lower valleys experience warmer temperatures with more variance between the lows and highs. The average annual temperature for the entire watershed is 45 degrees Fahrenheit, with a record high of 110 degrees Fahrenheit and a record low of -60 degrees Fahrenheit (Denton, 2007; Utah Division of Water Resources, 2004).

The large mountains found within the Bear River Watershed have a tremendous impact on the distribution of precipitation throughout the region. As elevation increases, so too does the amount of precipitation. Much of the lower valleys receive as little as 10 inches, whereas the higher elevations, such as the headwaters of the Bear River, can receive up to 65 inches per year (see Figure 4.2) (Utah Division of Water Resources, 2004). The major storm systems that impact the region include frontal systems from the Pacific Northwest during the winter and spring and thunderstorms that approach from the south and southwest in late summer to early fall (Utah Division of Water Resources, 2004). Since the majority of the storm systems approach from the west, the large mountain ranges such as the Bear Rive Range cause a rain shadow effect, leaving the east facing slope of the mountains relatively dry while the western slopes receive higher amounts of precipitation, comparatively.

Precipitation rising over the Wellsville Mountains (Danny White)

## Hydrology

Understanding the hydrology of a watershed is critical to understanding its function. A watershed, also referred to as a catchment, basin, or drainage area, is a basic hydrologic unit defined as the “area of land where all of the water that is under it or drains off of it goes into the same place” (US EPA, 2009). This is not the process of water simply flowing into streams, lakes, or oceans. On the contrary, a watershed is a complex network in which water moves across and beneath the earth’s surface through diverse processes from a variety of sources. The Bear River Basin is no exception – its waters undergo dynamic

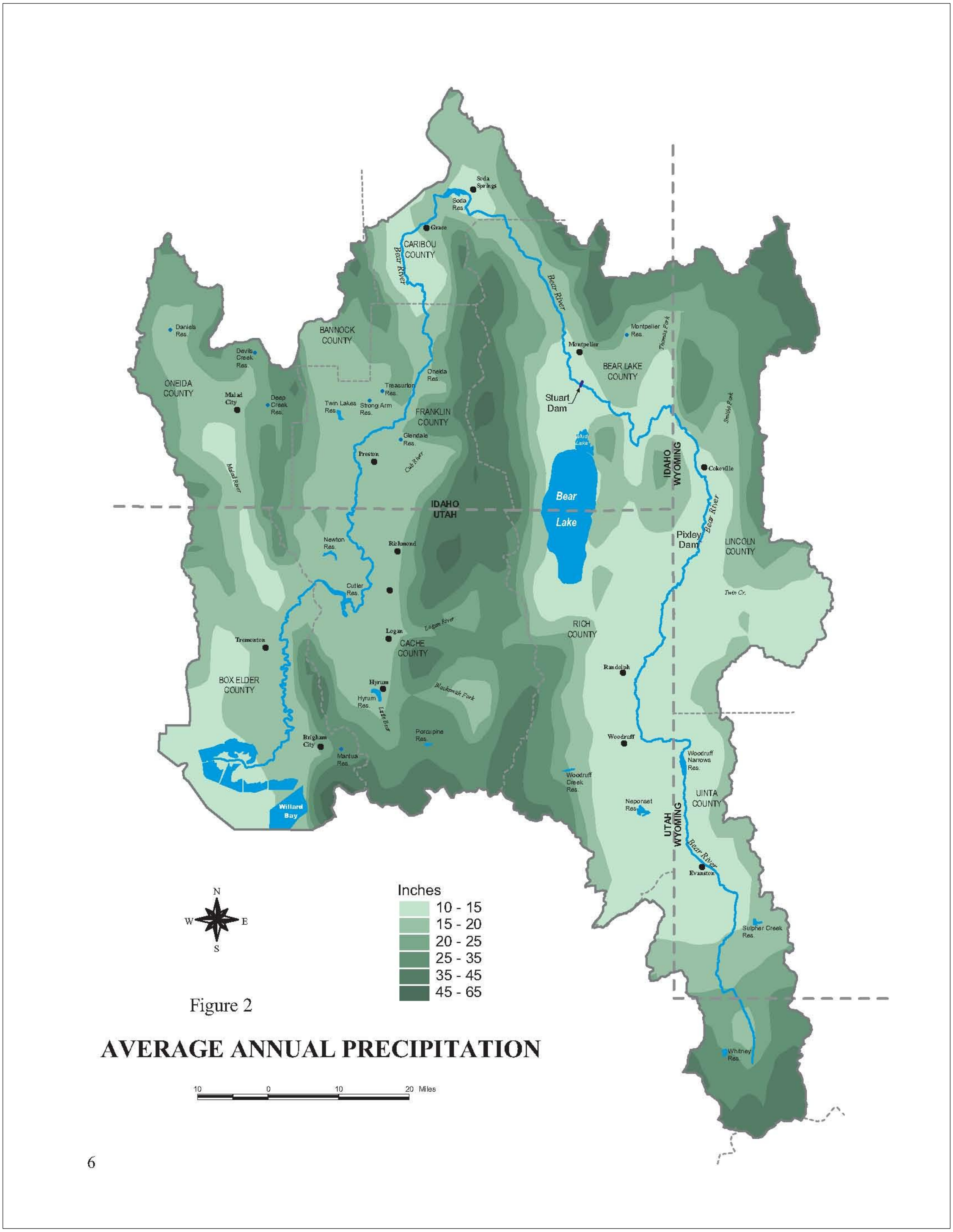


**Figure 4.2** Average annual precipitation in the Bear River Watershed (Utah Division of Water Resources, 2004)

hydrologic processes that ultimately determine the quality and quantity of water delivered to the Bear River Migratory Bird Refuge. To better understand these dynamic processes at work within the Bear River Basin, a basic overview of hydrology is necessary.

Simply defined, hydrology "is the science that deals with the processes governing the depletion and replenishment of water resources of the land areas of the earth" (Wisler & Brater, 1959, p. 1). Much like energy, water on a global scale is never created or destroyed, but adheres to a budget. Instead, it "moves in its different phases through the atmosphere, down over and through the land, to the ocean and back up to the atmosphere" (Brutsaert, 2005, p. 2). This is known as the water or hydrologic cycle (see Figure 4.3). Driving this cycle is the sun, which supplies the needed energy to transition water molecules from the ocean to the atmosphere through the process of evaporation. As water in the atmosphere moves inland, it rises and cools, resulting in various forms of precipitation. As precipitation reaches the ground, it moves along and beneath the earth's surface, eventually returning to the ocean to complete the cycle (Gutting, Houghten, & Snyder, 1979). The processes water undergoes as it moves through the atmosphere (precipitation and evaporation), along the earth's surface (surface water), and beneath the earth's surface (ground-water) are critical to understanding the hydrologic cycle.

The physical and climatic characteristics of the Bear River Basin impact the region's precipitation and evaporation to a large degree. The drastic differences in elevation within the region cause large disparities in precipitation, which can be readily seen in Figure 4.2.

The basin is also comprised of alternating mountains and valleys that are vertically oriented, with weather patterns moving primarily from the west. This results in orographic precipitation in the mountains, primarily on the west-facing slopes. Evaporation is impacted in many ways throughout the region, most notably by aspect. South-facing aspects receive more solar energy, which impacts vegetative cover and increases the evaporation rate.

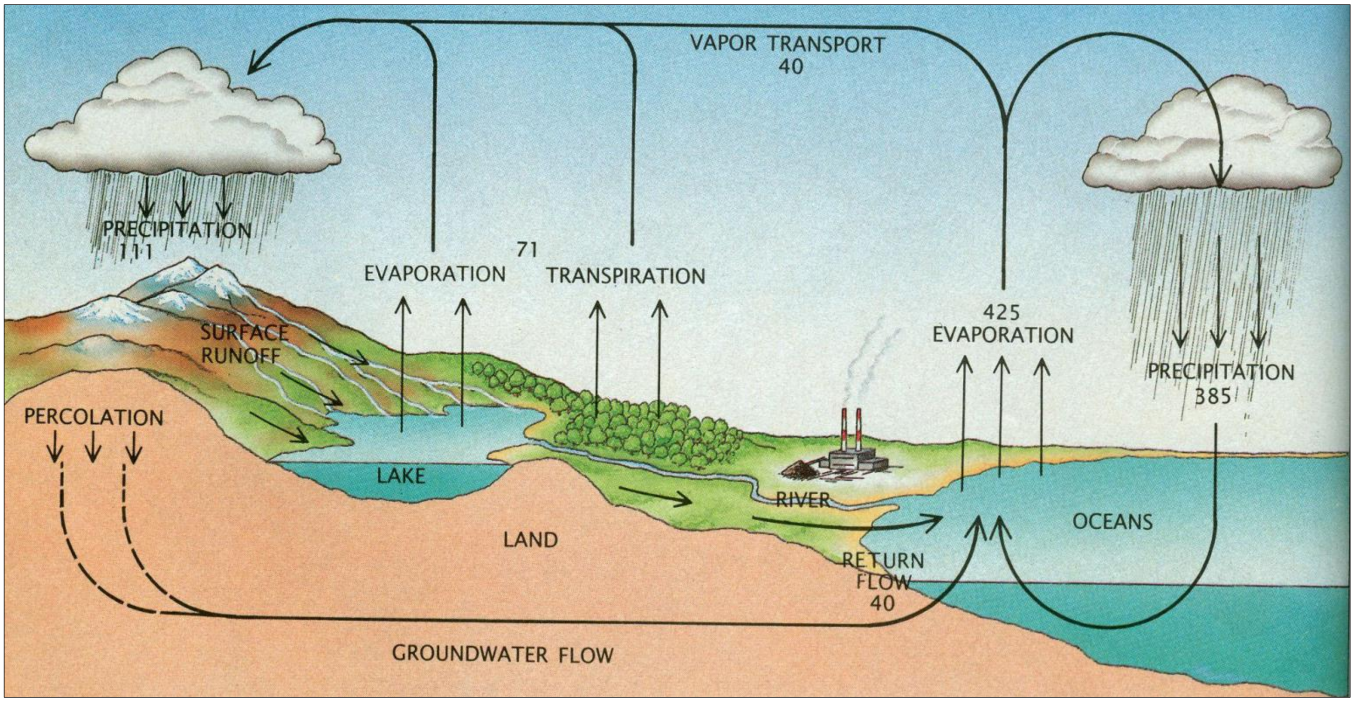


**Figure 4.3** The hydrologic cycle (Scientific American, 1989)

Impact of aspect on vegetative cover (Adam Perschon)

### Surface Water

Once precipitation makes contact with the earth's surface, it will either infiltrate the ground or begin to make its way toward depressions in the earth's surface (Wisler & Brater, 1959). Water that takes the latter route is collectively known as surface water and can form as runoff, flow in rivers and streams, or be deposited into water bodies, such as lakes or oceans (Gutting, Houghten, & Snyder, 1979). Precipitation can enter any of these forms of surface water directly but, when contacting soil first, it will typically flow through these stages first as runoff, second as streams and rivers, and finally as water bodies.

Rivers and streams are the primary channels through which water is transported from the land to the ocean (Gutting, Houghten, & Snyder, 1979). Historically, the Bear River was a tributary to the Snake River, which does flow into the sea. Due to lava flows turning the Bear River to the south, the Bear River Basin is unique in that its waters never reach the ocean but instead end their journey in the Great Salt Lake, a shallow inland sea (Denton, 2007). Rivers are characterized as open systems that have a continuous movement in one direction, change volume and velocity, have extreme level fluctuation, exhibit little stratification, and have continuous turbulence. The primary sources of water for rivers and streams are direct precipitation, overland flow, and groundwater (Gutting, Houghten, & Snyder, 1979). The characteristics of river channels are discussed in more detail in the fluvial section of this paper. The Bear River is the largest river within the Bear River Basin. Its largest tributaries include the Logan, Blacksmith Fork, Little Bear, and Smiths Fork rivers (Utah Division of Water Resources, 2004).

Water bodies, such as lakes and ponds, are closed systems that develop in depressed or enclosed areas that are fed by a water source, primarily rivers and streams. Water can also enter lakes and ponds through direct precipitation and overland flow (Gutting, Houghten, & Snyder, 1979). One of the main functions of a water body is storage.

Water storage needs have resulted in many man-made water bodies, especially in relatively arid regions like the Bear River Basin where numerous reservoirs have been established. Even Bear Lake, a large natural lake of note in the basin, is partially used for irrigation storage. Water bodies act to slow the flow of river water, allowing the deposition of sediments and creating large water surfaces that lend to faster evaporation rates. Water bodies also create important wildlife habitat and provide multiple recreational opportunities.

### Groundwater

Water that infiltrates the soil surface and enters saturated zones is groundwater. Groundwater is important to the hydrologic cycle and is critical to life within a watershed. Groundwater contributes 30% of all stream flow in the United States and comprises over 97% of liquid freshwater on the earth (Brooks, Ffolliott, Gregersen, & Thames, 1991). The Bear River Basin benefits immensely from its groundwater, the majority of which is potable with little or no treatment. Essentially all domestic, municipal, and industrial water in the basin comes from high-quality ground sources (Utah Division of Water Resources, 2004).

Aquifers are replenished through recharging, which is simply the process of surface water moving down into the groundwater. Because aquifers can be quite large, areas of recharge are not always easy to locate. In general, recharge areas are found higher in elevation than the aquifer on soils that are permeable and receive excess precipitation, such as upland forested areas (see Figure 4.4) (Brooks, Ffolliott, Gregersen, & Thames, 1991).

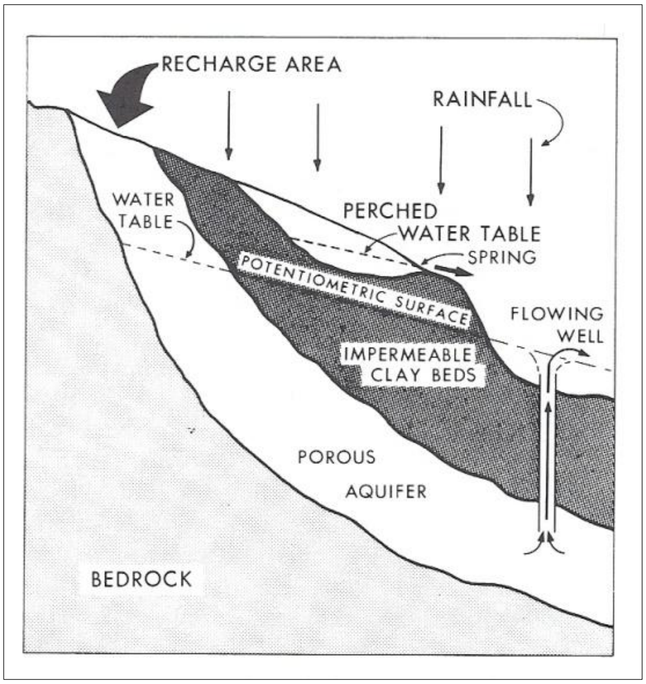


**Figure 4.4** Groundwater recharge process (Brutsaert, 2005)

## Fluvial Geomorphology

### Channels

As precipitation flows down slope, it builds in velocity and depth. Once the depth of the flowing water is able to shield the ground from splashing rain drops, and the velocity is high enough to begin carrying sediment, rills are formed (Leopold, 1994). Rills are small channels that carry runoff to larger channels like creeks and streams. Over time, rills may become eroded by the flowing water, widening their banks; if this continues for an extended period of time, the rill could become a creek or stream. It is also possible that over time these rills could be filled with sediment and no longer carry any water.

An example of a rill (Danny White)

Streams form further down the slope in catchments and are fed by a combination of rills, surface flow, and groundwater exfiltration. Perennial streams are those which carry water in their channel year-round, while ephemeral streams only carry water during the rainy season. There is a wide range of variability in the size of streams, which is why Horton and Strahler developed a classification system to order streams. In this system, a stream that receives no input from tributaries but still has a year-round flow is classified as a first order stream. When two first order streams meet, they form a second order stream; at the confluence of two second order streams a third order emerges, and so on (see Figure 4.5).

Although there is no definite size that distinguishes between creeks, streams, and rivers, it is generally understood that creeks and streams are younger in their geomorphic process than rivers. Rivers generally consist of the confluence of many streams, and large rivers, including the Bear River, consist of the confluence of many rivers.

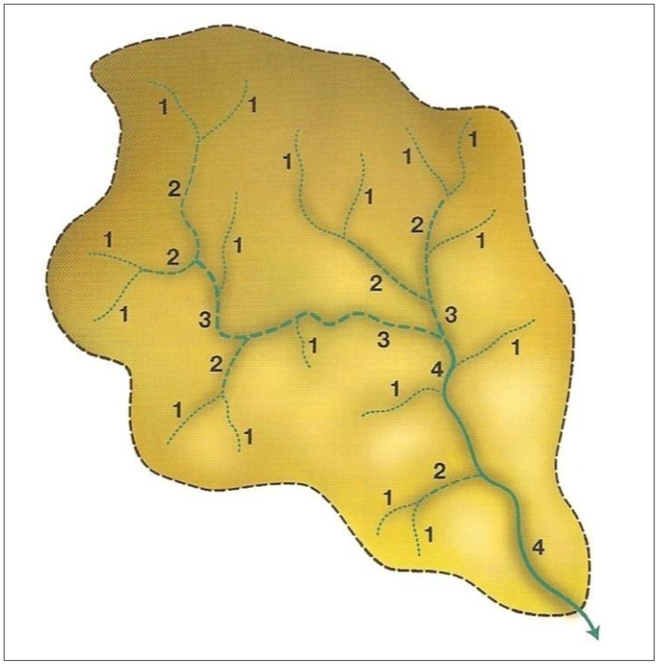


**Figure 4.5** Horton & Strahler stream ordering (Naiman, 2005)

The two primary functions that rivers perform are the transportation of water and the erosion and deposition of sediment. One way sediment is introduced to the river is by sheet flow over the soil surface. On steep slopes velocity increases and erosion of the soil occurs; if this overland flow continues to have a high velocity it will deposit the sediment into the river. Erosion also occurs in the river channel itself, especially on the outside edge of a river bend. Over time the river channel will begin to move laterally across the landscape as these processes of erosion and deposition continue to occur. It is important to note that, as the channel erodes along the outer bank, it deposits sediment along the inner bank so that the width of the channels remains nearly constant (Leopold, 1997).

Through the course of many generations of erosion and deposition, a meandering channel will shift, forming tighter and tighter meanders. Often these tightly formed loops will turn back on themselves; when this occurs, an oxbow lake is formed (Lamberti, 2007).

### Floodplain

All rivers experience periods of high discharge as a result of heavy precipitation. The river channel is not formed to handle such events; in fact, it is only capable of handling a discharge of modest size (Leopold, 1997). When a discharge is too great for the river channel to contain, the water must flow over the valley floor. This area of high discharge overflow makes up the river's floodplain. Most rivers will experience discharges "in excess of bankfull capacity approximately 2 or 3 times a year" (Leopold, 1997).

Floodplains are typically absent from headwaters but start to appear where ephemeral streams become perennial and the influence of groundwater becomes strong enough to affect the flow (Leopold, 1997). In these small perennial streams, the floodplain can be as small as a few feet wide.

## Wetlands

Although they cover only 6 percent of the earth's surface, wetlands are disproportionately important to ecology as they support both terrestrial and aquatic biota (Sharitz, 2006). They are also of significant importance because of their ability to store water runoff, reducing the impacts of floods, and their ability to filter toxins in the water.

Cold Water Lake near Mendon, Utah (Danny White)

## Wetland Hydrology

“The hydrology of a wetland creates the unique physiochemical conditions that make such an ecosystem different from both well-drained terrestrial systems and deepwater aquatic systems” (William J. Mitsch, 2007). By definition, all wetlands are saturated for at least some duration (hydroperiod) during the year. This hydroperiod will determine the chemistry of the soil, the ability of organic matter to decompose, and the floristic diversity and density of the wetland (Sharitz, 2006).

A wetland’s hydrology is a function of the climate of the region in which the wetland is located. Cool, moist climates such as those found in Alaska tend to have a lower evapotranspiration rate, while climates in Utah are much drier and warmer, resulting in more moisture loss to evapotranspiration. The second function is that of the geomorphology of the basin. Landscapes that are dominated by steep slopes tend to have fewer wetlands than landscapes that are flat or gently sloping. When the two functions of hydrology and geomorphology are combined, they are referred to as the wetland’s hydrogeomorphology (Mitsch, 2007).

## Wetland Soils

Soil represents the layer of the earth’s surface where “plants, animals, and microorganisms interact with the hydrologic cycle and other elemental cycles” (Sharitz, 2006).

Generally, soils are oxygen enriched or aerobic but, when they are saturated for an extended period of time (such as in wetlands), they become oxygen deficient or anaerobic. As this occurs, the physical and chemical properties of the soil begin to change. Physical properties of soil such as bulk density, porosity, soil texture, and soil structure are especially important to wetland function and formation, because they directly impact the ability to retain moisture (Sharitz, 2006). Soils with fine texture, such as clay and silt, have a low porosity and high bulk density, which result in a high capacity to retain moisture. These soils can also function as a shallow aquitard (a material within the substrate that does not allow water to easily pass through) which will perch water above its surface leading, to saturated soils.

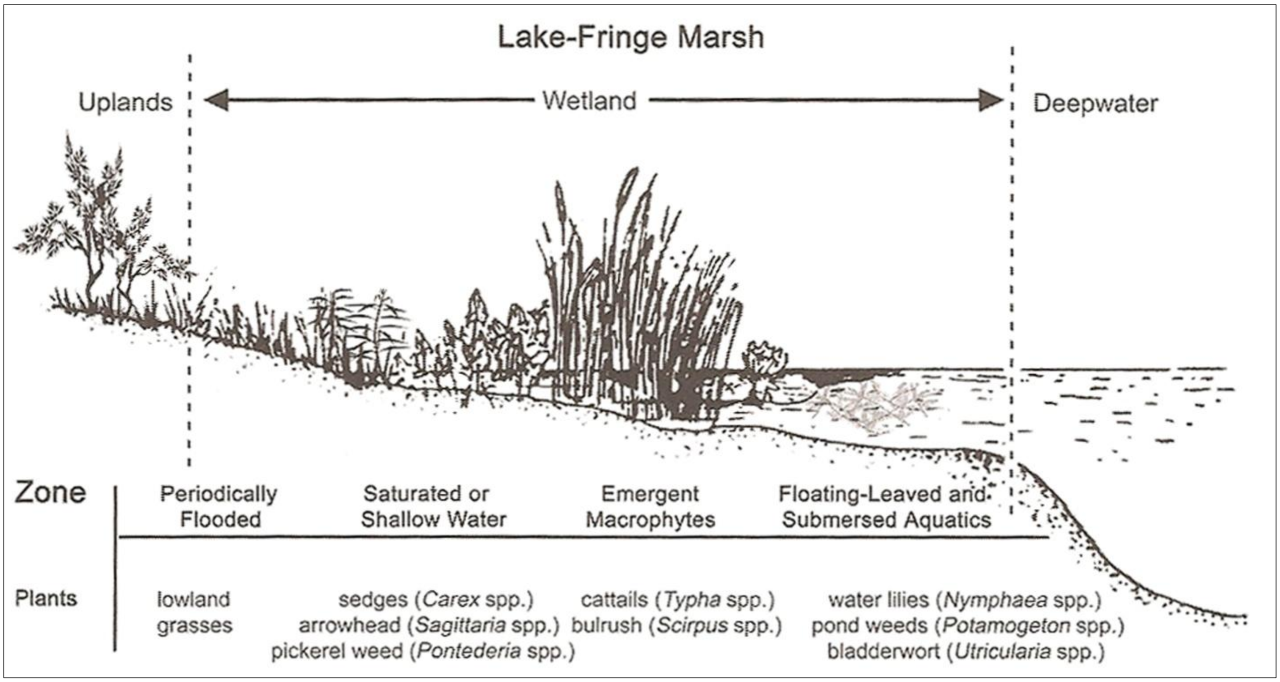


**Figure 4.6** Differentiation of wetland types as a function of their proximity to and depth of water (Sharitz, 2006)

### Wetland Vegetation

Wetland plants are influenced by a wide range of abiotic factors such as the position on the landscape, substrate, hydrologic conditions, climate, fertility, and environmental stress, and a variety of biotic factors including competition and herbivory. Many wetland soils are saturated for extended periods of time throughout the year, requiring wetland vegetation to be able to grow in anaerobic conditions. Hydrophitic plants are those that have adapted to living on or in aquatic environments.

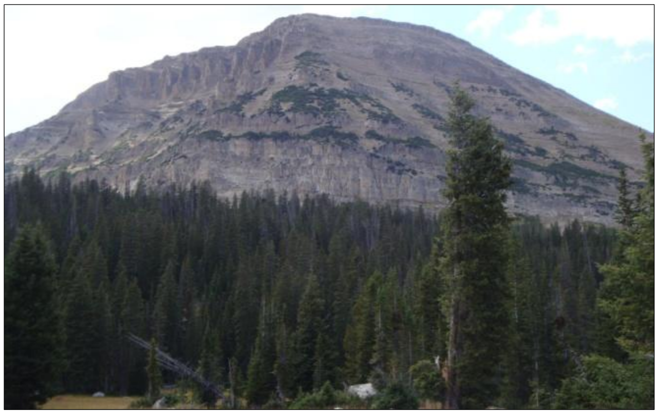
Although, by definition, all wetlands must have hydric soils, there is considerable variability in hydrology, which affects the floristic diversity of the wetland (Sharitz, 2006). Wetlands that experience prolonged periods of flooding or saturation will have a lower diversity of vegetation than wetlands that drain seasonally, such as a wet meadow. The proximity to the water table or a body of water can also determine the types of wetland vegetation that will be found (see Figure 4.6).

## Vegetation

The Bear River Watershed lies within the Intermountain West, which is characterized by dry weather and large mountain ranges. Low precipitation rates are the driving force behind the semi arid conditions, while the mountains shape the native vegetation by creating environmental extremes (Mee, 2003). As a result of these environmental extremes, such as slope, aspect, elevation, and soil type, there are many different plant communities that make up the vegetative cover of the Bear River Watershed.

### Subalpine

Within the elevation range of 8,000 and 11,000 feet lays the subalpine plant community, which may vary with aspect. This plant community is the upper limit of the timberline, above which very little grows. The growing season in this community is very short, and it is not uncommon for frost to occur even during the warmest months of the summer. As such, the plants that grow here must be extremely hardy which is why 70 percent of the tree cover is made up of coniferous species.



Subalpine community in the Uinta Mountains (Danny White)

### Montane

The montane community falls within the elevation range of 6,000 to 9,000 feet and is made up of four sub-communities consisting of montane parkland, montane coniferous forest, aspen forest, and montane meadow.

The **montane parkland** is set within the lower range of rainfall within the montane zone and is made up of ponderosa pine, douglas-fir, and quaking aspen, with total vegetative cover of 30 to 60 percent (Mee, 2003). Plant species such as bearberry, currant, and a mixture of grasses can be found along the understory of this sub-community.

Montane parkland near Peter’s Sink in the Bear River Range (Danny White)

The **montane coniferous forest** sub-community is typically found at the higher reaches of this zone and along the north and east facing slopes, which receive higher levels of precipitation and experience less evaporation. As a result of the higher precipitation, the vegetative cover is more dense (65 to 90 percent) (Mee, 2003). Douglas-fir is the dominate tree species of this zone with shrubs such as snowberry, ninebark, currant, and mountain lover.

The **aspen forest** sub-community is typified by dense forests of quaking aspen (which are actually clonal stands) with vegetative cover of 65 to 90 percent, which is also due to higher amounts of precipitation (Mee, 2003). This zone occurs throughout the montane plant communities and is typically found in areas of recent disturbance, such as avalanche or fire. Quaking aspen form the dominate tree cover for this zone, with an understory consisting of snowberry, rose, ninebark, and mountain-ash.

The **montane meadow** sub-community occurs where there is little drainage, inhibiting the growth of aspen and coniferous trees. Plants that make up this zone are mostly herbaceous and grass species such as sticky geranium, Indian paintbrush, mule's ear, showy cinquefoil, wild sweet pea, wild rye timber oatgrass, and mountain brome.

Foothills

The foothills plant community is located at an elevation range of 4,000 to 7,000 feet along the lower mountain slopes, just before they reach the valley bottom. As a result of its elevation above the valley floor, it experiences the greatest urbanization of all of the plant communities in the Intermountain West. Plants living within this community only receive 12 to 18 inches of precipitation per year. This community is also broken into sub-communities consisting of mountain brush, pinyon juniper, mountain mahogany forest, and shrub steppe communities.

The **mountain brush** sub-community is dominated by trees like the bigtooth maple and gambel oak, with an understory consisting of snowberry, creeping Oregon grape, big sagebrush, woods rose, and alderleaf mountain mahogany (Mee, 2003). Vegetative density for this zone ranges from 45 to 75 percent.

The **pinyon juniper** sub-community can be found in slightly drier areas that receive 12 to 16 inches of rainfall per year and is the dominate community in the Great Basin area. At its upper limits it is constrained by cold temperatures, while at its lower limits it is constrained primarily by the lack of precipitation. As elevation increases, the pinyon juniper sub-community changes from a Utah juniper dominated forest, to a juniper-pinyon mixed forest, to a solid pinyon pine forest at its upper reaches.

The **mountain mahogany forest** is a variation of the mountain brush sub-community with the dominate tree cover being mountain mahogany. The elevation range for this zone is from 6,000 to

Typical aspen forest in Logan Canyon (Danny White)

7,000 feet and forms primarily on well-drained soils (Mee, 2003). Vegetation cover is sparse, with a density range of 40 to 60 percent and, because mountain mahogany is an evergreen, very little light penetrates to the understory, resulting in very little vegetation near the ground. Black sage and a number of grasses can be found occupying the gaps within this community.

The **shrub steppe** sub-community lies at the lower and drier reaches of the foothills community and is typically found between 4,000 to 6,000 feet in elevation. This zone is distinguished by its lack of a dominate tree species. Its dominate vegetation consists of mountain big sagebrush and basin big sagebrush, with rubber rabbitbrush, dwarf smooth sumac, bitterbrush, and several species of grass making up the sub-dominate vegetation.

### Lowland Desert

The lowland desert community is typically found between 3,000 to 6,000 feet in elevation, on flat valley bottoms. This community is the driest of the Intermountain West, receiving only 5 to 10 inches of precipitation a year. As a result of the lack of moisture, vegetative cover only ranges from 10 to 40 percent (Mee, 2003).

The **cool desert** sub-community occurs in Utah where exposed parent material is present or where deep alluvial deposits have been left by ancient floods. The dominate shrubs of this zone are Mormon tea, Wyoming big sagebrush, and winterfat, with rubber rabbitbrush and matchbrush occupying the disturbed areas (Mee, 2003). Sub-dominates include a variety of grasses and herbaceous plants such as Dorr sage.

The **salt desert shrub** sub-community is found where drainage is poor and where soils are fine textured and frequently hydrophobic. Salts often build up on the soil surface as water is evaporated from deep within the soil, creating a harsh environment for plants. The dominate shrub species include shadscale, Gardner saltbrush, black greasewood, and lacey buckwheat. Sub-dominates include winterfat, matchbrush, and rubber rabbitbrush.

The **sand desert** sub-community is very similar to the salt desert shrub community, although the plants tend to be bigger. Green Mormon tea, furrowing saltbrush, and a variety of yuccas are the dominate plants of this zone. Some of the sub-dominates of this zone include evening primrose, verbena, and penstemon.

### Riparian Community

The riparian plant community occurs near the banks of rivers and streams and occurs in almost all of the elevation ranges, with the exception being above 11,000 feet. Dominant plants of this community consist of cottonwood and willow species. Other trees that occur in this community include western water birch, aspen, thinleaf alder, and black hawthorn. This community has an average tree canopy cover of 45 percent, with trees reaching up to 120 feet in height.

A shrub layer is typical at lower elevations and becomes dominate at higher elevations where cold temperatures and high wind limit tree cover. Red-osier dogwood, woods rose, and Rocky Mountain maple make up the dominate shrubs found in the riparian zone.

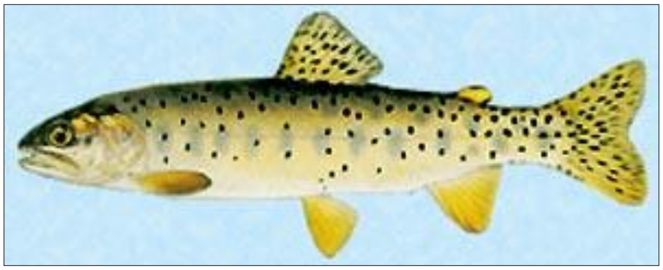
Typical riparian community, Ogden River (Danny White)

Dry riparian zones are areas that have a higher percentage of moisture than the surrounding soil yet only have water in the drainage intermittently. There is typically enough moisture in these zones to affect the type of vegetation growing along the banks.

## Wildlife

The Bear River Basin supports a large number and a wide variety of wildlife species. A range of habitats can be found in the basin, a product of differences in topography, vegetation communities, and the amount of water present throughout the region. Part of this habitat is found in the basin's 1,100 square miles of forestland, and more than 160 square miles of wetlands. More than one-third of the region is covered by lands administered by the Forest Service, BLM, and U.S. Fish and Wildlife Service (USU - Utah Water Research Laboratory, 2009). The state of Utah also manages several wildlife management units in the basin, designed to maintain and improve wildlife habitat. The Basin also sits on the edges of both the Pacific and Central Flyways, which are important migratory paths for numerous bird species (see Figure 4.7).

The Bear River Basin's network of streams, rivers, lakes, and even reservoirs provide plentiful habitat for a variety of fish. The region is known for several blue ribbon fisheries, including Bear Lake, Mantua Reservoir, Woodruff Reservoir, and the Blacksmith Fork and Logan Rivers (Utah Division of Wildlife Resources, 2009). Other portions of the Bear River, such as at Black Canyon in Idaho, are under consideration of blue ribbon status as well (Denton, 2007). Cold-water species are generally found in the upper areas of the Bear River and its tributaries, while warm water species stay within the lower Bear River on the west side of Cache Valley and in Box Elder County. Typical cold-water species include rainbow, brown, and cutthroat trout, mountain whitefish, and even Kokanee salmon. Common warm-water species are largemouth bass, bluegill, yellow perch, catfish, and carp. The wide variety and distribution of fish within the region creates plentiful fishing opportunities. An important species to note is the Bonneville cutthroat. Historically, the Bonneville cutthroat was found in up to 90% of the freshwater in the Bonneville Basin, but only remnant populations remain, many of which are within the Bear River Basin (Denton, 2007). Bear Lake is also home to four fish not found anywhere else in the world: the Bonneville Cisco, Bonneville whitefish, Bear Lake Whitefish, and the Bear Lake scalping (U.S. Geological Survey, 2001).



Bonneville cutthroat (U.S. Fish and Wildlife Service)

One of the most heavily used wildlife areas within the basin is the Bear River Migratory Bird Refuge, which is comprised of 74,000 acres of marsh, open water, uplands, and alkali mudflats administered by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service, 2009). This refuge is the last stop for the Bear River before its waters reach the Great Salt Lake. Hundreds of thousands of migratory birds utilize the refuge each year as nesting and resting stops along their migration routes. According to the U.S. Fish and Wildlife Service, 212 bird species occur on the refuge on a regular basis, 72 of which are known to breed there. An additional 36 species come within the refuge on rare or irregular intervals. Common types of birds in the refuge include a variety of ducks, swans, geese, pelicans, ibises, cormorants, herons, egrets, coots, and gulls (U.S. Fish and Wildlife Service, 2006). The wide variety of birds attracts large numbers of birders, photographers, and waterfowl hunters each year.

Another important wildlife area within the basin is the Bear Lake Wildlife Refuge, also administered by the U.S. Fish and Wildlife Service. The refuge is located immediately north of Bear Lake in southeastern Idaho. Fewer species and numbers of migratory birds use this refuge than the Bear River Refuge, but it still provides critical habitat and nesting sites for a variety of species. The refuge currently focuses on providing habitat for redhead and canvasback ducks, trumpeter swans, and white-faced Ibis, species that have experienced historical declines. Silt flowing into the refuge, and carp stirring up mud in its bottoms, have degraded much of the habitat within the refuge's boundaries (U.S. Fish and Wildlife Service, 2009).

In addition to waterfowl and shorebirds, raptors also migrate through the Bear River Basin in substantial numbers. The Wellsville Mountains, located in the southwestern corner of the basin, were one of the first areas for standardized raptor migration counts in the western United States. It serves as an important monitoring location along the Wasatch Range in Utah, which sits along a transition zone between the Rocky Mountain and Intermountain regional flyways. Annual raptor counts at the Wellsville Study area range between 2,400 and 5,600 birds of up to 17 species (Hawk Watch International, 2009).

Terrestrial habitat within the basin provides for big game, such as elk, deer, moose, and pronghorn. Upland game, such as pheasants, chukars, Hungarian partridge, sage grouse, forest grouse, doves, and rabbits can also be found throughout the region. Big game and upland species provide for popular wildlife viewing and hunting opportunities. The basin is also home to furbearers, such as beaver, muskrat, and raccoons, as well as non-game species (Utah Board of Water Resources, 1992). Due to the large proportion of land within the basin that is publicly owned, much of the terrestrial wildlife habitat is still intact. However, increased development continues to creep ever closer to that habitat, cutting off some migration routes and encroaching upon winter feeding grounds.

Red-tailed hawk (Utah Division of Wildlife Resources)

## Human Activities

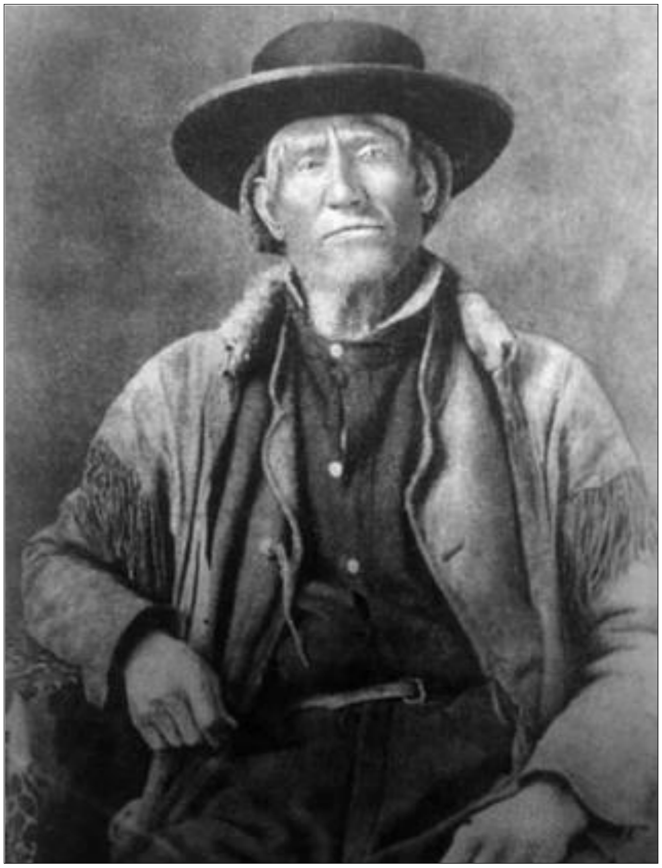
### Discovery and Settlement

The Bear River's first inhabitants appeared between 12,000 to 15,000 years ago. They were largely nomadic people, wandering around the Great Salt Lake and the Great Basin. Some theorize that this group evolved into the Fremont culture, a group that existed from the 4th to the 14th centuries. The Fremont people used the lower Bear River and surrounding wetlands for farming, as well as a staging area for hunting and gathering activities. Around the 14th century, the Fremont culture declined, giving way to more modern Native American tribes. The most common tribes in the basin were the Shoshones and the Bannocks (Denton, 2007).

Reports from Lewis and Clark's expedition along the Missouri and Columbia Rivers sparked the beginning of the fur trade in the Central Rock Mountains. Fur trappers, known as mountain men, began exploring the Rockies in search for beaver, which were plentiful (Haws & Hughes, 1973). Jim Bridger, one of the most famous of the mountain men, is credited as the first white man to float down the lower Bear into the Great Salt Lake. Bridger worked for the American Fur Company, which operated within the basin. Two British fur companies, the Hudson Bay and North West, also operated within the region. To facilitate fur trading and consolidate fur shipments to the eastern United States, these fur companies set up rendezvous each summer. Sixteen rendezvous were held in the Rockies between 1825 and 1850, several of which were held in the basin at Bear Lake and near present-day Hyrum, Utah. In between rendezvous, each mountain man would store or "cache" his furs, hiding them from other trappers and Native Americans. A popular area to store the furs was the Cache Valley, from which it derives its name (U.S. Soil Conservation Service, 1978).

Before the end of the fur boom and subsequent demise of the trapper era, Americans were moving westward, creating a myriad of trails through the basin and surrounding areas. One of the more famous immigration routes, the Oregon Trail, cut through the northern end of the basin from Fort Bridger to Soda Springs, Idaho. Those passing through to California developed a number of trails to the south of the basin that went around the Great Salt Lake.

Among the groups moving west were members of the Church of Jesus Christ of Latter-day Saints, or Mormons. In 1847, the Mormon leader, Brigham Young, settled his group near the Great Salt Lake. They soon established Salt Lake City and began colonizing cities throughout the region.



Jim Bridger (The Mountain Man Project)

Mormon settlement in the basin began in Box Elder Valley in 1851 and Cache Valley in 1856. Most of the towns in the basin were settled in typical Mormon fashion, with the streets laid out in block fashion with a north-south and east-west orientation. The only two towns in the basin not built around agriculture were Corinne, Utah and Evanston, Wyoming, both of which were built to support the railroads.

Due to the semiarid nature of the region, the Mormon settlers went to great lengths to divert water from the basin's rivers and streams to irrigate their crops, at which they were very successful. The early irrigation methods set a pattern for the region that is still widely in use today and established water claims that have been and will continue to be a source of strain on water users throughout the watershed (U.S. Soil Conservation Service, 1978).

Present-Day Use

The agricultural lifestyle upon which the Bear River Basin was settled persists today, although residential development in Box Elder County and in Cache Valley is beginning to change this sense of community to some degree. Approximately one-third of all private lands within the basin are still used for agricultural purposes (USU - Utah Water Research Laboratory, 2009). In the Utah portion of the basin, the net decrease in irrigated cropland was only 1 percent for the period between 1986 and 2003, most of which was in Cache County. Most of the agricultural land lost to development in recent years has been areas of dry-farmed land. Agriculture continues to be the largest consumer of the basin's developed water, accounting for 94 percent of the total developed water used on an annual basis. Municipal and industrial use accounts for the other 6 percent of water used within the basin (Utah Division of Water Resources, 2004).

Human populations continue to expand throughout the basin, with growth centered in the Cache Valley. The western half of the basin, in which Cache Valley is located, is well connected to the more populous Wasatch Front to the south, making it relatively easy for residents to commute to those metropolitan areas. Cache Valley is also home to Utah State University, which acts as an economic anchor that attracts residents to the basin. The eastern half of the basin has historically been sparsely populated and will most likely continue this trend. At the time of the 2000 census, the population of the Utah portion of the basin was just over 136,000, which is projected to increase to nearly 300,000 by 2050 (Utah Division of Water Resources, 2004).

One of the qualities of the Bear River Basin that continues to attract residents and visitors to the region is the plethora of recreation opportunities available. The basin offers substantial wildlife interactions, including birding, photography, wildlife viewing, hunting, and fishing. The rivers, streams, lakes, and reservoirs provide boating, canoeing, and kayaking settings, while the mountains offer hiking, backpacking, horseback riding, skiing, snowmobiling, and ATV riding.

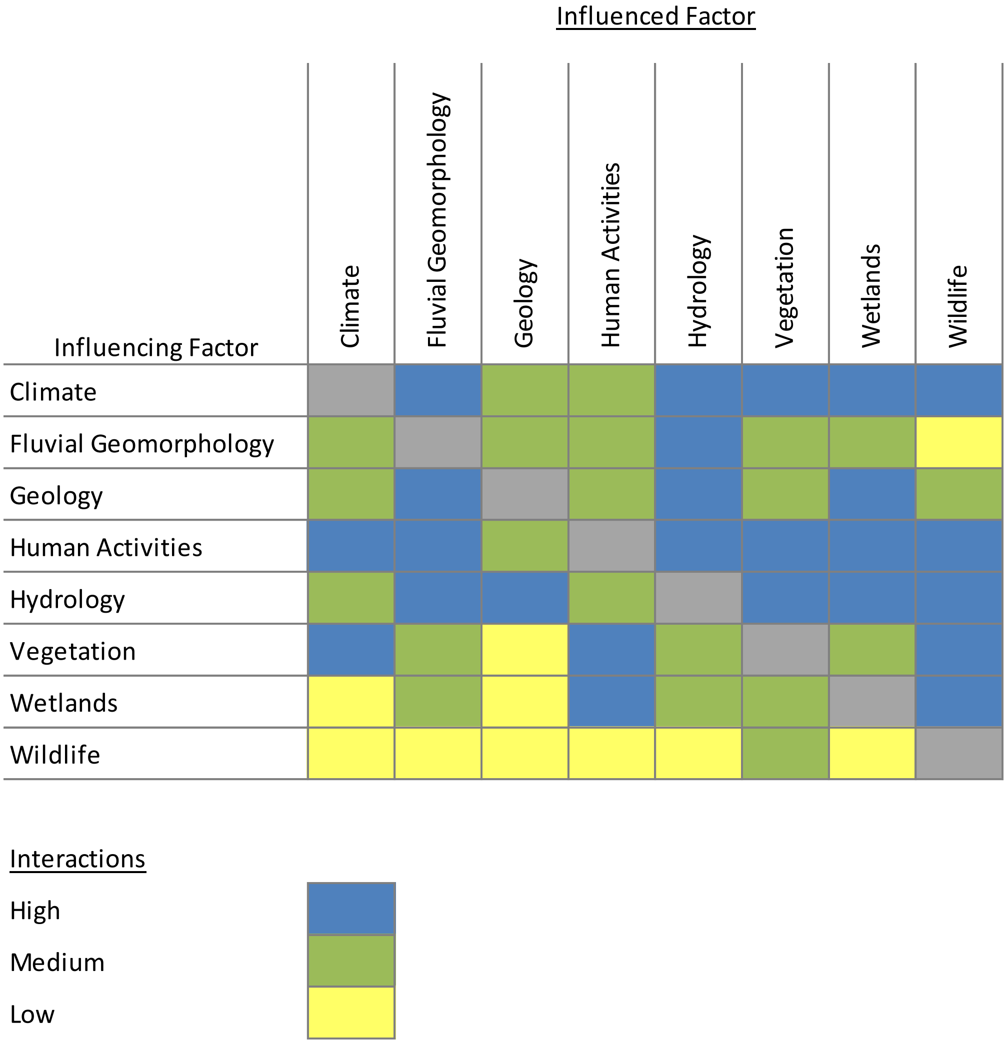

The Bear River in northern Cache Valley (Adam Perschon)

Water quality has become an important issue within the Basin, and will continue to be so as populations increase and demands for water elevate. The vast majority of water quality problems in the basin are human caused, with agriculture, feedlot operations, and grazing being the biggest offenders. It is estimated that 312 stream miles within the basin are degraded from these sources. Resource extraction is the next largest contributor to water quality problems, although it contributes only about one-sixth of the pollution that agriculture does. Pollution from urban runoff "is a distant third" (Denton, 2007). Other sources of water pollution in the basin include wastewater treatment, degraded stream banks, roads, and some oil and gas exploration (USU - Utah Water Research Laboratory, 2009).

Because the Bear River Basin has a large amount of water that has not yet been developed, concern over water has not been as prominent as in other areas in the west. The Bear River Basin is considered one of the few areas in and around Utah with a developable water supply (Utah Division of Water Resources, 2004). As the population in the basin grows, demand for this water will increase. Additionally, much of the undeveloped water is claimed by water conservancy districts in the Salt Lake area, which have already set forth several proposals for water development. These proposals have met with great resistance, primarily because they have included plans for adding an additional dam along the Bear for water storage. Several dams already exist along the Bear, including those at Soda Springs, Oneida, and the Cutler Reservoir. Many of the dams along the Bear provide multiple uses and benefits, such as hydroelectric power, recreation, and irrigation storage. Many argue that a new dam along the Bear will unnecessarily displace land owners and reduce the Bear's flow even further. While these arguments have merit, a dam is a likely inevitability unless more can be done to conserve and reuse the water already being used from the basin (Denton, 2007).

## Interactions

The following matrix broadly describes some of the interactions that occur between the factors described throughout this paper. The matrix displays a simple high, medium, or low rating for each factor in relation to one another. It also provides insight to the relationships between the factors considered to help the reader understand why the ranking was given and the potential need for mitigating between certain factors.



Influenced Factor

| Influencing Factor | Climate | Fluvial Geomorphology | Geology | Human Activities | Hydrology | Vegetation | Wetlands | Wildlife |
|---|---|---|---|---|---|---|---|---|
| Climate | ▨ | 🟦 | 🟩 | 🟩 | 🟦 | 🟦 | 🟦 | 🟦 |
| Fluvial Geomorphology | 🟩 | ▨ | 🟩 | 🟩 | 🟦 | 🟩 | 🟩 | 🟨 |
| Geology | 🟩 | 🟦 | ▨ | 🟩 | 🟦 | 🟩 | 🟦 | 🟩 |
| Human Activities | 🟦 | 🟦 | 🟩 | ▨ | 🟦 | 🟦 | 🟦 | 🟦 |
| Hydrology | 🟩 | 🟦 | 🟦 | 🟩 | ▨ | 🟦 | 🟦 | 🟦 |
| Vegetation | 🟦 | 🟩 | 🟨 | 🟦 | 🟩 | ▨ | 🟩 | 🟦 |
| Wetlands | 🟨 | 🟩 | 🟨 | 🟦 | 🟩 | 🟩 | ▨ | 🟦 |
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Interactions

| | |
|---|---|
| High | 🟦 |
| Medium | 🟩 |
| Low | 🟨 |

# Modeling Process

Effective models are caricatures of reality that integrate information into formats that are easier to understand and analyze than the reality they represent. Generating models that represent regional landscapes provides a better understanding of the spatial attributes that contribute to complex processes existing within the region. Models can also generate insight into what might occur across a landscape given different input scenarios.

To analyze the Bear River Watershed and its impacts upon the Bear River Migratory Bird Refuge, assessment models and alternative future models were developed based on the issues identified in the project's research and analysis phase. Assessment models are visual representations of key watershed attributes, which are also used to gauge the effectiveness of alternative futures at achieving a particular outcome. Alternative futures spatially display potential changes in land use patterns based upon a variety of selected inputs.

The models for this project were created using ArcGIS, a Geographic Information System (GIS) that allows geospatial data to be mapped and analyzed. A special feature of this technology is its map overlay features, which allows the user to display various data components singly or in a myriad of layered configurations. The overlay process dates back to Manning's use of hand overlays in 1912 and has proven to be an increasingly useful tool for land use planning with improvements in GIS technology (Steinitz et al, 1972). Figures 5.1 and 5.2 demonstrate the overlay process by displaying individual components used to create a composite image.

Each assessment and alternative future model is described in detailed narrative and visual formats in the pages that follow. Due to the large spatial extent of the study area, the visual displays for alternative futures include two smaller areas to show increased detail. One area of detail lies within the upper portion of the watershed, while the other lies within the lower portion of the watershed.

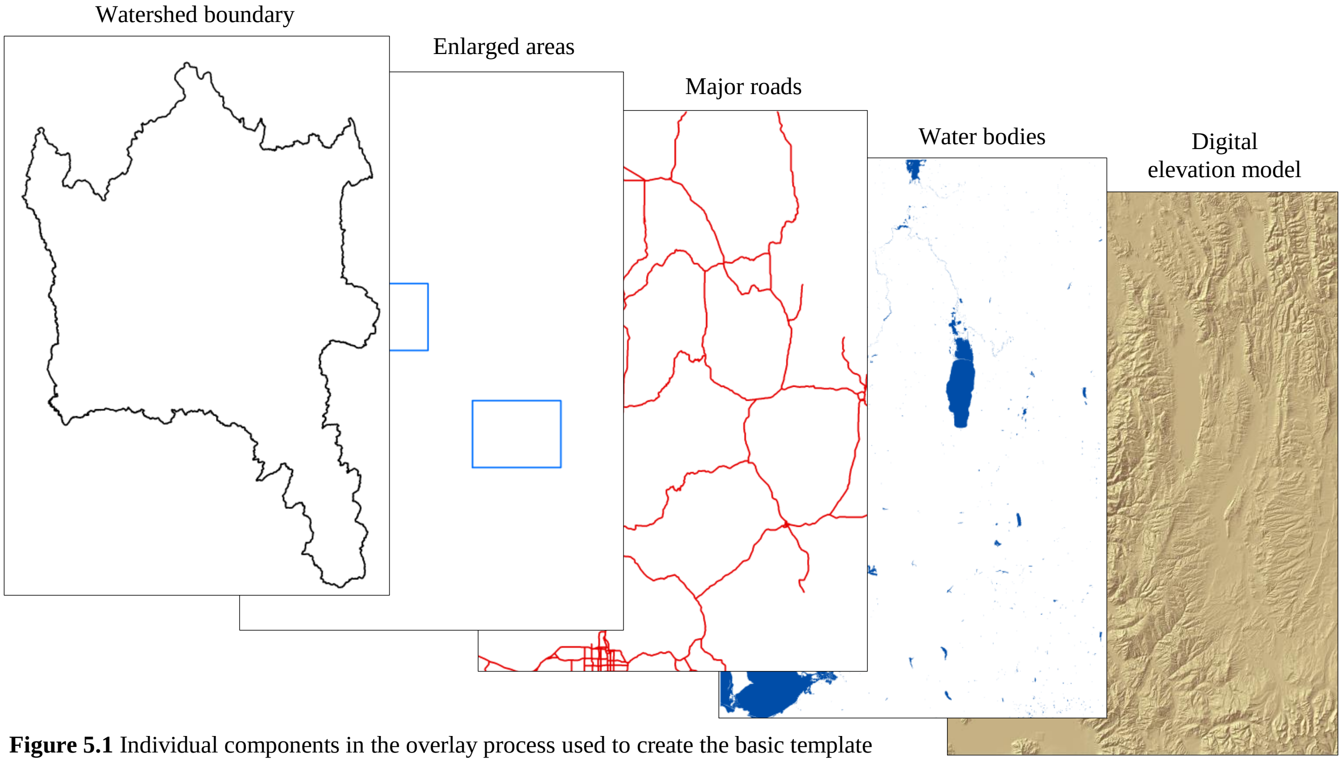


**Figure 5.1** Individual components in the overlay process used to create the basic template

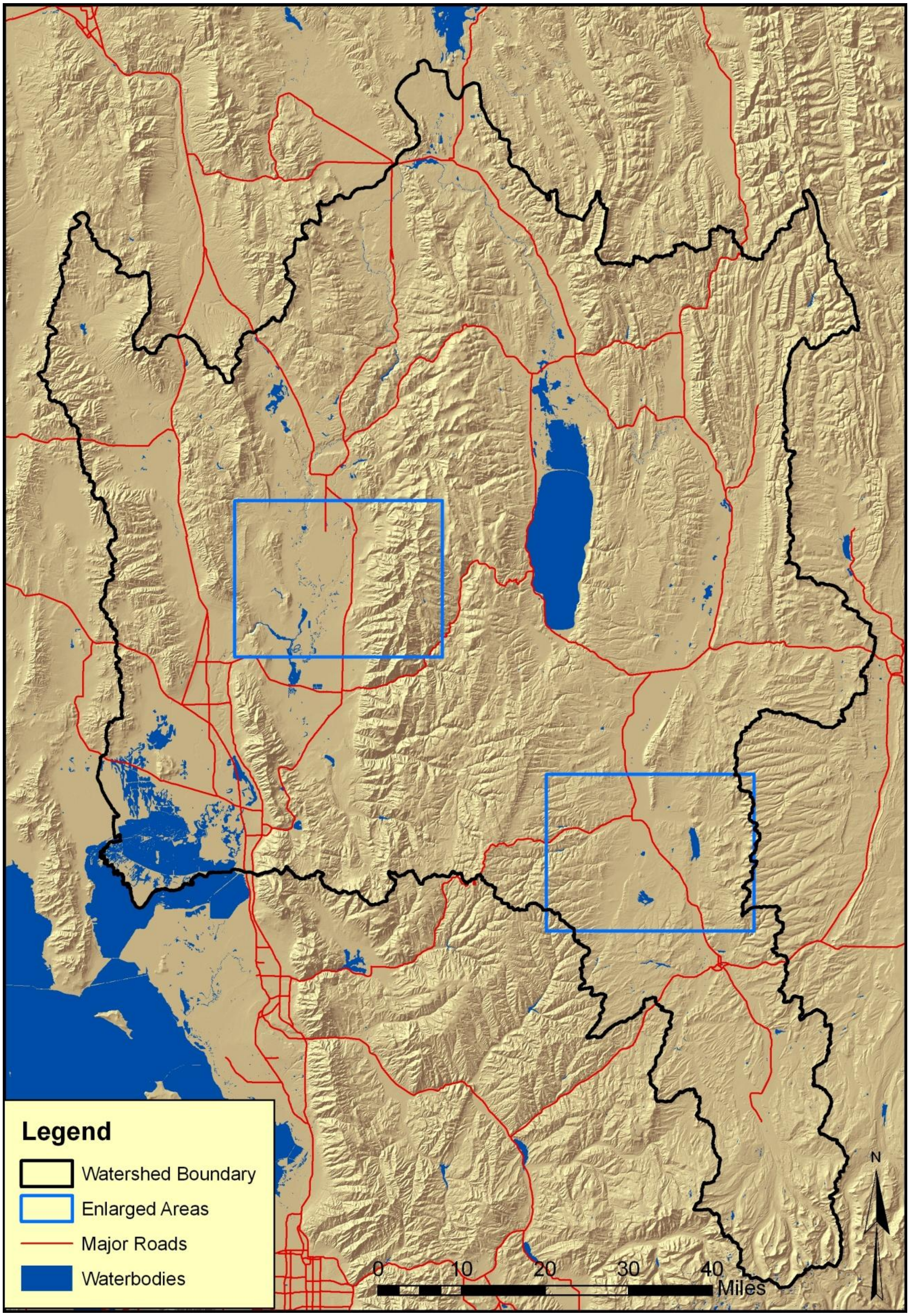


**Figure 5.2** Composite image using individual components to form the basic template

## Working Lands

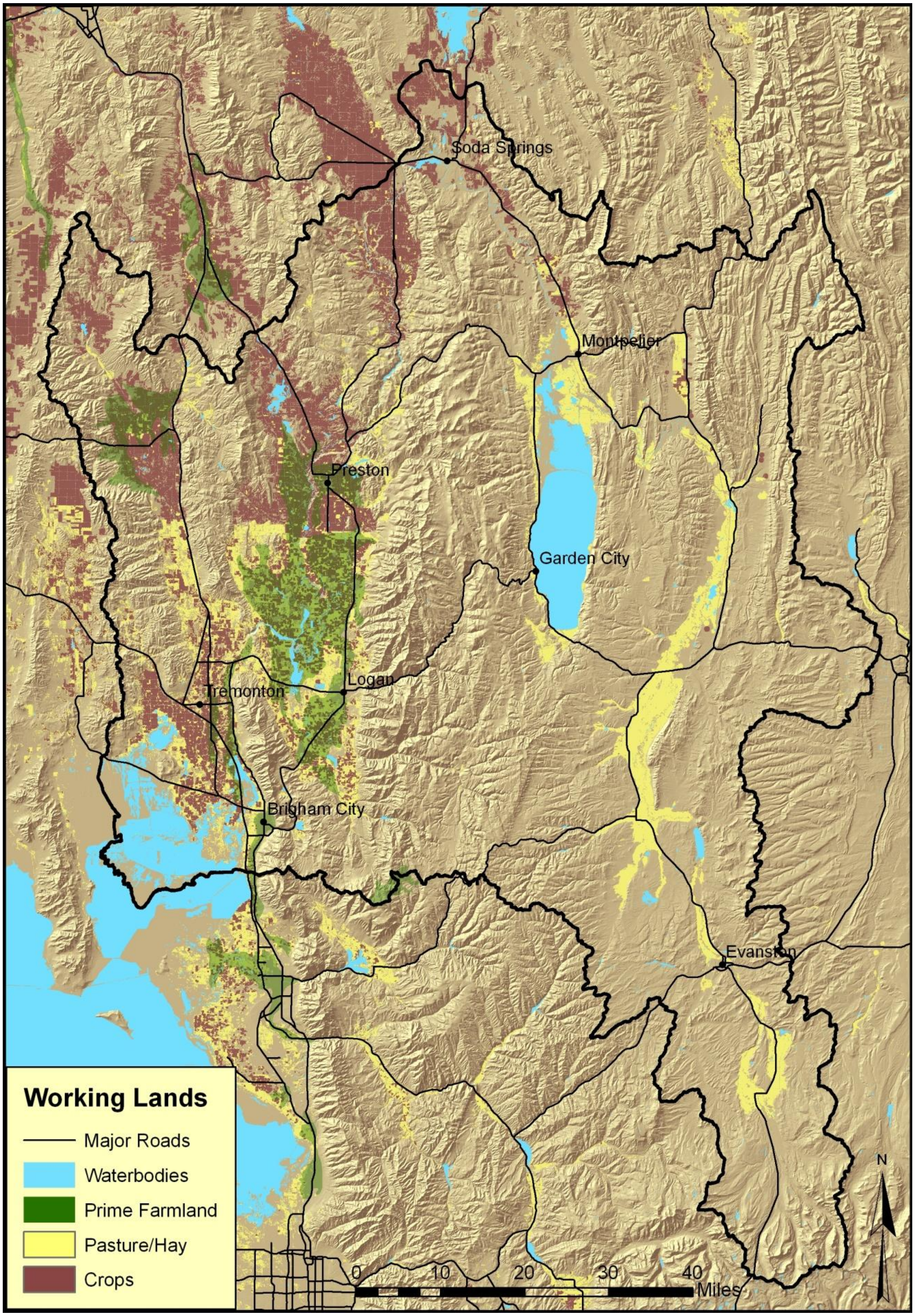
The working lands assessment model was designed to help identify lands within the Bear River Watershed that are capable of providing the essential sustenance to the inhabitants of the region. As populations throughout the watershed continue to rise, working lands will be developed for residential use as a result of their proximity to current infrastructure and their relative ease of development. From 1997 to 2002, Cache County lost 25,000 acres of agricultural land to development (a 9 percent decrease) (Toth et al., 2006). The working lands assessment model identifies areas within the watershed that should be protected from encroachment by development, providing an important metric to determine the impact of each alternative future on vital agricultural lands within the watershed.

In order to assess the current state of working lands within the watershed, a number of criteria were used to indicate areas of prime agricultural soils, current pasture, and croplands. Prime farmland is defined by the U.S. Department of Agriculture as “land 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 uses” (Staff, 1993). In an effort to preserve existing agricultural land that may not be considered prime farmland by the USDA, existing lands with pasture/hay and cultivated crops were included in this model. The protection of these lands will be a vital step to providing a sustainable future for the watershed.

### Model Criteria

- Prime farmland
- Existing pasture
- Existing hay fields
- Existing cultivated crops

Grain harvesting near Grace, Idaho (Danny White)


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Working Lands
Major Roads
Waterbodies
Prime Farmland
Pasture/Hay
Crops
0
10
20
30
40
Miles
N

## Public Health, Safety, and Welfare

The Public Health, Safety, and Welfare (PHSW) model was developed to illustrate the areas within the Bear River Watershed that have a high to moderate likelihood of a natural disaster that could cause harm to both the residents and structures of the area. The major hazards that are located within the watershed include floodplains, high landslide potential, faults, and soils susceptible to liquefaction. As populations continue to rise, more and more people will be placed in harm's way if potentials for natural disasters are not integrated into the planning process.

### Floodplains

Floodplains are located in low-lying areas in proximity to rivers and streams that are intermittently flooded. Flooding is a natural and necessary function of a river; according to Luna Leopold, river banks are only capable of handling a flood of modest size. While most rivers and streams within the Bear River Watershed are highly manipulated systems, regulated by dams and other manmade structures, flood events do occur on a regular basis. If these structures were to fail, or if a large flood event occurred, there would be the potential for significant property damage or loss of life.

### Landslide Potential

Landslides can occur on slopes of less than 5 percent and typically are the result of a buildup of water in the soil which increases the weight of the soil, increases pore pressure, and reduces the bonds that hold soil particles together (Case), (Shaw, 2007). Since landslides can occur in almost any soil with the right amount of water, we used slope as the major determinate of landslide potential. The model includes slope greater than or equal to 10 percent and less than or equal to 30 percent, as determined by the Utah Geologic Survey (see Figure 6.1).

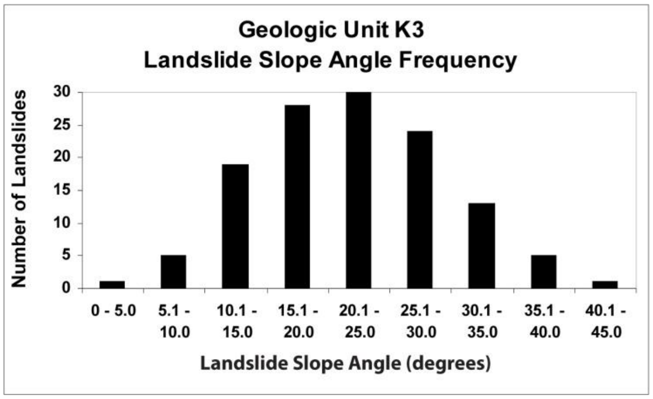


**Figure 6.1** Landslide slope angle frequency in geologic unit K3 showing a normal distribution

### Faults

Faults are present throughout the watershed and, as such, present a tremendous challenge to planners. The faults identified in this map indicate areas where development should be avoided, especially the placement of structures directly over faults.

### Liquefaction

Most of the damage that occurs during an earthquake is due to liquefaction (Bolt, 1999). Liquefaction occurs in areas where water saturated sandy soils are shaken to the point that the soil takes on the characteristics of a dense liquid due to an increase in pore pressure (Bryant, 1991). When soil stability is compromised due to liquefaction, the ability of the soil to support building foundations is lost. Soils with high liquefaction potential are frequently found in remnant lake beds, such as those found in the eastern portion of the watershed from the Pleistocene Lake Bonneville. Soils susceptible to liquefaction are also found in remnant floodplains, which can be found throughout the watershed where the Bear River has carved its way through the landscape. These soils should be avoided when considering locations for new development, and this information should be utilized in the event of an earthquake to identify areas that may have the most damage.

Oneida Narrows Dam (Danny White)

## Protecting Welfare

Another consequence of an ever-increasing population is the necessity to provide residents with clean water. With this in mind, criteria were added to the PHSW model to address these issues which include wetlands, rivers, and waterbodies.

### Wetlands

Wetlands act as filters that remove excessive nutrients and other contaminants from surface runoff. They also reduce the impact of flooding by absorbing much of the excess water and then releasing it slowly. Wetlands should be protected from the encroachment of development to ensure high quality water and for protection from floods.

### Rivers

Rivers are the conduit through which surface water is brought from the mountains to the valleys, where it is utilized by society. Since water is important to the well-being of the inhabitants of the watershed, the conduit through which it travels should be protected. The PHSW model illustrates the location of the major rivers and streams contained within the watershed, which planners should use to avoid conflicts with these rivers and streams.

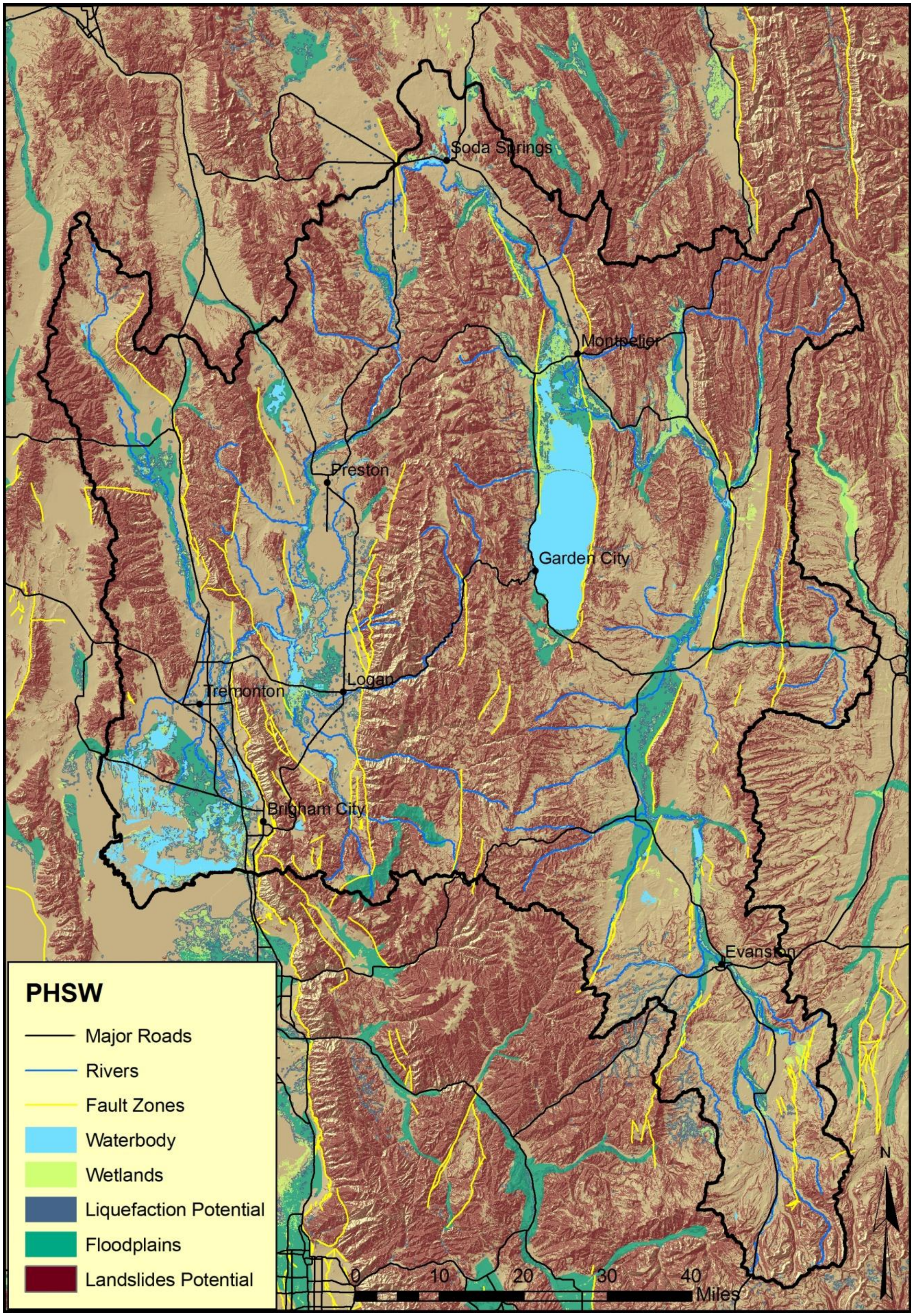
### Water Bodies

Precipitation in the watershed falls primarily in the form of snow, which melts in the spring. This spring melt stimulates a surge of water in the rivers at a time when it is not usable for agricultural purposes. To mitigate this early release of water, reservoirs have been constructed to catch much of this early runoff so that it may be utilized during the peak growing season. There are also several large lakes within the watershed that provide recreation and water storage. Both natural lakes and manmade reservoirs should be protected from development pressures to provide clean water for its multitude of users.

### Model Criteria

- Wetlands
- Water bodies
- Rivers
- Floodplains
- High landslide potential
- Faults

View of Bear Lake (Danny White)


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
PHSW
Major Roads
Rivers
Fault Zones
Waterbody
Wetlands
Liquefaction Potential
Floodplains
Landslides Potential
0
10
20
30
40
Miles
N

## Critical Habitat

The critical habitat assessment model seeks to identify the portions of the study area which provide the greatest amount of habitat for the greatest number of species. Its function is to assess how well each of the alternative future models preserves critical habitat areas, providing one indication of how well wildlife will thrive under different scenarios. Critical habitat was selected as an assessment model due to wildlife's economic contributions to the region, as well as their aesthetic qualities that contribute to the quality of life and sense of place for those living in and around the watershed.

Building a critical habitat assessment model necessitated a simple way to incorporate a variety of habitats for both aquatic and terrestrial species. Additionally, the project's focus on the impacts to the Bear River Migratory Bird Refuge mandated that wetlands and associated habitats be integrated into the model's outputs. Inclusion of wetlands in the model not only increases its ability to assess direct impacts to the refuge but aids in determining which futures impact similar habitats within the study area, which may lead to increased pressures on the refuge.

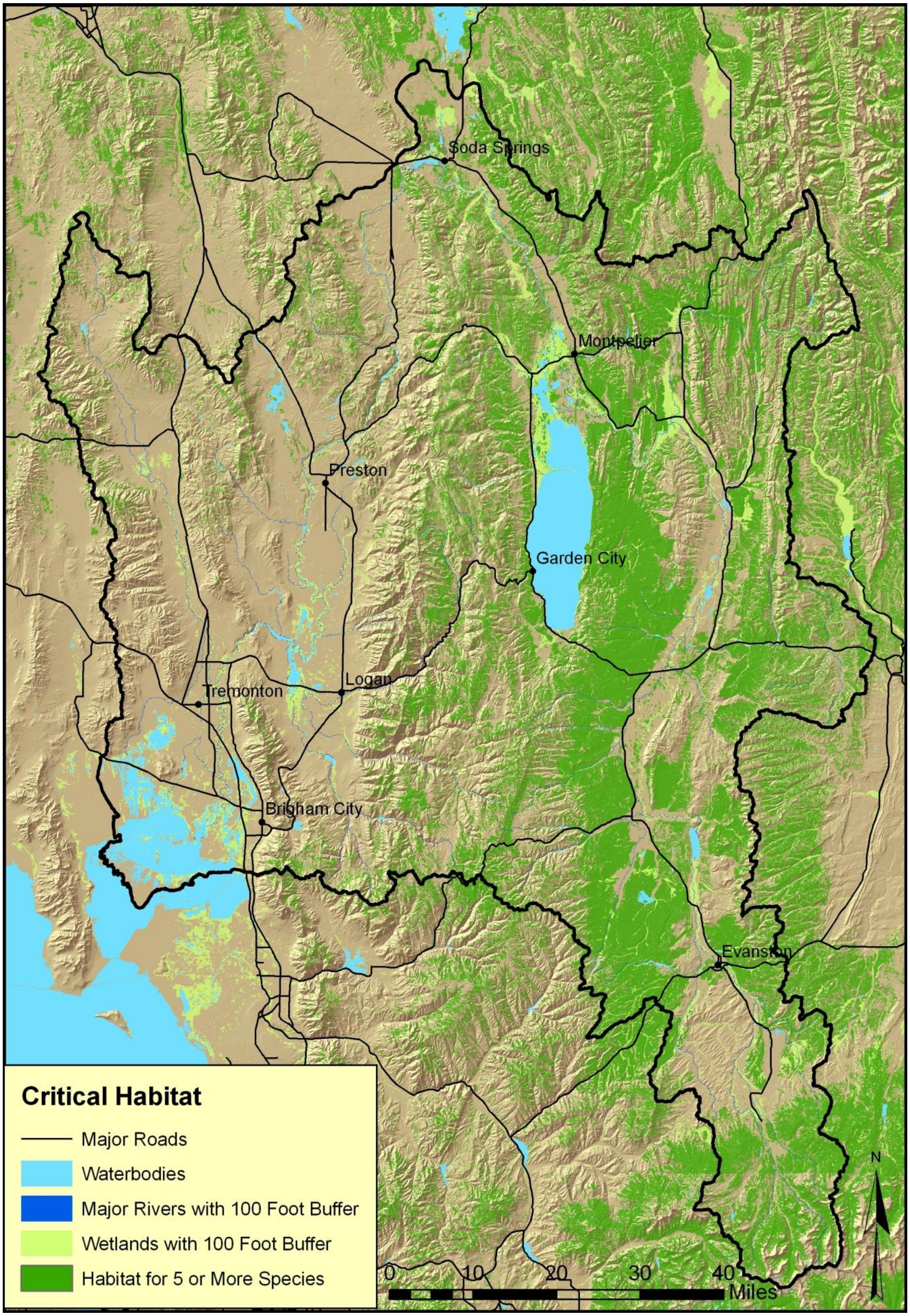
To address the needs of this model and to accommodate for the variety of habitats found within the watershed, the critical habitat assessment model was adapted from methods used in previous Bioregional Planning projects. Relying on the habitat criteria outlined in *Cache Valley 2030,* a GIS layer was created that included wetlands and major rivers, as well as adjacent areas within 100 feet (Toth et al., 2006). This part of the model provides assessment potential for a large number of aquatic species, waterfowl, and shorebirds, not to mention a myriad of terrestrial species that use wetlands and riparian areas for movement corridors and basic resources.

To further expand analysis of terrestrial species, a GIS layer for species richness was developed based on work done for the Upper Colorado River Ecosystem (Toth et al., 2008). Using vegetation cover types from the Southwest and Northwest Regional GAP analysis programs, habitat models were created for eight species, three of which are listed by the U.S. Fish and Wildlife Service as threatened or endangered. The eight habitat models were then analyzed to determine which areas in the watershed supported any arrangement of at least five of the species examined.

The final critical habitat model used to evaluate the alternative futures was created by merging the wetland/riparian and terrestrial habitat layers. This produced a single critical habitat layer designed to cull out those portions of the watershed with habitat capable of supporting a wide number and variety of wildlife.

### Model Criteria

- Wetlands
- Major rivers
- A 100-foot habitat buffer surrounding wetlands
- A 100-foot habitat buffer surrounding major rivers
- Critical habitat for Canada Lynx, gray wolf, black-footed ferret, elk, mule deer, moose, greater sage grouse, and ruffed grouse, based on Southwest and Northwest Regional GAP vegetative data.


Soda Springs
Montpelier
Preston
Garden City
Tremonton
Logan
Brigham City
Evanston
Critical Habitat
Major Roads
Waterbodies
Major Rivers with 100 Foot Buffer
Wetlands with 100 Foot Buffer
Habitat for 5 or More Species
0
10
20
30
40
Miles
N

## Integrated Resources

The Integrated Resources assessment model was developed to determine the impacts the alternative futures will have on the future of water throughout the watershed. Although this model does not produce a quantitative view as to the amount of water that will be lost or gained given a specific future model, it does indicate areas that, if impacted, will result in a either a loss of quantity or quality of water. The criteria this model is based on comes from multiple case studies as well as input from various Utah State University faculty.

Since water is so important to the well-being of the inhabitants of the watershed, the conduit through which it travels should be protected. For this reason, the conservation model identifies various mitigation zones for rivers, wetlands, and inter-basins.

### Mitigation Zones

A mitigation zone represents a portion of land that remains under the ownership of the landholder but provides restrictions to certain land uses that would have an impact to water quality or quantity. Any proposed use that occurs within a mitigation zone must be brought before the county planning commission to determine potential impacts to the water. If the proposed use is allowed, the planning commission would also determine what type of mitigation efforts the landowner would be required to implement. As an incentive for agreeing to these initiatives, the landowner would maintain the right to exclude public access to their property.

In an effort to reduce the impact river mitigation zones will have on private land owners, a tiered approach has been applied. River mitigation zones will be based on landownership as follows:

- Federally owned land, 300-foot mitigation zone
- State owned land, 200-foot mitigation zone
- Privately owned land, 100-foot mitigation zone

To retain and enhance the functional benefits provided by wetlands, the model includes wetland mitigation zones of 100 feet. This 100-foot mitigation zone is essential to reducing the concentration of sediments and excess nutrients from degrading the wetlands.

Confluence areas are portions of the landscape that permit runoff to travel as sheet flow instead of being channelized. This model identifies confluence areas of high, medium, and low importance where mitigation zones should be placed. The three levels of confluence area mitigation were determined using slope categorizations: confluence areas of high mitigation priority have slopes greater than 20 percent; confluence areas of medium mitigation priority have slopes between 12 and 20 percent; and confluence areas of low mitigation priority have slopes of less than 12 percent.

### Floodplain Avoidance

Floodplains are located in low-lying, areas in proximity to rivers and streams that are intermittently flooded. Throughout the Bear River Watershed, development and agricultural use have occurred within the floodplain. This type of activity is not only potentially harmful to those living on a floodplain, it can also lead to contaminants entering the river system. The conservation model delineates land that has experienced flooding in the past.

### Groundwater Recharge

Nearly all the municipal and domestic water use in the watershed is dependent upon groundwater sources (Utah Division of Water Resources, 2004). Given the high dependence on groundwater, the Integrated Resources model identifies key areas within the watershed that act as groundwater recharge zones, represented by highly permeable soils.

## High Precipitation Zones

The average amount of annual precipitation for the watershed is 22 inches, although there are areas in the higher elevations that receive greater than 30 inches, and these areas indicate where development should not occur to protect the natural hydrology of the region (Utah Division of Water Resources, 2004).

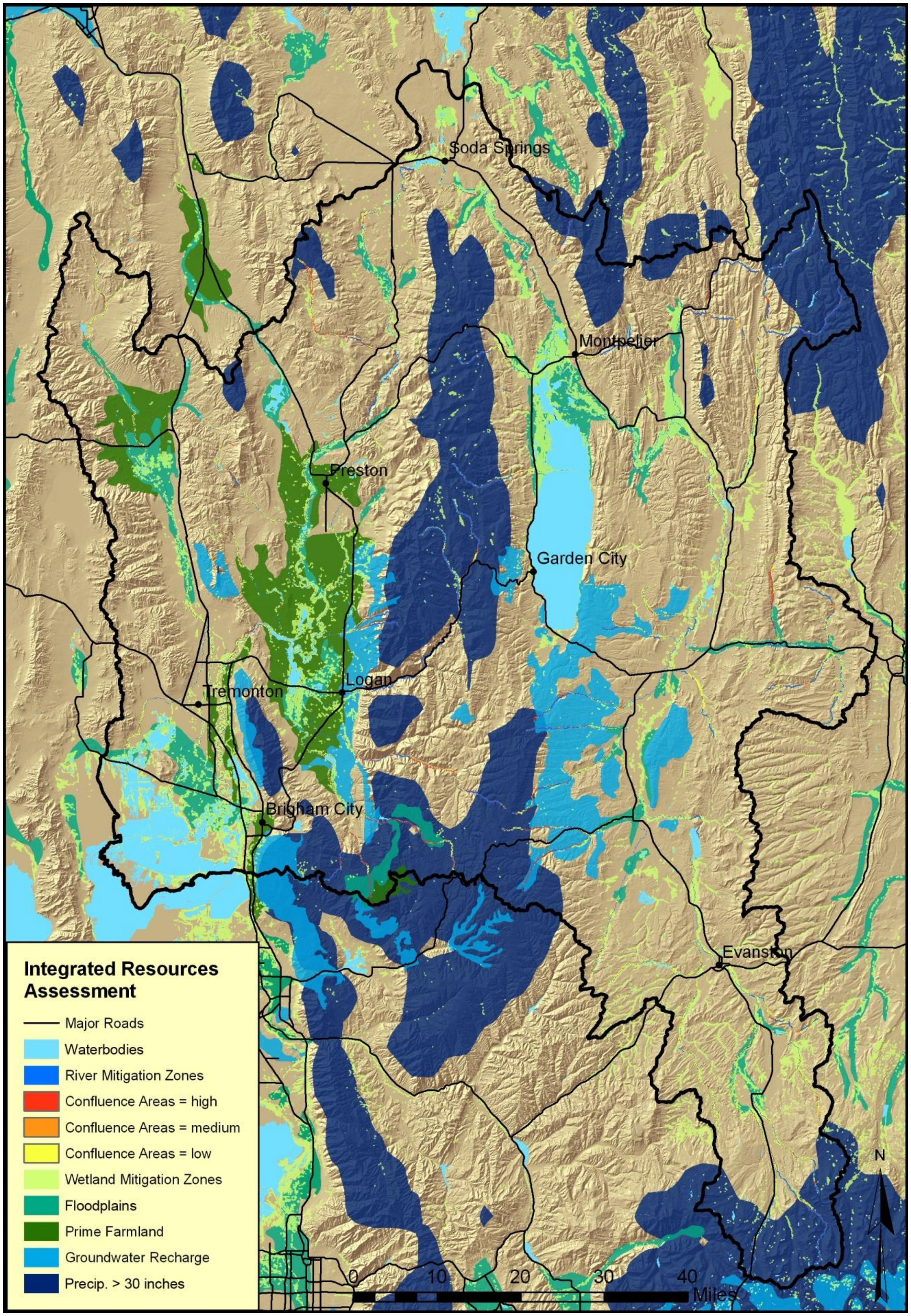
## Prime Farmland

Agriculture currently accounts for approximately 94 percent of the developed water in the watershed. In an effort to reduce the amount of water being consumed by agricultural practices, it is suggested that only prime farmland soils within the watershed be irrigated. The Integrated Resources model highlights prime farmlands that should be preserved through restrictions on development, setting aside those agricultural lands with the greatest production potential given increasingly limited water supplies.

## Model Criteria

- River corridor mitigation zones
- Wetland mitigation zones
- Confluence area mitigation zones
- Floodplains
- Groundwater recharge areas
- High precipitation zones
- Prime farmland

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


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Integrated Resources Assessment
Major Roads
Waterbodies
River Mitigation Zones
Confluence Areas = high
Confluence Areas = medium
Confluence Areas = low
Wetland Mitigation Zones
Floodplains
Prime Farmland
Groundwater Recharge
Precip. > 30 inches
N
0
10
20
30
40
Miles

Once assessment models were identified and constructed, a series of alternative futures were generated to determine how various planning policies might impact the assessment model critieria. Each alternative future demonstrates a different planning focus or approach, highlighting varying effects to both natural and cultural resources. The alternative futures created include:

- Plan Trend
- Build Out
- Networked Communities
- Integrated Resources

## Plan Trend

The Plan Trend model projects a trend line of existing and future development pressures based on current growth and development patterns. This "status quo" model emphasizes low-density suburban growth, commuter-based infrastructure, and few critical land protections. In essence, Plan Trend attempts to demonstrate what the Bear River Watershed might look like in the future if current building and development policies continue as they are today.

Plan Trend fills the important role of acting as a baseline measurement of future growth and development trends. As each alternative future is assessed, their results are compared to the results of Plan Trend, thus providing a better sense of the effectiveness of those futures compared to the projected results of current land use plans and practices.

The model criteria for Plan Trend were adapted from a previous study of the Bear River Watershed conducted in the Bioregional Planning program during the 2004-2005 academic year (Toth et al., 2005). In keeping with current growth trends, the model focuses its growth projections on existing developed areas, areas adjacent to existing development and existing roads, and on slope gradients of 15 percent or less.

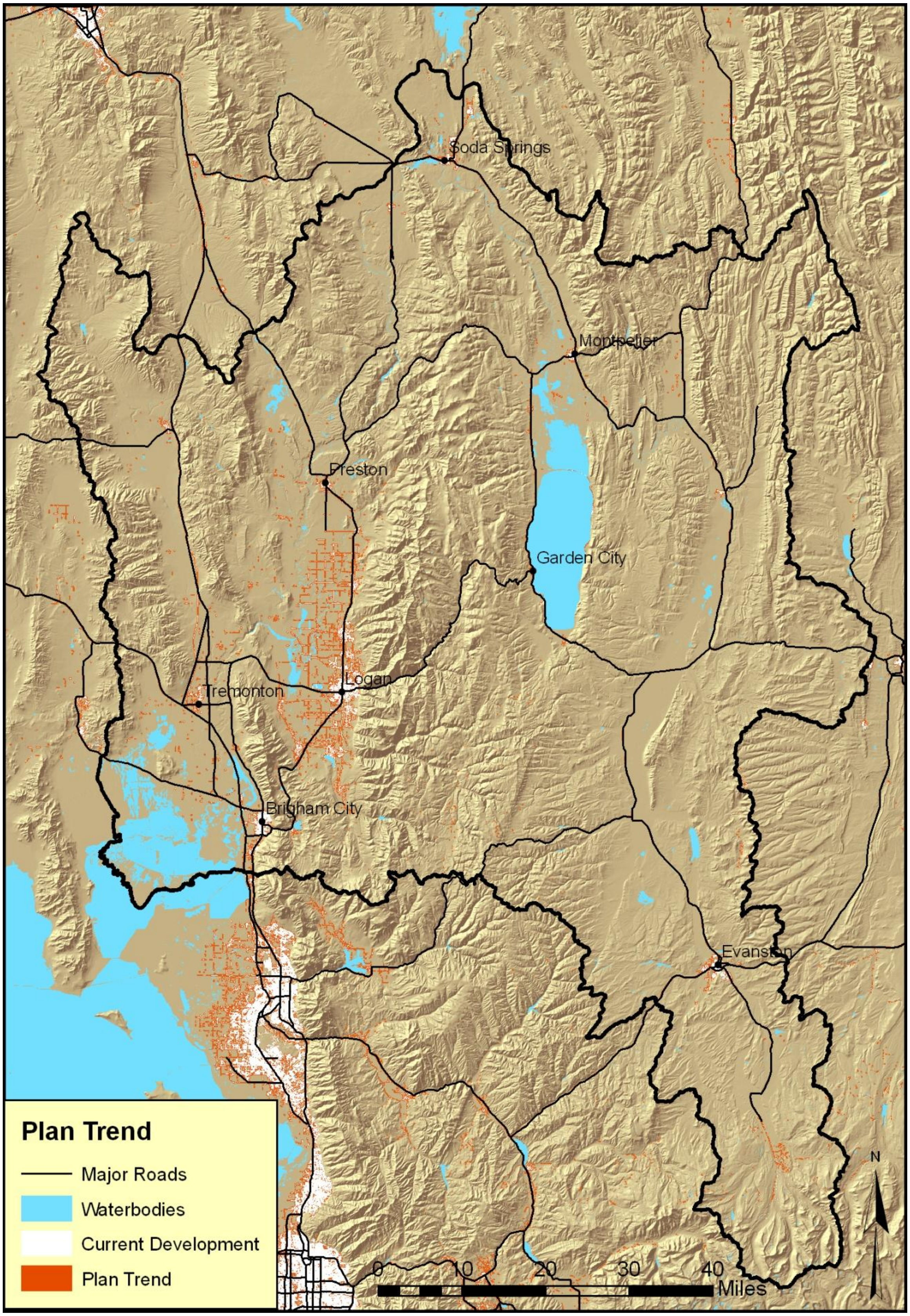
Public lands were excluded from the Plan Trend output, except in locations where current development on public land already exists. The model assumes that the majority of public lands in the watershed, primarily under the purview of the U.S. Forest Service and Bureau of Land Management, will remain largely unaffected by development directly for the foreseeable future. However, steady population growth will certainly add pressure to public lands as the increased number of residents in the watershed utilize public lands for a variety of needs, such as recreation. It is also important to note that private land comprises more than 50 percent of the watershed's land area, much of which is interspersed with public land in checker-board fashion.

The resulting map displays the spatial arrangement of development as it might appear in the future based upon current development trends.

### Model Criteria

- Existing development
- Development zone within 400 feet of existing development
- Development zone within 400 feet of existing major roads
- Slope gradient of 15 percent or less
- Exclude public land (except for areas where current development exists)

New Development near Smithfield, Utah (Adam Perschon)


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Plan Trend
Major Roads
Waterbodies
Current Development
Plan Trend
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Miles
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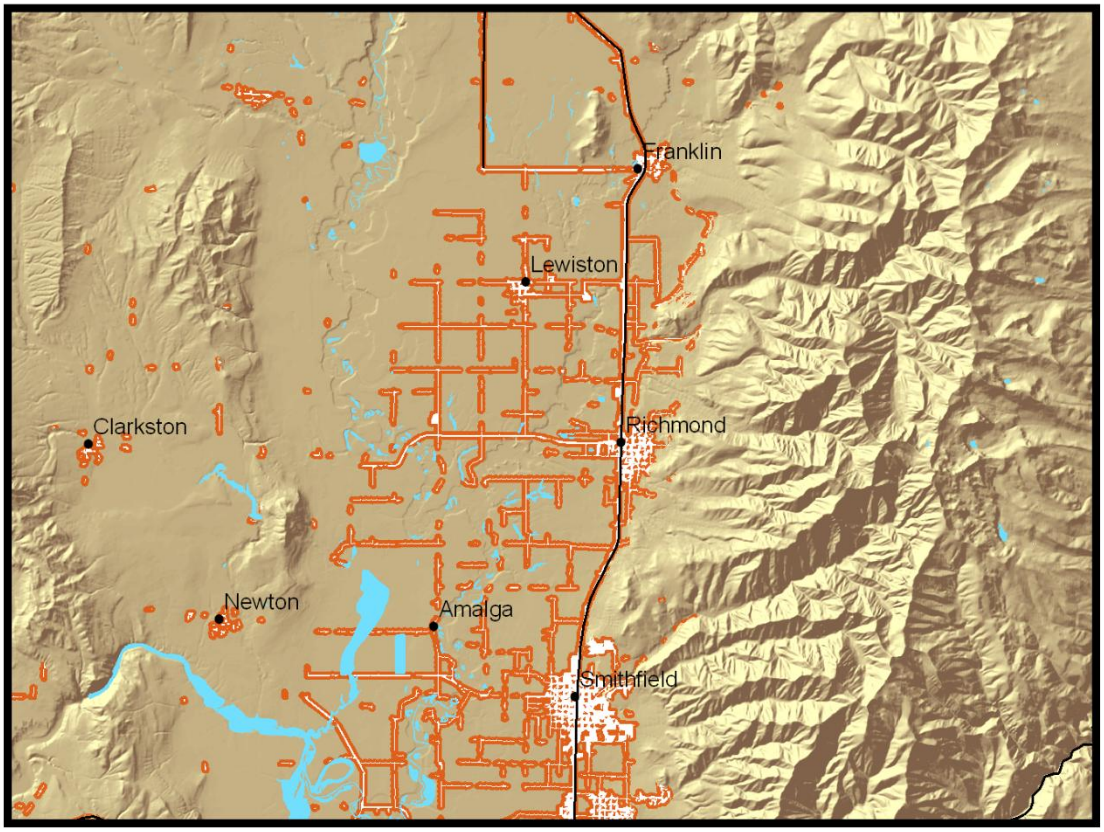
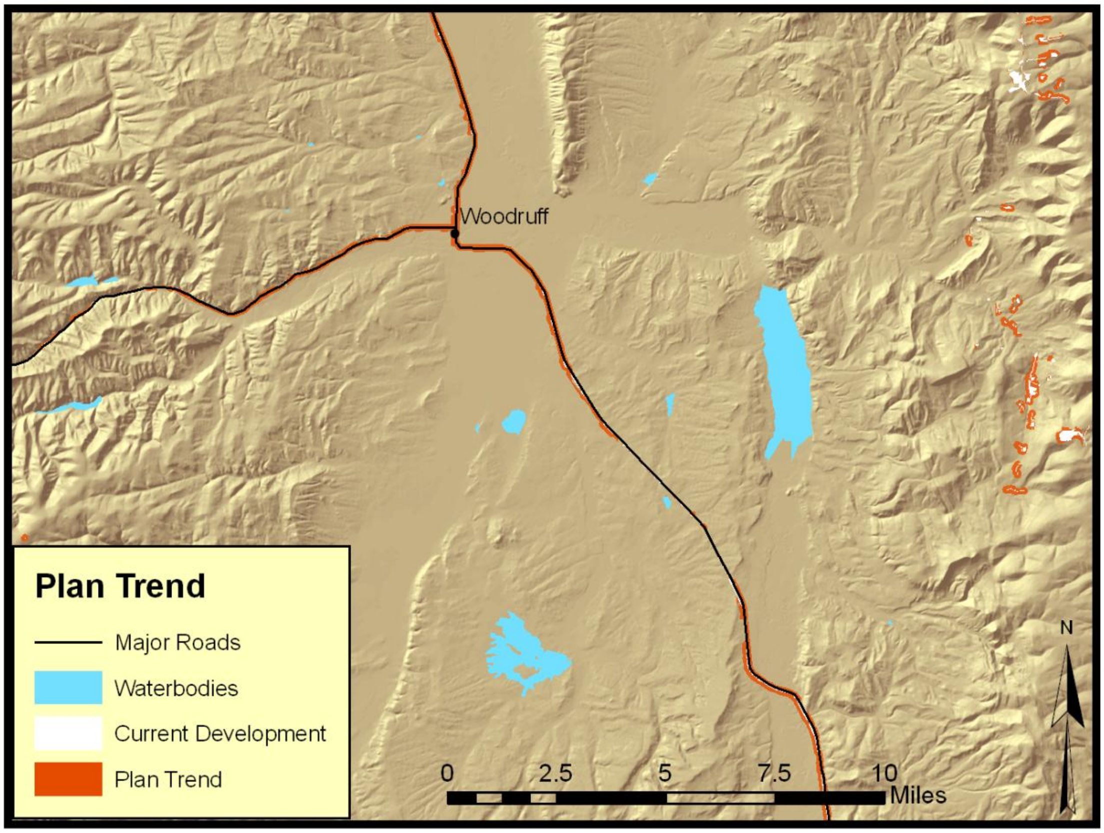


Lower Bear River Watershed Detail



Upper Bear River Watershed Detail

## Build Out

The Build Out future is characterized by an aggressive growth pattern with few constraints on development. Like Plan Trend, Build Out emphasizes suburban growth, road infrastructures that accommodate individual commuters, and few critical land protections. Its purpose is to spatially demonstrate what future growth patterns may look like if development were to proceed at a much more rapid rate than existing trends currently indicate. One of the primary assumptions behind this model is that future development will occur on any lands where it is economically feasible to build, yet still maintain a relatively close proximity to existing development.

The model criteria for Build Out are based upon the criteria for Plan Trend, with adaptations to accommodate faster development rates and the utilization of lower-cost building sites. Build Out still focuses its growth projections on existing developed areas, but the limitations on development adjacent to existing developed areas and existing major roads is increased to one-quarter mile. The slope gradient is also increased, with development allowed on slope gradients up to 25 percent. One criterion used in Build Out that is not considered in Plan Trend is that of soil drainage. Building upon poorly drained soils can add significantly to the cost of a structure, not only in terms of added structural requirements, but also in terms of potential costs to mitigate the use of designated wetlands or other sensitive areas. To account for the potentially higher costs of building upon poorly drained soils, the Build Out model restricts future development to soils that are moderately-well drained.

The Build Out model also excludes future growth on public lands, based on the assumption that the majority of public lands will not directly experience the types of development pressures expected for private lands. It is important to consider, however, that the less restrictive slope gradient used in this model makes it much more likely for private land development to occur immediately adjacent to public lands, potentially putting additional pressure on public lands from development.

The resulting map displays the spatial arrangement of the more aggressive development patterns produced by the Build Out alternative future model.

### Model Criteria

- Existing development
- Development zone within ¼ mile of existing development
- Development zone within ¼ mile of existing major roads
- Slope gradient of 25 percent or less
- Moderately well-drained soils or better
- Exclude public land (except for areas where current development exists)

Scattered development near Bear Lake (Adam Perschon)


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Build Out
Major Roads
Waterbodies
Current Development
Build Out
0
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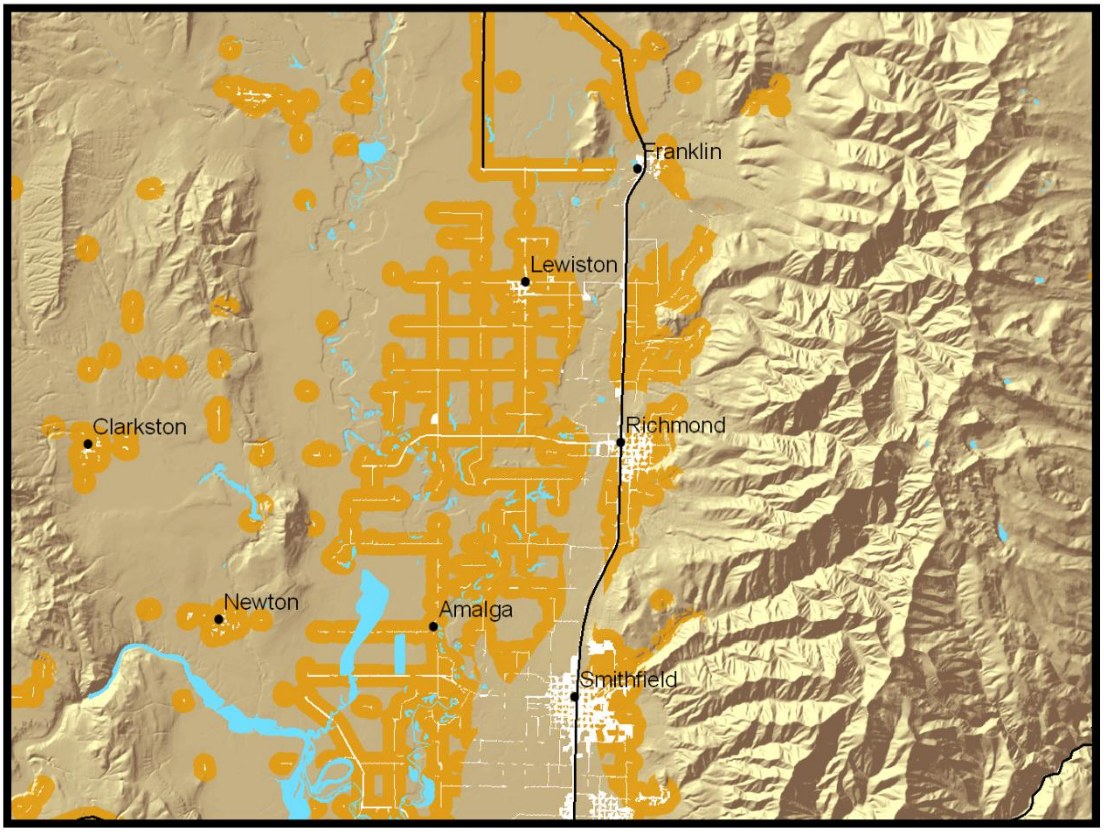
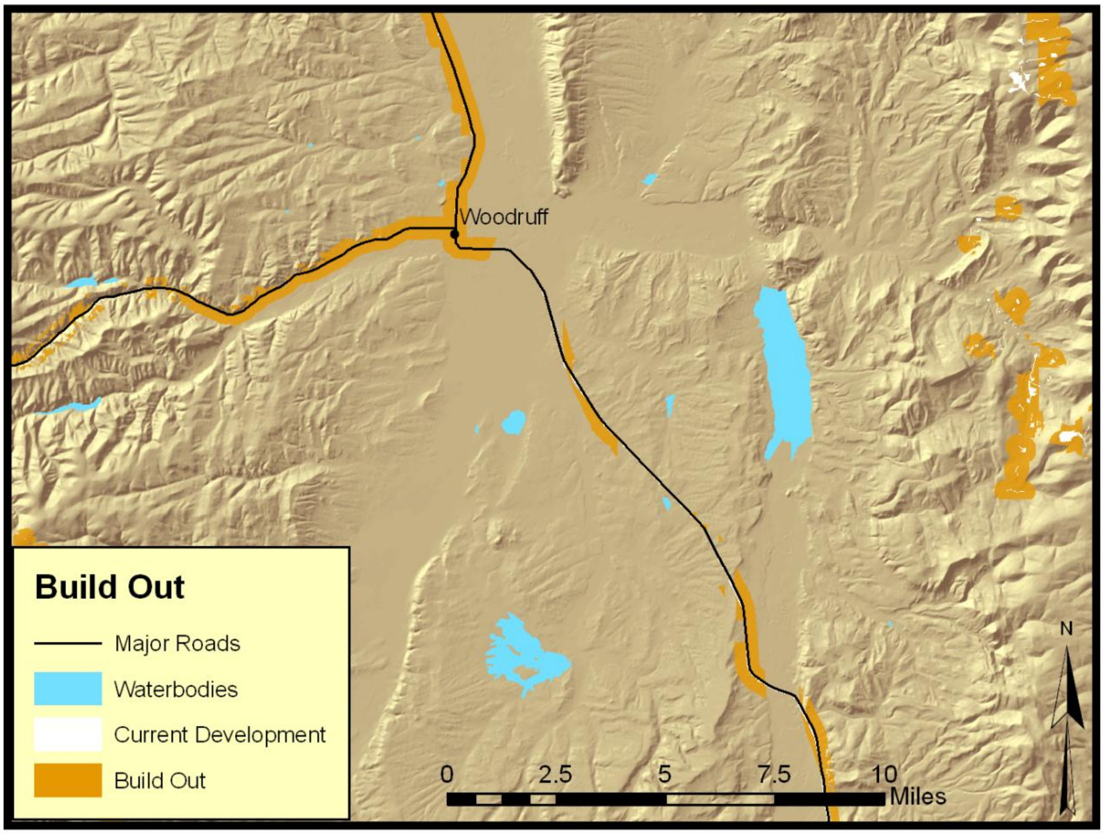


**Lower Bear River Watershed Detail**



**Upper Bear River Watershed Detail**

## Networked Communities

It is predicted that the world’s oil supply will begin to decrease over the coming decades (see Figure 7.1) In order to adapt to a future with less oil, planners need to take immediate action to reduce their region’s dependence on oil. The Networked Communities model incorporates smart growth planning initiatives such as LEED, and those proposed by Peter Calthorpe, that may assist in the reduction of oil dependence. Several of the ideas in this model also come from Pat Murphy’s book, *Plan C*, which presents ideas about community survival strategies in the wake of peak oil.

One of the most important aspects of this model is local food production. According to Murphy, a community in short supply of fossil fuel will depend on food that is locally grown. To accommodate the concept of locally grown food, the Networked Communities model identified prime farmland, locating and expanding communities near these areas. It also shows a limit of municipal boundaries to not more than 1 mile from prime farmland, as well as growth boundaries on rural communities located on prime farmland to protect this valuable resource.

Efficient public transportation will also be needed to reduce the dependence on fossil fuels. The model specifies major roads to act as transit corridors, creating networked communities. It also shows existing rail lines that could potentially be used for light rail transit routes. By using existing transportation infrastructure, communities will be able to cut costs and reduce the need for fossil fuels to construct new corridors.

Four major service centers were suggested throughout the watershed. These centers act as hubs through which essential services are provided (see Appendix B)

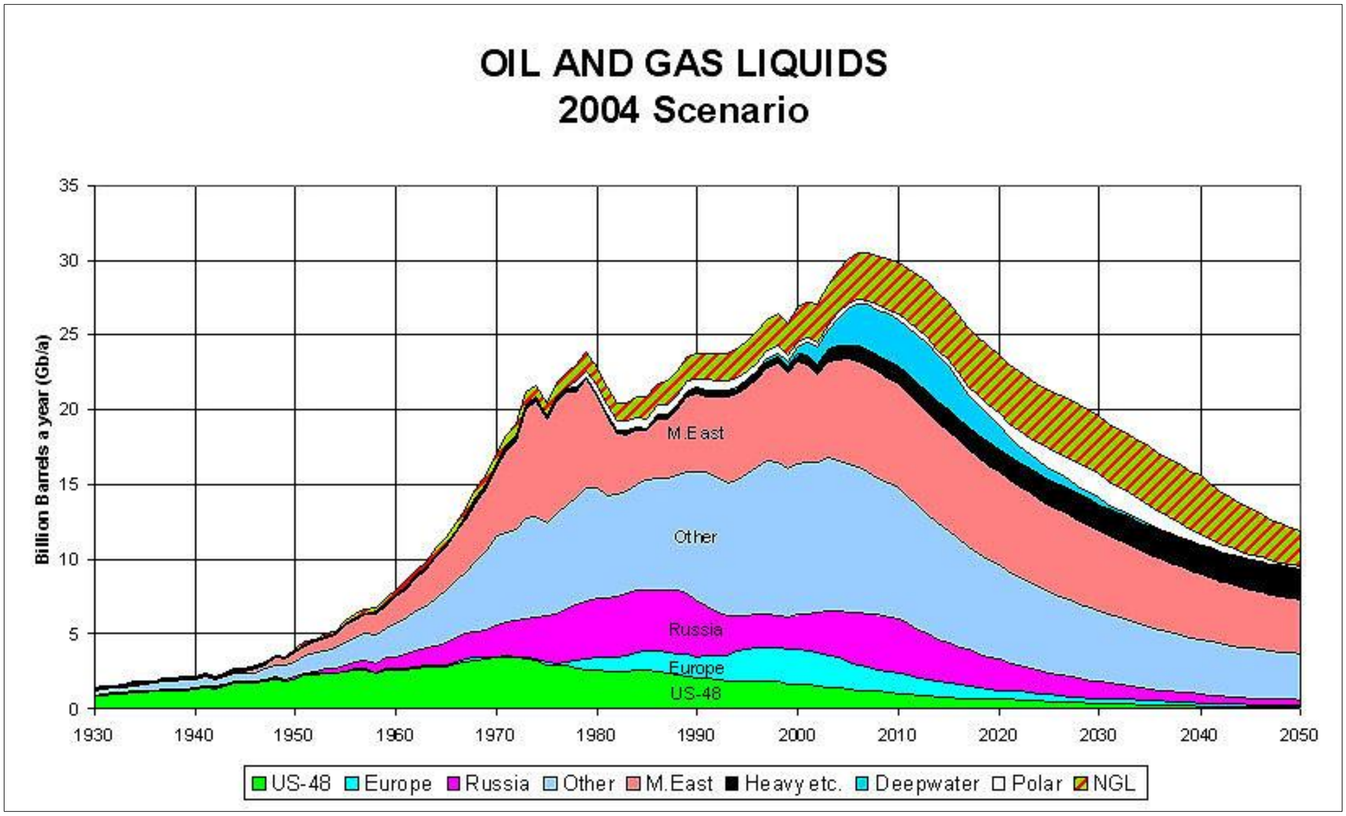


**Figure 7.1** http://www.peakoil.net/uhdsg/

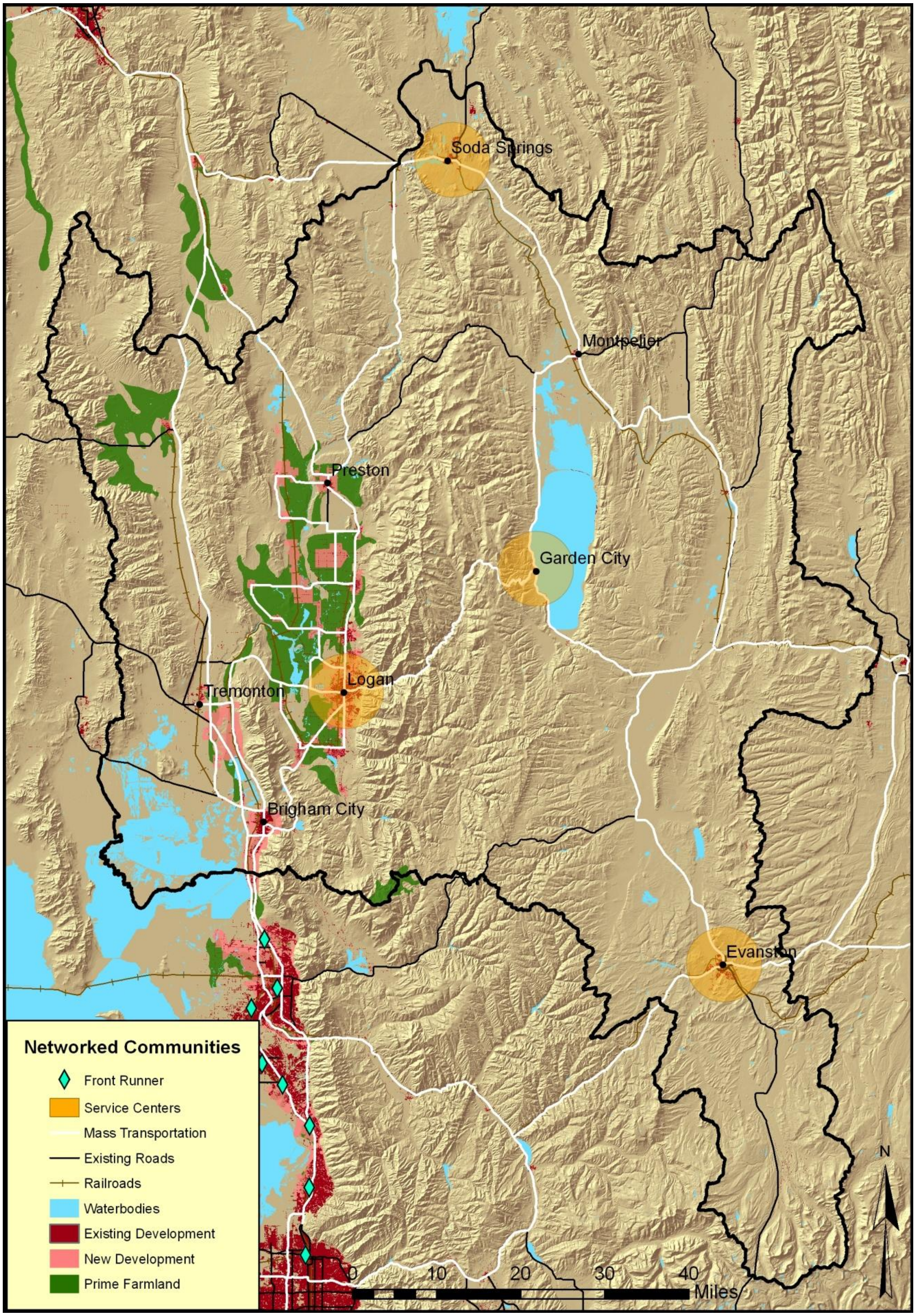
Example of a walkable street (http://www.greenstonehomes.com/images/blog/Residential-Streetscape.jpg)

The service centers will also provide electrical power for the surrounding communities through the use of solid waste powered generators. These networked power generators will decrease the region's dependence on fossil fuel and will decrease the amount of energy lost by locating the power generators within close proximity to the communities they serve. An additional benefit to having these solid waste power plants near the communities they serve is that they will supplement the heating of nearby buildings. Finally, the solid waste power plants will significantly decrease the amount of space needed for solid waste disposal in the region.

Another way to assist in the reduction of fossil fuel use is to design more walkable communities, with at least 50 percent of the dwelling units within a ¼ mile walking distance of a minimum of 19 diverse uses (see Appendix B) (U.S. Green Building Council, 2009). This will decrease the need for private transportation. In addition to providing basic services within a ¼ mile walking distance, streets should be designed to accommodate the safety and comfort of the pedestrian (see Appendix B).

**Model Criteria**

- Prime farmland
- Existing roads
- Existing rail lines
- Existing municipality boundaries
- FrontRunner stations


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Networked Communities
Front Runner
Service Centers
Mass Transportation
Existing Roads
Railroads
Waterbodies
Existing Development
New Development
Prime Farmland
N
0
10
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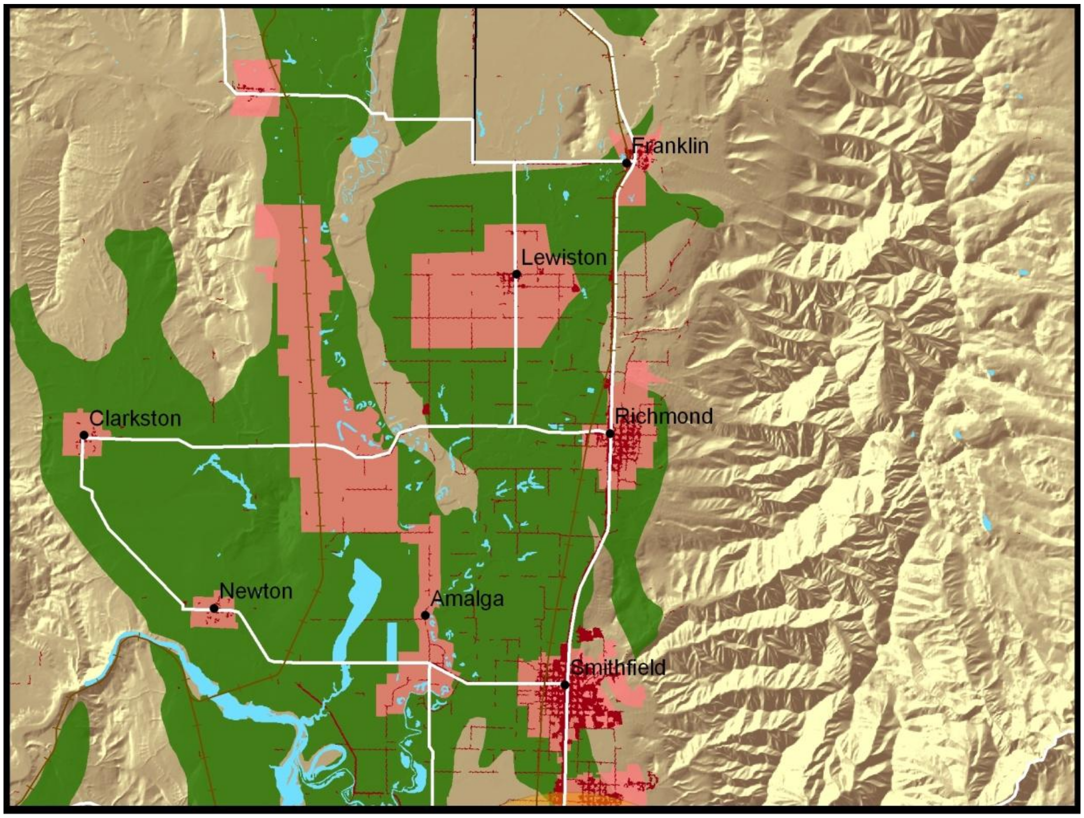
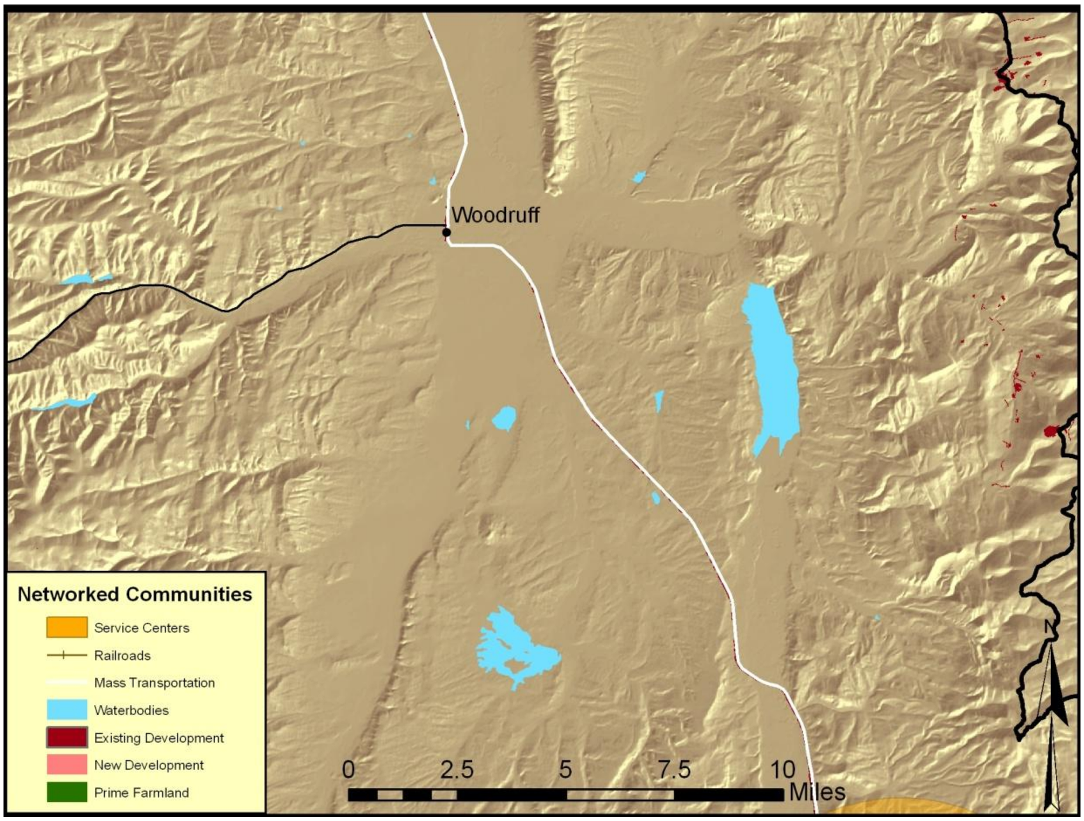
40
Miles



Lower Bear River Watershed Detail



Upper Bear River Watershed Detail

## Integrated Resources

The Integrated Resources future was developed to determine key areas within the watershed that need to be conserved and/or restored to maintain and enhance the quality and quantity of water available to the Bear River Migratory Bird Refuge. This model is based on criteria from multiple case studies as well as input from various Utah State University faculty.

Since water is important to the economic and social wellbeing of the inhabitants of the watershed, the conduit through which it travels should be protected. The conservation model identifies various mitigation zones for rivers, wetlands, and confluence areas.

### Mitigation Zones

A mitigation zone represents a portion of land that remains under the ownership of the landholder but provides restrictions to certain land uses that would have an impact to water quality or quantity. Any proposed use that occurs within a mitigation zone must be brought before the county planning commission to determine potential impacts to the water regime. If the proposed use is allowed, the planning commission could also determine what type of mitigation efforts the landowner would be required to implement. The landowner would also have the right to exclude all public access to their property.

In order to allow for a more measured policy, a tiered approach has been applied. River mitigation zones will be based on land ownership and distance as follows:

- Federally owned land, 300-foot mitigation zone
- State owned land, 200-foot mitigation zone
- Privately owned land, 100-foot mitigation zone

To retain and enhance the functional benefits provided by wetlands, the model includes wetland mitigation zones of 100 feet. This 100-foot zone is essential to reducing the concentration of sediments and excess nutrients from degrading the wetlands.

Confluence areas are portions of the landscape where two streams meet and where runoff is permitted to travel as sheet flow instead of being channelized. This model indicates three confluence areas and places higher mitigation priorities on those with the greatest slope, since water travels more quickly when slope is increased, allowing less time for percolation into the soil. Confluence areas with a slope greater than 20 percent have been given a high mitigation priority; confluence areas with a slope greater than 12 percent but less than 20 percent have been given a medium mitigation priority; and confluence areas with a slope less than 12 percent have been given a low mitigation priority.

### Floodplain Avoidance

Floodplains are located in low-lying areas in proximity to rivers and streams that are intermittently flooded. Throughout the Bear River Watershed, development and agricultural use have occurred within the floodplain. These activities are not only potentially harmful to those living on a floodplain, they can also lead to contaminants entering the river system. The integrated resources model delineates land that has experienced flooding in the past. There are three separate flood frequencies that are identified: frequent, occasional, and rare.

### Groundwater Recharge

Nearly all the municipal and domestic water use in the watershed is dependent upon groundwater sources (Utah Division of Water Resources, 2004). Given the high dependence on groundwater, the integrated resources model identifies key areas within the watershed that act as groundwater recharge zones and have been identified by highly permeable soils. By limiting development on these areas, communities will be protecting their future groundwater supplies and reducing the need to develop additional water resources to meet growing water demands.

### High Precipitation Zones

The average annual precipitation for the Bear River Watershed is 22 inches, although there are areas in the higher elevations that receive greater than 30 inches (Utah Division of Water Resources, 2004). It is critically important that development not occur in these areas to protect the natural hydrology of the region. Areas of high precipitation have been included in this model as an exclusionary layer.

### Prime Farmland

Agriculture currently accounts for approximately 94 percent of the water used in the watershed (Utah Division of Water Resources, 2004). In an effort to reduce the amount of water being consumed in the watershed, the research team suggests that no irrigation be applied to soils that are not designated as prime farmland by the U.S. Department of Agriculture. The Integrated Resources future highlights these areas to help planners restrict development from occurring within them and to reduce the use of water in areas that are not designated as prime farmland.

### Tiers

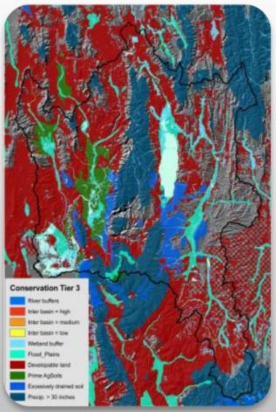
This model has been segmented into three tiers to give planners the ability to pick and choose criteria based on what level of protection fits their values and the needs of their projects (see Figure 7.2).

### Model Criteria

- River corridor mitigation zones
- Wetland mitigation zones
- Confluence area mitigation zones
- Floodplains
- Groundwater recharge areas
- High precipitation zones
- Prime farmland

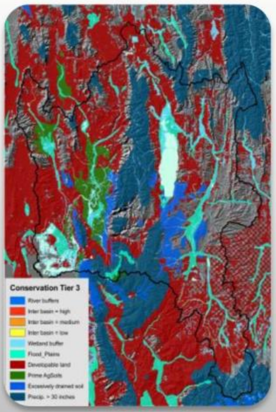
An example of stream bank degradation (Richard Toth)

## Tier 1



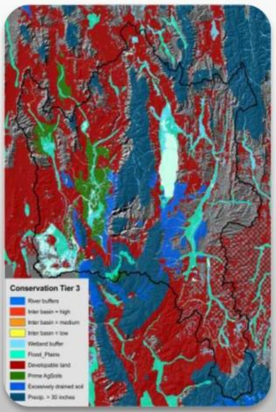
- Exclude highly permeable soils
- 100 foot wetland mitigation zone
- 300 foot riparian mitigation zone on federal land
- 200 foot riparian mitigation zone on state land
- Exclude frequently flooded areas
- Confluence areas - high

## Tier 2



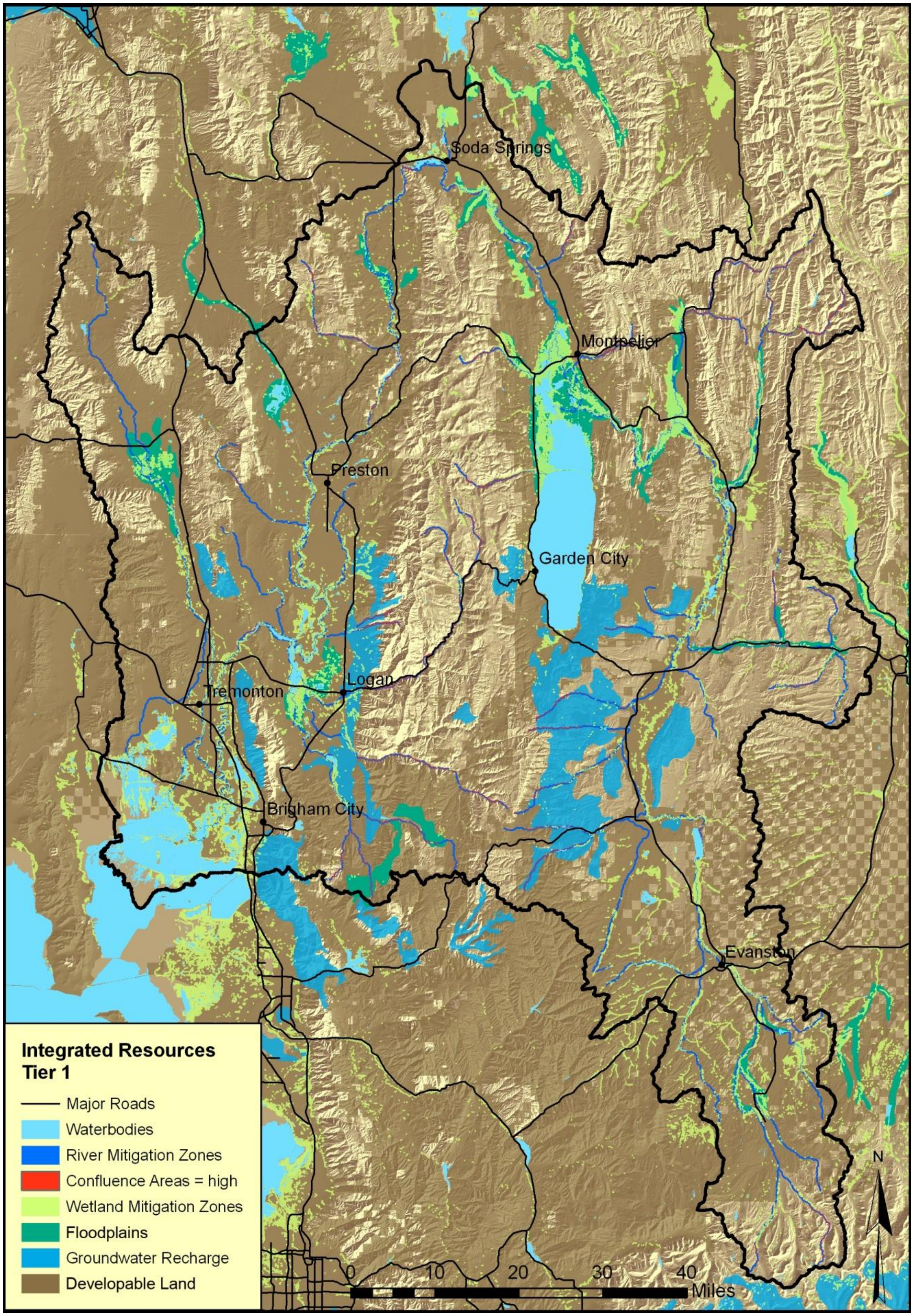
- Exclude highly permeable soils
- 100 foot wetland mitigation zone
- 300 foot riparian mitigation zone on federal land
- 200 foot riparian mitigation zone on state land
- Exclude frequently flooded areas
- Exclude occasionally flooded areas
- Confluence areas - high
- Confluence areas - medium
- Precipitation zones > 40 inches

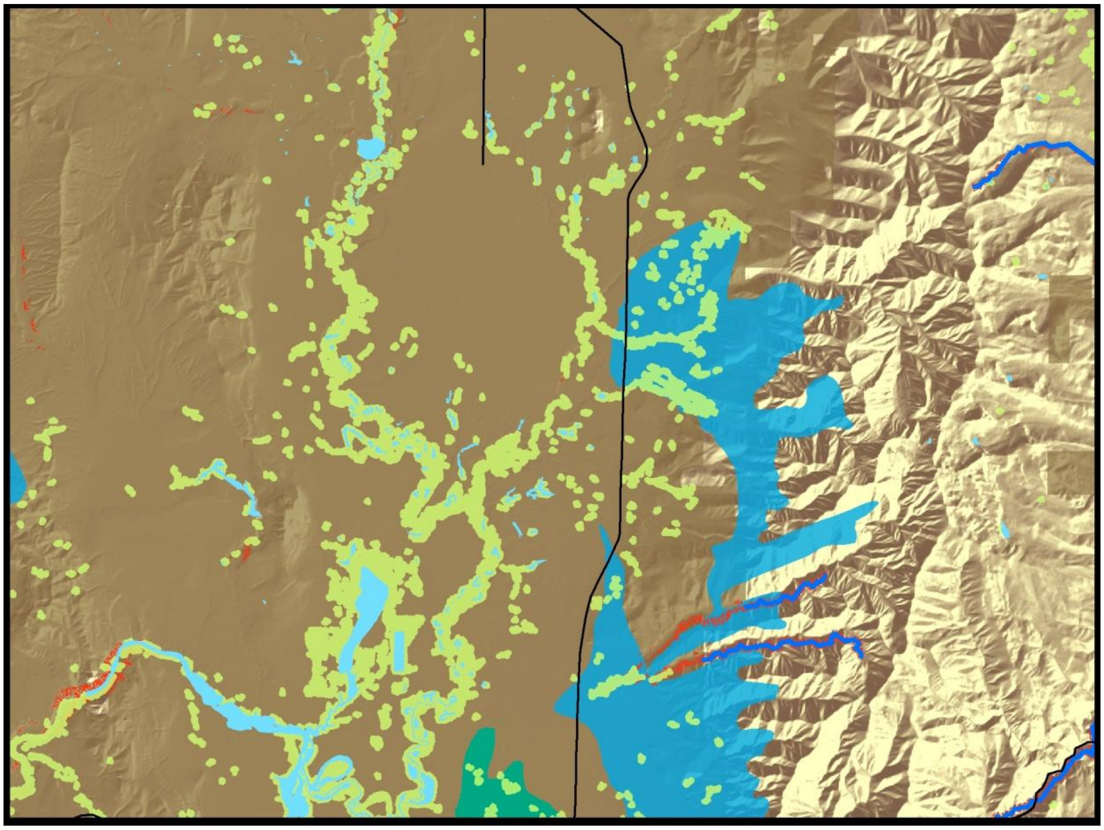
## Tier 3



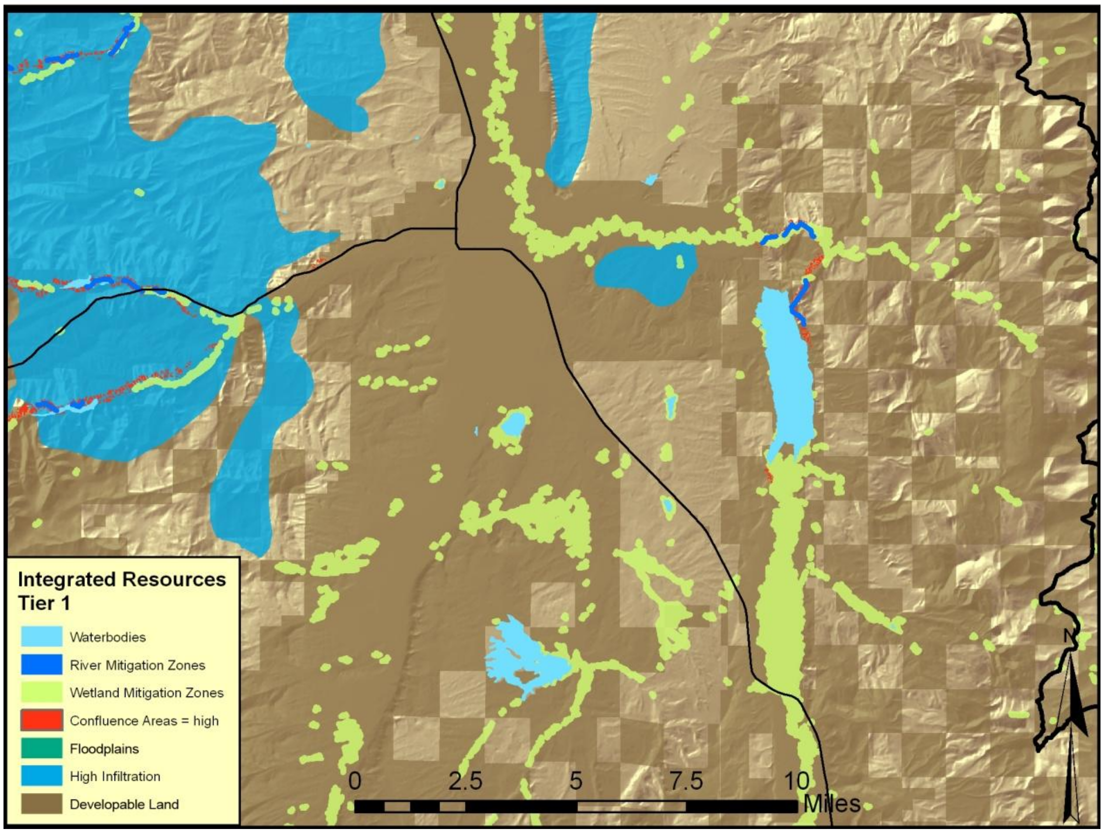
- Exclude highly permeable soils
- 100 foot wetland mitigation zone
- 300 foot riparian mitigation zone on federal land
- 200 foot riparian mitigation zone on state land
- Exclude frequently flooded areas
- Exclude occasionally flooded areas
- Exclude rarely flooded areas
- Confluence areas - high
- Confluence areas - medium
- Confluence areas - low
- Precipitation zones > 30 inches

**Figure 7.2** Criteria used in each tier of the Integrated Resource future

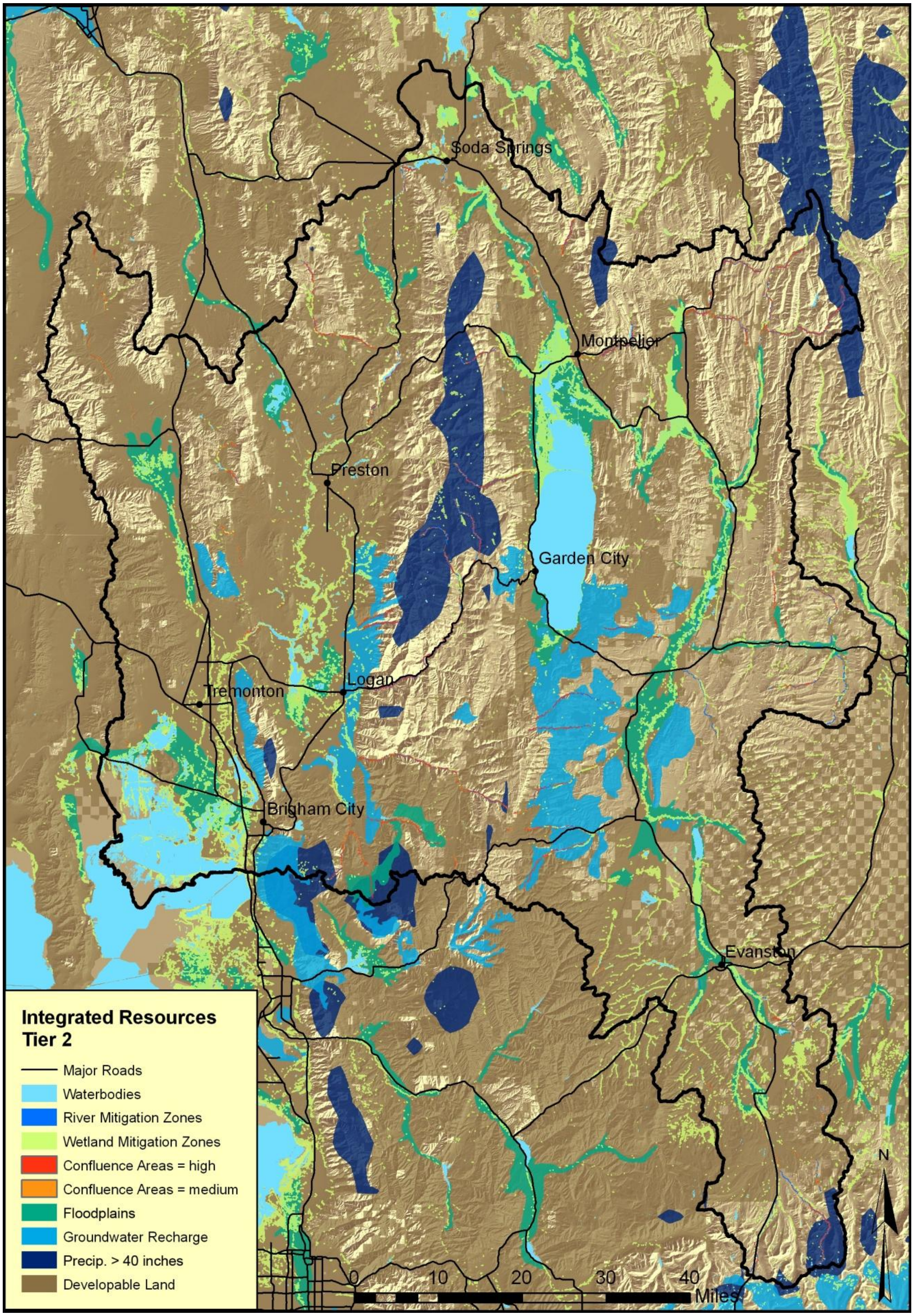

Integrated Resources
Tier 1
Major Roads
Waterbodies
River Mitigation Zones
Confluence Areas = high
Wetland Mitigation Zones
Floodplains
Groundwater Recharge
Developable Land
Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
N
0 10 20 30 40
Miles

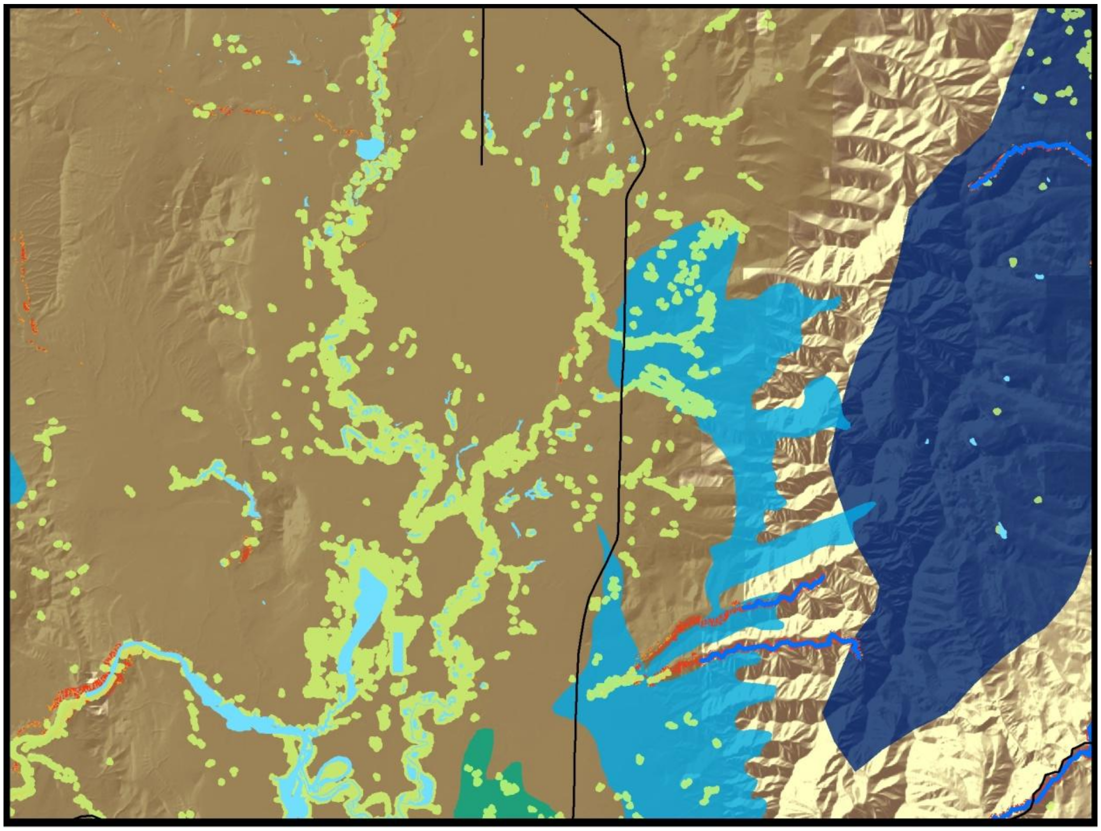


Lower Bear River Watershed Detail

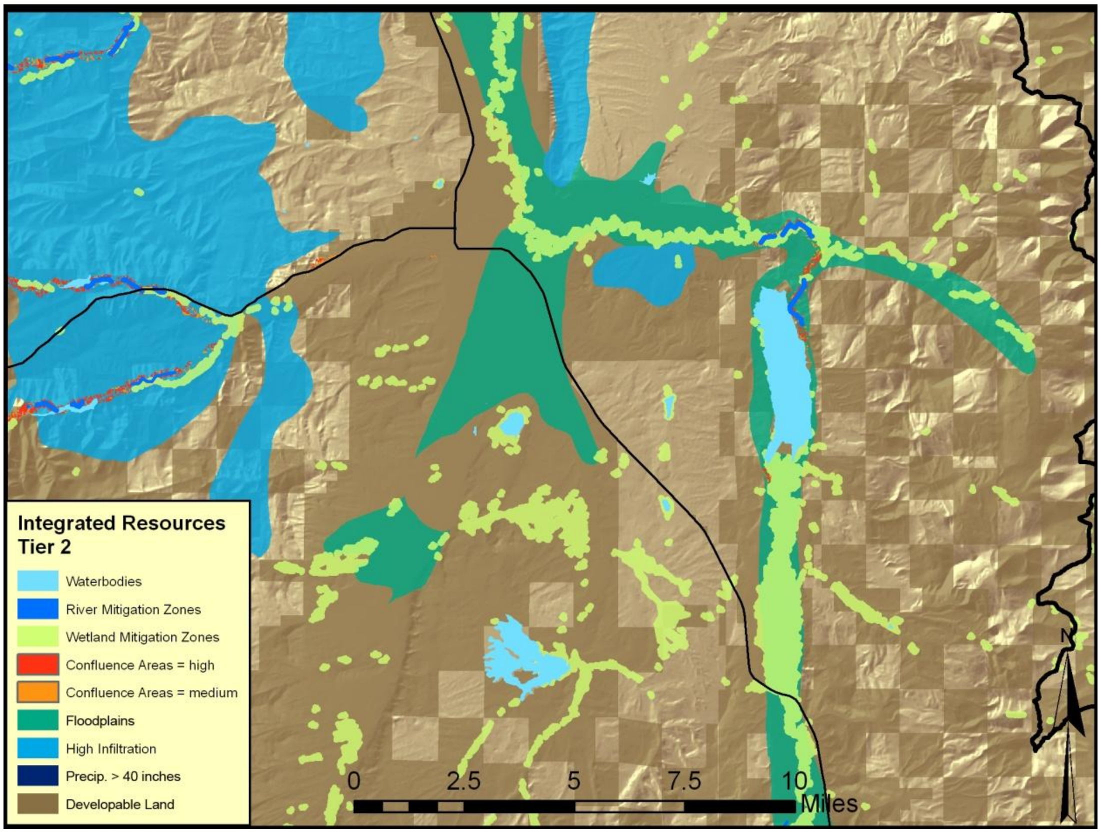


Upper Bear River Watershed Detail

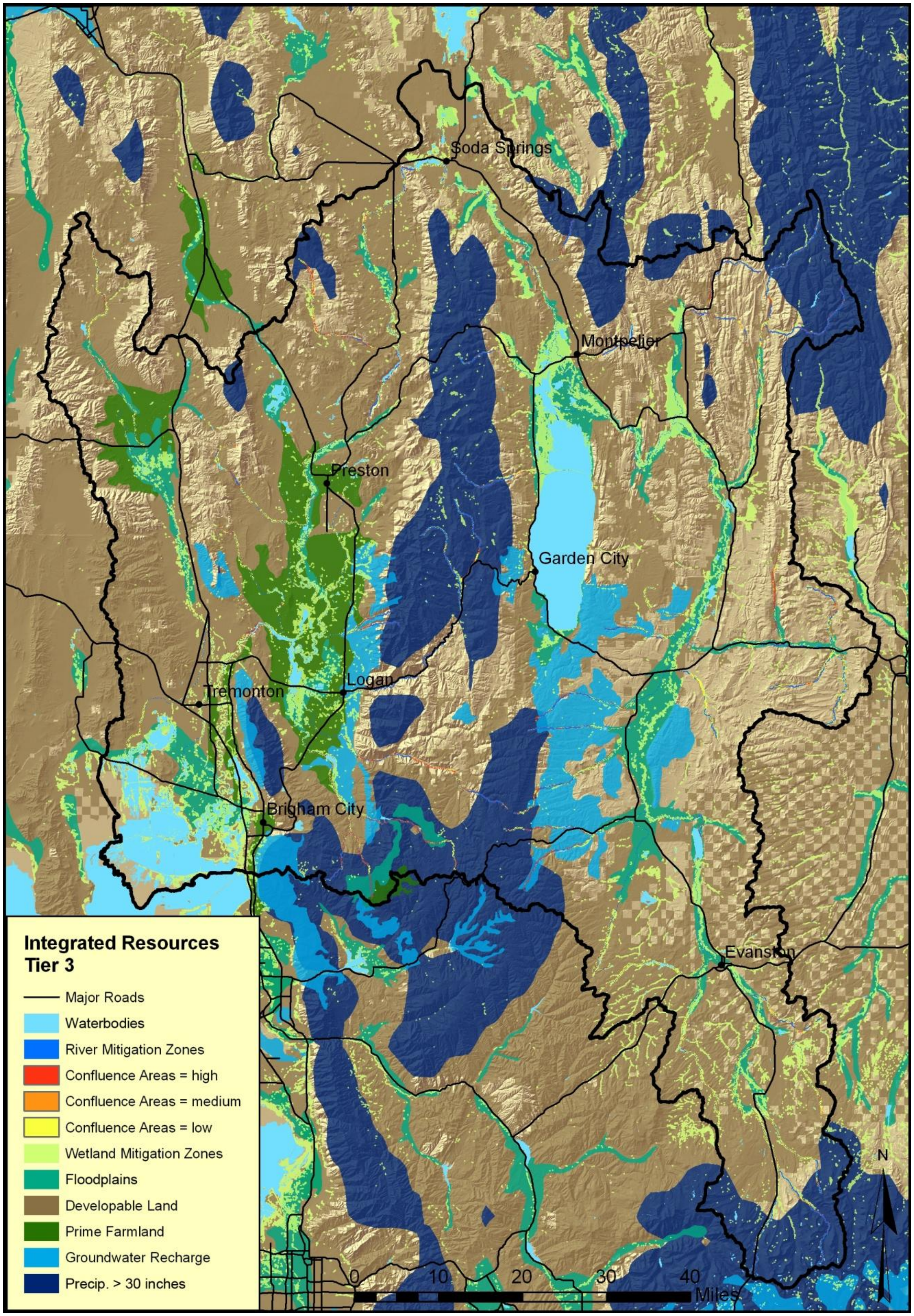

Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Integrated Resources
Tier 2
Major Roads
Waterbodies
River Mitigation Zones
Wetland Mitigation Zones
Confluence Areas = high
Confluence Areas = medium
Floodplains
Groundwater Recharge
Precip. > 40 inches
Developable Land
N
0
10
20
30
40
Miles

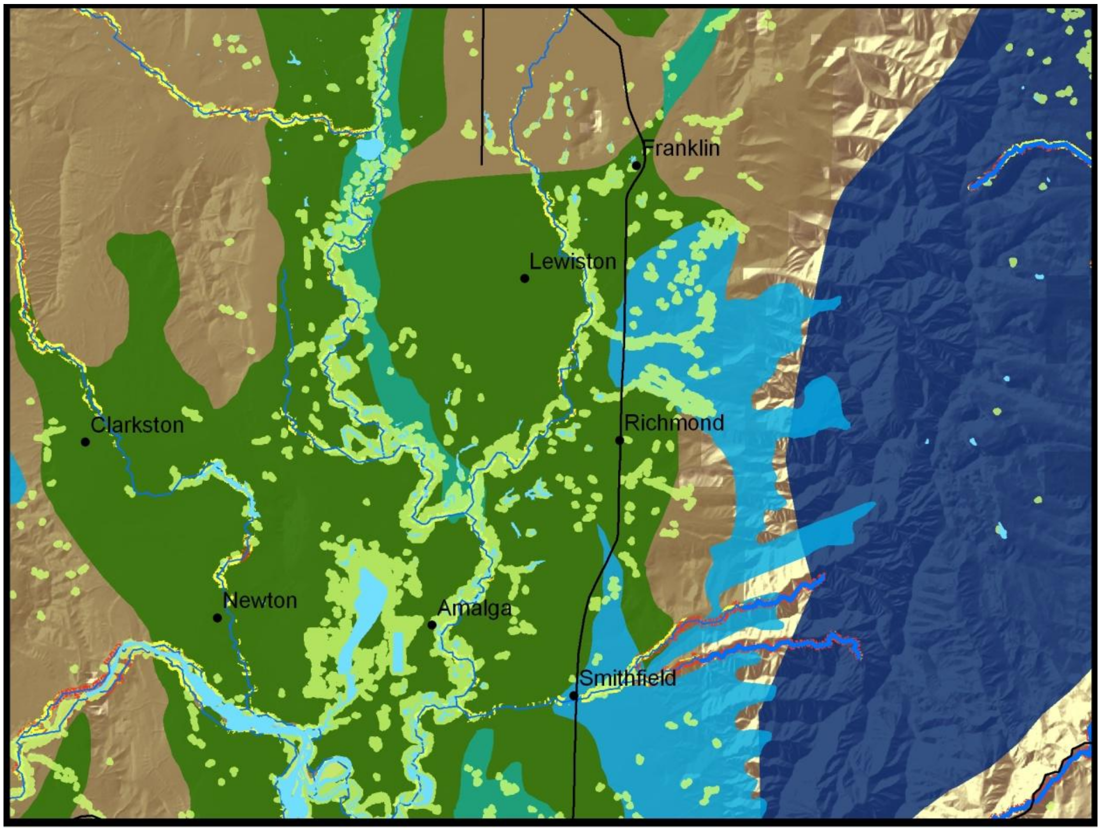


Lower Bear River Watershed Detail

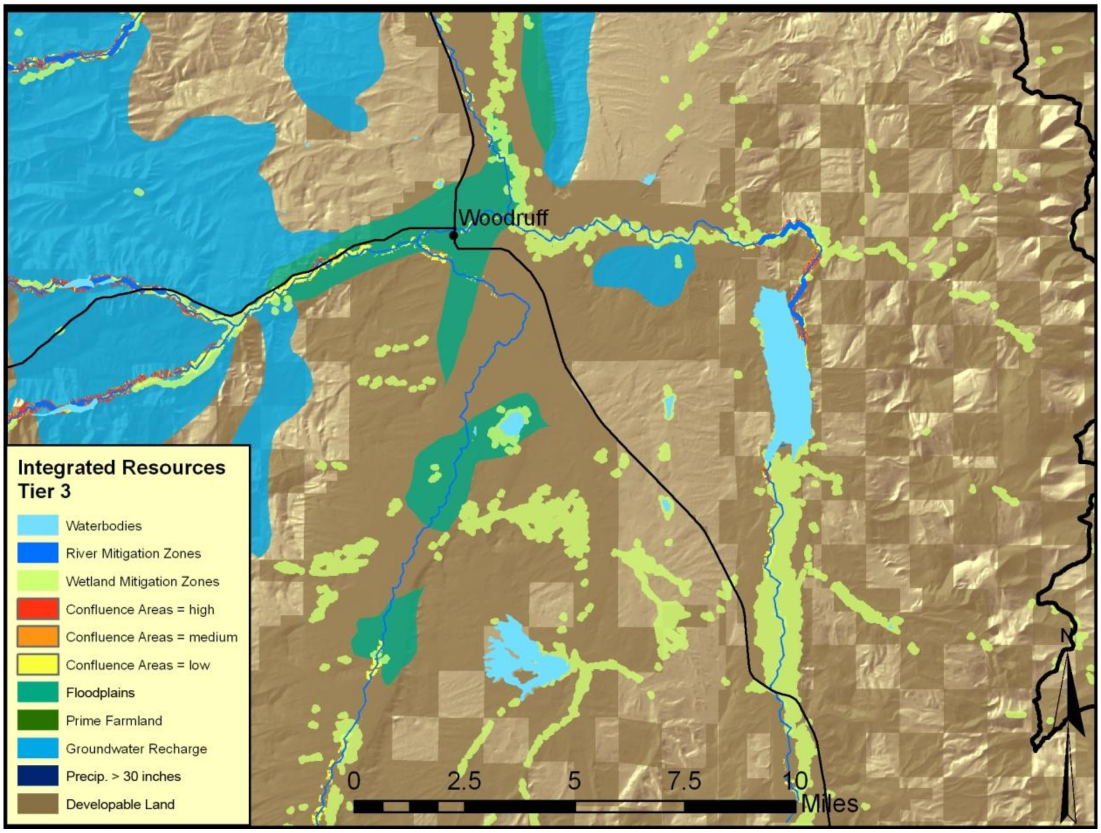


Upper Bear River Watershed Detail


Soda Springs
Montpelier
Preston
Garden City
Logan
Tremonton
Brigham City
Evanston
Integrated Resources
Tier 3
Major Roads
Waterbodies
River Mitigation Zones
Confluence Areas = high
Confluence Areas = medium
Confluence Areas = low
Wetland Mitigation Zones
Floodplains
Developable Land
Prime Farmland
Groundwater Recharge
Precip. > 30 inches
0
10
20
30
40
Miles
N



**Lower Bear River Watershed Detail**



**Upper Bear River Watershed Detail**

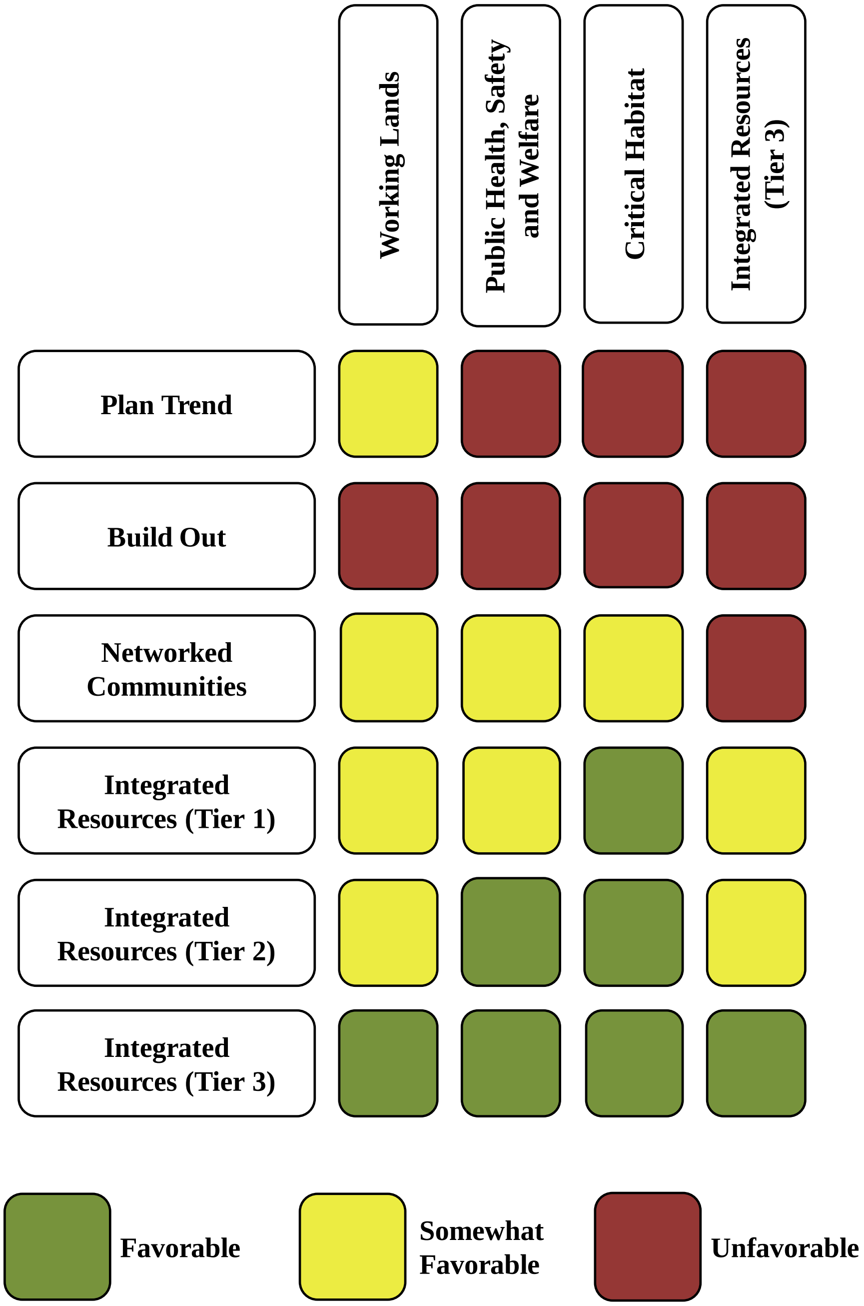
## Evaluation of Alternative Futures

A key step in the planning process is evaluating how well the alternative futures perform on the landscape and what impacts they might have upon the key issues identified in the research process. This allows planners and policy makers to better understand the effects of potential actions prior to developing and implementing land use policies.

Using ArcGIS, the studio team compared the alternative futures against each of the assessment models. This process identified which portions of the projected development areas within each alternative future might be in conflict with each assessment model's criteria. The conflicting areas were then compared across all futures within each assessment category. Based on the results of the analysis, each output was classified with an unfavorable, somewhat favorable, or favorable designation, depending on the severity of the conflict. These categories evolved from a matrix that quantified each alternative future's impact to a particular assessment in relation to the average impact on that assessment by all futures. Unfavorable designations were applied to futures with a greater than average impact to the assessment. Somewhat favorable designations were applied to futures with an impact that was less than average, but within one standard error less than the average impact for the assessment. Finally, favorable designations were applied to futures whose impact was more than one standard error below the average impact for the assessment. Figure 8.1 displays the results of the alternative futures evaluations.

The assessment models used in the evaluation process were discussed in detail in previous sections of this report. It is important to note that the Integrated Resources assessment model is based upon the criteria used in the Integrated Resources Tier 3 alternative future, which was designed to produce maximum water quality and quantity while still allowing necessary growth and development. Additionally, the critical habitat assessment model was weighted more heavily toward wetlands and riparian habitat due to their disproportionate value to wildlife and their more direct impact on the Bear River Migratory Bird Refuge.

The lower Bear River near Elwood, Utah (Adam Perschon)



| | Working Lands | Public Health, Safety and Welfare | Critical Habitat | Integrated Resources (Tier 3) |
|---|---|---|---|---|
| Plan Trend | 🟨 | 🟥 | 🟥 | 🟥 |
| Build Out | 🟥 | 🟥 | 🟥 | 🟥 |
| Networked Communities | 🟨 | 🟨 | 🟨 | 🟥 |
| Integrated Resources (Tier 1) | 🟨 | 🟨 | 🟩 | 🟨 |
| Integrated Resources (Tier 2) | 🟨 | 🟩 | 🟩 | 🟨 |
| Integrated Resources (Tier 3) | 🟩 | 🟩 | 🟩 | 🟩 |

🟩 Favorable

🟨 Somewhat Favorable

🟥 Unfavorable

**Figure 8.1:** Evaluation of alternative futures against assessment models

**Plan Trend**

The Plan Trend future was designed to illustrate how current planning policies may shape development practices throughout the watershed within the foreseeable future. This creates a baseline to which other alternative futures can be compared. An evaluation of the Plan Trend future revealed an unfavorable impact to three of the four assessment models, Working Lands being the exception. Plan Trend's impact to Working Lands was designated as somewhat favorable, which is understandable since its criteria call for development to occur within 400 feet of major roads and existing development. This means that, even though new development stays within a relatively short proximity to existing development, most of the new development will occur on agricultural lands.

The impact of Plan Trend to the Public Health, Safety, and Welfare, Critical Habitat, and Integrated Resources assessment models is unfavorable in all three cases. A common criterion among these three assessments negatively impacted by Plan Trend is the buffer or mitigation zones around riparian and wetland areas. Plan Trend does not include protections for these areas, meaning development can occur in close proximity to rivers and wetlands. This could result in development within potential flood hazard zones, on critical riparian and wetland habitat, or in areas that could experience a decrease in water quality from nearby human activities. Plan Trend's development patterns also affect other criteria within these assessment models, contributing to the overall unfavorable designations received by Plan Trend in the three assessment categories. It is clear from this analysis that over time, current planning practices may have an undesirable impact to several key resources within the watershed, including those that make significant contributions to the quality of life presently enjoyed by the watershed's residents.

**Build Out**

The Build Out future illustrates a more aggressive development model than Plan Trend, designed to provide insight into landscape patterns resulting from few constraints on development. Not surprisingly, Build Out's impact to all four assessment models is unfavorable. A notable change from Plan Trend to Build Out is the impact upon the Working Lands assessment model. The criteria for Build Out allows for a quarter-mile development zone from existing development and major roads, which is more than three times the size of Plan Trend's development zone. This translates into more land being consumed for development, much of which is agricultural land.

The impact of Build Out on the Public Health, Safety, and Welfare, Critical Habit, and Integrated Resources assessment models is similar to that of Plan Trend, although those impacts are much more severe. Build Out impacts riparian and wetland areas to a greater degree which, again, affects all three of these assessment models. Additionally, since Build Out allows development on steeper slopes, structures have the potential to be located in areas prone to landslides, on previously undisturbed wildlife habitat, or within confluence areas that contribute sheet flow into streams and rivers. As with Plan Trend, Build Out significantly impacts key resources within the watershed, creating a highly undesirable future development pattern.

### Networked Communities

The Networked Communities future integrates smart growth planning initiatives into development policies that are designed to reduce dependence upon fossil fuels. The result is more walkable towns, connected by efficient public transportation systems, regional service centers, and local food production networks. The nature of this future leads to development patterns that are more defined, with fewer opportunities for sprawl to occur.

Networked Communities' development pattern tends to use less land for growth than is used in either Plan Trend or Build Out. The result is a somewhat favorable impact to the Working Lands, Public Health, Safety, and Welfare, and Critical Habitat assessment models. Networked Communities does not reduce impacts to these assessments completely, but its focused growth on fewer acres of land makes it less likely that development will consume agricultural lands, be placed in areas with public health and safety concerns, or destroy critical wildlife habitat.

The impact of Networked Communities to the Integrated Resources assessment model is unfavorable. This is primarily due to existing and future development near wetland and riparian areas, as well as within potential flood zones. Additionally, some agricultural land must also be consumed to accommodate for some of the population growth in the region. While not perfect, the Networked Communities future does begin to approach some level of preservation for key resources within the basin and could be modified to incorporate some additional protections for the Integrated Resources assessment criteria, making Networked Communities a potentially viable planning option within the watershed.

### Integrated Resources

The Integrated Resources future was developed to determine key areas within the watershed that need to be conserved and/or restored to maintain and enhance the quality and quantity of water available within the watershed and to the Bear River Migratory Bird Refuge. This future was constructed in three tiers, with each successive tier adding additional protections to the previous tier. Any private lands outside these critical conservation areas would be available for development.

Each tier of the Integrated Resources future had at least a somewhat favorable impact on each assessment model, with tier 3 having a favorable impact in each assessment category. This is understandable since many of the criteria built into the Integrated Resources future were similar to those found in some of the assessment models. Interestingly, the quantitative analysis showed little difference between the impact of tiers 1 and 2 on each assessment model. Moving from the protections found in tier 2 to those in tier 3 shows a dramatic improvement to the impact on all four assessment models, leading to much more favorable conditions.

It is interesting to note that the focus of the Integrated Resources future is the protection of water quality and quantity. However, this emphasis yields benefits to the preservation of working lands and critical wildlife habitat, as well as an increase in the public health, safety, and welfare functions of the landscape.

## Conclusion

Situated within a largely arid region, the Bear River Watershed has been richly endowed with a myriad of natural and cultural resources. The region’s unique characteristics and beautiful landscapes have beckoned to humans for centuries, openly inviting them to dwell among its mountains and valleys and partake of its ample harvest. This trend continues today. Growth and development within the basin are an inevitable consequence of a region that provides a high quality of life and a true sense of belonging. However, with this growth comes challenges. As people continue to move into the basin, increased demands are placed upon the very resources that drew them to the area. Left unchecked, demands placed upon those resources, most notably water, may alter the region’s ability to sustain itself.

Given current water and land management practices, water availability in the Bear River Watershed and for the Bear River Migratory Bird Refuge will be an ever increasing issue. Although agricultural irrigation currently has the most significant impact on the reduction of water in the Bear River, population growth, both inside and outside of the basin, is placing additional burdens on the basin’s water supplies. (Utah Division of Water Resources, 2004). This will add to the difficulty of successfully managing the Refuge, which already struggles to maintain habitat during the critical growing season.

Climate change is another issue the Refuge will have to address to survive. It is predicted that the climate in the West may rise by 3° C by 2050 (Steenburgh, 2010). This warming trend has the potential to cause snow to melt more quickly and earlier in the year, resulting in even less water availability during the growing season. Predicting how climate change will impact precipitation in northern Utah is far less precise given that northern Utah lies along a transitional zone. The best estimates predict that there may be a slight increase in winter precipitation, though much of it may come in the form of rain instead of snow. This further complicates water availability for the Refuge. Snowpack acts as a natural reservoir, holding the water for the spring thaw and allowing the Refuge and others to receive the water in the spring and summer months.

Considering the increased demands being placed on limited water resources leads one to ask what can be done throughout and around the basin to maintain and/or enhance the health and vitality of the Refuge? This project has attempted to answer that question by researching various public and private implementation strategies aimed at protecting regionally significant critical lands from future development within the Bear River Watershed.

It is evident that current planning policies in the region are unlikely to address water resources in an adequate way. Water resource planning is a dynamic process that occurs within a complex system, making a narrowly focused approach impractical for satisfying innumerable water needs. A multifaceted approach is needed to satisfy the many demands placed on the water of the Bear River Watershed. The Integrated Resources future attempts to not only satisfy these demands but to exceed the current need, so that there is clean water within the basin for future generations and an adequate supply of water to allow the Refuge to perform its critical role in caring for millions of migratory birds annually.

The Integrated Resources future was developed in three tiers, making implementation of its strategies more realistic and economically feasible. Planners and policy makers might start by putting into place the level of resource protections outlined in tier 1, which, if nothing else is done, provides important conservation and improvement measures for water quality throughout the basin. Through time, the additional resource conservation strategies outlined in tiers 2 and 3 could be formulated into policy as well, increasing the likelihood that the basin's residents and the Refuge will have adequate, good-quality water for years to come.

## Final Thoughts

**The benefits of the Integrated Resources future do not stop at preserving and/or enhancing water quality and quantity. As can be seen in the evaluations portion of this report, the Integrated Resources future also provides the basin with protections for prime agricultural land and critical wildlife habitat, as well as development exclusions that promote building on areas less prone to natural disasters. As a result, even though the Integrated Resources future seeks to maintain and enhance water quality and quantity, particularly for the Bear River Migratory Bird Refuge, it provides substantial benefits to the region's inhabitants. Consequently, implementing the resource protection criteria within the Integrated Resources future will not only accommodate future development and growth throughout the watershed, but will likely maintain the overall quality of life currently enjoyed by the basin's residents.**

The Bear River Migratory Bird Refuge (Adam Perschon)

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# Appendices

Appendix A: GIS Data Sources

Appendix B: Networked Communities Supplement

Appendix C: Example Case Study

# Appendix A: GIS Data Sources

## GIS Data Sources

### Computer Software

Data Analyses were performed using Environmental Systems Research Institute's (ESRI) ArcGIS, version 9.3.

### Map Projection Data

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

### Primary Data Sources

Bear River Watershed Information System (Utah Water Research Laboratory)
http://www.bearriverinfo.org

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

National Atlas of the United States
http://www.nationalatlas.gov/atlasftp.html

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

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

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

United States Census Bureau
http://www.census.gov/geo/www/tiger/

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

Utah Automated Geographic Reference Center (AGRC)
http://gis.utah.gov

## Networked Communities Supplement

### Basic Services

<u>Food Retail</u>

Supermarket
Other food store with produce

<u>Community-Serving Retail</u>

Clothing store or department store selling clothes
Convenience store
Farmer's market
Hardware store
Pharmacy
Other retail
**Services**
Bank
Gym, health club, exercise studio
Hair care
Laundry, dry cleaner
Restaurant, café, diner (excluding establishments with only drive-throughs)

<u>Civic and Community Facilities</u>

Adult or senior care (licensed)
Child care (licensed)
Community or recreation center
Cultural arts facility (museum, performing arts)
Educational facility (including K–12 school, university, adult education center, vocational school, community college)
Family entertainment venue (theater, sports)
Government office that serves public on-site
Place of worship
Medical clinic or office that treats patients
Police or fire station
Post office
Public library
Public park
Social services center

**Walkable Streets**

Requirements

Design and build the *project* to achieve all of the following:

a. For 90% of new building frontage, a principal *functional entry* on the front façade faces a public space, such as a street, square, *park*, *paseo*, or *plaza*, but not a parking lot, and is connected to sidewalks or equivalent provisions for walking. The square, park, or plaza must be at least 50 feet wide at a point perpendicular to each entry.

b. At least 15% of *existing* and new street frontage within and bordering the project has a minimum building height-to-street-width ratio of 1:3 (i.e., a minimum of 1 foot of building height for every 3 feet of street width).

- Nonmotorized rights-of-way may be counted toward the 15% requirement, but 100% of such spaces must have a minimum building-height-to-street-width ratio of 1:1.
- Projects with bordering street frontage must meet only their proportional share of the height-to-width ratio (i.e., only on the project side of the street).
- Street frontage is measured in linear feet.
- Building height is measured to eaves or the top of the roof for a flat-roof structure, and street width is measured façade to façade. For *block* frontages with multiple heights and/or widths, use average heights or widths weighted by each segment's linear share of the total block distance.
- *Alleys* and driveways are excluded.

c. Continuous sidewalks or equivalent all-weather provisions for walking are provided along both sides of 90% of streets or frontage within the project, including the project side of streets bordering the project. New sidewalks, whether adjacent to streets or not, must be at least 8 feet wide on retail or mixed-use blocks and at least 4 feet wide on all other blocks. Equivalent provisions for walking include *woonerfs* and all-weather-surface footpaths. Alleys, driveways, and reconstructed existing sidewalks are excluded from these calculations.

d. No more than 20% of the street frontages within the project are faced directly by garage and service bay openings. Projects in a designated *historic district* subject to review by a local historic preservation entity are exempt from (b), (c), and (d) if approval for compliance is not granted by the review body. Projects in historic districts listed in or eligible for listing in a state register or the National Register of Historic Places that are subject to review by a state historic preservation office or the National Park Service are exempt from (b), (c), and (d) if approval for compliance is not granted.

## Case Study

# *The Plan and the Program for the Brandywine*

**John C. Keene and Anne Louise Strong**

## Abstract

*The Plan and the Program for the Brandywine* outlines a multi-prong approach for planning and development in the Upper East Branch of Brandywine Creek in Chester County, Pennsylvania. Its purpose was to determine a solution for preserving water supply and quality, and the natural amenities enjoyed by area residents, while accommodating natural growth and urbanization. The plan offered specific recommendations to achieve these goals based upon sub studies directed by John C. Keene, Anne Louise Strong and their research team. Research focused on hydrology, geology, population projections, land use, real estate and land values, legal issues, and the attitudes of area residents. Based upon this research, the primary recommendation was to purchase conservation easements for lands critical to the preservation of the watershed and the area's natural amenities. The easements would restrict development along streams, wooded areas, and upon slopes. The plan was presented to the Chester County Water Resources Authority and the eight townships affected by the plan. Strong and Keene reasonably demonstrated that the conservation easements would allow the area's water resources to be preserved adequately well, while accommodating normal growth and development.

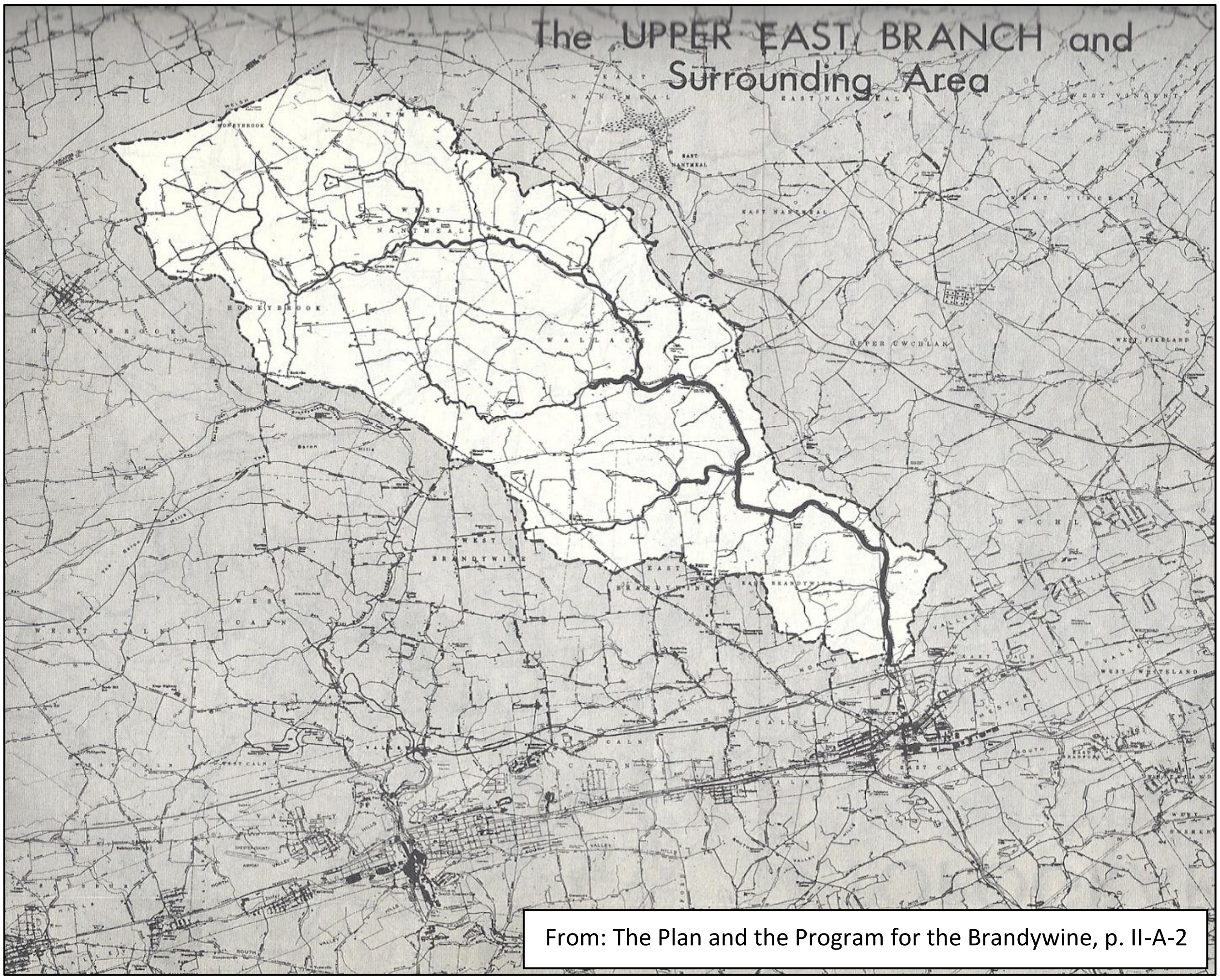
## Case Study

*The Plan and the Program for the Brandywine* was a multifaceted study focused on the Upper East Branch of Brandywine Creek, in Chester County, Pennsylvania. It outlined a method by which the area’s water supply and quality could be maintained, and natural amenities preserved, amidst inevitable population growth and land development. The well formulated and comprehensive nature of the study ultimately enabled the researchers to set forth several specific and realistic recommendations to guide development while preserving water quality. The following case study will outline the main points of the Brandywine study, including its proposals, and offer some analysis as to its effectiveness.

The Brandywine project had its roots in research conducted by one of its lead authors, Anne Louise Strong of the Institute of Environmental Studies at the University of Pennsylvania. She spent the five years preceding the project, starting in 1960, studying methods of preserving open space through fee purchase programs. Noting that little had been done in the way of actual experimentation in this area of research, Strong looked for an opportunity to further demonstrate approaches to the preservation of open space through practical application. Partnering with John C. Keene, also of the Institute of Environmental Studies, Strong found her opportunity in the Upper East Branch of Brandywine Creek, an area with a large degree of open area, but poised for further development. The area was made even more attractive by the presence of the Chester County Water Resources Authority, a legal entity in the area which had the desire and commitment to implement a plan to minimize damage to water, scenery and other natural resources through effective management of population growth and land development. In addition to the Chester County Water Resources Authority, the eight townships covered in the research area were a critical element to the acceptance or rejection of the plans proposed by the study.

The Upper East Branch of the Brandywine is located entirely in Chester County, Pennsylvania and covers eight townships. The area is approximately 35 miles west of Philadelphia and 25 miles north of Wilmington, covering 23,500 acres (see Figure 1).

It is important to note once again that Strong and Keene were seeking to determine how to accommodate growth within the study area while limiting negative impacts to water quality and the type of natural amenities enjoyed by the area’s citizens. This required a detailed and multi-prong approach, involving specialists in the areas of geography, hydrology, land use, population projections, land value assessments, legal issues, and social science. Strong and Keene organized a “Technical Advisory Committee” to help guide the efforts of sub-studies, which were carried out by a variety of institutions, such as the United States Geological Survey and the Drexel Institute of Technology. Most of the elements of the study were carried out separately, but used in the aggregate to formulate the specific recommendations for the Brandywine plan. Research on the Brandywine began in 1966 and concluded in 1968 when the report was presented and published.

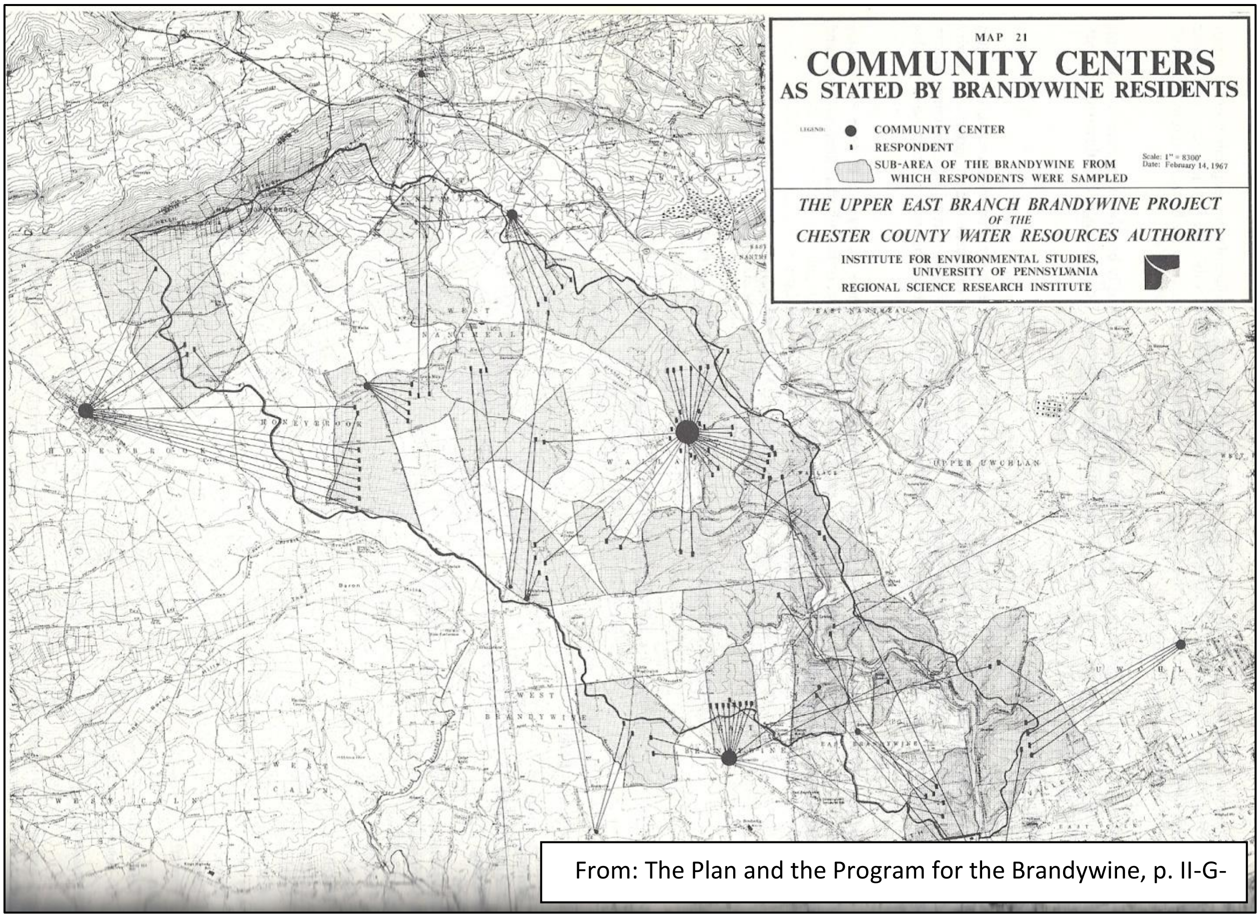


From: The Plan and the Program for the Brandywine, p. II-A-2

**Figure 1** Upper East Branch of the Brandywine

A brief review of some of the sub-elements of the study is appropriate. One of the pivotal portions of the research was an attitude survey given to residents within and around the study area. The survey instrument helped researchers determine how people felt about the area, how they used the land, and how they felt about land preservation. In general, residents in the

Brandywine area seemed to be more concerned about the natural environment than those living outside the study area. The survey also indicated what physical points within the study area Brandywine residents felt were their community centers, which helped researchers better understand how residents viewed their sense of belonging (see Figure 2). Interestingly, the survey indicated that Brandywine residents had quite limited knowledge of land use controls, such as zoning and easements. This may have contributed to the plan’s overall rejection since the backbone of the Brandywine plan included the purchase of conservation easements. A key theme from the survey was the strong desire for land preservation, but with sensitivity to land owner’s rights. Among other things, the attitude assessment allowed the researchers to distance their own bias from the research and apply the feelings and values of the areas’ residents to the plan recommendations, which researchers felt was critical to implementation of the plan.



From: The Plan and the Program for the Brandywine, p. II-G-

**Figure 2** Community Centers in the Brandywine Area

Hydrology was another important, if not the most central, element in the Plan for the Brandywine. Most of the hydrology work was conducted or directed by Luna B. Leopold, a specialist working for the United States Geological Survey. Leopold and his team studied the Brandywine area for water supply, which included stream flow, sediments, chemical quality, and biological quality. Earlier studies throughout the country indicated a pattern of increased flooding, increased erosion and sedimentation, and decreased water supply through the process of urbanization. Since little, if any, research of this kind had been performed specifically on this section of the Brandywine, much of the study’s hydrologic work established a baseline to monitor future changes. Leopold’s work determined that the portions of the Brandywine watershed whose use would most affect water resources were steep slopes, woods, land adjacent to streams and areas within the flood plain. Leopold asserted that limiting land use in these areas would help reduce erosion, decrease flooding, and limit pollutants and sediments from entering the stream system. This work guided the research team in developing a plan for the purchasing of conservation easements in the areas of the watershed most critical to maintaining water quality.

Real estate and land value studies were also an essential element to the Brandywine plan. The researchers felt that zoning ordinances were not strong enough to accomplish the types of protections they felt were necessary to maintain water quality and natural amenities throughout the study area. This was due to the nature of zoning laws, which can be easily and quickly changed for short term rather than long-term planning purposes. The researchers also felt that it was not necessary to purchase outright the critical land areas, instead proposing that conservation easements be purchased from land owners. This would allow land owners to retain their property but limit what areas of their property they could develop. The easement would be retained by the purchasing government entity so that if a parcel were sold, the new land owner would be under the same easement restrictions as the original owner had been. The researchers looked at how land values would be affected by the conservation easements, believing that land with restrictions may not be as appealing to prospective buyers and thereby bring overall land values down. The research found that land prices in the long run would not be significantly affected in most of the study areas, especially those in which larger tracts of land were desirable.

Researchers used population projections to ascertain where and what type of population growth would occur in the study area over the next several decades. Admittedly, the area was small, which made it difficult to accurately forecast growth. However, the researchers felt confident that their population projections were accurate enough to help guide the plan’s proposals. Researchers concluded that the population would double in the area as a whole by 1990, with a large portion of the growth in the southern portion of the study area, meaning that low population densities would continue throughout much of the area. This further solidified the recommendation for purchasing easements on larger tracts of land that were most likely not going to be developed within the foreseeable future.

After the various sub-elements of the study were concluded, a comprehensive plan was formulated to set forth recommendations for land use controls. As was mentioned earlier, the Chester County Water Resources Authority was the primary government entity sponsoring the plan, which also had the ability to implement many of the recommendations. Other land use controls were the responsibility of township governments or other county agencies. The underlying principals of the plan’s proposals were:

1. Maintain the water supply, water quality, and amenity of the Upper East Branch basin
2. Provide for normal urban growth in the basin
3. Assure fair compensation for development restriction
4. Develop a plan which can be more economically beneficial than customary urban development
5. Carry out the plan only if local endorsement is obtained (Keene & Strong, p. III-A-1)

Using these principals, the study team formulated three very specific recommendations for the Upper East Branch of the Brandywine:

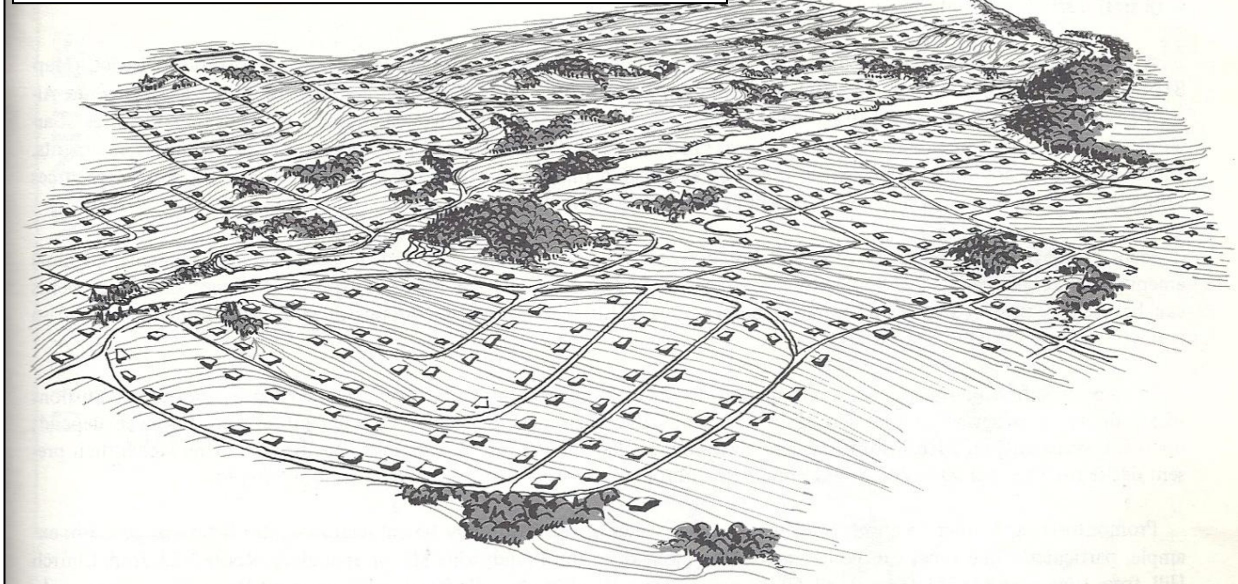
1. Further development should be kept out of the flood plains and three hundred foot wide strips on each side of streams and their natural drainage network. Development should be limited in wooded areas and on steep slopes.
2. The townships in the Upper East Branch should begin now to do long range planning for the design, financing, and construction of sewerage and water supply systems so that action can be taken quickly when future population growth makes these facilities necessary.
3. The townships should enact strong regulations governing the lay-out and construction of subdivisions, roads, and storm sewers, and the control of erosion during construction (Keene & Strong, p. I-A-1).

The eight townships and the Chester County commissioners were responsible for the acceptance or rejection of these proposals. If accepted the plan also recommended that the Water Authority take specific action to carry out the proposals. The additional actions steps included establishing a Water Resources Protection District, which primary purpose was the protection of the lands in the first recommendation outlined previously. Conservation easements should be purchased from land owners in the critical land areas on a voluntary basis. The easement purchases would begin in the first sub-watershed and then expanded throughout the watershed upon successful initial implementation. It is appropriate to once again reiterate that the easement purchase program was the lynchpin of *The Plan and the Program for the Brandywine*. The authors felt zoning laws were not permanent enough to create the types of protection needed for the watershed, and since the restrictions placed on land owners were so stringent, just compensation was necessary. Outright purchase of the critical lands was not necessary since the easements would fulfill the need to protect the watershed but allow land owners some control over the use of the land. Figure 3 illustrates what the authors reasonably believe the Upper East Branch of the Brandywine might look like with and without implementation of the plan's proposals.

*The Plan and the Program for the Brandywine* is a solid example of regional planning intended to meet specific and critical goals of water quality and land preservation. Strong and Keene built an excellent research team that created strong evidence for their recommendations that would both protect the watershed and quality of life for the area's resident, while not be too imposing on land owners' rights. The science behind the research was firm, and the proposals seemed very sensible. Two of the most critical elements of the plan were the attitude survey and the hydrological research, giving the researchers access to the value's that the area citizens placed upon protecting the natural surroundings and the science to demonstrate how the watershed could be protected in large part. The plan was to be accepted voluntarily and showed reasonably well that the intended outcomes of the plan could be accomplished by the recommendations set forth by the research team.

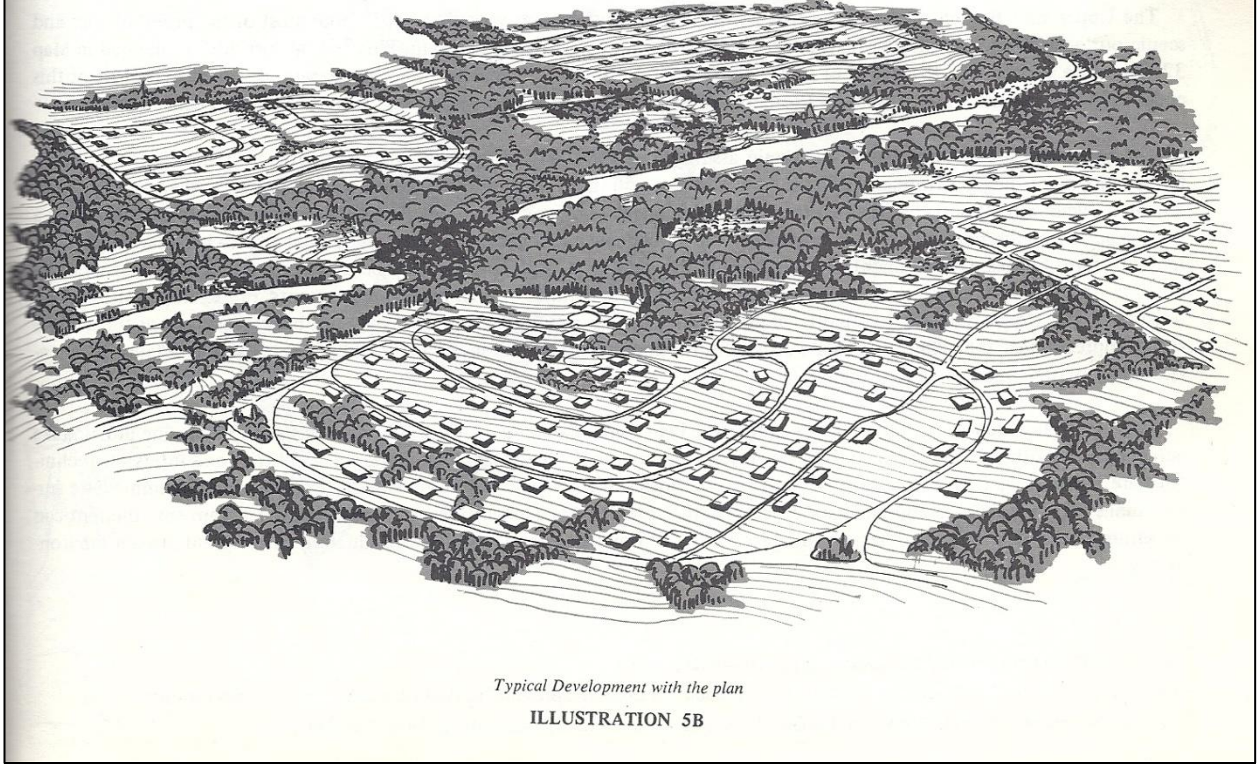
The major drawback to the plan was not in the plan itself, but in public perception and acceptance of the plan. As was mentioned previously, few residents in the Brandywine area had much knowledge of zoning laws and conservation easements, which may have lead to some uneasiness about the plan's

From: The Plan and the Program for the Brandywine, p. V-D-3



*Typical Development without the plan*

ILLUSTRATION 5A



*Typical Development with the plan*

ILLUSTRATION 5B

**Figure 1** Development With and Without the Plan intentions. Many landowners may have felt that the various government entities were striving to take away more of their property rights than the plan was proposing. This, coupled with the requirement that the plan be adopted unanimously by all eight townships in the Upper East Branch area, lead to the plan's ultimate rejection on the scale recommended by Strong and Keene. Despite this shortcoming, *The Plan and the Program for the Brandywine* is an excellent early example of planning designed to balance urbanization and the need to protect critical lands and resources.

## Bibliography

*Keene, J.C. and Strong, A.L., October 1968. *The Plan and the Program for the Brandywine*, Institute for Environmental Studies, 3400 Walnut Street, Philadelphia, PA.19104.

*Note: All quotations and figures in this study are attributed to Keene and Strong's work.