A DIGITAL ATLAS OF UTAH WILDERNESS

by

Richard Michael Warnick

A thesis submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Geography

The University of Utah

December 2011

The University of Utah Graduate School

STATEMENT OF THESIS APPROVAL

The thesis of **Richard Michael Warnick**

has been approved by the following supervisory committee members:

Merrill K. Ridd	, Chair	**4/22/11** Date Approved
Chung-Myun Lee	, Member	**4/22/11** Date Approved
Daniel C. McCool	, Member	**4/22/11** Date Approved

and by **George F. Hepner**, Chair of the Department of **Geography**

and by Charles A. Wight, Dean of The Graduate School.

ABSTRACT

Human-environment interaction has long been a primary theme of geographic thought. Public lands policies, and particularly wilderness designations, significantly shape the natural environment in western states such as Utah. Geographic information science and the Internet are now important parts of the policy-making toolkit, replacing paper maps and potentially leading to more democratization of wilderness and other important, long-term land use decisions. Geographical concepts such as regions are often employed in public land debates. Nongeographers have driven many of these developments.

The goal of this research is to demonstrate a simple, low-cost, and accurate geographic information system (GIS) using an open-source approach and freely distributable datasets. The online *Utah Wilderness Atlas* will provide spatial and descriptive wildlands resource information to a general audience. It is now easier than ever to produce and exchange geospatial data; however, such data can still be difficult to use. Datasets vary in accuracy, source scale, and spatial extent and may be poorly documented. Casual users may not know where to look for the most appropriate or reliable data, and they may not have the skills or the computer software to convert specialized file formats into meaningful maps. The *Utah Wilderness Atlas* provides maps that can be read with a standard Web browser.

Over more than 40 years, Utah wilderness issues have attained a level of complexity that requires some introduction. The *Utah Wilderness Atlas* includes issue analyses and background information to aid in understanding the maps.

Utah is characterized by wide geographical diversity. An understanding of Utah wildlands requires a regional approach to the varied landscapes and their unique qualities. The *Utah Wilderness Atlas* organizes geospatial information about wildlands according to geographical regions.

This thesis is dedicated to my wife Denise, for many years of patience.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

ACKNOWLEDGMENTS

Dr. Merrill Ridd has my deepest gratitude for his extraordinary teaching and support. I also thank committee members Dr. Daniel McCool and Dr. Chung-Myun Lee for their patience and encouragement.

I owe my introduction to Utah wilderness issues to Dick Carter, Gary Macfarlane, and George Nickas of the now-dormant Utah Wilderness Association.

The late C. Alfred Frost of Monticello taught me more than anyone how to explore and learn from Utah wildlands.

It is also important to acknowledge the work of the many nonprofit organization volunteers and government employees who created most of the spatial datasets used in the digital atlas.

CHAPTER 1

INTRODUCTION

The goal of this research is to demonstrate a simple, low-cost geographic information system (GIS) using an open-source approach and freely distributable datasets for Utah wildlands. Such a GIS is well suited to individuals, small nonprofit groups, and educational users because it requires a minimum of computer hardware, software, and training. The GIS forms the core of the online and DVD *Utah Wilderness Atlas*.

Users of geographic information traditionally relied solely on paper maps produced mainly by government agencies. This has changed, especially since 1995, with the increasing availability of personal computers and Internet access. The World Wide Web replaced printing as the major medium for the dissemination of maps (van Elzakker, 2001). There are qualitative changes as well; the latest software makes it possible for users to create an endless variety of digital maps using only a web browser or data viewer. Michael Peterson (2001) observed, "More than any other technological development in the past century, the Internet forces us to examine the purpose of cartography and our means of map distribution."

The advent of GIS made it easier than ever before to create geospatial data, make maps, and do spatial analysis. What is changing most rapidly now is the means of sharing geographic information (see Chapter 3).

At first, the lack of digital datasets was a limiting factor for GIS implementation. It took a lot of effort and resources to digitize paper maps. By the end of the 1990s, however, a great deal of GIS data concerning public lands was routinely made public by state and federal agencies. This is particularly true for Utah, where the state's Automated Geographic Reference Center (AGRC) has been a leader in GIS since 1991 (Utah AGRC, 2010a). Without the burden of creating all their own data, it became more practical for nongovernmental organizations, schools, and even individuals to develop GIS capabilities.

Even though easy to acquire, spatial data can be difficult to work with. Casual GIS users may not know where to look for the most appropriate or reliable data. They may lack the ability to convert specialized file formats into meaningful maps. The original Utah AGRC State Geographic Information Database was published in ArcInfo export format, which requires a conversion tool. The CD-ROM *Digital Geologic Resources Atlas of Utah* (Sprinkel, 1999) requires the user, at a minimum, to be able to install and learn how to use the freeware ArcExplorer data browser.

In recent years, more and more spatial data has become available in Web-enabled form. This means only a web browser is needed to view data. Various software solutions are available; these are discussed in Chapter 2. The method chosen for the *Utah Wilderness Atlas* uses scalable vector graphics (SVG), an open standard that has excellent potential for cartographic applications. Additional datasets are provided as ArcView shapefiles and MrSID files for GIS users to download and copy.

Nonspecialists often encounter a steep learning curve when attempting to understand wilderness, protected areas, and related natural resource management issues.

Details concerning wilderness policy often get bogged down in specialized jargon: what are RARE II, RS 2477, FLPMA, or LAC (see Glossary, Appendix A)? The *Utah Wilderness Atlas* will include issue analyses and historical background aimed at a general audience, and linked to an extensive glossary of terms.

Utah is characterized by geographical diversity. An understanding of Utah wilderness requires an appreciation of the unique qualities of the wide variety of landscapes under discussion. The *Utah Wilderness Atlas* uses a regional (areal differentiation) approach, based on 14 homogeneous natural/political wilderness regions (see below, Section 1.4).

1.1 Problem Statement and Thesis Objective

Implementing a Web-enabled GIS can be a financial and technical challenge for individuals, small nonprofit groups, and educational users.

The objective of this thesis is to publish a low-cost digital atlas of Utah wilderness and other protected areas on the World Wide Web, in order to provide accurate, accessible spatial and descriptive wildlands geospatial information to a general audience. The atlas will utilize public datasets. It will make use of open source software standards as much as possible, given the current state of GIS and Web mapping.

1.2 Wilderness and Geography

As an integrative discipline, Geography is uniquely suited to the study of wilderness/protected area allocation and management issues. The relevant policy and planning questions are both interdisciplinary in nature and well within the human-environment geographic tradition.

For educators, the study of wilderness is an excellent means of teaching the K-12 National Geography Standards (Boehm, 1994). These standards are endorsed by the Utah State Office of Education as part of the core curriculum for Social Studies. The *Utah Wilderness Atlas* deals directly with four of the five themes of Geography: location, place, region, and human-environmental interaction. Another theme, the movement of people and ideas, is also relevant because of the international currency of the wilderness idea and the practice of setting aside protected areas.

Few geographers have directly addressed the subject of wilderness— it is usually subsumed into broader subject areas such as recreation and tourism or rural land use. There have been a few wilderness-related geography journal articles, and at least one book chapter (Hall & Page, 2006). Gundars Rudzitis of the University of Idaho seems to be the only academic geographer to have written a book solely dedicated to wilderness issues in the western United States (Rudzitis, 1996).

The subject of wilderness has received attention from philosophers, historians, biologists and legal scholars writing from their various perspectives. Frequently, these studies fail to address the essentially geospatial nature of wilderness areas or the practical matters of concern to the land management agencies that actually plan and administer these areas. These practical management issues do get addressed by researchers associated with the Aldo Leopold Wilderness Research Institute, and the discipline of recreation resource management.

The wilderness idea is dependent on geographical concepts. In the abstract, wilderness boundaries separate the natural landscape and the cultural landscape. This is generally recognized to be impossible in a practical sense; the intent is that human influences will be minimized within wilderness areas. In the word chosen by Howard Zahniser, the principal author of the Wilderness Act of 1964, these areas will be left "untrammeled" (Nash, 2001). Often some impacts of human land use (such as unused roads, dams, and mines) are accommodated within wilderness areas because they are considered "substantially unnoticeable," not detracting significantly from the natural landscape.

Wilderness and protected area boundaries are cultural artifacts. They are products of the congressional legislative process or administrative decisions. By definition, wilderness boundaries circumscribe areas of federal land that generally appear to have been affected primarily by the forces of nature. As a result, they frequently coincide with road buffers or surveyed lines indicating land status. Older wilderness boundaries are likely to follow Public Land Survey System (PLSS) section lines to simplify the legal descriptions that were included in legislation prior to the 1980s.

Map layers have been a key public land management tool since the early 1900s. Prior to personal computers and GIS, clear thematic overlays were used in conjunction with a topographic base map. In the public land management agencies, each resource specialist (range conservationist, recreation planner, minerals specialist, forester, wildlife biologist, archaeologist, and so forth) would maintain a clear acetate overlay for the local management unit (e.g., a BLM resource area or a Forest Service ranger district). Planning could be integrated by coregistering all the overlays together over a topographic map.

In principle, resource management planning ought to be a purely professional, interdisciplinary exercise aimed at maximizing total benefits and minimizing harm by resolving conflicts among different land uses (McHarg, 1969). This is how the time-honored principles of multiple use and sustained yield are supposed to work (Ridd, 1976). In practice, there is usually a healthy dose of politics involved in determining which land uses (and users) get priority.

Wilderness inventory and designation first became part of this land use planning paradigm in a small way during the late 1920s, when Aldo Leopold and Arthur Carhart persuaded the U.S. Forest Service (USFS) to set aside the first administratively designated wilderness areas in New Mexico and Colorado (Dawson & Hendee, 2009). The Wilderness Act of 1964 (Public Law 88-577, 78 Stat 890) initiated the National Wilderness Preservation System (NWPS) and required the USFS and the National Park Service (NPS) to conduct formal wilderness studies according to the criteria identified in the Act. The Federal Land Policy and Management Act of 1976 (Public Law 9-579, 90 Stat 2743, abbreviated FLPMA) began a similar 15-year wilderness study process on Bureau of Land Management (BLM) lands. State and local governments and citizen advocacy groups have put a lot of effort into influencing the direction of these studies, sometimes conducting their own independent inventories. Wilderness inventory is first and foremost an application of the areal differentiation concept central to geography.

Wilderness inventory procedures tend to be subjective. As Roderick Nash (2001), explained in the prologue to his *Wilderness and the American Mind*:

> "Wilderness" has a deceptive concreteness at first glance. The difficulty is that while the word is a noun it acts like an adjective. There is no specific material object that is wilderness. The term designates a quality (as the "-ness" suggests) that produces a certain mood or feeling in a given individual and, as a consequence, may be assigned by that person to a specific place. (p. 1)

It ought to be noted that the quality of subjectivity is not unique to wilderness. Most other public land resources also defy accurate mapping. Expert analyses often differ regarding wildlife habitat, available forage for livestock, energy and mineral reserves, merchantable timber, water resources, cultural resources, and so forth. Federal land policy set by Congress and the regulations written by management agencies attempt to set objective standards. In particular, the Wilderness Act of 1964 (U.S. Code Title 16, Chapter 23, Section 1131(c)) defines wilderness as an area of undeveloped federal land which:

> (1) generally appears to have been affected primarily by the forces of nature, with man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least 5,000 acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological or other features of scientific, educational, scenic or historical value.

In the course of implementing this definition, government wilderness inventory efforts frequently encounter political issues that can only be settled by the legislative process. In the Roadless Area Review and Evaluation (RARE) inventories of the 1970s, for example, the U.S. Forest Service held that wilderness ought to be scenic and far from population centers as well as devoid of commercial timber and other resource conflicts. Criticism of this so-called "rock and ice" approach led to the Eastern Wilderness Act of 1975 (Public Law 93-622, 88 Stat. 2096) and the Endangered American Wilderness Act of 1978 (Public Law 95-237, 92 Stat. 40), in both of which Congress pointedly designated wilderness areas that the Forest Service had rejected in its inventory (Roggenbuck, Stankey, & Roth, 1990). Later controversies arose during the 1980s concerning BLM wilderness inventories mandated by FLPMA, most notably in Utah and Colorado.

Because the concept is so highly politicized, it has been pointed out with some irony that wilderness preservation is in fact part of the social construction of nature. William Cronon (1995) said of wilderness: "Far from being the one place on earth that stands apart from humanity, it is quite profoundly a human creation…" (p. 69). Wilderness is representative of our cultural values. For the geographer, "It matters where the lines are drawn. It matters which reasons are advanced as justification for drawing the line in one place rather than another" (Delany, 2001, p. 489).

Wilderness designation falls within a broader category of protected areas. The World Conservation Union (IUCN) defines a protected area as, "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN-WCPA and UNEP-WCMC, 1994). The wilderness picture is not complete unless protected areas, which in many cases are practically equivalent to designated wilderness, are included. Even military reservations, though not dedicated to biodiversity, in some cases can be considered the functional equivalent of protected areas because they contain large natural areas closed to public use.

There is a geographical concept that is common in recreation resource management: "the space" and "the place." Some areas are valued for their suitability as space for certain recreational activities or commodity uses, interchangeably with other such spaces. Other areas become known for their uniqueness as special places unlike any other, particularly scenic areas (Hall & Page, 2006). Protected areas can also be designated for other than recreational purposes, to protect scientific resources such as a rare plant population. The Wilderness Act definition contemplates both space and place as part of the construct to set aside wilderness.

A concept related to space/place is acreage versus area. At times, the wilderness debate revolves around aggregate acreage numbers, as if acres of wildland were a commodity. At other times, particular places come under consideration for their special features or because they have a vocal political constituency. It is common for interest groups to be formed to promote a certain area for wilderness or national park/monument designation.

Geography is also concerned with land cover and land use. There are many ways to classify land cover— probably the most common is the Anderson system used for the USGS National Land Cover Database (NLCD). Land use is harder to map than land cover, but some types of land use (e.g., urban) are implied by land cover. Other types, for example grazing and mineral resource extraction, require ancillary data. A modified version of the NLCD classes is included in the *Utah Wilderness Atlas* (see Chapter 4). The atlas also includes ancillary land use layers such as grazing allotment boundaries and mining and oil and gas sites.

Protected areas datasets commonly make use of two classification systems: one developed by the World Conservation Union (IUCN), an international body based in Gland, Switzerland, and another that is used in the Gap Analysis Program (GAP) [http://gapanalysis.nbii.gov] (Prior-Magee et al., 2007). IUCN categories describe the management objectives for various areas, and are intended for worldwide application. The IUCN does not take into account the effectiveness of management in meeting objectives. GAP status codes are more geared to actual on-the-ground land management, and were developed for use within the USA. The Conservation Biology Institute's Protected Areas Database (PAD) uses both systems (Conservation Biology Institute, 2001). These classifications provide standards of comparison for the complicated array of designations in use today. Table 1.1 is a brief summary of the IUCN and GAP status codes.

1.3 Mapping Utah Wilderness

During the 1980s, obtaining or even viewing spatial data on public land resources could be difficult and expensive, sometimes prohibitively so on the part of small non-governmental organizations. For example, the BLM created and stored administrative boundaries on acetate overlays maintained in the field offices. The only way to copy these data was by going to visit each office to make a tracing of their overlay.

Table 1.1 Relationship of IUCN Categories to GAP Codes

IUCN Category	Description	GAP Code/Comments
Ia	Scientific reserve/research natural area	Gap Status 1
Ib	Strict nature reserve/wilderness area	Gap 1 or 2 based on level of development and use
II	National park	Gap 1 or 2 based on level of development and use
III	Natural monument/natural landmark	Gap Status 1, 2 or 3 depending on biologic nature and use
IV	Managed nature reserve/wildlife sanctuary	Gap Status 1, 2 or 3 depending on use
V	Protected landscapes	Gap Status 3 or 4
VI	Multiple-use management area/managed resource area	Gap 3 or 4 depending on level of protection

(Adapted from Crist, 2000)

Protected area boundaries other than units of the National Park System (NPS) were seldom published. For example, the *Atlas of Utah* (Greer et al., 1981) had NPS boundaries, but only point locations for the Forest Service primitive area on the High Uintas, and three BLM primitive areas: Grand Gulch, Dark Canyon, and Paria Canyon. The Lone Peak Wilderness, which was designated in 1979, did not get included in this atlas at all.

To calculate area on a map, a clear plastic dot grid used to be the most common tool. Counting the dots within a polygon yielded an approximation of the acreage. Another crude method was to make a cutout from a paper map and weigh it on a sensitive scale, then compare it against the weight of a cutout from a known area (Lukez & Wheeler, 1991).

Digital mapping of wilderness resources made the sharing of geospatial data a great deal easier. GIS data and software now makes calculating the area of a polygon (and many other operations) relatively simple and much more precise than the old manual methods. Of course, accuracy of results depends on the quality of the dataset. For example, wilderness boundaries digitized from a 1:500,000-scale map exhibit a coarser level of generalization than data based on a 1:24,000 source scale.

During the 1990s, adding spatial data to a GIS often involved many hours of digitizing from paper maps. As the sharing of GIS datasets became more common, there was less need for digitizing.

New GIS datasets have resulted from various initiatives. The Gap Analysis Program in the early 1990s mapped vegetation in order to analyze which ecosystems were underrepresented within protected areas. Utah was one of the first states to benefit from this national program. The Utah Wilderness Coalition extensively revised its "citizens' inventory" from 1996 to 1998. The BLM published a new wilderness inventory in 1999 as part of its WSA Planning Project (Bureau of Land Management, 1999). Some Utah county governments mapped road rights of way and human intrusions that might disqualify areas from wilderness consideration. Much of the road data have since been made available through the State Geographic Information Database (SGID).

GIS datasets for other public land resources related to wilderness also became available. For example, the Utah Division of Wildlife Resources and the U.S. Fish & Wildlife Service have produced useful wildlife habitat layers. A Utah State University research study created a map of potential wolf habitat (Switalski et al., 2002). The Digital Geologic Resources Atlas of Utah provided a good deal of mineral data (Sprinkel, 1999). For many years, the BLM oil and gas lease information was provided only in tabular form, with spatial data available only through private sources on a proprietary basis (which means it could not be freely shared). By 2010, the Utah BLM itself was providing lease datasets on its website.

Frequent land status modifications during recent years have altered the maps of Utah and neighboring states. Proclamation of the Grand Staircase-Escalante National Monument in 1996 was followed by two extensive state-federal land exchanges. The last year of the Clinton administration saw designation of the Black Ridge Canyon Wilderness and its surrounding Colorado Canyons National Conservation Area on the Utah-Colorado border. New national monuments included Grand Canyon-Parashant and Vermilion Cliffs in Arizona, Canyons of the Ancients in Colorado, and additions to

Craters of the Moon NM. All of these protected areas are at least partly within the extent of the *Utah Wilderness Atlas*.

Improvements in wilderness mapping became possible as a result of advancements in the integration of remote sensing and GIS. In Utah, the Grand Staircase-Escalante National Monument planners used digital orthophotos to align management zone boundaries with cliff faces and other terrain features (Craig & Kandell, 2000). The practice of screen digitizing from georeferenced digital orthophotos became commonplace over the last decade, as high resolution (1-meter) imagery for Utah wildlands is now freely available through the National Agricultural Imagery Program (NAIP). NAIP acquired imagery for all of Utah in 2006 and 2009, and this imagery became part of the SGID.

Map accuracy depends not only on the availability of spatial datasets, but on knowing how to use them. Figure 1.1 compares a detail from the printed 1995 Utah Gap Analysis Program (GAP) land ownership map (based on GIS data digitized from 1:100,000 BLM land status maps), and the current PAD. The 1995 map cuts off the Dark Canyon Primitive Area east of 110º west longitude (National Biological Service, 1995). That line marks a mapsheet boundary; the adjacent sheets (which contain the bulk of the primitive area) had not been updated at the time they were digitized.

GIS feature coding can also lead to errors. An incorrect High Uintas Wilderness boundary has appeared on the GAP map and a number of subsequent maps, including some produced by the Wild Utah Project (Norton and Catlin, 2001). The example shown in Figure 1.2 is from an otherwise authoritative land ownership map published by the

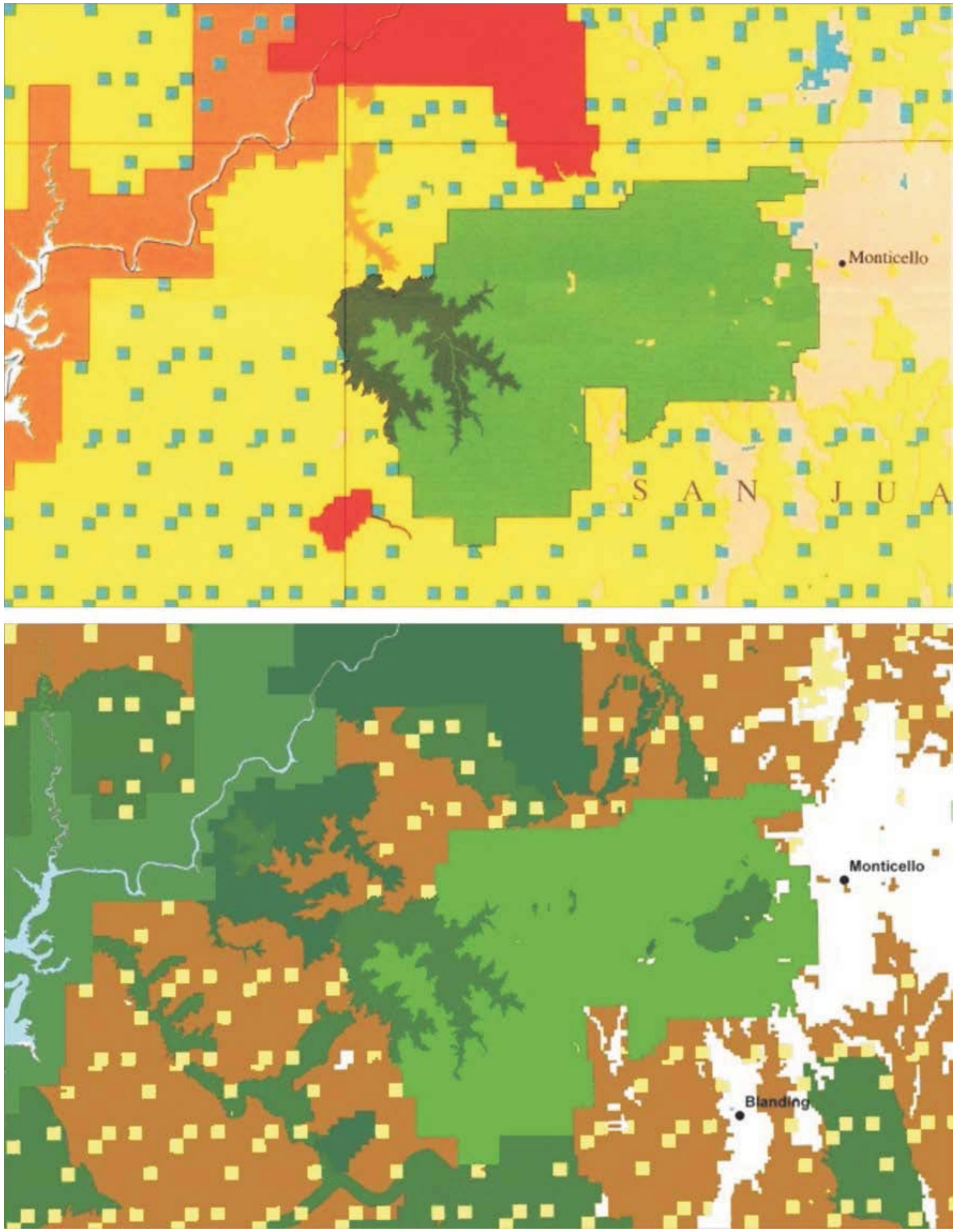


Figure 1.1 Detail from printed 1995 GAP land ownership map (above) and 2010 PAD showing the area south of Canyonlands NP. Dark Canyon Wilderness is at the center, with adjacent Dark Canyon Primitive Area just to the west. (National Biological Survey, 1995).

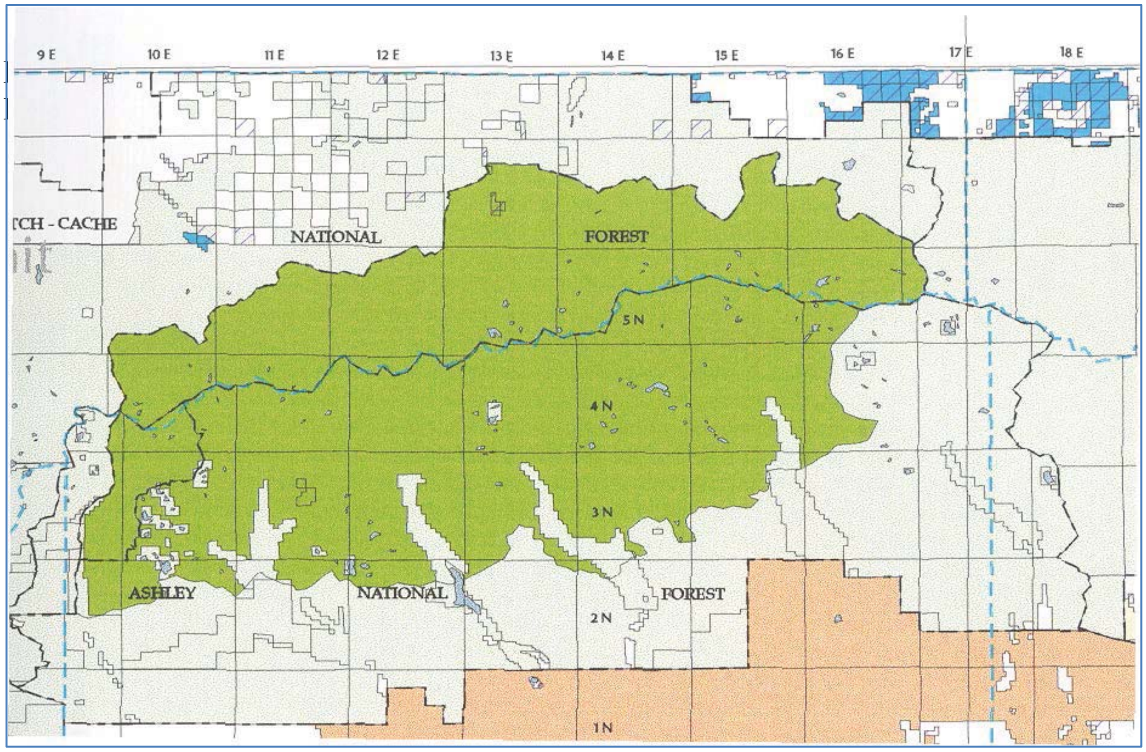


Figure 1.2 High Uintas Wilderness boundary, a detail from Utah School and Institutional Trust Lands Administration land ownership map (SITLA, 2001). The watershed exclusions on the south boundary of the wilderness are erroneous.

Utah School and Institutional Trust Lands Administration (Utah School and Institutional Trust Lands Administration, 2001). The actual High Uintas boundary does not exclude major watersheds on the south; the apparent problem is that the Utah AGRC coded some of the wilderness area as separate polygons because of reclamation withdrawals. Both the Dark Canyon and High Uintas errors can also be found in the second edition of the CBI Protected Areas Database (Conservation Biology Institute, 2001).

Most mapping of Utah wilderness and public lands is clipped to the state boundary. Since landscapes and ecosystems do not follow political subdivisions, the *Utah Wilderness Atlas* is designed to help visualize connections with adjacent areas in neighboring states. The Atlas extent carries over to the next degree of latitude and longitude beyond Utah (see Chapter 4).

The "what" and "why" of wilderness preservation are largely defined by law. The "how" is a matter for public debate. Geographical analysis is the key to addressing the crucial issue of "where." The *Utah Wilderness Atlas* is intended to contribute to public understanding of wilderness and protected areas issues by making the best available geospatial data accessible to nonspecialist users.

1.4 Utah Wilderness Atlas Regions

The purpose of defining wilderness regions for the *Utah Wilderness Atlas* is to establish a comprehensive and coherent geographical framework. Utah wilderness, protected areas, and adjacent wilderness-eligible public lands have been grouped into 14 named regions (see Chapter 5 for a full discussion of the regions). These regions contain Utah public land with high wilderness values, plus some areas in adjacent states. Federal land management agencies and citizen wilderness-advocacy groups have identified these areas in a series of inventories since the 1970s.

Unavoidably, due to geographic generalization, small areas within the region boundaries do not meet the legal criteria for wilderness designation. There are even some inclusions of nonfederal land; for example, Utah state school trust lands. It should be kept in mind that these regions are accounting units, not legislative proposals. Not all areas within the Atlas extent are included in a wilderness region.

The concept of Utah wilderness regions originated in early 1985, with the Utah Wilderness Association (UWA). Up to that time, wilderness proposals had only addressed national forests, and always focused on individual areas such as Lone Peak and the High Uintas. The statewide conservationist wilderness proposals for RARE II contained no more than two dozen proposed wilderness areas, most of which were already well known.

The leadership of UWA realized that the Bureau of Land Management (BLM) wilderness review had broadened the geographic area and extent of the Utah wilderness issue so much that discussions in terms of single units would be difficult. The BLM eventually identified 95 wilderness study areas (WSAs) and an additional 142 wilderness inventory units. Many areas not recommended as suitable for designation by the official studies were nonetheless included in proposals by wilderness advocates. Most of these WSAs and associated units bore unfamiliar names or in some cases simply numbers assigned by the BLM (Bureau of Land Management, 1986).

Another concern of UWA and other wilderness advocacy groups was that the 15-year BLM inventory process tended to fragment the original inventory units. In several cases, roadless areas were mapped as two separate units because they were bisected by an agency administrative boundary. Many WSAs are closely adjacent, separated only by a single dirt road. Conservationists were concerned that the suitability analysis in the final statewide environmental impact statement (EIS) would differentiate too much among these artificially separated units, recommending some for wilderness designation and rejecting others despite, or even because of, their geospatial proximity and geographic similarity. An example of this was in the Henry Mountains, where the BLM chose the Mount Ellen WSA for wilderness suitability while rejecting the adjacent Mount

Pennell WSA because the attributes of the area were too similar (Bureau of Land Management, 1991).

Table 1.2 compares the Atlas regions with six different sets of regions. The UWA decided to highlight nine regions in an early BLM wilderness proposal (Utah Wilderness Association, 1985). UWA envisioned a series of regional wilderness bills in place of a single statewide bill, an approach eventually embraced by Utah Governor Mike Leavitt during the 1990s (Wharton, 1997). A proposal from the Utah Wilderness Coalition (UWC) also made use of the regional concept (with eight regions), even though the UWC remained committed to a statewide bill (Utah Wilderness Coalition, 1985).

For many years, the UWC and nationally-based wilderness advocates tended to dismiss the idea of regionally-based legislation, saying that the U.S. Congress lacked the time and patience to revisit Utah wilderness issues in multiple bills. Contrary to this view, every 2 years, Congress usually passes an omnibus public lands act that contains many such locally-initiated designations.

The draft BLM statewide wilderness EIS included five regions (Bureau of Land Management, 1986). The UWC came up with a set of regions in 1999 (Swanson, 1999). In 1999, the second Utah BLM wilderness inventory divided areas into seven regions (Bureau of Land Management, 1999). Most recently, in 2010, the Southern Utah Wilderness Alliance (SUWA) put 11 regions on their website (SUWA, 2010). All these regional schemes pertain only to BLM public lands and wilderness proposals.

The new system of regions created for the *Utah Wilderness Atlas* is explained in Chapter 5. The Atlas is intended to be inclusive of all protected areas and wilderness-

Table 1.2 Utah Wilderness Atlas Regions Comparison

Utah Wilderness Atlas Regions	**SUWA Regions** (SUWA, 2010)	**BLM Regions** (BLM, 1999)	**UWC Regions** (Swanson, 1999)	**State of Utah Regions** (Wharton, 1997)	**UWC Regions** (UWC, 1985)	**UWA Regions** (UWA, 1985)
Bear River	N/A	N/A	N/A	N/A	N/A	N/A
Canyonlands	Canyonlands Basin & Moab/La Sal	Southeast	Greater Canyonlands Dirty Devil River	Canyonlands	Canyonlands Glen Canyon Moab	Dirty Devil/ Canyonlands
Desolation Canyon	Book Cliffs /Desolation Canyon	Northeast	Book Cliffs – Desolation Canyon	Book Cliffs	Book Cliffs	Desolation/ Book Cliffs
Escalante	Glen Canyon	South Central	Escalante Canyons	Grand Staircase-Escalante NM	Grand Staircase	The Escalante
Grand Gulch	San Juan - Canyonlands	Southeast	White Canyon - Cedar Mesa	Canyonlands	San Juan	Grand Gulch Plateau
Henry Mountains	Henry Mountains	East Central	Henry Mountains	Henry Mountains	Henry Mountains	The Henry Mountains
High Plateaus	N/A	N/A	N/A	N/A	N/A	N/A
High Uintas	Dinosaur	N/A	Uinta Basin	N/A	Dinosaur	N/A
Hovenweep	N/A	N/A	N/A	N/A	N/A	N/A
Kaiparowits	Grand Staircase-Escalante	South Central	Grand Staircase Kaiparowits Plateau	Grand Staircase-Escalante NM	Grand Staircase	Kaiparowits Plateau
San Rafael	San Rafael Swell	East Central	San Rafael Swell	San Rafael Swell	San Rafael Swell	San Rafael
Wasatch Mountains	N/A	N/A	N/A	N/A	N/A	N/A
West Desert	Great Basin	Northwest West Central	Great Basin Desert	West Desert	Great Basin	The West Desert
Zion	Zion-Mojave	Southwest	Greater Zion Mojave Desert	Southwestern Utah	Zion-Hot Desert	Zion/Canaan Mountain

eligible public lands (that is, lands that meet the minimum criteria for designation as wilderness according to one or more sources). Previous arrangements of regions omitted the National Park System and National Forest System in order to bring attention to BLM wilderness. The Atlas regions are more comprehensive, and 4 of the 14 regions are composed primarily of national forest land: Bear River, High Plateaus, High Uintas, and Wasatch Mountains.

The process of defining regions was somewhat arbitrary. The Atlas regions are aggregations of protected areas and inventory units. Where regions are adjacent to one another, there is often a choice of dividing lines that would serve equally well.

CHAPTER 2

LITERATURE REVIEW

This literature review is divided into four topic sections: Web mapping, areal differentiation and ecoregions, Utah atlases, and Utah wilderness and wilderness mapping.

2.1 Web Mapping

The literature of Web mapping and cartography is rapidly changing. Most information on this subject is published on the World Wide Web itself. New applications are introduced several times a year (Peterson, 2001), and sometimes it can be difficult to sort through what works and what does not, and what to use for a particular cartographic purpose. See Chapter 3 for a discussion of recent trends in delivering of maps via the Web. While most of the new software is driven by the needs of large corporate and governmental enterprises, this thesis is focused on relatively simple and cheap approaches suitable for small nonprofit groups.

Two edited works summarize the techniques of multimedia and Web cartography. *Multimedia Cartography* (Cartwright, Peterson, & Gartner, 1999) deals with cartography on CD-ROM and the Internet. Subjects include dynamic, interactive maps, multimedia and Internet atlases, and the 3-D virtual reality modeling language (VRML). VRML never saw widespread use, because it was introduced before broadband Internet access became common. It has now been re-engineered as X3D, the ISO standard XML-based file format for representing 3-D computer graphics.

Web Cartography: Developments and Prospects (Kraak & Brown, 2001) explores the practical aspects of web map design and functionality. Particular attention is given to the design principles that apply to static versus dynamic/interactive Web maps. As Table 2.1 illustrates with examples, static and dynamic maps can be either interactive or noninteractive. An animated GIF image is defined as a noninteractive dynamic map, for example, because the viewer has no control over the display other than to start and stop the animation. More sophisticated animation methods (for example, using JavaScript) offer more interactivity, such as being able to select a particular point in a time series. Most interactive maps on the Web are interfaces linked to GIS servers. With a Web browser, the user can perform basic map display functions by sending commands to a server application. ESRI's ArcGIS Server is an example of the GIS server approach. It supports several application programming interfaces (APIs), including JavaScript, Adobe Flex, and Microsoft Silverlight.

One of the first guides to Internet map servers was *GIS Online* (Plewe, 1997). The Internet map server approach has been made obsolete by GIS servers. Figure 2.1 depicts the multitier architecture of an Internet map server. The map user has client software connected to the Internet (typically a Web browser). The page being viewed is coming from a Web server via the Internet. The Web server, in turn, is getting HTML documents from an application server running ArcIMS or comparable software. The application server is connected to a spatial server that is running a GIS program. The spatial server gets its data from a data source (e.g., a set of shapefiles).

Table 2.1 Static Versus Dynamic Web Maps

	Interactive	Noninteractive
Static	HTML image map, a “clickable”image	Digital raster graphic (DRG) such as a USGS quad map
Dynamic	JavaScript, Adobe Flex, Microsoft Silverlight	Animated GIF

This multitier architecture was the earliest method devised for allowing large numbers of users to access geospatial data simultaneously, and it had the advantage that it was scalable by multiplying the number of server machines to keep up with demand.

It can be argued that five tiers are too many. The user is not directly viewing the data, only seeing a raster image of the GIS that is produced on the fly by the application server. The response time is much slower than it might be with a simpler system. Hardware and software costs can be expensive. Finally, the need for an application server means the content cannot be distributed on disk.

Scalable Vector Graphics (SVG) is an open standard, XML-based format for the creation of vector images that can be viewed with a web browser. For some browsers, a plug-in is required, such as the Adobe SVG Viewer, a free download from Adobe Systems [http://www.adobe.com/svg/]. The viewer enables the user to zoom (change

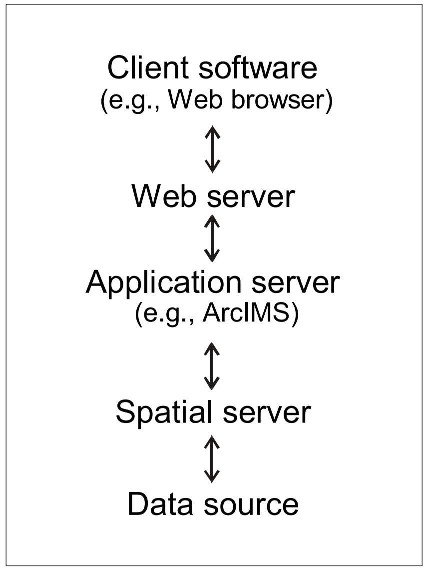


Figure 2.1 Internet map server multitier architecture.

scale) and pan across the map. With the addition of HTML and JavaScript, it is possible to turn map layers on and off and to query attribute data.

Compared to raster images, SVG files are much smaller and take less computer memory. The rendering of vector objects is far superior to the rasterization common to Internet map servers.

SVG files consist of text. Therefore, they are easily editable and can be readily searched. For example, if you want to view a labeled map feature, you can type the name in a JavaScript search window and automatically pan the map to that location.

Cartographic applications of SVG can incorporate a number of interactive features by using JavaScript with SVG files. For example, mouseover (rollover) events include change fill color, change stroke width/color, show/hide elements, and drop-down menus. Objects in an SVG map can also be linked to HTML documents, for example to display attribute information in an interactive map.

Several tools have been developed to export GIS layers to SVG format. These include SVGMapper (an ArcView 3.x extension), Shape2SVG (a script for ArcView), and Map2SVG, an extension for MapInfo Professional. Prototype maps for the *Utah Wilderness Atlas* were created using SVGMapper. Then MapViewSVG for ArcGIS was adopted. This software underwent a name change, and is now known as Mappetizer for ArcGIS.

Mappetizer can export a map project from ArcGIS to an interactive Web page that utilizes either a JavaScript or a Silverlight interface.

Unlike Internet map servers, the newer GIS server technology such as ArcGIS Server delivers performance equal to or better than the SVG approach. In addition, the latest server functionality allows users to perform sophisticated GIS operations. The advent of "cloud computing" basically eliminates the need for organizations to maintain an application server. However, GIS servers remain more costly than SVG, and nowhere near as simple to understand. The system architecture remains multitiered, although performance has improved greatly over the Internet map server They also retain the drawback that the interactive maps cannot be distributed on a disk.

See Chapter 3 for a discussion of GIS server technology.

2.2 Areal Differentiation and Ecoregions

The regional concept is central to geography. Geographical analysis depends on the ability to classify natural and cultural phenomena according to location. This is areal differentiation, and it is a combination of art and science. It can never be completely objective, because there are many legitimate variations on boundaries for the same region. For example, geographers have drawn at least 50 boundaries for the Great Plains (Rossum & Lavin, 2000).

Because wilderness regions are the organizational units for the *Utah Wilderness Atlas*, it is worthwhile to discuss some relevant sources, particularly for ecoregions.

McDonald (1972) is a good source on the basic problems of regional definition, especially the tendency of regional boundaries (particularly political/administrative boundaries) to reinforce and nest inside one another whether this makes geographic sense or not. A wilderness-related example would be the cutoff of wilderness study area boundaries at BLM district boundaries during the Utah wilderness inventory in the 1980s.

A classic theory of areal differentiation is the modifiable areal unit problem or MAUP (Openshaw, 1984). This states that the results of statistical analysis of data by region can be varied at will by changing the region boundaries. The problem includes two parts: the problem of scale, involving the aggregation of smaller units into larger ones; and the problem of alternative allocations of component spatial units to larger regions, also known as gerrymandering. Avoidance of the MAUP requires that region boundaries not be arbitrary with respect to the phenomena contained within.

Ecoregions were an important consideration in the formation of wilderness regions for the Atlas. Robert G. Bailey (1976, 1995, 1996) did the seminal work on multiscale ecosystem analysis. Table 2.2 shows the Bailey ecoregion hierarchy, as implemented by the U.S. Forest Service in the national hierarchical framework of ecological units (ECOMAP) (USDA Forest Service, 1993).

Bailey's original map was used for the 1979 Forest Service RARE II wilderness inventory, and his ecoregion boundaries have been published and republished in many forms, for example in the *Utah GAP Education Project* CD (Utah Geographic Alliance, 1997). Bailey's method is based primarily on climate; therefore, ecoregion boundaries tend to be generalized and not suitable for use at a scale finer than 1:7,500,000. Bailey's mapping criteria have been adapted to larger scales down to the section level for Utah, and in a few selected areas all the way down to the landtype (Kilbourne, 2001),.

The approach used by James Omernik (1987) includes the patterns and composition of biotic and abiotic phenomena that affect ecosystems. Omernik's system incorporates geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. This approach does not begin by treating any one phenomenon with more

Table 2.2 ECOMAP Ecoregion Hierarchy

Ecoregion	Domain
	Division
	Province
Subregion	Section
	Subsection
Landscape	Landtype Association
Land Unit	Landtype
	Landtype Phase

weight than any other. The idea is to look for patterns of coincidence between geographic phenomena that cause or reflect differences in ecosystem characteristics.

The EPA and the conservation biology community have made good use of the Omernik method, notably in *Terrestrial Ecoregions of North America* (Ricketts et al., 1999) and the World Wildlife Federation ecoregions (Olson et al., 2001). The level of generalization is more useful for GIS, and noncontiguous "island" ecoregions (e.g., the isolated alpine areas in the Great Basin) are better represented.

2.3 Utah Atlases

There are some published digital atlases that cover aspects of Utah's public lands, along with some traditional book-form atlases worth noting here.

In 1995, the Utah Automated Geographic Reference Center (AGRC) produced the first digital atlas of Utah on a CD-ROM in the form of the Utah State Geographic Information Database (SGID) (Utah AGRC, 1995). This early version of the SGID was produced using ArcView Data Publisher. A wide variety of data layers was included, as statewide 1:500,000 scale and tiled 1:100,000 scale. The SGID is now maintained online at the Utah GIS Portal (http://agrc.its.state.ut.us/) (Utah AGRC, 2010a).

The *Utah GAP Education Project* CD-ROM (Utah Geographic Alliance, 1997) is probably the prior work that comes closest in concept to the proposed *Utah Wilderness Atlas*. Developed at Utah State University under the direction of Cliff Craig, it includes descriptions and photos of 13 Utah wilderness areas plus information on selected BLM wilderness study areas. The emphasis is more about ecoregions and wildlife habitat than wilderness, because the purpose of the CD is to bring the results of the GAP Analysis Project to the classroom.

With the exception of some animated fly-throughs, all of the maps on the CD are static maps. There is no way to overlay wildlife habitat with wilderness boundaries, for example. All the wilderness maps are scanned from a 1:1,000,000-scale BLM wilderness status map (BLM, 1992) that shows only generalized boundaries. Some of these static maps are interactive; for example, clicking on an ecoregion or a wilderness brings up associated data and photos. No GIS layers are provided on the CD. The authoring software, HyperStudio, does not require any installation but will not work unless the user's computer screen is set to 256 colors.

The *Utah GAP Education Project* CD was based on the original set of Gap Analysis CDs (Edwards, Homer, & Bassett, 1997). Gap analysis is intended to identify "gaps" in the representation of ecosystems within protected areas. The GAP dataset consists primarily of a statewide land cover classification and vertebrate habitat layers, with the addition of ancillary data such as a Landsat mosaic of Utah. A second-generation database was developed by the Southwest Regional Gap Analysis Project (SW ReGAP) for Arizona, Colorado, Nevada, New Mexico, and Utah. SW ReGAP data are available on the Web (http://fws-nmcfwru.nmsu.edu/swregap/).

Another published atlas is the *Digital Geologic Resources Atlas of Utah*, published in CD-ROM format as a bulletin of the Utah Geological Survey (Sprinkel, 1999). It consists of ESRI shapefiles that can be read after installing ArcExplorer. Atlas text is presented as PDF files that can be read using Adobe Acrobat Reader. ArcExplorer and Adobe Acrobat Reader are included on the CD.

This geologic atlas contains a very large collection of geospatial data, both statewide in extent and separated into 30 x 60 minute quadrangle tiles. Most layers depict mineral resources, for example coal, petroleum, hardrock minerals, and geothermal compiled from federal and state data. This atlas also has data on political boundaries, land status, water bodies, roads, and towns obtained from AGRC and SITLA. There is also a layer for the UWC's 5.7 million-acre BLM wilderness proposal.

The drawback of this atlas from the standpoint of the casual user is there is a learning curve associated with ArcExplorer. Nonprofessionals will have difficulty producing legible maps from the data, and much of it is point themes. The Utah Geological Survey followed the *Digital Geologic Resources Atlas of Utah* with additional, more specialized digital atlases on CD-ROM, such as *A Digital Atlas of Utah's Geothermal Resources* (Blackett & Wakefield, 2004).

The Utah Water Atlas (http://www.neng.usu.edu/uwrl/atlas/) is an excellent online atlas; despite a paucity of maps, it covers the subject well with text and photos. The maps are all static maps (Hemphill, 1998).

Although it is not really an atlas but an index of maps, the maps.utah.gov site deserves a mention here. Static and dynamic maps are listed by subject, geographic area, and host agency (http://www.maps.utah.gov/) (Utah AGRC, 2010b).

Brandon Plewe (2002) of BYU produced the first online Utah atlas in the scalable vector graphic (SVG) format. The *Utah and Nevada Atlas of Historical County Boundaries* (no longer available online) was a good example of the interactive cartographic possibilities of SVG.

In the realm of book-form Utah atlases, the *Atlas of Utah* (Greer et al., 1981) is an excellent work, unsurpassed although no longer up to date 30 years after publication. A number of the maps are only of historical value now. Most of this atlas presents economic and political information, while national parks appear only in the context of recreation and tourism. There is no mention of wilderness *per se*, even though the Forest Service had just completed its RARE II roadless area maps in 1979. Wilderness mapping in Utah was still at an early stage, and did not catch the attention of the atlas editor.

In contrast to the *Atlas of Utah*, Stewart Aitchison's (1987) *Utah Wildlands* focused entirely on wilderness. Although not nominally an atlas, this book includes eight carefully drawn maps of national parks, wilderness areas, roadless lands, and wilderness proposals.

Utah is portrayed in a regional context in the *Atlas of the New West* (Riebsame & Robb, 1997). This atlas illustrates the economic and cultural tensions between a fading "old west" and an emerging "new west" or "next west." The New West region is defined as land west of the Great Plains except for the more populated areas of the west coast. A number of maps attempt to illustrate the influence of public lands in the West, and several show aspects of the wilderness issue. There is a map of "outback" areas, defined as more than 10 miles from the nearest paved highway. The map of Utah wildlands is highly generalized and not very useful. On the other hand, there is a map depicting ecosystem linkages from Canada to Mexico that does a good job putting Utah wildlands in the context of the entire Rocky Mountains.

2.4 Utah Wilderness and Wilderness Mapping

The decades-long debate over wilderness designation in Utah and the western USA has generated a substantial literature. The *Utah Wilderness Atlas* will include a comprehensive bibliography. Here are some notable sources on wilderness issues in Utah and the West.

Roggenbuck et al. (1990) wrote authoritatively about the Forest Service Roadless Area Review and Evaluation (RARE) process of the late 1970s and early 1980s.

Gundars Rudzitis (1996) of the University of Idaho might be the only American geographer to write a book specifically about wilderness, *Wilderness and the Changing American West*. This work demonstrates the usefulness of an integrative approach, and includes probably the best account of the development of Gap Analysis.

The Bureau of Land Management (1986, 1991, 1999) has documented wilderness characteristics of Utah BLM lands in two separate statewide studies, including maps and detailed descriptions of areas. Wilderness advocates have published their own inventories and proposals (Utah Wilderness Association, 1985; Utah Wilderness Coalition, 1985; Utah Wilderness Coalition, 1990).

Historical accounts exist that cover political struggles over Utah wilderness, including the internecine battles between locally and nationally oriented environmental groups and a variety of subsidiary issues such as road rights of way (Fradkin, 1989; Brennan, 1998; Goodman & McCool, 1999; Watkins, 2000).

Davidson et al. (1996) laid out the case for wilderness designations to protect biodiversity in Utah, which is an important supporting argument for expanding the acreage of wilderness proposals.

Both the proclamation of the Grand Staircase-Escalante National Monument in 1996 (Keiter, George, & Walker, 1998) and the original proposal for an Escalante National Monument in the 1930s (Richardson, 1965) have received scholarly attention.

The Wilderness Society did a creditable job of making a regional atlas centered on Utah's Grand Staircase-Escalante National Monument in the "Crown of the Canyons" (Aplet, Morton, Thomson, & Hartley, 1999). The authors made extensive use of publicly available GIS data to put the monument into context with the biophysical and socioeconomic environments of the surrounding region, and even tried to apply geospatial data to analysis of wilderness qualities such as solitude, remoteness, and naturalness.

The previously-mentioned Gap Analysis Project and subsequent Southwest Regional Gap Analysis Project both produced maps of protected areas that have been superseded by the Protected Areas Database (see below).

In 2002, a Utah State University study included a GIS wolf habitat suitability model that mapped gray wolf habitat in Utah (Switalski et al., 2002). Potential habitat was rated as "best," "good," and "fair" according to a number of criteria including topography (wolves tend to avoid high elevations), adequate prey base, proximity to perennial streams and lakes, and a minimum of human interference (low road density was used as a surrogate). The map indicates the Desolation Canyon-Book Cliffs region is by far the best wolf habitat in Utah, while the High Uintas offers good quality habitat but very little area in the "best" category.

Westcliffe Publishers added a Utah volume to its series of wilderness guidebooks in 2005. *Utah's Wilderness: The Complete Guide* included information about 99 Utah wilderness areas and wilderness study areas, and 48 maps (Howard, 2005).

The United States Geological Survey (USGS) published the first standardized map of the whole National Wilderness Preservation System (NWPS) in 1987. This 1:7,500,000 scale map showed wilderness areas in the contiguous United States on the front, with Alaska and Hawaii on the back. Areas were color-coded according to the four wilderness land management agencies: the U.S. Forest Service, National Park Service, Bureau of Land Management, and Fish & Wildlife Service.

In 1989, The Wilderness Society published a new map commemorating the 25th anniversary of the Wilderness Act. To commemorate the 35th Anniversary of the Wilderness Act in 1999, The Wilderness Society, Trails Illustrated of National Geographic maps, the Aldo Leopold Wilderness Research Institute, and Arthur Carhart National Wilderness Training Center collaborated to update the Wilderness Society map.

For the 40th anniversary of the Wilderness Act in 2004, a 1:5,000,000 scale NWPS map was published by the USGS National Atlas. Alaska and Hawaii are shown at the same scale as the contiguous United States. This is important because more than half the National Wilderness Preservation System is in Alaska. The back of the map includes a table showing acreage, year of proclamation, and administrative unit for each wilderness.

As additional wilderness areas were designated since 2004, updated wilderness boundaries were published as a map layer on the USGS National Atlas website (http://www.nationalatlas.gov/mld/wildrnp.html).

Wilderness.net (http://www.wilderness.net) is a website formed in 1996 through a collaborative partnership between The University of Montana's College of Forestry and Conservation, the Arthur Carhart National Wilderness Training Center, and the Aldo Leopold Wilderness Research Institute. This site is the home of the NWPS Database, which has expanded over the years (Meyer & Landres, 2000). At first, Wilderness.net relied on the National Atlas NWPS map. More recently, this site has offered interactive web mapping and downloadable GIS datasets.

Another important source for wilderness mapping is the Protected Areas Database of the United States (PAD-US, originally called the Managed Areas Database) (http://www.protectedlands.net/padus/). Protected areas are crucial for biodiversity conservation because they provide safe havens for species threatened by land-use change and resulting habitat loss. However, protected areas are only effective when they stop habitat loss within their boundaries, and are connected via corridors to other wild areas. The mission of PAD-US is to let the public know exactly what lands are protected anywhere the United States.

Probably the most ambitious wilderness mapping effort of all is the World Database on Protected Areas (WDPA) (http://www.wdpa.org/). This is an effort to compile all available geospatial information on protected areas worldwide according to a common standard, and eliminating duplicate records. There are approximately 138,000 sites now available through the WDPA.

CHAPTER 3

DEVELOPMENTS IN THE PAST DECADE

Over the last decade (2001 – 2011), there have been some significant developments affecting Internet mapping and Utah wilderness policy, which are summarized in this chapter. These developments affected the development of the *Utah Wilderness Atlas*.

3.1 Internet Mapping

Techniques for publishing maps and GIS data on the Internet have changed greatly during the decade. Probably the most dramatic development has been the increased commercial availability of fast Internet access. An estimated 68 % of U.S. households had broadband Internet access at home in 2010, up from just 9.2 % in 2001 (U.S. Department of Commerce, 2011). Improved Internet access has made possible the success of breakthrough applications such as Google Earth, and geo-wikis such as OpenStreetMap. The design of web maps has become more sophisticated, as commercial web mapping software evolved from the ArcIMS™ raster approach to vector-based formats such as Microsoft Silverlight and Adobe Flex. Open-source scalable vector graphic (SVG) applications also improved.

3.1.1 SVG Applications

Scalable Vector Graphics (SVG) is an XML-based language for displaying vector graphics. SVG 1.0 became a World Wide Web (W3C) recommendation in September 2001. From the beginning, this open source vector format was used for web mapping even though web browser support was slow to develop. SVG and the proprietary Macromedia Flash SWF format (which became Adobe Flash in 2007) enabled the creation of crisp-looking static and (with the use of JavaScript) interactive vector maps for the Web. Wikipedia has standardized on SVG and PNG formats for its static maps.

European entrepreneurs have come up with the most useful SVG development tools. SVGMapper™ was one of the first SVG extensions for ArcView™ 3.x. Developed by Uros Preloznik in the Czech Republic in 2001, it could export a view to a web map using SVG, JavaScript, and HTML. SVGMapper was still in use through at least 2005.

Armin Mueller of uismedia in Germany introduced MapView SVG™ in 2003 as an extension for ESRI ArcView 3.x. It converted maps from ArcView projects into SVG –based web pages, with the option of incorporating JavaScript for interactive features. Because no server-side applications are needed, these web maps are easy to publish either on the Web or on CD-ROM. Subsequent versions of MapView SVG supported ArcGIS Desktop™ (or ArcMap™), the successor to ArcView.

Beginning with version 8.1, MapView SVG was renamed Mappetizer™. Mappetizer for ArcGIS outputs both to SVG and to Microsoft Silverlight. It also supports the free online map OpenStreetMap, an open source alternative to Google Maps and Bing Maps.

The user-friendliness of the SVG format has improved as browser market share has evolved. Users still must install a plug-in in order to view SVG files in Microsoft Internet Explorer. Other browsers support SVG without one. Measures of traffic at popular websites record that Internet Explorer use has declined from a high of more than 90 % in 2000 to around 56 % in 2011. The principal competing browsers are Mozilla Firefox (22 %), Google Chrome (11 %), Apple Safari (approximately 7 %), and Opera (approximately 3 %). Other browsers account for the remaining 1 % (NetMarketShare, 2011).

3.1.2 ArcGIS Server

Environmental System Research Institute (ESRI) released ArcGIS ™ version 8.1 in April 2001 as a successor to ArcView™ and ArcInfo™. This was the first ESRI geographic information system (GIS) software with the capability to access online data over the Internet. The ArcIMS™ (Arc Internet Map Server) extension added the capability to publish dynamic maps via the Web. Users equipped with only a web browser could zoom, pan, and turn map layers on and off. ArcIMS provided a highly scalable framework for GIS Web publishing for enterprise-level intranets and public worldwide Internet access. One of the first ArcIMS applications was the National Geographic Map Machine, an online world atlas that was hosted by ESRI.

ArcIMS web maps were often slow-loading and not particularly well designed. This was due in part to the multitiered architecture. The original map was stored as an MXD file on a GIS server, which might have to access data on other machines. A map server converted the map to a set of tiled raster files, which could then be added to a website on a Web server. This process had to be repeated every time a user changed his/her view of the map in a browser, and could be quite slow if multiple users were accessing the site at the same time.

ESRI introduced a new approach to online mapping, ArcGIS Server™, beginning with the release of ArcGIS 9.0 in May 2004. ArcGIS Server services support a number of different application programming interfaces (APIs), enabling web browsers, mobile devices, and desktop systems to act as clients (see Figure 3.1). In addition to map services, ArcGIS Server supports a variety of other types of services such as geoprocessing services and image services. These services can be accessed via the ArcGIS Desktop, and via the APIs with some limitations. The freeware ArcGIS Explorer enables those without an ArcGIS license to view map and image services.

To a limited degree, ArcGIS Server also provides support for Open Geospatial Consortium (OGC) standards. For example, the Web Map Service Interface Standard (WMS) provides a means of sharing imagery and prerendered maps. The Web Coverage Service Interface Standard (WCS) requires client-side rendering, and allows for analysis of geospatial data.

Later versions of ArcGIS Desktop, from 9.1 to 9.3.1, included the capability to export maps to geospatial PDF format. The georeferencing of PDF files was pioneered by TerraGo Technologies in the development of their GeoPDF-branded map and imagery products. The Adobe PDF format is widely accepted and is considered the de facto standard for printable documents on the web. PDF documents can be viewed in all commonly-used web browsers. Originally a proprietary format, PDF was officially

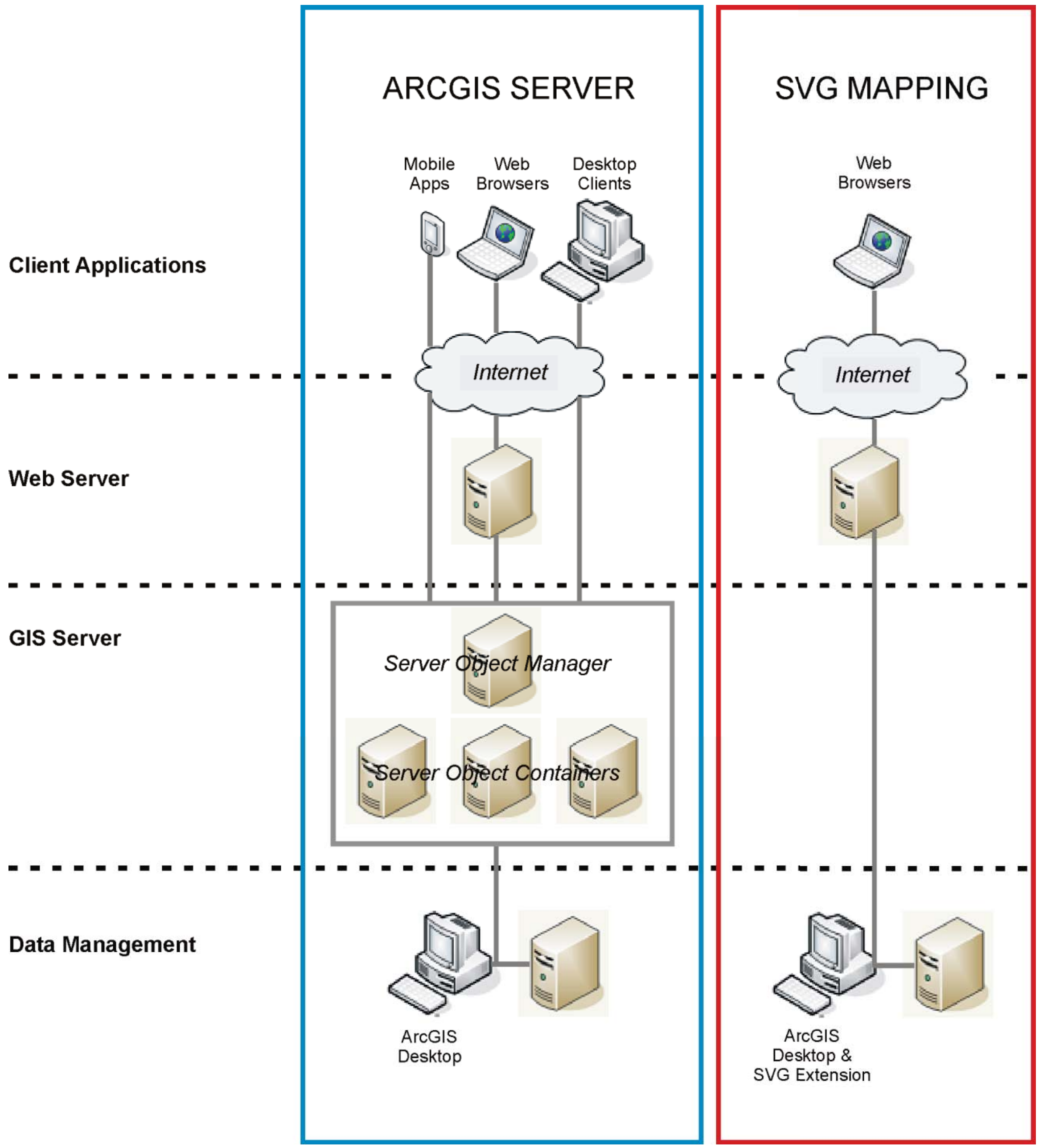


Figure 3.1. Simplified side-by-side comparison of ArcGIS Server and SVG Internet mapping architecture.

released as an open standard in July 2008, and published by the International Organization for Standardization (ISO). The geospatial PDF standard supports interactive map features such as layer control, access to GIS attribute tables, and coordinate readouts.

The newest version of ArcGIS is ArcGIS 10, released in 2010. This version includes many improvements, especially in working with imagery. With ArcGIS 10, ESRI has embraced cloud computing (see section on cloud computing below).

3.1.3 Google Maps

Google Maps (http://maps.google.com - formerly Google Local) is a web mapping service application provided by Google, free for noncommercial use. It offers street maps, high-resolution imagery, a route planner, live traffic updates, and an urban business locator. According to one of its creators (Lars Rasmussen), Google Maps is "a way of organizing the world's information geographically." Google Maps can be integrated with Google Earth, if the user installs the Google Earth Plug-in. Introduced in 2007, Google Street View is a technology featured in Google Maps that provides continuous panoramic views from street-level in many urban areas, and some rural areas.

Google launched the Google Maps application programming interface (API) in June 2005 to allow developers to integrate Google Maps into their websites. It is a free service. By using the Google Maps API, it is possible to embed Google Maps site into an external website, on to which site specific data can be overlaid. Over 350,000 web sites use the Google Maps API, making it the most heavily used web API.

At this writing, Google Maps indicates national forest and national park boundaries using the same green polygon symbol. It does not show wilderness areas. The Google Maps API is used by Wilderness.net, a website at the University of Montana College of Forestry and Conservation's Wilderness Institute. Wilderness.net does maintain up-to-date wilderness boundaries, using Google Maps as a background.

3.1.4 Google Earth

Google Earth is a virtual globe, map, and geographic information program that was originally called EarthViewer 3D, created by Keyhole, Inc., a company acquired by Google in 2004. It maps the Earth by the superimposition of images and vector graphics on a GIS globe. Google Earth allows users to search for addresses for some countries, enter coordinates, or simply use the mouse to browse to a location.

Google acquires imagery for Google Earth from a variety of sources, which causes a patchwork appearance in many areas. Spatial resolution of the imagery is generally 15 meters (pan-sharpened Landsat) or better (high-resolution aerial or satellite imagery). In some places, for example Las Vegas, Nevada, ground sample distance is as good as 6-inches. Imagery is frequently updated, for example when new National Agricultural Imagery Program (NAIP) 1-meter datasets become available.

The orthographic imagery is draped on a digital elevation model (DEM) to create a three-dimensional illusion, enabling users to view terrain from oblique angles. In urban areas, major buildings are often represented as true 3-D models. In April 2008, with version 4.3, Google fully integrated its Street View into Google Earth.

In December 2006, Google Earth added a new layer called "Geographic Web" that included integration with Wikipedia and Panoramio (the latter company was later acquired by Google). In March 2010, Google removed the "Geographic Web" layer. The "Panoramio" layer became part of the main layers and the "Wikipedia" layer was placed in the "More" layer. Panoramio enables users to insert icons that link to ground-level and aerial photos taken at various locations.

Panoramio also offers interactive panoramic views of the type first introduced by Apple in 1992 as the QTVR format (for “QuickTime Virtual Reality”). The website VirtualParks.org offers some of the best examples of these panoramas of natural landscapes.

One of the most useful features of Google Earth is the ability of users to overlay their own spatial data. This is done in the form of KML (Keyhole Markup Language) files, often compressed to the gzipped KMZ format. If you have Google Earth installed, clicking on a KMZ file will start the application and show you the contents of the file against the Google Earth base map. KMZ files can easily be created using several free ArcGIS Desktop extensions.

3.1.5 Bing Maps

Bing Maps (http://www.bing.com/maps/ --previously Live Search Maps, Windows Live Maps, and Windows Live Local) is a web mapping service provided as a part of Microsoft's Bing suite of search engines and powered by the Bing Maps for Enterprise framework. It has most of the same features found in Google Maps. Like Google Maps, Bing Maps allows users to share maps, and embed maps into websites.

At this writing, Bing Maps shows national forest and national park boundaries using two different shades of green, but not wilderness areas.

3.1.6 OpenStreetMap

OpenStreetMap (http://www.openstreetmap.org/) is a free editable map of the whole world. It was founded in July 2004 by Steve Coast in London, UK. Users can view, edit, and use geographical data in a collaborative way. By the end of 2009, OpenStreetMap had nearly 200,000 registered contributors. Editing makes use of donated commercial data, data from portable GPS devices, aerial photography, other free sources, and local knowledge.

Like Google Maps and Bing Maps, OpenStreetMap allows embedding in web pages. Unlike the commercial map services, there is no imagery layer.

At this writing, OpenStreetMap shows national forest and national park boundaries using two different shades of green. Wilderness boundaries are indicated using a dashed line polygon and a lighter shade of green. There are inconsistencies due to the collaborative nature of the project, and many areas have not been mapped yet. For example, Utah national forests and wilderness areas are mapped only for the southwestern part of the state.

Mappetizer, the SVG mapping extension for ArcGIS, makes it easy to incorporate OpenStreetMap in other web maps.

OpenStreetMap is the most successful example of a geo-wiki, a geospatial implementation of the wiki concept popularized by Wikipedia, and other sites such as Wiki.GIS.com. Another example is the Geo-Wiki Project (Fritz et al., 2009;

http://www.geo-wiki.org/). This is a volunteer global land cover validation effort started in 2009 by the International Institute for Applied Systems Analysis, the University of Applied Sciences Wiener Neustadt , and the University of Freiburg.

3.1.7 Cloud Computing

The newest development in Internet mapping is the rising popularity of cloud computing, also known as service-centered architecture for GIS. The Amazon Elastic Compute Cloud (EC2) led the way, with ESRI working in partnership with Amazon.com. Cloud platforms are becoming ubiquitous, as Microsoft (Windows Azure), Google, Oracle America (formerly Sun Microsystems), and other computing industry giants get into the business (Buyya, Broberg, & Goscinski, 2011).

Cloud computing is an Internet-based system that provides shared resources, software, and data on demand, like a public utility. Customers rent "machine instances" (the virtual equivalent of a desktop computer) instead of having to purchase their own hardware and software. Costs can range from 1 to 100 dollars per day. This arrangement has the potential to lower costs for individuals and small nonprofits lacking their own enterprise-level GIS resources.

Cloud computing had its beginnings in large organizations that decided to centralize their computing resources. The U.S. Forest Service, for example, is transitioning to an Enterprise Data Center which provides full access to GIS applications and datasets via a web browser over their intranet (FSWeb). Users have access to "virtual machines" that simulate the characteristics of physical computers with installed software applications. Users are freed from the tasks of updating software and databases.

In the public version, GIS applications and data are accessed via the Internet "cloud" instead of an internal network. Services on the "cloud" can make use of licensed GIS datasets that are not freely distributable, such as certain types of high-resolution imagery. ArcGIS.com, a website introduced in May 2010, offers cloud-based resources on both a free and subscription basis. For example, users can create a map for sharing on the Web by making use of a number of different base maps and imagery layers, including Bing Maps and OpenStreetMap. ArcGIS.com also hosts a free client application, ArcGIS Explorer Online, which works with the online content.

OpenNRM (Open Natural Resource Management), an Open GIS suite of Web-based tools for analyzing and managing natural resources, was developed in 2009 by 34 North, Inc., a Web services, GIS, and visualization company in San Luis Obispo, California. The beta version of OpenNRM.org is described as "an online collaboration toolset for resource managers, conservation groups, scientists, legislators, educators, and stakeholders working to save our planet." At this writing, it is too soon to tell whether this sort of free implementation of cloud computing for conservation will be successful.

ESRI Conservation Program Coordinator Charles Convis (2010) has indicated that ESRI intends to add Amazon Machine Instances to their grant program for nonprofit conservation groups. The ESRI Conservation Program now provides software and hardware in partnership with Hewlett-Packard. Through cloud computing, it would be possible to make the program more efficient, and even to increase the number of grants.

Provided costs are kept low, cloud computing offers the near-term prospect that small groups and large organizations could maintain similar GIS capabilities.

3.2 Utah Wilderness Policy

3.2.1 Wilderness Inventory and Designations

The National Wilderness Preservation System expanded from 628 designated wilderness areas (104.7 million acres) in 1999 to 756 areas (109.5 million acres) in 2010. About half of this growth was due to one piece of legislation, the Omnibus Public Land Management Act of 2009. During the last decade, Congress increased the number of wilderness areas within the Utah Wilderness Atlas extent from 27 to 74. In the State of Utah during the same period, the number of wilderness areas doubled from 15 to 30. Utah also received its first-ever wild river designation in 2009, on the Virgin River in Zion National Park.

A little historical background is needed to help understand where Utah wilderness policy is today. None of the wilderness areas designated as part of the original 1964 Wilderness Act were in Utah, although the Act required a suitability review of all existing national forest primitive areas within 10 years. The High Uintas Primitive Area was subject to this provision. Although Forest Service and citizen wilderness proposals were drafted, there was little progress on Utah wilderness designation until Congress passed the Endangered American Wilderness Act of 1978. This legislation established the Lone Peak Wilderness, citing it as an example of where the first Forest Service roadless area review process had rejected an area worthy of designation.

Following the second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, a window of opportunity for wilderness designations opened up in the 1980s. California's Ninth Circuit Court invalidated RARE II. Congressional delegations in Utah and other states got to work on new legislation to head off a third roadless area review.

The Utah Wilderness Act of 1984 designated a dozen national forest wilderness areas, including the High Uintas Wilderness. The Arizona Wilderness Act of 1984 added two Bureau of Land Management (BLM) wildernesses that straddled the Utah-Arizona border. By September 1984, Utah had 15 designated wilderness areas.

The 15-year Bureau of Land Management (BLM) wilderness review, mandated by the Federal Land Policy and Management Act of 1976, conducted inventories and studies that finally came to a conclusion in 1991. Secretary of the Interior Manuel Lujan signed a decision establishing 95 BLM wilderness study areas (WSAs) in Utah (Bureau of Land Management, 1991). These WSAs continue to exist until released by an Act of Congress. Through the Interior Board of Land Appeals, wilderness advocates had some influence over this review process even though they were not satisfied with the results.

Beginning in 1985, prowilderness interest groups became divided over whether to demand a new BLM administrative inventory or to proceed with legislative proposals. Some locally-based groups embraced a regional approach to legislation, while other groups insisted on a single statewide BLM wilderness bill. This split contributed to a 15-year hiatus in Utah wilderness designations.

In 1993 and 1994, the Coalition for Utah's Future/Project 2000 worked with wilderness advocates and Emery County officials on a compromise wilderness proposal for the San Rafael Swell. Although the effort seemed promising, it failed after key stakeholders withdrew. Members of the Utah congressional delegation, including Rep. Jim Hansen (R-UT), also saw an opportunity to pursue a statewide BLM bill after the

Republicans gained control of both houses of Congress in the 1994 election (Coalition for Utah's Future/Project 2000, 1994).

A statewide BLM wilderness bill (H.R. 1745) was drafted in 1995 and went through a series of public hearings. Due to the small acreage (1.8 million acres compared to conservation group proposals ranging from 3.8 to 5.7 million acres) and a number of provisions that seemed designed to circumvent the Wilderness Act, the bill never made it to the floor of the House of Representatives for a vote. A companion bill introduced in the Senate also failed.

During his 1996 re-election campaign, President Bill Clinton exercised his authority under the Antiquities Act to proclaim the Grand Staircase-Escalante National Monument in southern Utah on September 18, 1996 (Clinton, William J., 1996). This was accomplished without prior consultation with Utah Governor Mike Leavitt or members of Congress. The announcement was made in a presidential press conference held on the South Rim of the Grand Canyon in Arizona. The Grand Staircase-Escalante National Monument was the first to be administered by the BLM, and the 1996 proclamation led to the establishment of the National Landscape Conservation System.

Also during the Clinton administration, Secretary of the Interior Bruce Babbitt ordered a new BLM wilderness inventory for Utah (Bureau of Land Management, 1999). The Babbitt re-inventory recommended additional lands to be set aside as potential wilderness through the resource management planning process. Some of these were adjacent to the 3.2 million acres of WSAs established in 1991, and some areas were stand-alone.

The re-inventory determined that another 2.6 million acres of BLM land in Utah had wilderness characteristics as defined by The Wilderness Act. The State of Utah responded by suing the Department of the Interior.

In 2003, prior to the completion of new BLM resource management plans, the Bush administration put these additions on hold. Secretary of the Interior Gale Norton signed an out-of-court settlement with Utah Governor Mike Leavitt that rescinded the previous administration's BLM wilderness policies (U.S. District Court, Utah, 2003).

While the controversy over the BLM wilderness re-inventory played out, in the year 2000, a bill sponsored by Rep. Scott McInnis (R-CO) brought about the first new wilderness designation in Utah since 1984 (see Table 3.1). The Black Ridge Canyons Wilderness included 75,418 acres. The part of this area that extends across the state boundary into Utah contains approximately 5,099 acres.

Rep. Rob Bishop (R-UT) inserted the designation of the Cedar Mountain Wilderness into the 2006 National Defense Authorization Act. At the time, Utah elected officials were concerned that a proposed spent nuclear fuel repository on the nearby Goshute Reservation might interfere with the continued operation of a major military facility, the Utah Test and Training Range. This circumstance helps explain the unusual inclusion of a wilderness area in a defense authorization bill.

In 2002, the regional approach to BLM wilderness designation re-emerged -- not in Utah, but in Nevada. Wilderness advocates, county officials, and local stakeholders in the Las Vegas area worked out a compromise agreement on a broad array of public land concerns that included wilderness designation. This negotiation process led to the Clark

Table 3.1 Major Utah Wilderness Legislation

Endangered American Wilderness Act of 1978	Public Law 95-237, 92 Stat. 40	February 24, 1978
Arizona Wilderness Act of 1984	Public Law 98-406, 98 Stat. 1485	August 28, 1984
Utah Wilderness Act of 1984	Public Law 98-428, 98 Stat. 1657	September 28, 1984
Colorado Canyons National Conservation Area and Black Ridge Canyons Wilderness Act of 2000	Public Law 106-353, 114 Stat. 1374	October 24, 2000
National Defense Authorization Act for Fiscal Year 2006	Public Law 109-163 [Division A-Title III-Subtitle H—Utah Test and Training Range- Sec. 384, Designation and management of Cedar Mountain Wilderness, Utah], 119 Stat. 3217	January 6, 2006
Omnibus Public Land Management Act of 2009	Public Law 111-11 [Title I- Subtitle O—Washington County, Utah], 123 Stat. 1075	March 30, 2009

County Conservation of Public Land and Natural Resources Act of 2002, cosponsored by Senators Harry Reid (D-NV) and John Ensign (R-NV).

Senator Bob Bennett (R-UT) saw the possibility of doing the same thing across the border in Washington County, Utah. Like Las Vegas, the St. George area needed additional land for development. In 2006, the first draft of what was then called the Washington County land use bill was condemned by wilderness groups as a "developer's dream" because it would have allowed the sale of between 17,000 and 25,000 acres of public land to private developers. They also criticized the proposed wilderness designations for being too small (Wilkison, 2006). A renewed consensus effort in Washington County produced a much-improved bill that in the end was praised by all sides.

On March 30, 2009, President Barack Obama signed the Omnibus Public Land Management Act of 2009. This established and/or modified a significant number of wild and scenic rivers, wilderness, and other congressionally designated areas. The Washington County Growth and Conservation Act was incorporated as Title I, Subtitle O of the law.

The act designated Canaan Mountain, Black Ridge, Beaver Dam Wash, Doc's Pass, and other BLM areas as wilderness, as well as most of Zion National Park. A segment of the Virgin River became Utah’s first designated wild and scenic river. The act also established the Beaver Dam Wash National Conservation Area and the Red Cliffs National Conservation Area.

Encouraged by the success of the Washington County process, other Utah counties initiated similar efforts. As of 2011, the most progress has been made in San Juan County, which is considering wilderness designation for nearly all the BLM WSAs in the county.

During the summer of 2010, Rep. Jim Matheson (D-UT) worked with Salt Lake County and wilderness groups to propose additions to the Wasatch Front wilderness areas designated in 1984. This effort did not result in a bill being introduced in Congress, but may have pointed the way to future legislation.

After being lobbied by conservation groups, the Obama administration decided in December 2010 to reverse the 2003 Leavitt-Norton agreement. Secretary of the Interior Ken Salazar issued Secretarial Order 3310, which directs the BLM to “designate appropriate areas with wilderness characteristics under its jurisdiction as ‘Wild Lands’ and to manage them to protect their wilderness values” (Salazar, 2010). Although the order once again allows the BLM to set aside wildlands through the planning process, at this writing it is unclear what the near-term practical effect will be in Utah, where the BLM has recently completed a round of resource management plans.

3.2.2. National Landscape Conservation System (NLCS)

The newest American land system was created in June 2000 by former Interior Secretary Bruce Babbitt, as an outgrowth of the Clinton administration's proclamation of Bureau of Land Management (BLM) national monuments. The NLCS includes some 27 million acres, roughly 10 % of the BLM's holdings. Wilderness areas, national monuments, national conservation areas, wild and scenic rivers, national historic trails, and wilderness study areas (WSAs) are all counted as units of the NLCS. On March 30, 2009, the National Landscape Conservation System was permanently established by statute in the Omnibus Public Lands Act of 2009.

3.2.3. Roadless Area Conservation Rule

During the final year of the Clinton administration, U.S. Forest Service Chief Michael Dombeck directed a rulemaking process designed to protect inventoried roadless areas on the national forests that were not part of the National Wilderness Preservation System. An environmental impact statement setting forth the new policy was based primarily on a compilation of GIS data from all national forests, which was then published in map form, and made available to the public via the Web.

In January 2001, the Roadless Area Conservation Rule took effect, barring road building and logging on 58.5 million acres. The Bush administration blocked implementation of the rule, and left its fate to be decided by the outcome of legal challenges.

For 8 years, the rule bounced around the federal courts. Meanwhile, the Bush administration set up a petition process that allowed individual states to create their own plans for managing roadless areas, which the Forest Service would be bound to follow.

In May 2009, the Obama administration announced that roadless area projects would require approval by the Secretary of Agriculture, except in Idaho. On August 5, 2009 the Ninth Circuit Court of Appeals affirmed a district court decision invalidating the Bush state petitions rule, and reinstating the 2001 Roadless Rule.

3.2.4 Off-road Vehicles (ORVs)

The use of ORVs has risen dramatically over the years. While the numbers of these machines have increased, manufacturers have also improved their capabilities. For example, higher-powered snowmobiles can now traverse steep slopes – making it easier to cross wilderness boundaries and enter other areas that are off limits to vehicles.

Land management agencies have struggled with the challenge posed by the popularity of go-anywhere vehicles. In 2001, the U.S. Forest Service declared its intention to create a better system for motor vehicle regulation. The agency now makes use of GIS to do transportation analysis, using a decision support system to identify unnecessary routes that cause environmental damage. Each year, national forests issue free motor vehicle use maps that indicate where motorized travel is allowed, and which routes are closed during certain seasons.

In planning documents issued since 2005, the Forest Service has closed over 6,000 miles of roads to motorized travel. The BLM also has adopted policies that aim to curtail cross country motor vehicle use.

<u>3.2.5 R.S. 2477</u>

The State of Utah and several counties continue to make use of an obscure Civil War-era law to assert rights-of-way for “highways” across federal lands. Originally part of the Mining Law of 1866, Revised Statute 2477 (R.S. 2477) became a rallying cry from the late 1980s to the present day. Though this law was repealed by the Federal Land Policy and Management Act of 1976, counties can still claim ownership of an R.S. 2477 right-of-way across if they can prove extended preexisting use. Most of these proposed "highways" are remote jeep trails, dry desert streambeds, or cow paths. In Utah, there are more than 10,000 R.S. 2477 claims for primitive trails in national parks, forests, wilderness areas, and lands proposed for wilderness protection.

The Bush administration published a rule and initiated a policy that made it easier for R.S. 2477 litigation to proceed, even in cases of routes that the BLM found not to be significant enough to amount to real roads. A coalition of conservation groups intervened in these court cases, preventing the issuance of rights-of-way.

In February 2009, Interior Secretary Ken Salazar put a stop to the processing of R.S. 2477 applications pending policy review.

In September 2010, Kane County and State of Utah were awarded five R.S. 2477 rights-of-way in a settlement of a quiet title suit filed in U.S. District Court. One of these routes is a paved road that leads to Coral Pink Sand Dunes State Park. The others are well-maintained dirt roads outside the areas proposed for wilderness protection. Although not controversial, this decision was significant because it marked the first successful R.S. 2477 court case.

GIS technology has played an important role in the R.S. 2477 campaign. The counties filing road claims have done extensive field work, using global positioning systems (GPS) to create spatial datasets of thousands of vehicle ways. Following a 2008 decision of the Utah State Supreme Court, these extensive geospatial data have been made public (Southern Utah Wilderness Alliance v. Automated Geographic Reference Center, 2008 UT 88, 200 P.3d 643).

CHAPTER 4

METHODOLOGY AND RESULTS

4.1 Objective

The objective of this thesis was stated in Chapter 1:

"Publish a low-cost digital atlas of Utah wilderness and other protected areas on the World Wide Web and DVD to provide accurate, accessible spatial and descriptive wildlands geospatial information to a general audience. Utilize public datasets and open source standards."

The lowest-cost approach is to make spatial data available in Web-enabled form. This means only a web browser is needed to view maps and download data. Various software solutions are available; these have been discussed in Chapters 2 and 3. The method chosen for the *Utah Wilderness Atlas* uses scalable vector graphics (SVG), an open standard that is ideal for cartographic applications. The same and additional datasets are also provided as ArcView shapefiles for experienced GIS users.

Nonspecialists often encounter a steep learning curve when attempting to understand wilderness, protected areas and related natural resource management issues. Details concerning wilderness policy often seem to be full of jargon: what are RARE II, RS 2477, FLPMA, or LAC? (see glossary). The *Utah Wilderness Atlas* will include issue analyses and historical background aimed at a general audience, and linked to an extensive glossary of terms.

Utah is characterized by geographical diversity. An understanding of Utah wilderness requires an appreciation of the unique qualities of the wide variety of landscapes under discussion. The *Utah Wilderness Atlas* employs a regional approach, based on 14 wilderness regions (see Chapter 5).

4.2 Data Formats

The data file formats used for the *Utah Wilderness Atlas* conform to open standards (with the exception of MrSID). Open standards are based on specifications that are publicly adopted by the software industry and not proprietary to a single developer. The principal advantages of open standards are interoperability and data sharing, but they are also typically the low cost solution and take longer to become obsolete than standards that are less widely supported.

4.2.1 Scalable Vector Graphics

Scalable Vector Graphics (SVG) is an open standard, XML-based format for the creation of vector images that can be viewed with a web browser. SVG is supported by nearly all web browsers, with the notable exception of Microsoft Internet Explorer 8 (IE8), which is still in wide use (Svensson, 2008). Adobe SVG Viewer, a free plug-in from Adobe Systems Incorporated, must be downloaded before IE8 can display SVG objects. However, IE9 (released March 14, 2011) does support the basic SVG feature set.

Compared to raster images, SVG files are much smaller and take less computer memory and bandwidth. The rendering of vector objects is clearer than the raster images used in the early web mapping applications.

SVG files actually consist of text. Therefore, they are easily editable and can be readily searched. For example, if you want to view a labeled map feature, you can type the name in a JavaScript search window and automatically pan the map to that location.

Table 4.1 lists SVG-related software that has been tested for the *Utah Wilderness Atlas*. SVG export tools include SVGMapper (an ArcView 3.x extension), Shape2SVG (a script for ArcView), and Map2SVG, an extension for MapInfo Professional. SVGMapper was used to create prototype web maps, before it was decided to switch to MapView SVG (now renamed Mappetizer). Both SVGMapper and Mappetizer were developed in Europe (Czech Republic and Germany, respectively).

Table 4.1 SVG-Related Software

Adobe SVG Viewer	Web browser plug-in
SVGMapper	ArcView 3.x extension
Shape2SVG	ArcView 3.x script
Map2SVG	MapInfo extension
SVG Maker	Windows program
MapView SVG	ArcView 3.x extension ArcGIS extension
Mappetizer	ArcGIS extension

Web mapping applications of SVG can incorporate a number of interactive features by using JavaScript with SVG files. Users can pan and zoom (change map scale), and turn layers on and off. Drop-down menus and attribute queries are also supported. Objects in an SVG map can also be linked to HTML documents, for example to display attribute information in an interactive map.

4.2.2 HTML (Hypertext Markup Language)

This is the standard file format supported by all web browsers. It is an ASCII text file (.htm or .html) that uses protocols such as document tags and JavaScript that web browsers can read. The browsers display text and images as formatted documents. HTML documents usually contain hyperlinks that enable the user to bring up other files with a mouse click. JavaScript is supported by all browsers, and is used to add interactivity to web pages. The HTML 4.01 standard is promulgated by the World Wide Web Consortium (W3C) (www.w3.org).

4.2.3 ESRI ArcView Shapefiles

The Environmental Systems Research Institute (ESRI) shapefile is the format for downloadable geospatial datasets included with the *Utah Wilderness Atlas*. The shapefile format was introduced by ESRI with the release of ArcView 2.0 in the early 1990s; it is now an open-source industry standard that is readable or can be imported into nearly every GIS program or data viewer on the market. Each shapefile is actually made up of three or more component files, with the same name and different file type extensions (see Table 4.2). These files record the entire feature and attribute data for an ArcView data layer (ESRI, 1998).

Table 4.2 ESRI Shapefile Structure

File Type	Extension
Shape	.shp
Shape index	.shx
dBase	.dbf
Spatial bin	.sbn
Spatial bin index	.sbx
Legend	.avl
Projection data	.prj
Metadata	.xml & .htm

Shapefiles can be copied more easily than the old ArcInfo coverages (still in use), which require importing and exporting as .e00 files. They are more widely supported than the more versatile file geodatabases, introduced by ESRI with ArcGIS 9.2. For distribution on the Internet, it is customary to "zip" the component shapefiles into a single (.zip) file using WinZip.

4.2.4 XML Metadata files

Each shapefile in the *Utah Wilderness Atlas* will have corresponding metadata files in HTML and XML format. These files contain data documentation in the standard Federal Geographic Data Committee (FGDC) format. Metadata files can be produced using the ArcCatalog FGDC metadata editor, a desktop application for ArcGIS. ArcCatalog itself can view and print XML-formatted metadata conforming to the ESRI standard (ESRI, 2001). It can also provide the user with a thumbnail view of a dataset. Any web browser can of course read the HTML-formatted metadata.

With ArcGIS version 10, ArcCatalog stopped supporting FGDC metadata. This was rectified by the release of Service Pack 3 for ArcGIS 10.

4.2.5 MrSID Compressed Image Files

Raster files distributed with the *Utah Wilderness Atlas* include a shaded relief layer, satellite imagery, a land cover layer, and scanned paper maps. The uncompressed files are too large for convenient Internet and disk distribution, making image compression a necessity. The MrSID format was chosen as the best available for raster data.

Image compression techniques fall into two general categories: lossless and lossy. Lossless compression allows the image to be decompressed with no loss of quality, but compression ratios are typically limited to 2:1. Lossy techniques can achieve much higher compression ratios with a trade-off involving some permanent loss of image data.

MrSID (.sid) is a lossy compressed raster file format developed by LizardTech and supported by ESRI and some other GIS and image processing software. The acronym stands for Multiresolution Seamless Image Database. The method used is known as discrete wavelet transform, which converts the original pixel array to a mathematical model. MrSID can also preserve georeferencing, but this requires the use of auxiliary files.

Visual quality of the compressed images is comparable to the originals at ratios of up to 20:1. LizardTech touts this as a “visually lossless” feature. MrSID is capable of compressing files at 50:1 or more, with varying loss of visual detail (Johnson & Greenfield, 1999). Compressed images also load more quickly because there is less data to read from a disk drive. Roaming and zooming are faster than with an original uncompressed file because of multiresolution wavelet levels.

MrSID is widely supported, for example by ESRI's ArcGIS and ArcView 3.x, as well as Leica Geosystems' ERDAS Imagine and other software. Freeware viewers are available from LizardTech. MrSID remains a proprietary file format, and the encoder software is not free, although it is bundled with ERDAS Imagine and as an extension to ArcGIS.

Another format comparable to MrSID was considered for use in the *Utah Wilderness Atlas*. This was the Enhanced Compression Wavelet (ECW), which was developed by Earth Resource Mapping (Earth Resource Mapping, 2001). ECW was a feature of the ER Mapper image-processing program, and was supported by a number of freeware plug-ins and standalone applications. Originally, ECW was an open standard, but it is now proprietary, owned by Leica Geosystems.

There is an open standard for wavelet compression, JPEG 2000. This is a great improvement over the existing JPEG standard, both for quality and compression ratios. Unfortunately, JPEG 2000 is not as widely supported as MrSID.

4.2.6 Adobe PDF Files

The Utah Wilderness Atlas includes static maps and illustrated articles in Adobe PDF (Portable Document Format), which was developed by Adobe Systems Incorporated. This is a self-contained file format based on the PostScript language. PDF documents can be viewed and printed independently of the software, hardware, and operating system used to create the file. Originally a proprietary format, PDF was officially released as an open standard in July 2008, and published by the International

Organization for Standardization (ISO). A free Adobe Reader is available for viewing and printing PDF files.

The Adobe PDF format is widely accepted and is considered the de facto standard for printable documents on the web. PDFs can be viewed in all commonly-used web browsers, although sometimes a free plug-in is required. PDF format can be optimized for small file size, and for "streaming" over the Web so that the document can be viewed while it is downloading.

ArcGIS 9.1 introduced the capability to export maps to geospatial PDF format. The georeferencing of PDF files was pioneered by TerraGo Technologies in the development of their GeoPDF-branded map and imagery products. The geospatial PDF standard supports interactive map features such as layer control, access to GIS attribute tables, and coordinate readouts.

4.3 Atlas Extent and Projection

The *Utah Wilderness Atlas* extent is "Utah plus one degree." Note that Utah's eastern and western boundaries are not even degrees of longitude, although they originally were before 1879, when Washington, D.C. was the prime meridian for maps of the United States. Figure 4.1 illustrates the Atlas extent, based on the same 1 x 1 degree blocks that have become standard for USGS geospatial data. The Atlas is bounded by lines of latitude and longitude at 43° N, 110° W, 42° N, 108° W, 36° N, and 115° W. As mentioned in Chapter 1, Utah's wilderness geography is deprived of context when clipped to the state boundary.

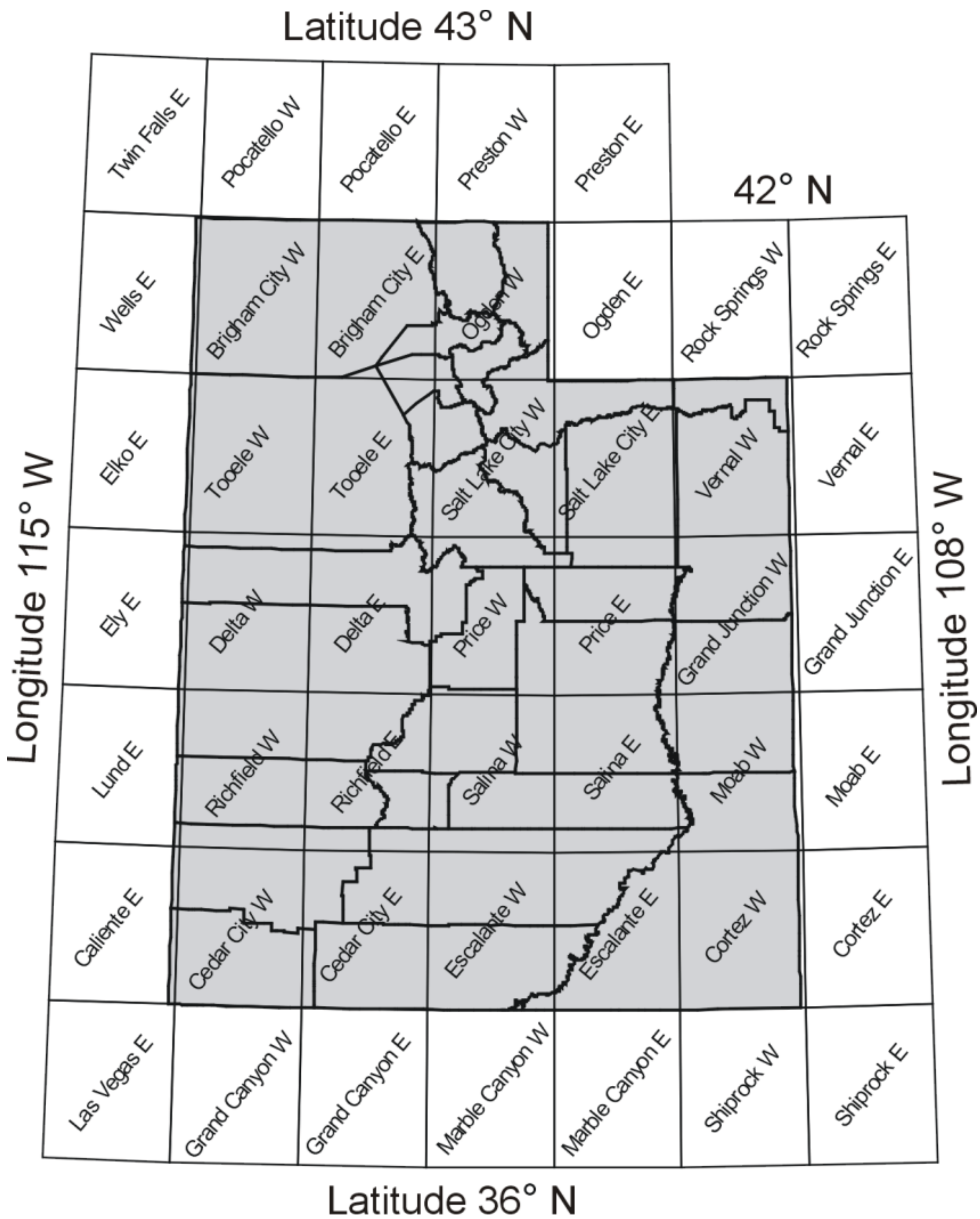


Figure 4.1 Atlas extent and USGS 1-degree blocks, Utah and vicinity. Utah is shaded in gray and county boundaries are shown. Projection is UTM Zone 12N.

Utah's boundaries are not defined by landforms. Administrative units often extend into adjoining states, as do Utah's three designated BLM wilderness areas. Boundaries of a number of Utah protected areas do coincide with the state boundaries. In order to show this clearly, we need to go a bit beyond the ordinary extent of a state atlas.

The map projection proposed for the *Utah Wilderness Atlas* is Universal Transverse Mercator (UTM), Zone 12 North. This is also the standard projection for geospatial data published by the Utah Automated Geographic Reference Center (AGRC).

The UTM projection is constructed by dividing the globe into 60 north and south zones, each with its own central meridian and its own transverse Mercator projection. For zones in the northern hemisphere, the origin of latitude is the Equator. A false easting of 500,000 meters is used in each zone so that all coordinates are positive numbers (Snyder, 1987). Utah lies almost entirely within a single zone (Figure 4.2).

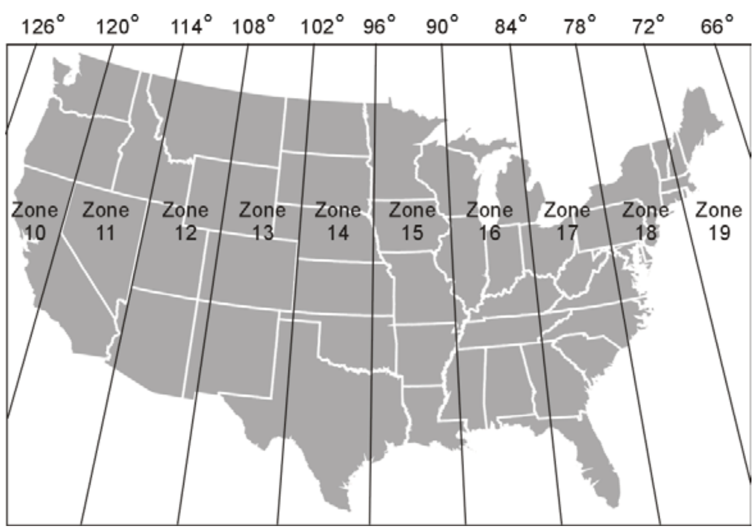


Figure 4.2 Zones of the Universal Transverse Mercator (UTM) grid in the contiguous United States. Projection shown is Lambert Conformal Conic.

UTM preserves direction (it was originally used by the United States Army for land navigation and computing artillery trajectories, so local angles are true). UTM is also conformal; it provides for accurate representation of small shapes, with minimal distortion of large shapes within the same zone. Distortion of area is also minimal within the zone. Scale is constant along the central meridian. This feature helps preserve the accuracy of distance measurements for a scale error not exceeding 0.1 % within each zone (Kennedy and Kopp, 2000).

UTM zones span six degrees of longitude. Zone 12 runs from 114° W to 108° W. The proposed atlas extent is 7 degrees wide; therefore, the area west of 114° W will have to be projected in Zone 12 although properly belonging in Zone 11.

The horizontal datum for the Atlas is the 1983 North American Datum (NAD 83). The Federal Geographic Data Committee recommends the NAD 83 datum, based on the GRS 1980 spheroid.

Here is a summary of the atlas projection parameters, as they are recorded in the metadata for each atlas layer:

Horizontal Coordinate System
- *Projected Coordinate System Name:* NAD_1983_UTM_Zone_12N
  - **Grid Coordinate System Name:** Universal Transverse Mercator
    - *UTM Zone Number:* 12
    - **Transverse Mercator Projection**
      - *Scale Factor at Central Meridian:* 0.999600
      - *Longitude of Central Meridian:* -111.000000
      - *Latitude of Projection Origin*: 0.000000
      - *False Easting:* 500000.000000
      - *False Northing:* 0.000000
  - **Planar Coordinate Information**
    - *Planar Distance Units:* meters
  - **Geodetic Model**
    - *Horizontal Datum Name*: North American Datum of 1983
    - *Ellipsoid Name*: GRS 1980

4.4 Atlas Base Layers

Base layers in the Utah Wilderness Atlas provide a geographic reference for the thematic layers, enhance the appearance of maps, and provide content that is not available in vector format. They include a raster digital shaded relief layer, a land cover layer, and satellite imagery from MODIS and Landsat.

4.4.1 Digital Shaded Relief

One of the base map layers in the *Utah Wilderness Atlas* is a digital shaded relief layer produced using ArcGIS from the USGS National Elevation Dataset (Gesch et al., 2002). The purpose of a shaded relief map is to give the appearance of a three-dimensional image of the landscape in two dimensions. By convention, illumination for shaded relief is from the northwest because our eyes are used to seeing shadows underneath objects. Sun elevation should be 45 degrees. This is actually contrary to nature in the Northern Hemisphere, but shading that is more realistic would cause relief inversion (mountains would look like valleys, and vice versa) (Ramachandran 1988).

Shaded relief looks best with “warm” colors because they do not interfere with the shadowing effect. The shaded relief layer also uses a single color ramp, rather than multicolor hypsometric (elevation) tinting in order to work well with other layers displayed as semitransparent polygons. Principal water bodies and rivers are shown in blue. Tree cover is shown in green. Two file formats are used, MrSID and JPEG. The JPEG format is compatible with scalable vector graphics (SVG) web mapping.

Figure 4.3 shows an example of the shaded relief base layer. The tree cover tint was derived from the MODIS Vegetation Continuous Fields (VCF) product developed by the University of Maryland.

ERDAS Imagine was used to create the digital shaded relief layer.

The processing steps were as follows:

1. Import National Elevation Dataset 90 meter DEM data (USGS).
2. Mosaic NED data.
3. Reproject to UTM Zone 12
4. Clip to Atlas extent.

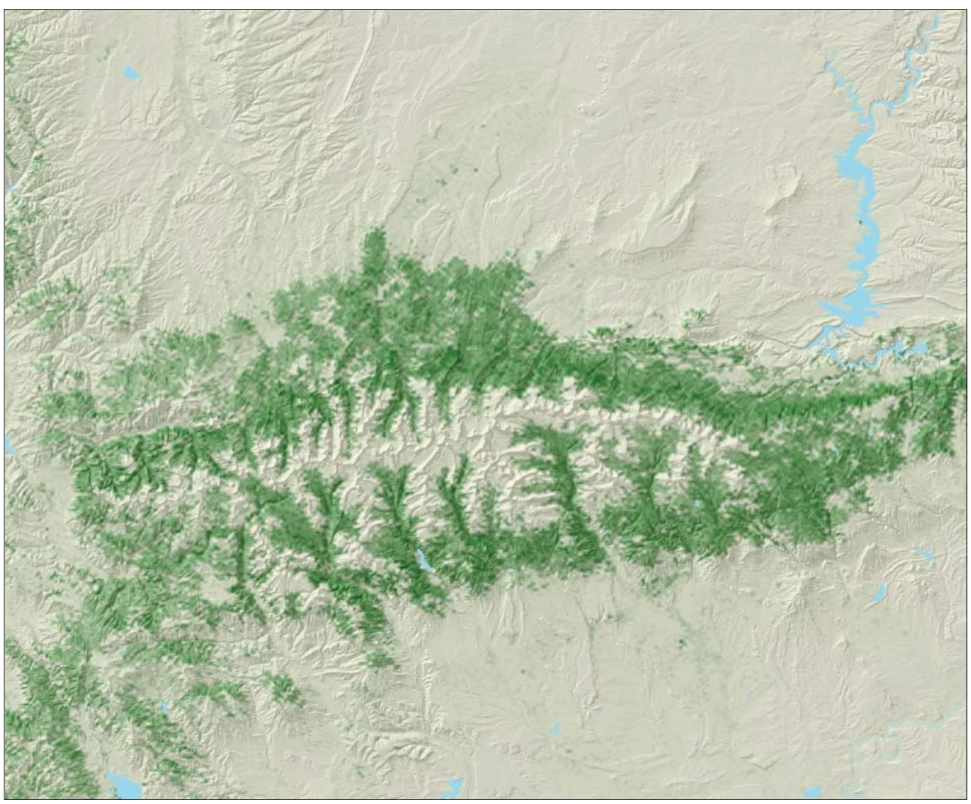


Figure 4.3 Example digital shaded relief for the High Uintas region.

5. Import Vegetation Continuous Fields (VCF) percent tree cover data (University of Maryland).
6. Reproject to UTM Zone 12.
7. Clip to Atlas extent.
8. Apply color ramp to VCF in raster attributes.
9. Generate shaded relief (model themerelief.pmdl). Azimuth = 315 degrees. Altitude = 45 degrees. Z-factor = 1.
10. Add VCF layer as a semitransparent overlay in ArcGIS.
11. Add water bodies (mjwater.shp) layer.
12. Export to MrSID format (resample to 180 m pixels to get under file size limitation).
13. Export to JPEG at 90 m resolution.

4.4.2 NLCD Land Cover Layer

National Land Cover Data Sets (NLCD) for the conterminous USA are published by the U.S. Geological Survey (USGS). The primary objective of the NLCD mapping project is to meet data requirements for applications at the regional to continental scale, including watershed management, environmental inventories, fire risk assessment, and land management. The classification scheme used is based on Anderson Level II (Anderson et al., 1976).

Unlike the Gap Analysis Program vegetation classifications, the NLCD is consistent across state lines. This made the creation of the land cover layer possible.

The NLCD 1992 product was used to create the Atlas land cover layer. This is a nationally consistent raster GIS dataset derived from early to mid-1990s Multi-Resolution Land Characterization (MRLC) Landsat Thematic Mapper (TM) satellite imagery (Vogelmann et al., 2001). The USGS later developed and published NLCD 2001 and NLCD 2006 products, which are intended for use in land cover change investigations. These newer land cover layers will be added to the Atlas in the future.

The NLCD data consists of a 30-meter grid, although it is best utilized in a spatially aggregated form (for example, as 3x3 pixel blocks) whenever possible. This alleviates the "salt and pepper" effect existing in the original full resolution product. Similarly, if a generalized land cover classification scheme (e.g., Anderson Level I) meets the application requirements, it is wise to aggregate the NLCD data accordingly (USGS, 2001).

The NLCD land cover layer for the Utah Wilderness Atlas was spatially aggregated to a 90-meter resolution using a block majority function in ArcGIS. Block majority divides the data into 3x3 pixel blocks, and then a code is assigned to each block based on the majority value within that block. In addition, the classes were recoded as shown in Table 4.3. The increase in accuracy and the reduction in file size more than compensate for the loss of precision. The results are adequate for display at the 1:750,000 nominal scale of the Atlas.

Figure 4.4 shows an example of the NLCD land cover layer for the Uinta Mountains region. See the legend entries in Table 4.3 for a key to the map colors.

Table 4.3 Aggregation of NLCD Dataset to Anderson Level I

NLCD	Class Name	Recode	Class Name	Legend
11	Open Water	11	Water	Blue
12	Perennial Ice/Snow	12	Snow	White
21	Low Intensity Residential			
22	High Intensity Residential	20	Urban	Red
23	Commercial/Industrial/Transportation			
31	Bare/Transitional			
32	Quarries/Strip Mines/Gravel Pits	30	Barren	Beige
33	Bare Rock/Sand			
41	Deciduous Forest	41	Deciduous Forest	Green
42	Evergreen Forest	42	Evergreen Forest	Dark green
43	Mixed Forest	43	Mixed Forest	Chartreuse
51	Shrubland	51	Rangeland	Tan
61	Orchard/Vineyards/Other	80	Agricultural	Yellow
71	Grasslands/Herbaceous	71	Grass	Gold
81	Pasture/Hay			
82	Row Crops	80	Agricultural	Yellow
83	Small Grains			
84	Fallow			
85	Urban/Recreational Grasses	20	Urban	Red
91	Woody Wetland	90	Wetland	Cyan
92	Herbaceous Wetlands			

Figure 4.4 Example of the NLCD land cover layer for the High Uintas region.

4.4.3 MODIS Images

Atlases have made use of satellite imagery for about 40 years. Georeferenced, cloud-free satellite scenes can be mosiacked and combined with GIS vector layers to produce a useful map display of landforms and water bodies as viewed from space. Typically, these images are presented in the form of “natural color” (red, green, and blue bands) or “false color” (near infrared, red, and green bands).

Some earlier Utah digital atlases, such as the Utah AGRC State Geographic Information Database (SGID) and the Utah GAP Analysis dataset, featured Landsat TM mosaics that have been resampled to reduce file size. The original spatial resolution of 30 meters is changed to 180-meter pixels in the published file (Edwards et al., 1996; Vaughn, 1995).

Most Utah satellite image mosaics are clipped to the state boundary. As mentioned in Chapter 1, this is a shortcoming for wilderness mapping. Also, these mosaics are made up of imagery that was acquired on different dates.

MODIS (Moderate Resolution Imaging Spectroradiometer) imagery was originally included in the Atlas base layers in lieu of a Landsat mosaic. Later, the Landsat Geocover product was made available in the public domain, and it was added (see below).

NASA launched the first Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard the Earth Observing System (EOS) satellite Terra on December 1999. A second MODIS instrument orbited with the Aqua satellite in May 2002.

The objective of MODIS is to provide a comprehensive series of daily global observations of the Earth's land, oceans, and atmosphere in the visible and infrared regions of the spectrum (Justice et al., 1998).

The MODIS instrument is a 36-band "whisk-broom" sensor that scans from side to side as it passes overhead at an altitude of approximately 700 km; the swath width is 2,330 km. MODIS points straight down, with a view angle of 55 degrees to either side. As it passes over Utah, it records an image much wider than the entire state.

The MODIS swath has its best spatial accuracy down the centerline (nadir) of the image, and becomes more distorted towards either side due to the "bow-tie effect," a combination of the scan angle and the curvature of the Earth (see Figure 4.5). Georeferencing works best with direct overpasses.

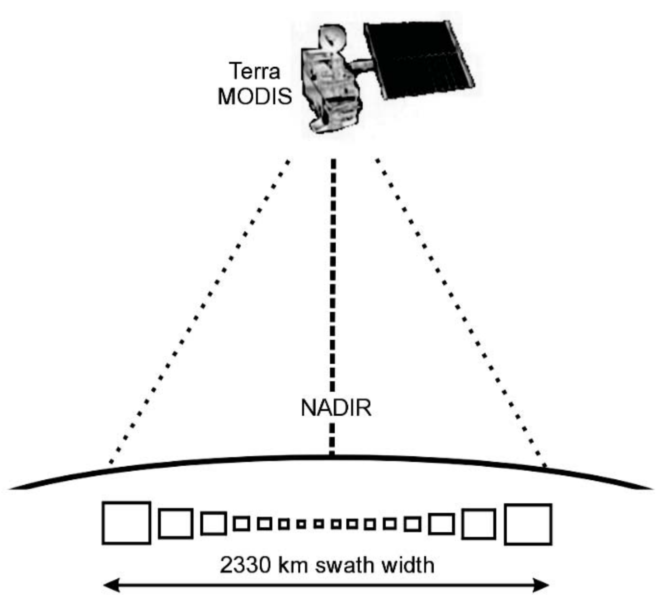


Figure 4.5 MODIS swath data "bow tie effect." MODIS pixel dimensions, cross-track and along-track, change with scan angles: 0º - 250 x 250 m; 15º - 270 x 260 m; 30º - 350 x 285 m; 45º - 610 x 380 m (adapted from Huete et al., 1999).

The MODIS "land bands" (bands 1-7) are centered at 648 nm, 858 nm, 470 nm, 555 nm, 1240 nm, 1640 nm, and 2130 nm, respectively (Table 4.4). The MOD02 radiance data can be corrected to approximate reflectance, i.e., an estimate of the spectral reflectance for each band as it would be measured at ground level without the effects of atmospheric scattering or absorption (NASA, 2000).

MODIS swath data are distributed on the Web by the USGS EROS Data Center (http://edcdaac.usgs.gov), the University of Wisconsin Space Science and Engineering Center (SSEC) (ftp://terra.ssec.wisc.edu/pub/terra/modis/), Oregon State University (http://Picasso.oce.orst.edu/ORSOO/MODIS/DB/data1b.html), and other institutions.

MODIS imagery is produced as HDF-EOS (Hierarchical Data Format – Earth Observing System), a file format that was not supported by the leading image processing software programs at the time the Atlas MODIS layer was produced.

The MODIS image selected for the *Utah Wilderness Atlas* was acquired September 23, 2002 (Figure 4.6). It is nearly cloud-free over the Atlas extent. Level 1b data from the SSEC were processed using software from the NASA Goddard Space Flight Center. Georeferencing is from a geolocation file (MOD03) produced on board

Table 4.4 MODIS Land Bands

MODIS Band	Band Width (nm)	Spatial Resolution (m)	Landsat Equivalent
1	620-670	250	TM Band 3 (red)
2	841-876	250	TM Band 4 (near IR)
3	459-479	500	TM Band 1 (blue)
4	545-565	500	TM Band 2 (green)
5	1230-1250	500	None
6	1628-1652	500	TM Band 5 (mid IR)
7	2105-2155	500	TM Band 7 (mid IR)

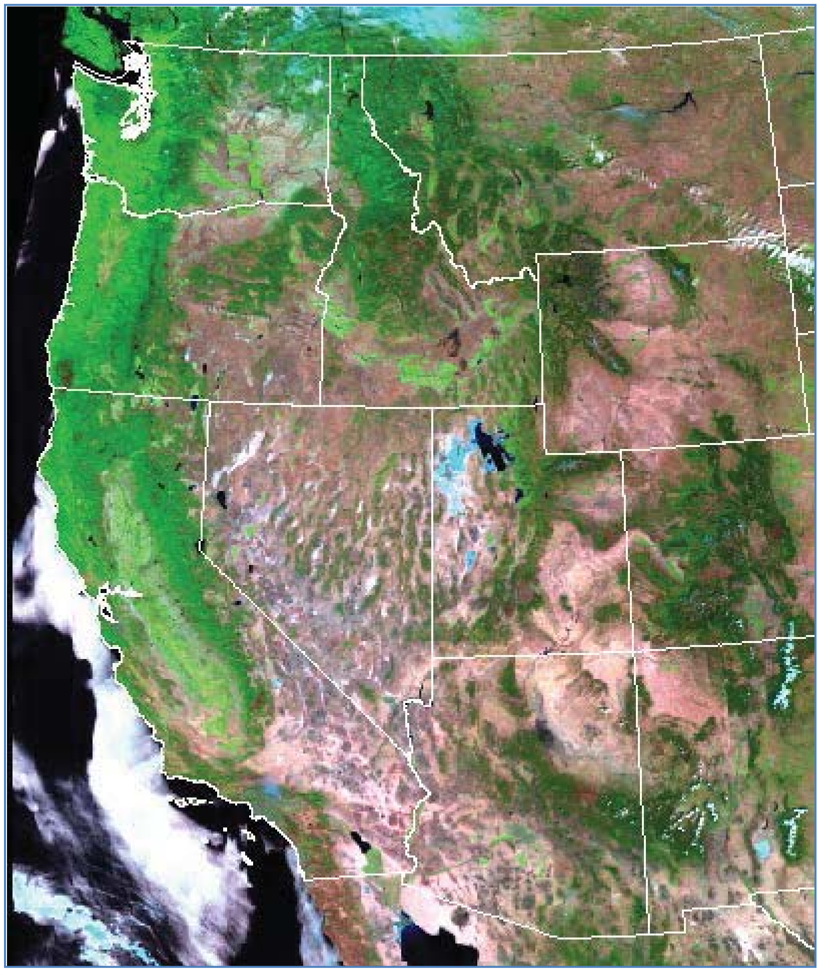


Figure 4.6 MODIS browse image from September 23, 2002.

the Terra satellite, and correction to surface reflectance uses the MODIS atmospheric bands.

Figure 4.7 is a flow chart illustrating the processing of MODIS for the *Utah Wilderness Atlas*. The layers produced include a quasi-true-color image (MODIS bands 1,4,3 = RGB) of the entire atlas extent with 250-meter spatial resolution, and a false color image to show vegetation and burned areas from wildfires.

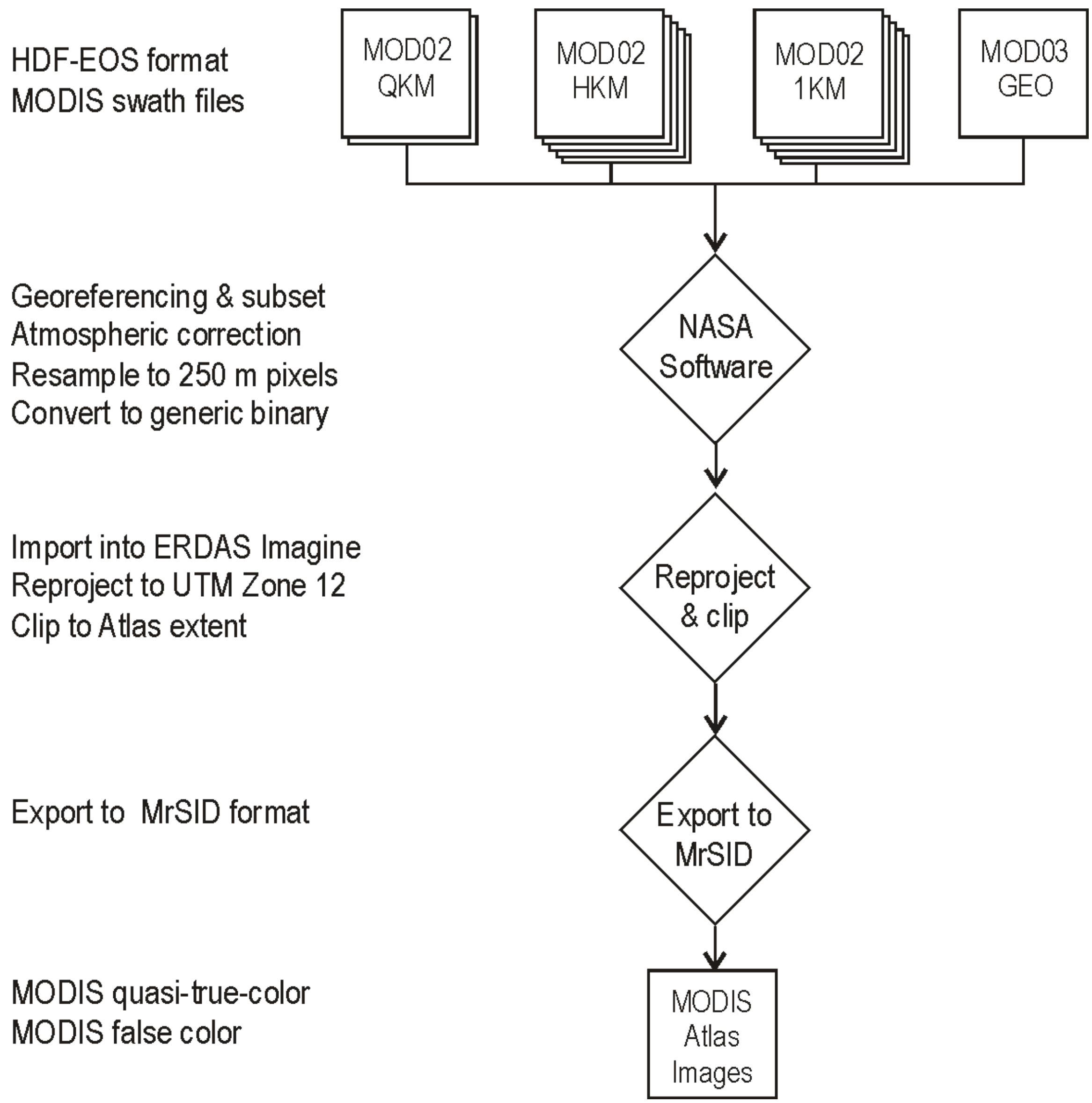


Figure 4.7 Workflow for MODIS image processing.

A method of processing MODIS imagery is shown in Figure 4.7. Custom-written software obtained from the NASA Goddard Space Flight Center was used to convert the HDF-EOS files to 250-meter georeferenced and atmospherically corrected generic binary files. MOD02 products are the swath image data. The MOD03 product is a geolocation file. The image was first projected to Lambert Azimuthal Equal-area and then reprojected to UTM using ERDAS Imagine, and clipped to the Atlas extent. The final images were compressed in MrSID format.

4.4.4 Landsat GeoCover

The Landsat GeoCover dataset is a collection of high resolution Landsat TM imagery provided in a standardized, orthorectified format, covering the entire land surface of the world (except Antarctica). The Landsat scenes were selected according to the least cloud cover and highest quality data. The finished product has been pan sharpened to 15-meter resolution, making use of the Landsat 7 ETM+ panchromatic band. This mosaic is also color-balanced and accurately georeferenced to within 50 meters (Tucker, Grant, & Dykstra, 2004).

Using the GeoCover product made it relatively easy to add a Landsat Atlas base layer. A Landsat mosaic of the State of Utah alone requires all or part of 16 Landsat scenes. A mosaic of the *Utah Wilderness Atlas* extent would take 32 Landsat scenes (see Figure 4.8). Ideally, these would be cloud-free scenes all acquired at nearly the same date.

The mosaicking process for 32 scenes, even with the best available software, requires a great deal of time and effort to do well. Color-matching scenes along rows is

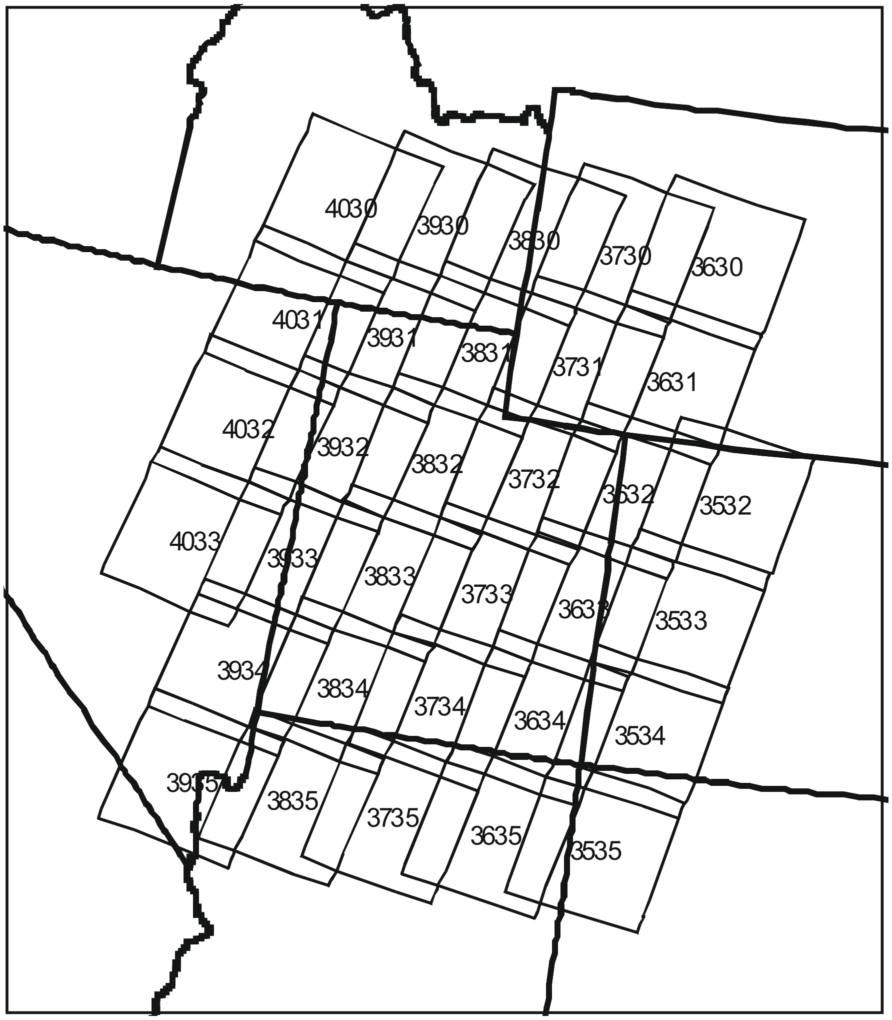


Figure 4.8 Landsat scenes for Utah and vicinity: 32 scenes identified by WRS path and row numbers (e.g., 4030 for path 40, row 30).

particularly difficult, because there is at least a 16-day difference in acquisition dates.

With GeoCover, it was only necessary to mosaic four tiles, reproject them, and clip to the Atlas extent. This was done using ERDAS Imagine.

The Landsat GeoCover layer offers more detail at larger map scales than MODIS imagery. It has some drawbacks, too. MODIS has a single date of acquisition, and can readily be used for a temporal reference, while GeoCover cannot. Also, the file size of the GeoCover layer makes it less practical to distribute via the Web. At nearly 100 megabytes (MB), it is roughly 100 times larger than the MODIS layers.

4.4.5 Other Atlas Base Layers

Two vector GIS layer are included with the Atlas base layers: the Atlas extent polygon, and a point layer for populated places. The Atlas extent is mostly a tool for clipping other layers. The populated places layer is from ESRI, and it did not seem to fit anywhere else.

4.5 Atlas Thematic Layers

In addition to the base layers, the *Utah Wilderness Atlas* includes a collection of thematic layers organized by theme (see Table 4.5). Many of these appear in the Atlas maps, and all will be available for download on the Atlas website. Figure 4.9 is a flow chart that summarizes the workflow used to produce the Atlas layers and map products.

When necessary, each layer was reprojected and clipped to the Atlas extent. The layer attributes were edited as appropriate. In some cases, it was necessary to edit geographic features to correct geospatial errors. Federal Geographic Data Committee (FGDC) compliant metadata was created for each layer.

Layers were then used to create map compositions in ArcMap. These were used to produce Atlas map products in different formats, such as Adobe PDF and scalable vector graphic (SVG) based interactive Web maps.

Table 4.5 Utah Wilderness Atlas Data Layers

Name	*Extent*	*Type*	*Filename*	*Data Sources*
Atlas Base Layers				
Atlas Extent Polygon	Atlas	Polygon	atlas	N/A
Digital Shaded Relief (180 m)	Atlas	Raster	relief_180	USGS & UMD
Digital Shaded Relief (90 m)	Atlas	Raster	relief_90	USGS & UMD
National Land Cover Dataset	Atlas	Raster	nlcd	USGS
September 2002 MODIS Natural Color Image	Atlas	Raster	modis_nc_2002266	SSEC
September 2002 MODIS False Color Image	Atlas	Raster	modis_fc_2002266	SSEC
July 2003 MODIS Natural Color Image	Atlas	Raster	modis_nc_2003191	RSAC
July 2003 MODIS False Color Image	Atlas	Raster	modis_fc_2003191	RSAC
September 2003 MODIS Natural Color Image	Atlas	Raster	modis_nc_2003270	RSAC
September 2003 MODIS False Color Image	Atlas	Raster	modis_fc_2003270	RSAC
Populated Places	Atlas	Point	place	ESRI
Landsat GeoCover Mosaic	Atlas	Raster	geocover	NASA
Graticule & Grids				
Lat/Lon 1-degree Graticule	Atlas	Line	grat1deg	N/A
USGS 24K Map Index	Atlas	Polygon	index24	USGS
USGS 100K Map Index	Atlas	Polygon	index100	USGS
Public Land Survey System	Atlas	Polygon	plss	USGS
Landsat WRS Scenes	Atlas	Polygon	pathrow	USGS
Natural Regions				
Utah Wilderness Regions	Atlas	Polygon	wildreg	N/A
WWF Terrestrial Ecoregions	Atlas	Polygon	eco_wwf	CBI
Bailey Ecoregions	Atlas	Polygon	eco_usfs	USFS
Physiographic Regions	Atlas	Polygon	physreg	USGS
Wilderness & Protected Areas				
World Wilderness Areas	World	Polygon	unepwild	UNEP/GRID
National Wilderness Preservation System	USA	Polygon	nwpswild	ALWRI
Atlas Wilderness Areas	Atlas	Polygon	wildarea	Various
National Park System	Atlas	Polygon	npsunits	NPS
BLM National Landscape Conservation System	Atlas	Polygon	nlcsunits	BLM
National Forest Inventoried Roadless Areas	Atlas	Polygon	usfsira	USFS
National Wildlife Refuges	Atlas	Polygon	nwrunits	FWS
State Parks	Atlas	Polygon	statepark	AGRC & others
High Uintas Wilderness LAC Classes	Utah	Polygon	huwlac	USFS

Table 4.5 Continued

Name	*Extent*	*Type*	*Filename*	*Data Sources*
Wilderness & Protected Area Proposals/Inventories				
Canyonlands National Park Proposed Boundaries 1961-75	Utah	Polygon	cnp61-75	NPS
NPS Wilderness Recommendations	Utah	Polygon	npswild	NPS & AGRC
NPS Nationwide Rivers Inventory	Atlas	Line	npsnri	NPS
UWA RARE II Wilderness 1979	Utah	Polygon	uwa79	UWA
Sierra Club RARE II Wilderness 1984	Utah	Polygon	sc84	Sierra Club
UWA BLM Wilderness 1985	Utah	Polygon	uwa85	AGRC
Utah Wilderness Coalition 1989	Utah	Polygon	uwc89	AGRC
BLM Recommendations 1991	Utah	Polygon	blm91	AGRC
County BLM Proposals 1995	Utah	Polygon	county95	AGRC
HR 1745 1995	Utah	Polygon	hr1745	AGRC
HR 1500 1995	Utah	Polygon	hr1500	AGRC
Utah Wilderness Coalition 1998	Utah	Polygon	uwc98	SITLA
Wasatch Wilderness Additions 1998	Utah	Polygon	wwadd98	Salt Lake City
HR 3625 (San Rafael) 1998	Utah	Polygon	hr3625	Emery County
HR 3035 (West Desert) 1999	Utah	Polygon	hr3035	AGRC
BLM WSA Project 1999	Utah	Polygon	blm99	AGRC
HR 3605 (San Rafael) 2000	Utah	Polygon	hr3605	Emery County
HR 2488 (Pilot Range) 2001	Utah	Polygon	hr2488	AGRC
San Rafael National Monument 2002	Utah	Polygon	srnm02	AGRC
Wasatch Front 2003	Utah	Polygon	wf2003	USFS
Wasatch Front 2010	Utah	Polygon	wf2010	AGRC
Political Boundaries				
State Boundaries	Atlas	Polygon	statebd	ESRI
County Boundaries	Atlas	Polygon	countybd	AGRC & ESRI
Congressional Districts - 108	Atlas	Polygon	cd108	USGS
Congressional Districts - 107	Atlas	Polygon	cd107	USGS
Administrative Boundaries				
Land Status	Atlas	Polygon	landstat	AGRC & others
National Forest Boundaries	Atlas	Polygon	usfs_nf	USFS
BLM Administrative Boundaries	Atlas	Polygon	blmadmin	BLM
BLM Grazing Allotments	Atlas	Polygon	blm_all	SITLA
National Forest Grazing Allotments	Atlas	Polygon	usfs_all	USFS
Transportation				
Interstate Highways	Atlas	Line	int_hwy	FHA
Roads	Atlas	Line	road	ESRI
Railroads	Atlas	Line	railroad	ESRI
Airports	Atlas	Point	airport	AGRC & others

Table 4.5 Continued

Name	*Extent*	*Type*	*Filename*	*Data Sources*
Wildlife Habitat				
UDR Critical Habitat	Utah	Polygon	dwr_ch	UDWR
Mexican Spotted Owl Critical Habitat	Atlas	Polygon	mso_ch	FWS
Threatened & Endangered Species	Utah	Polygon	species	FWS
Geology & Mineral Resources				
Utah Surface Geology	Utah		ugs_geol	UGS
USGS Mining Claims	Atlas		claims	USGS
Coal Fields	Atlas		coalfld	NPS
Coal Mines	Atlas		coalmine	NPS
Petroleum Resources	Utah		petrol	UGS
Hardrock Minerals	Utah		minerals	UGS
Oil & Gas Leases	Atlas		oglease	NILS
Water				
Major Water Features	Atlas	Polygon	mjwater	ESRI
Streams	Atlas	Line	streams	ESRI
Dams	Utah	Point	dams	Utah Division of Water Rights
Hydrologic Units	Atlas	Polygon	huc250	USGS

List of Source Abbreviations

AGRC	Utah Automated Geographic Reference Center
ALWRI	Aldo Leopold Wilderness Research Institute
BLM	U.S. Department of the Interior, Bureau of Land Management
CBI	Conservation Biology Institute
ESRI	Environmental Systems Research Institute
FHA	Federal Highway Administration
FWS	U.S. Fish & Wildlife Service
LAC	Limits of Acceptable Change
NASA	National Aeronautics and Space Administration
NILS	BLM National Integrated Land System
NPS	National Park Service
RSAC	USDA Forest Service Remote Sensing Applications Center
SITLA	Utah School & Institutional Trust Lands Administration
SSEC	Space Science and Engineering Center, University of Wisconsin
UDWR	Utah Division of Wildlife Resources
UGS	Utah Geological Survey
UMD	University of Maryland Department of Geography
UNEP/GRID	United Nations Environment Program Global Resource Information Database
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UWA	Utah Wilderness Association

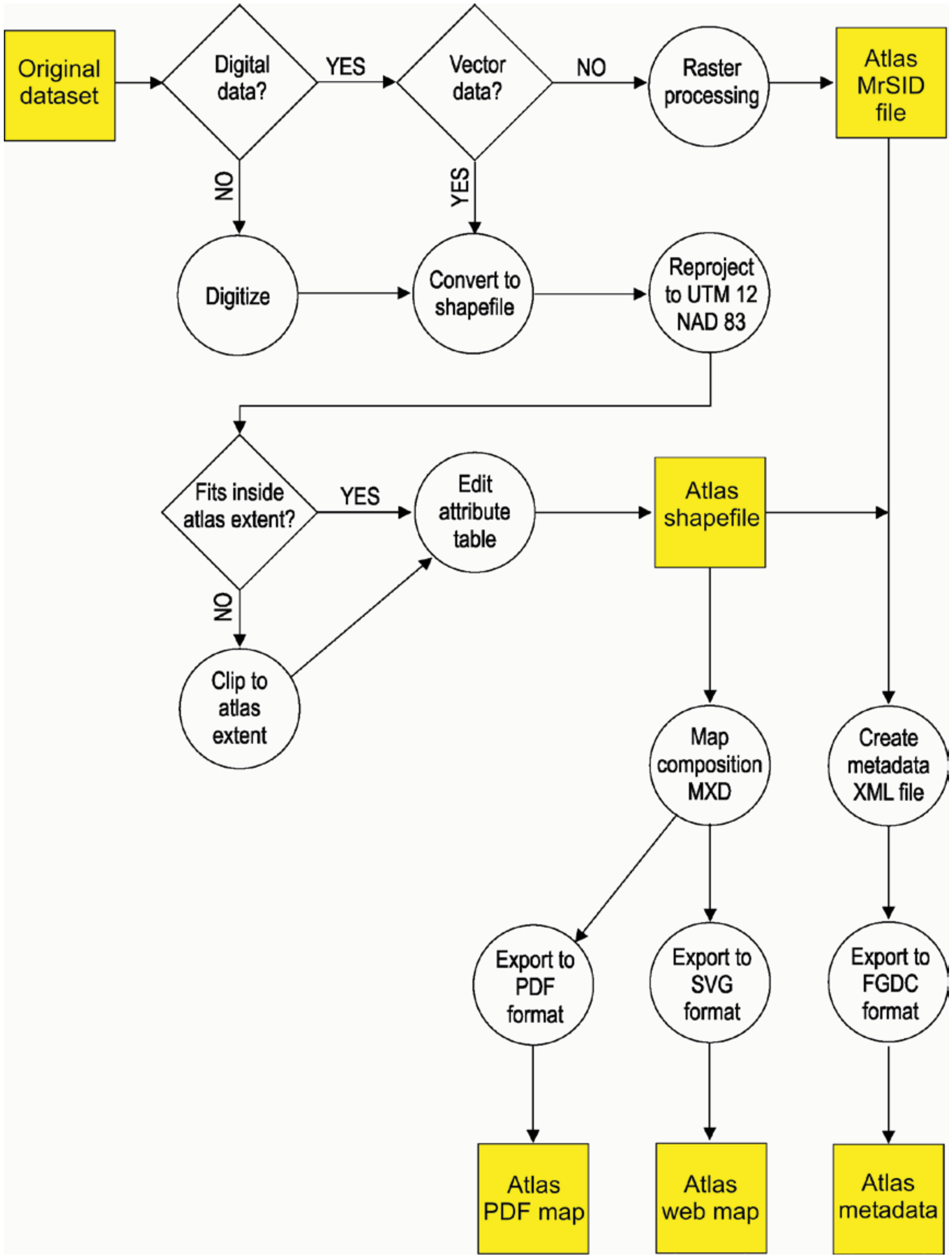


Figure 4.9 Workflow for Atlas layers and maps.

4.5.1 Graticule and Grids

This theme contains locational information for the Atlas extent. A graticule is a network of lines of latitude and longitude. A 1-degree graticule layer was constructed for the Atlas. This theme also includes map indices for 1:24,000 and 1:100,000 scale USGS topographic map quadrangles. A Public Land Survey System (PLSS) grid is included for locating areas according to Township and Range. Sections may be added later. There is also an index to Landsat scenes according to the path/row Landsat World Reference System (WRS).

4.5.2 Natural Regions

This theme includes the Utah wilderness regions constructed for the Atlas (see Chapter 5). For comparison and analysis, it also includes World Wildlife Federation terrestrial ecoregions, U.S. Forest Service (Bailey) ecoregions, and physiographic regions.

4.5.3 Wilderness and Protected Areas

Wilderness and protected areas are existing designated areas on public land, whether legislative or administrative. There are several layers depicting the National Wilderness Preservation System (NWPS) at different scales and extents. Within the High Uintas Wilderness, there are internal subdivisions called Limits of Acceptable Change (LAC) classes that were established in the wilderness management plan (USDA Forest Service, 1997).

Special attention was given to the Atlas extent wilderness boundaries, which were edited according to the most authoritative source maps available. For example, national forest wilderness area boundaries were adjusted to conform to Primary Base Series maps published by the Forest Service. Attributes were edited as well, for example to give the year of designation for each wilderness area.

National Park System and state park units are part of this theme. This theme also includes BLM national monuments, national conservation areas, and wilderness study areas (units of the National Landscape Conservation System). National forest inventoried roadless areas compiled for the Roadless Area Conservation Initiative are part of this theme because these areas are administratively protected.

4.5.4 Wilderness and Protected Area Proposals/Inventories

This theme includes an archive of protected area proposals and inventories past and present. The goal is to be as comprehensive as possible. At present, the list of layers only goes back to the original Canyonlands National Park boundary proposal from 1961. In the future, we could add older proposals going back to the 1930s, when an Escalante National Monument was proposed in southern Utah by the FDR administration.

Agency wilderness recommendations are included, as well as legislative proposals from different years made by elected officials and advocacy groups, such as the Utah Wilderness Association and Utah Wilderness Coalition. Some proposals (for example, former Congressman Bill Orton's National Conservation Area proposal) are omitted because no maps were available. Some agency inventories that did not result in administrative land designations are included, for example the National Park Service Nationwide Rivers Inventory, and the BLM wilderness re-inventory from 1999.

4.5.5 Political Boundaries

This theme includes state, county, and congressional district boundaries. The current configuration of Utah's three congressional districts dates from the 108th Congress. Previously, the 2nd District was confined to Salt Lake County – which contains little in the way of wilderness-eligible public lands aside from some potential additions to existing national forest wilderness areas. Redistricting changed the political landscape so that all three districts now have large expanses of public lands. New congressional districts will be drawn up soon, giving Utah four congressional districts.

4.5.6 Administrative Boundaries

This theme covers overall land ownership, national forest boundaries, BLM administrative areas, and grazing allotments on public land.

4.5.7 Transportation

This theme includes highways, roads, railroads, and airports. It might also include RS 2477 right-of-way claims if these can be compiled into one layer. Another idea for this theme would be to use old highway maps to classify the Utah highway network at different times from 1950 to the present, adding a temporal attribute to highway segments.

4.5.8 Wildlife Habitat

This theme includes critical habitat designation for the Mexican Spotted Owl and other threatened/endangered species. Other layers document lands important to wildlife habitat in general, for analysis and to highlight the importance of "keeping common species common."

4.5.9 Geology and Mineral Resources

Several of this theme's layers were obtained from the Utah Geological Survey, which does a good job of publishing data for Utah. Mining claims and oil and gas leases obtained from the federal government are obviously a snapshot of datasets that are frequently revised. The Atlas will post periodic updates. Until recently, oil and gas lease information was only available in tabular form except for industry proprietary GIS layers that could not be licensed for free distribution.

4.5.10 Water

This theme includes major water features such as lakes and reservoirs, watersheds (hydrologic units), streams, dams, and anything else to do with water resources.

4.6 Atlas Map Products

Utah Wilderness Atlas map products consist of PDF maps, SVG web maps, and metadata files. The Map Appendix at the end of this document includes maps of all the Utah wilderness regions created for the Atlas. SVG web maps can be found on the Atlas website and on the DVD. Metadata files created for all Atlas layers are located with the downloadable GIS datasets.

CHAPTER 5

UTAH WILDERNESS ATLAS REGIONS

5.1 Constructing the Atlas Regions

The geography of Utah is a complex patchwork of land ownership, administrative and political boundaries, geology, physiography, climate, vegetation, and watersheds. In the process of defining wilderness regions, it was clear from the outset that preexisting classifications would have to be adapted somehow. The previous systems of wilderness regions noted in Chapter 1 did not include Utah's national forests, for example.

Regions can be constructed using a top-down or a bottom-up method: in other words, a gestalt view or an aggregation of smaller areas (Wertz & Arnold., 1972). A combination of these two methods proved to be the most practical approach.

Long-established physiographic subdivisions (Atwood, 1940; Crampton, 2000; Fenneman, 1931; Ridd, 1963; Stokes, 1977) provided the starting point for the areal differentiation of Atlas regions. Physiography generally matches the right scale for this purpose. Physiographic subdivisions roughly correspond with clusters of wilderness-eligible public lands. In some cases, such as the Colorado Plateau Canyonlands Section, the subdivision is too inclusive. In other cases, such as the Wasatch Mountains, a cluster crosses the boundaries of one or more subdivisions. See Figure 5.1 and Table 5.1.

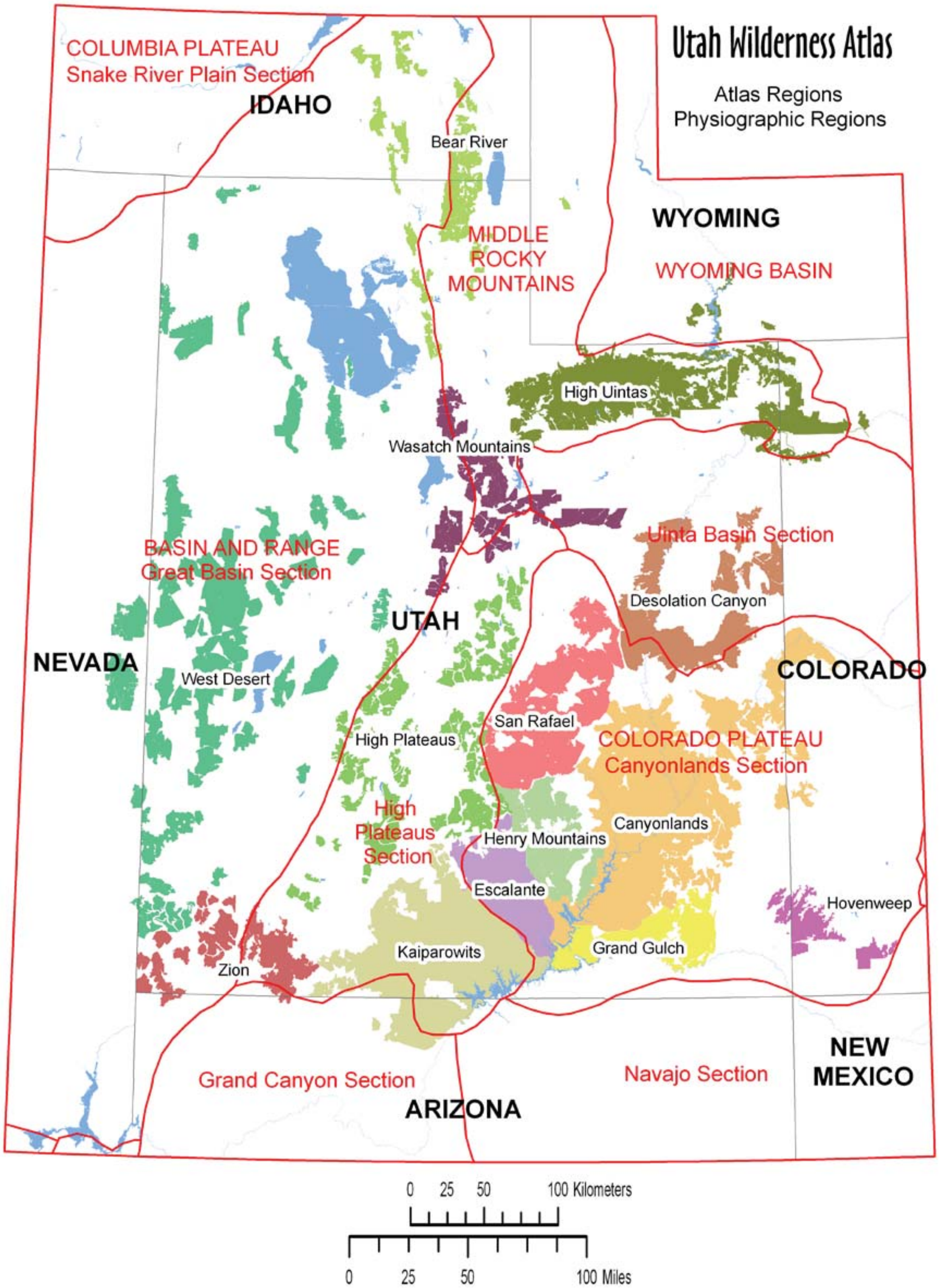


Figure 5.1 Map of Atlas regions and physiographic regions.

Table 5.1 Utah Wilderness Atlas Wilderness Regions

Utah Wilderness Atlas Regions	**Physiographic Provinces & Sections** (Stokes, 1977)	**WWF Ecoregions** (Ricketts and others., 1999)	**Utah Counties**
Bear River	Middle Rocky Mountains, Basin and Range (Great Basin Section)	Wasatch and Uinta montane forests, Great Basin shrub steppe	Cache, Box Elder, Rich, Weber, Davis, Morgan
Canyonlands	Colorado Plateau (Canyonlands Section)	Colorado Plateau shrublands	San Juan, Wayne, Grand, Emery, Garfield, Kane
Desolation Canyon	Colorado Plateau (Uinta Basin Section)	Colorado Plateau shrublands, Wasatch and Uinta montane forests	Grand, Emery, Carbon, Uintah, Duchesne
Escalante	Colorado Plateau (Canyonlands Section) (High Plateaus Section)	Colorado Plateau shrublands, Wasatch and Uinta montane forests	Garfield, Kane
Grand Gulch	Colorado Plateau (Canyonlands Section)	Colorado Plateau shrublands	San Juan
Henry Mountains	Colorado Plateau (Canyonlands Section)	Colorado Plateau shrublands	Garfield, Wayne
High Plateaus	Colorado Plateau (High Plateaus Section) Basin and Range (Great Basin Section)	Wasatch and Uinta montane forests , Colorado Plateau shrublands, Great Basin shrub steppe	Garfield, Wayne, Piute, Sevier, Sanpete, Emery, Millard, Beaver, Iron, Carbon, Kane
High Uintas	Middle Rocky Mountains, Wyoming Basin	Wasatch and Uinta montane forests, Colorado Plateau shrublands, Wyoming Basin shrub steppe	Duchesne, Summit, Uintah, Daggett, Utah
Hovenweep	Colorado Plateau (Canyonlands Section)	Colorado Plateau Shrublands	San Juan
Kaiparowits	Colorado Plateau (High Plateaus Section) (Grand Canyon Section) (Canyonlands Section)	Colorado Plateau shrublands, Wasatch and Uinta montane forests	Kane, Garfield
San Rafael	Colorado Plateau (Canyonlands Section)	Colorado Plateau shrublands	Emery, Wayne, Sevier
Wasatch Mountains	Middle Rocky Mountains, Basin and Range (Great Basin Section), Colorado Plateau (Uinta Basin Section)	Wasatch and Uinta montane forests	Utah, Salt Lake, Duchesne, Wasatch, Juab, Sanpete, Carbon
West Desert	Basin and Range (Great Basin Section)	Great Basin shrub steppe, Great Basin montane forests	Box Elder, Tooele, Juab, Millard, Beaver, Iron, Washington
Zion	Basin and Range (Great Basin Section), Colorado Plateau (High Plateaus Section) (Grand Canyon Section)	Colorado Plateau shrublands, Wasatch and Uinta montane forests, Mojave desert	Washington, Kane, Iron

Ecoregions were another geographic concept that had to be considered (Bailey, 1976, 1995, 1996; ECOMAP, 1993; Olson, 2001). The World Wildlife Fund (WWF) has identified and mapped a total of 867 terrestrial ecoregions worldwide, which fall within 14 biomes (formally known as Major Habitat Types). These ecoregions are defined as relatively large units of land that contain a distinct assemblage of natural communities sharing a large majority of species, dynamics, and environmental conditions. Ecoregions function effectively as conservation units because they encompass similar biological communities and because their boundaries roughly coincide with the area over which key ecological processes most strongly interact (WWF, 2001). The Utah Wilderness Atlas incorporates 10 WWF ecoregions representing two biomes. The Atlas extent includes all of the Wasatch and Uinta montane forests, plus parts of nine other ecoregions according to both the Omernik and WWF systems (Omernik, 1987; Ricketts et al., 1999). Some Atlas regions are characterized by within-region ecosystem homogeneity (e.g., the Wasatch Mountains), while others (e.g., Zion) have considerable heterogeneity (Figure 5.2, Table 5.1).

Because wilderness legislation often is packaged at the county level, we also have to look at the Atlas regions in terms of the number of Utah counties in each region (Figure 5.3). During the political process of preparing wilderness legislation and holding hearings, it is easier to coordinate with as few county governments as necessary. Because physiographic subdivisions were given priority in defining the regions, 12 of the 14 regions involve multiple counties. This was necessary to avoid cutting up regions along political boundaries. The region that intersects the most counties is the High Plateaus, with 11 of the 29 counties in Utah (see Table 5.1).

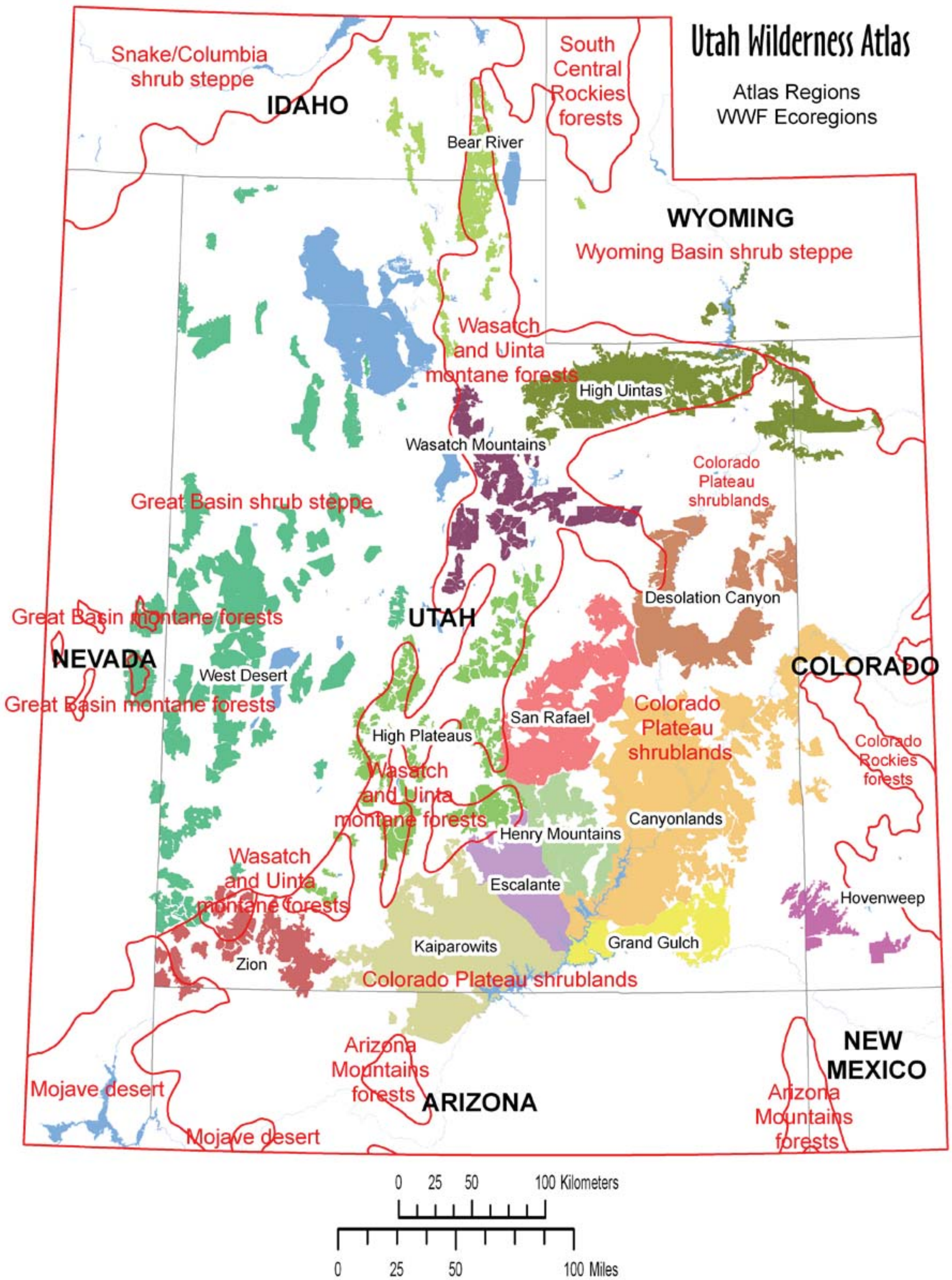


Figure 5.2 Map of Atlas regions and WWF ecoregions.

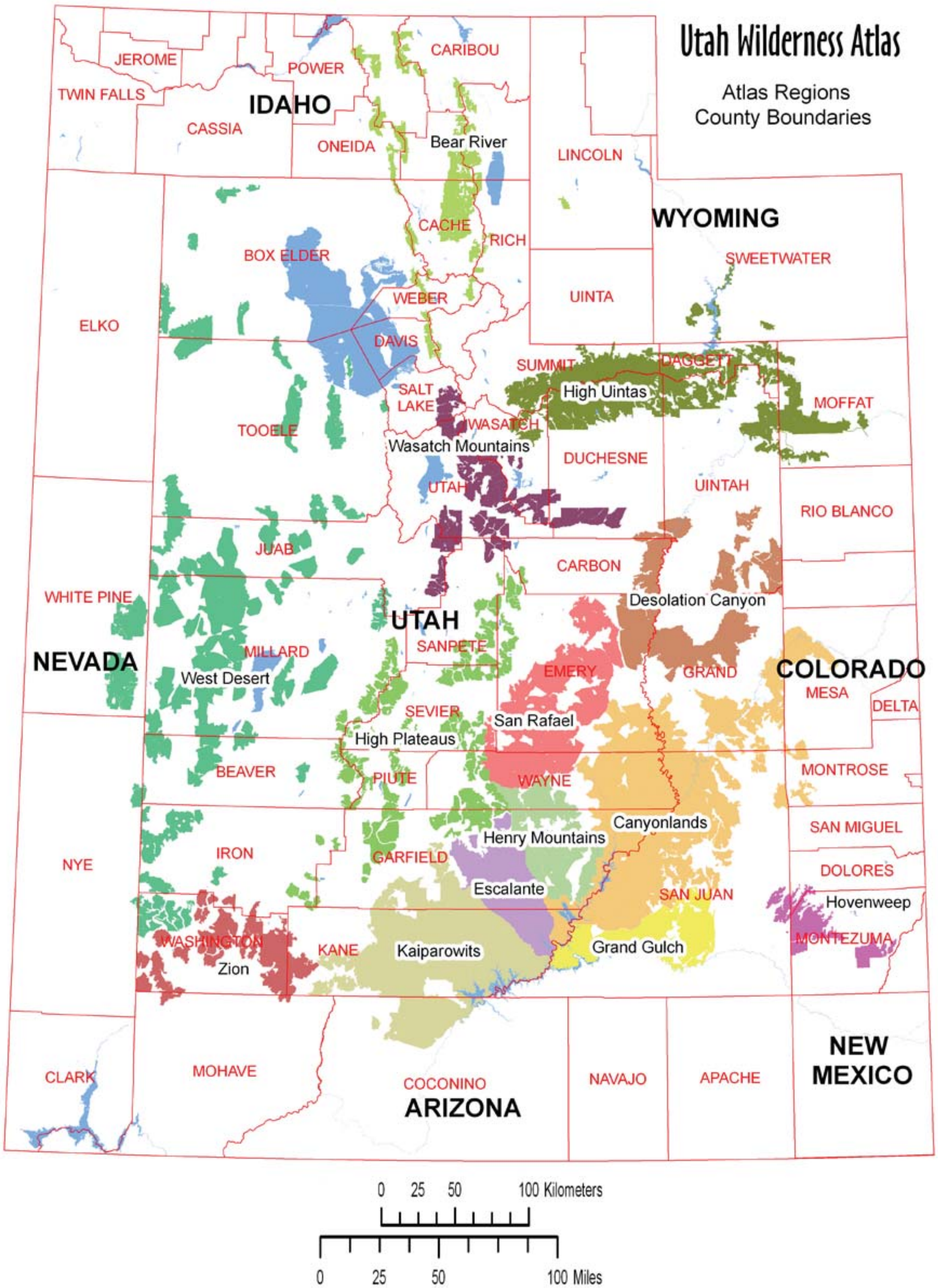


Figure 5.3 Map of Atlas regions and county boundaries.

One issue is avoiding the "irrationality of political limits" (McDonald, 1972, p. 43) in the definition of regions, while acknowledging the relevance of political jurisdictions to the wilderness designation process.

To give an example of how political boundaries can become irrational in the context of protected areas, the proclamation establishing the Grand Staircase-Escalante National Monument in 1996 set the monument boundary so as to include BLM land meeting certain natural criteria, but excluded contiguous land in Arizona that met the same criteria. Ironically, President Clinton proclaimed the new monument in a speech delivered in Arizona (Clinton, 1996).

In 2009, the otherwise comprehensive Washington County wilderness legislation omitted Parunuweap Canyon, an important area adjacent to Zion National Park, because it lies in Kane County.

Watersheds were a fourth factor used to help organize the Atlas regions. Figure 5.4 shows the relationship between regions and U.S. Geological Survey watershed boundaries at the subbasin level of hydrologic units, digitized at a source scale of 1:250,000 (Seaber, Kapinos, & Knapp, 1987). In some cases, aggregations of watersheds fit well with the clusters of wilderness-eligible public lands. Elsewhere, Atlas region boundaries had to cut across watershed boundaries (the Escalante region boundary offers examples of both of these cases).

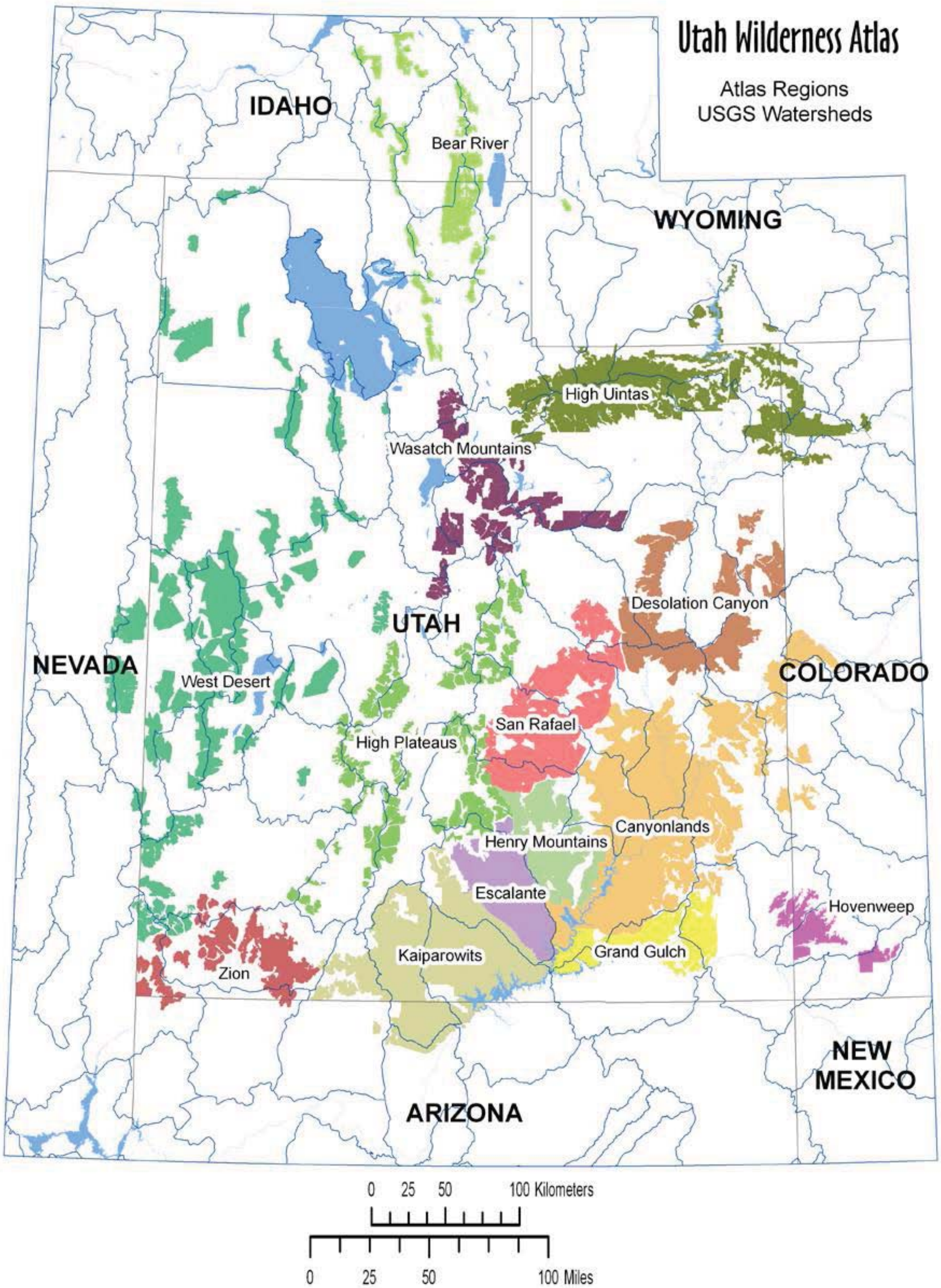


Figure 5.4 Map of Atlas regions and watersheds.

In summary, the atlas regions derive from aggregations of wilderness, protected areas, and other public lands with wilderness characteristics. Each region:

- Includes a cluster of geographically similar federal wildlands
- Has a core that consists of one or more significant protected areas and/or proposed wilderness areas
- Is centered primarily in one physiographic region
- Lies mostly within a single ecoregion
- Intersects a minimum number of Utah counties
- Follows watershed boundaries where appropriate

See Section 5.3 below for brief descriptions of all 14 Utah wilderness regions.

5.2 GAP Status Codes

Utah wilderness regions have two functions. First, regions are the organizing principle for the *Utah Wilderness Atlas*. They are a convenient way to categorize information and maps by geographic area. Second, the regions can also serve as units for GIS analysis. For example, the Protected Areas Database Technical Working Group assigned GAP status codes to the land units composing each region, based on the GAP Stewardship Database (Protected Areas Database (PAD-US) Technical Working Group, 2009). These attribute data make it possible to summarize the GAP status of the regions.

GAP status codes were developed by the U.S. Geological Survey GAP Analysis Program (GAP). They are a simple measure of management intent to conserve biodiversity. The four GAP status codes are defined as follows (Crist, 2000):

> Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.
>
> Status 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.
>
> Status 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area.
>
> Status 4: There are no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout.
> (p. 185)

As implemented in the Protected Areas Database, GAP status codes do not always have a one-to-one correspondence with administrative or legislated land status. Instead, the GAP status is intended to reflect differences in actual land management. For example, part of a wilderness area that is closed to grazing of domestic livestock might be assigned GAP 1, and another part of the same wilderness that is open to grazing according to the management plan might be assigned GAP 2.

In general, GAP 1 or 2 indicates a protected area managed primarily to preserve natural values. GAP 3 indicates a national forest inventoried roadless area (IRA) or BLM wilderness study area (WSA). GAP 4 indicates an area managed for the full spectrum of multiple uses for public land. This is summarized in Table 5.2.

Table 5.2 Default GAP Status Codes for Utah Protected Areas

Description	GAP Code/Comments
Research natural area	GAP Status 1
Wilderness area	GAP Status 1 or 2 based on level of development and use
National park, national monument	GAP Status 1 or 2 based on level of development and use
National forest inventoried roadless area (IRA), BLM wilderness study area (WSA)	GAP Status 3
National forest, BLM public land, national wildlife refuge	GAP 3 or 4 depending on level of protection

The GAP Stewardship Database uses a sequence of steps for assigning GAP status codes. Figure 5.5 illustrates this process in flow chart form. A key attribute for GAP Status 1 is whether natural disturbance events (e.g., wildfires) are allowed or suppressed according to the management plan for the area. A key difference between GAP 2 and 3 is whether the area is managed to preserve natural values or for intensive use. For example, IRAs and WSAs may be GAP 2 unless open to motor vehicles, and therefore are classed as GAP 3. GAP Status 4 indicates an area open to all uses, for example logging, oil and gas, and mining operations.

For each of the 14 Utah wilderness regions, ArcGIS Spatial Analyst was used to determine how much land corresponded with the four GAP status attribute values in the PAD shapefile, using the "Tabulate Area" function in ArcToolbox. The results were exported to Microsoft Excel in order to calculate percentages and create the pie charts in Section 5.3. Table 5.3 summarizes the results for each region.

The Zion region contains the largest percentage of GAP 1 (21 %) because it is dominated by Zion National Park, and there are 10 designated wilderness areas in

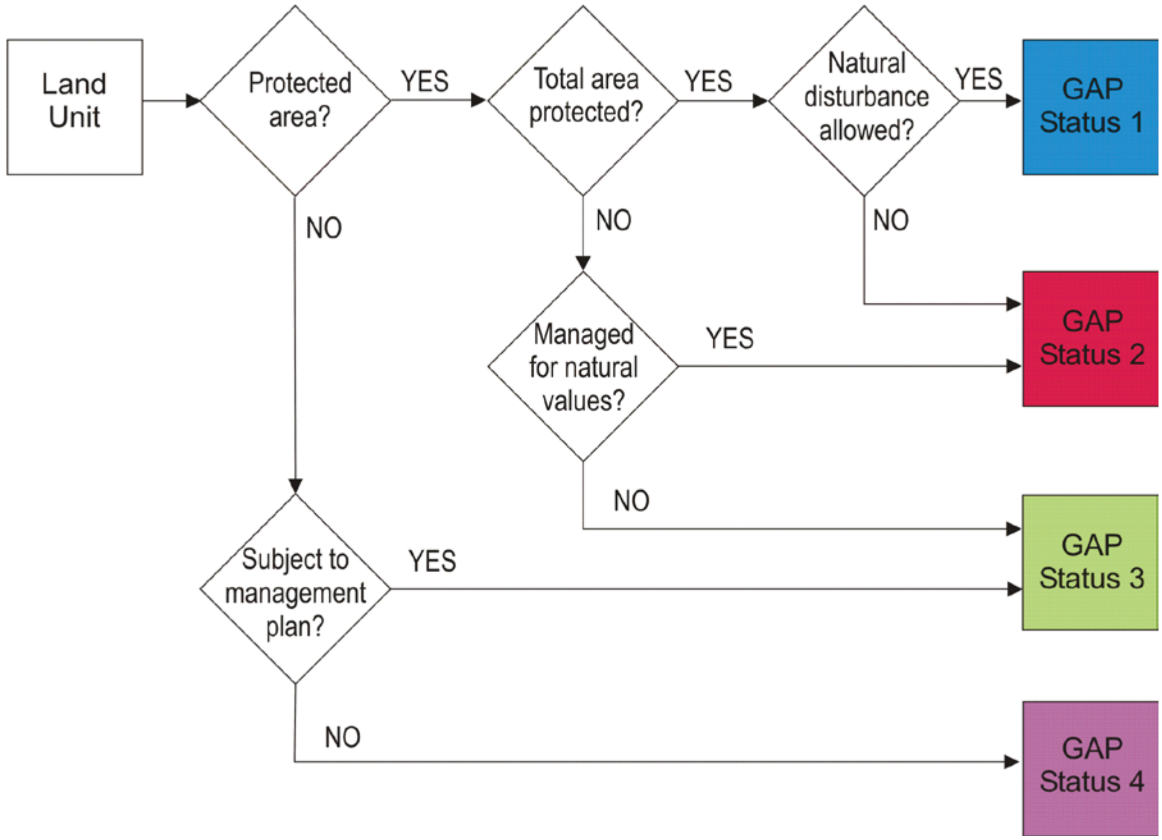


Figure 5.5 System for assigning GAP status codes, adapted from National GAP Analysis Program (2010).

addition to the park. The Hovenweep, Canyonlands, and High Uintas regions also stand out from the rest for relatively large areas of GAP 1. At the other extreme, Desolation Canyon and Grand Gulch are regions that contain no wilderness areas or parks, but do have large concentrations of BLM WSAs that show up as GAP 2. The High Plateaus, Wasatch Mountains, and Bear River regions consist mainly of GAP 3 national forest inventoried roadless areas (IRAs).

Maps of all the regions can be found in the Map Appendix.

Table 5.3 Analysis of Utah Wilderness Atlas Regions by GAP Status

Region	GAP 1 Percent	GAP 2 Percent	GAP 3 Percent	GAP 4 Percent
Bear River	7.3	13.8	78.7	0.1
Canyonlands	15.5	19.9	58.7	5.9
Desolation Canyon	0.0	52.0	37.5	10.4
Escalante	7.7	51.0	41.4	0.0
Grand Gulch	0.0	45.4	47.9	6.7
Henry Mountains	0.5	49.8	41.1	8.6
High Plateaus	0.6	2.7	96.1	0.6
High Uintas	15.2	35.8	48.2	0.8
Hovenweep	18.5	64.3	15.7	1.6
Kaiparowits	1.6	78.2	19.2	1.0
San Rafael	0.5	29.8	58.4	11.4
Wasatch Mountains	3.0	9.0	88.0	0.0
West Desert	3.3	22.0	69.0	5.7
Zion	21.0	33.4	41.3	4.2

5.3 Region Descriptions

See Tables 5.4 and 5.5 for complete summaries by region of wilderness and other protected areas.

5.3.1 Bear River

The Bear River region is centered near Logan, Utah. The nearby Bear River was named in 1818 by Michel Bourdon, a French Canadian trapper with the Hudson Bay Fur Company (Van Cott, 1990). This region includes the Mount Naomi Wilderness and neighboring Wellsville Mountain Wilderness, designated by the Utah Wilderness Act of 1984.

This region lies predominantly along the Bear River Ranger in Utah and Idaho. It includes Cache County, and parts of Box Elder, Rich, Weber, Davis, and Morgan

Table 5.4 Utah Wilderness Atlas Regions and the NWPS

Utah Wilderness Atlas Regions	National Wilderness Preservation System Units	Agency	State	Year
Bear River	Mount Naomi Wilderness	FS	UT	1984
	Wellsville Mountain Wilderness	FS	UT	1984
Canyonlands	Black Ridge Canyons Wilderness	BLM	CO	2000
	Dark Canyon Wilderness	FS	UT	1984
Desolation Canyon	N/A	-	-	-
Escalante	Box-Death Hollow Wilderness	FS	UT	1984
Grand Gulch	N/A	-	-	-
Henry Mountains	N/A	-	-	-
High Plateaus	Ashdown Gorge Wilderness	FS	UT	1984
High Uintas	High Uintas Wilderness	FS	UT	1984
Hovenweep	Mesa Verde Wilderness	NPS	CO	
Kaiparowits	Paria Canyon-Vermilion Cliffs Wilderness	BLM	AZ-UT	1984
San Rafael	N/A	-	-	-
Wasatch Mountains	Lone Peak Wilderness	FS	UT	1978
	Mount Nebo Wilderness	FS	UT	1984
	Mount Olympus Wilderness	FS	UT	1984
	Mount Timpanogos Wilderness	FS	UT	1984
	Twin Peaks Wilderness	FS	UT	1984
West Desert	Cedar Mountain Wilderness	BLM	UT	2006
	Cougar Canyon Wilderness	BLM	UT	2009
	Deseret Peak Wilderness	FS	UT	1984
	Doc's Pass Wilderness	BLM	UT	2009
	Highland Ridge Wilderness	BLM	NV	2006
	Mt. Moriah Wilderness	FS-BLM	NV	1989
	Slaughter Creek Wilderness	BLM	UT	2009
	Tunnel Spring Wilderness	BLM	NV	2004
	White Rock Range Wilderness	BLM	NV	2004
Zion	Beaver Dam Mountains Wilderness	BLM	AZ-UT	1984
	Blackridge Wilderness	BLM	UT	2009
	Canaan Mountain Wilderness	BLM	UT	2009
	Cottonwood Canyon Wilderness	BLM	UT	2009
	Cottonwood Forest Wilderness	FS	UT	2009
	Cottonwood Point Wilderness	BLM	AZ	1984
	Deep Creek North Wilderness	BLM	UT	2009
	Deep Creek Wilderness	BLM	UT	2009
	Pine Valley Mountain Wilderness	FS	UT	1984
	Red Mountain Wilderness	BLM	UT	2009
	Zion Wilderness	NPS	UT	2009

Table 5.5 Utah Wilderness Atlas Regions and Protected Areas

Utah Wilderness Atlas Regions	National Park System	National Landscape Conservation System (BLM)	National Wild and Scenic Rivers System	Utah BLM Wilderness Study Areas	USFS Inventoried Roadless Areas
Bear River	Fossil Butte NM	N/A	N/A	N/A	42
Canyonlands	Canyonlands NP, Arches NP, Glen Canyon NRA, Natural Bridges NM, Colorado NM	McInnis Canyons NCA	N/A	17	10
Desolation Canyon	N/A	N/A	N/A	9	N/A
Escalante	Glen Canyon NRA	Grand Staircase-Escalante NM	N/A	4	4
Grand Gulch	Glen Canyon NRA	N/A	N/A	4	1
Henry Mountains	Capitol Reef NP	N/A	N/A	5	N/A
High Plateaus	Cedar Breaks NM	N/A	N/A	1	66
High Uintas	Dinosaur NM	N/A	N/A	3	40
Hovenweep	Hovenweep NM, Mesa Verde NP	Canyons of the Ancients NM	N/A	2	N/A
Kaiparowits	Bryce Canyon NP, Glen Canyon NRA	Grand Staircase-Escalante NM Vermilion Cliffs NM	N/A	10	8
San Rafael	Capitol Reef NP	N/A	N/A	7	N/A
Wasatch Mountains	Timpanogos Cave NM	N/A	N/A	N/A	45
West Desert	Great Basin NP	N/A	N/A	11	21
Zion	Zion NP	Beaver Dam Wash NCA Red Cliffs NCA	Virgin River	3	7

Counties in Utah. The region also extends into six counties in Idaho, and one county in Wyoming.

Fossil Butte National Monument in southwestern Wyoming is part of the Bear River region. Another unit of the National Park System, Golden Spike National Historic Site, was not included due to the fact it contains no wildlands.

The bulk of this region is made up of 42 inventoried roadless areas (IRAs) on national forest lands, which are located on mountain ranges interspersed with settled land mostly devoted to agriculture (private land is excluded from the region definition). A cluster of IRAs in Wyoming and southeast Idaho were excluded because they are not contiguous with Utah wildlands, and are located in the separate South Central Rockies forests ecoregion. GAP analysis indicates the majority of this region to be GAP status 3 (see Figure 5.6). The region definition includes areas of the Caribou-Targhee National Forest in southern Idaho and northern Utah, plus the northern part of the Uinta-Wasatch-Cache National Forest.

5.3.2 Canyonlands

Utah's Canyonlands are well known for the scenic vistas created by deeply dissected sandstone mesas and an abundance of "redrock." This is a large region centered on the confluence of the Colorado and Green Rivers within Canyonlands National Park.

This region also includes Arches National Park, Natural Bridges National Monument, Colorado National Monument, part of Glen Canyon National Recreation Area, and long segments of the Colorado and Green Rivers that are eligible for wild and scenic river designation. Kent Frost of Monticello, Utah, and other local guides popularized the name Canyonlands in the 1960s (Frost, 1998).

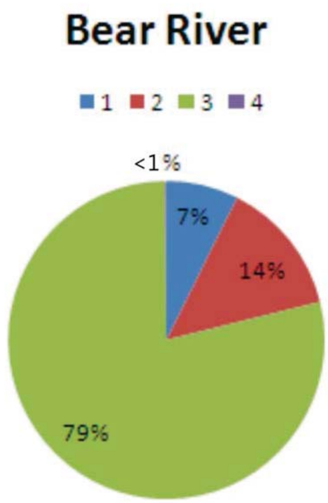
The largest part of the Canyonlands region is in San Juan County, Utah. It extends into Wayne, Grand, Emery, Garfield, and Kane Counties, plus two counties in Colorado.

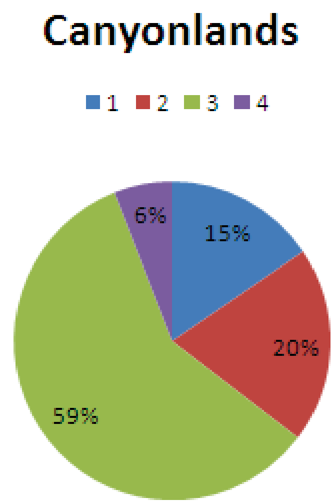
At the southern end of this region, Dark Canyon Wilderness on the Monticello Ranger District of the Manti-La Sal National Forest was designated by the Utah

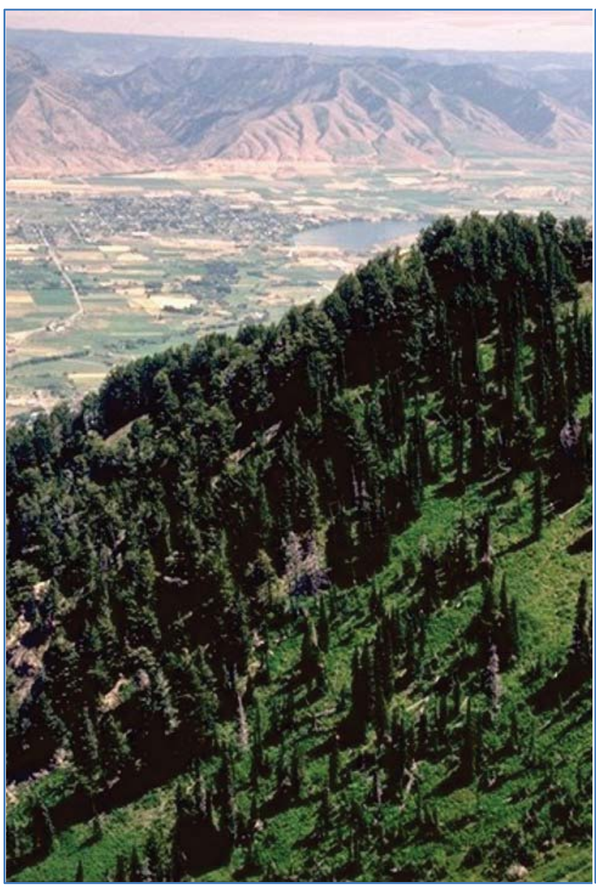
Wilderness Act of 1984. The lower reaches of Dark Canyon have been administratively endorsed for wilderness designation by the BLM and National Park Service. In the north, the Black Ridge Canyons Wilderness, designated in 2000, lies along the Colorado River's Ruby Canyon just upstream from Westwater Canyon WSA.

The McInnis Canyons NCA (mostly in Colorado) includes the Black Ridge Canyons Wilderness. The region also has 17 BLM WSAs, and 10 national forest IRAs on the Manti-La Sal National Forest. This region also encompasses large areas not set aside as WSAs that have been proposed for wilderness designation by the Utah Wilderness Coalition (UWC). GAP analysis indicates the majority of this region to be GAP status 3, with a large component (15%) of GAP status 1 due to Canyonlands National Park (see Figure 5.7).

The region definition includes WSAs and additional UWC-proposed BLM roadless lands east of State Highway 24, west of Canyon National Recreation Area, and along Labyrinth Canyon of the Green River. Then there is Arches National Park and adjacent BLM areas, including three WSAs near Moab. Upstream along the Colorado River are more UWC-proposed roadless areas, Westwater Canyon WSA, McInnis Canyons NCA, and Colorado NM. Going south along the Utah-Colorado border is a cluster of IRAs on the Manti-La Sal National Forest and Colorado BLM WSAs. In the center of the region are Canyonlands National Park and adjacent BLM WSAs and UWC-proposed areas, and another cluster of national forest IRAs east of the Dark Canyon

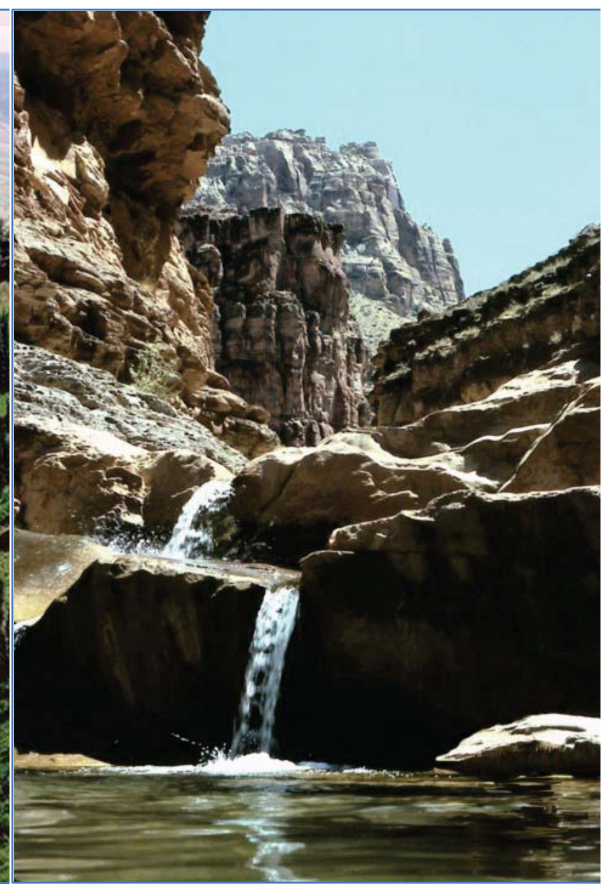






Wellsville Mountain Wilderness.

Figure 5.6 Bear River Region GAP status.



Dark Canyon, Glen Canyon NRA.

Figure 5.7 Canyonlands Region GAP status.

Wilderness. South of Dark Canyon are Natural Bridges NM and BLM WSAs and UWC proposals along White Canyon and in the Mancos Mesa area. The Canyonlands region includes the northern part of Glen Canyon National Recreation Area.

This entire region lies within the Canyonlands Section of the Colorado Plateau Province, and the Colorado Plateau Shrublands ecoregion.

5.3.3 Desolation Canyon

Desolation Canyon is a 97-mile-long wild stretch of the Green River that was named by the 1869 John Wesley Powell Expedition (Van Cott, 1990). This region is composed of a series of BLM WSAs on the West and East Tavaputs Plateau, including the Book Cliffs, plus associated UWC-proposed roadless areas.

This region covers parts of Grand, Emery, Carbon, Uintah, and Duchesne Counties in Utah.

The Desolation Canyon WSA is the largest Utah wilderness study area, and together with adjacent wilderness-eligible public lands makes up more than 350,000 contiguous acres. The Green River through Desolation and Gray Canyons is an outstanding candidate for wild and scenic river designation.

UWC-proposed areas adjacent to the WSAs make up the remainder of this region. The UWC proposal ends at the Colorado boundary. GAP analysis indicates the majority of this region to be GAP status 2 and 3 (see Figure 5.8).

The region definition begins with the Desolation Canyon complex of WSAs on the west side of the Green River, then continues south and east to include the Book Cliffs areas. North of the Book Cliffs is another cluster of BLM wildlands. The region excludes Uintah and Ouray tribal lands east of the river, because these are not classified as public lands subject to wilderness designation. It is largely within the Colorado Plateau Shrublands ecoregion.

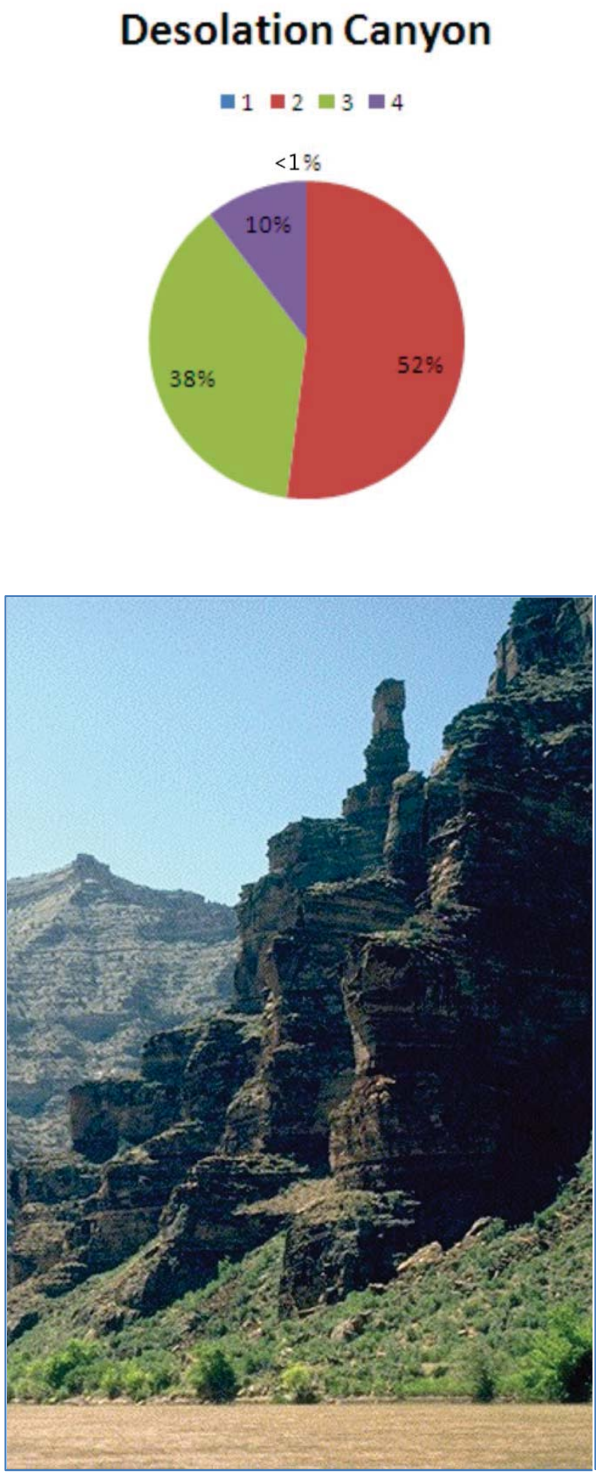
5.3.4 Escalante

The Escalante region is composed of the bulk of the Escalante River drainage, including the northeastern part of the Grand Staircase-Escalante National Monument and a portion of Glen Canyon National Recreation Area. Almon Thompson of the Powell Surveys first applied the name Escalante to honor the Dominguez-Escalante Expedition of 1776, which actually passed far to the west of this area. A town, a river, a mountain, a basin, and a canyon system all share the name (Van Cott, 1990).

This region lies within Garfield and Kane Counties, Utah. The Box-Death Hollow Wilderness on the Dixie National Forest, designated by the Utah Wilderness Act of 1984, is part of this region.

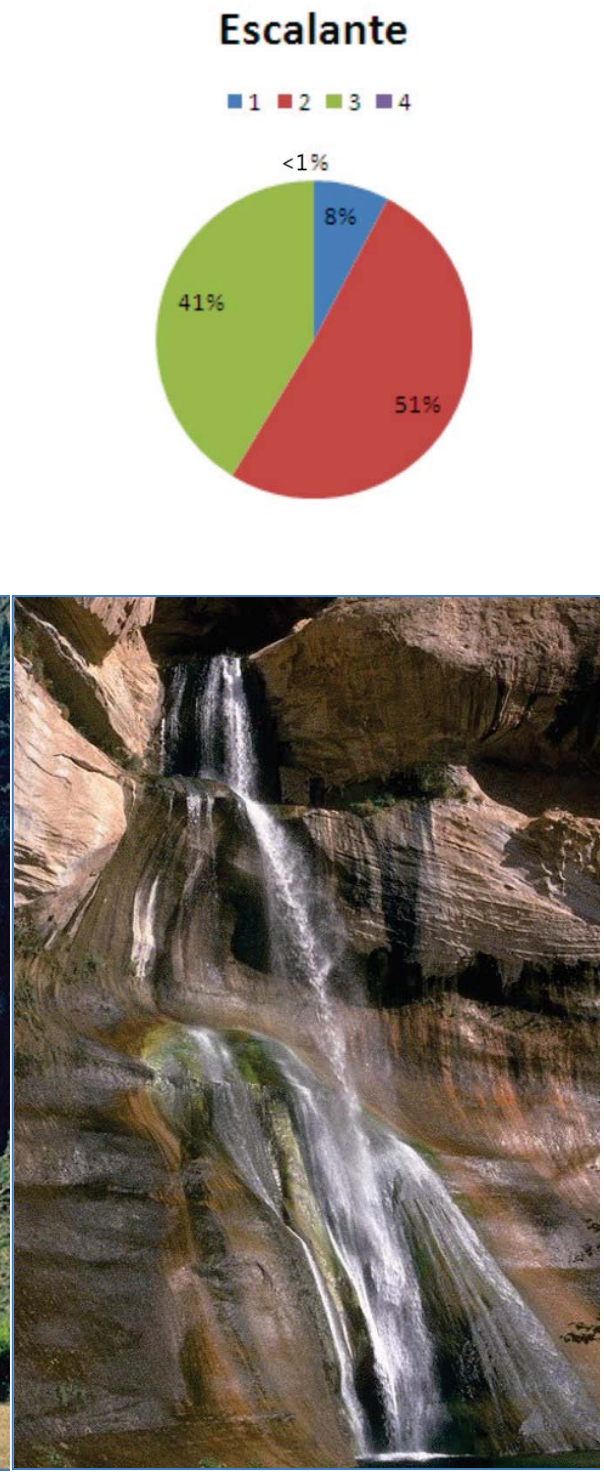
This region lies within the Grand Staircase-Escalante National Monument, Glen Canyon National Recreation Area, and on the Dixie National Forest. Within the monument, there are several BLM WSAs. GAP analysis indicates the majority of this region to be GAP status 2 and 3 (see Figure 5.9).

Starting with the Box-Death Hollow Wilderness, the region definition includes several national forest IRAs, then the public lands west of the Capitol Reef National Park boundary. The eastern edge of the region continues along the Escalante watershed boundary to Lake Powell. From there, the perimeter turns northwest along the Hole-in-



Green River, Desolation Canyon WSA.

Figure 5.8 Desolation Canyon Region GAP status.



Calf Creek, Phipps-Death Hollow ISA Complex.

Figure 5.9 Escalante Region GAP status.

the-Rock Road at the base of the Straight Cliffs, then follows the Grand Staircase-Escalante NM boundary.

5.3.5 Grand Gulch

The Grand Gulch region consists primarily of a series of rugged canyons draining south to the San Juan River. The name Grand Gulch was bestowed by members of the 1880 San Juan Expedition, also known as the Hole-in-the-Rock Expedition. The 30-mile-long Gulch forced the expedition to detour to the north while pioneering a trail from Escalante to present-day Bluff, Utah.

This region is entirely within San Juan County, Utah. It lies just to the north of the Navajo Reservation and Monument Valley Tribal Park, which are excluded because tribal lands are not subject to the Wilderness Act.

The Grand Gulch Primitive Area was administratively designated by the BLM in 1970. Cedar Mesa, which includes the primitive area and adjacent BLM WSAs, is a world-renowned outdoor museum of ancestral Puebloan culture. The hundreds of miles of side canyons are full of ancient ruins and rock art panels, and the mesa tops contain numerous significant archaeological sites.

GAP analysis indicates the majority of this region to be about evenly divided between GAP status 2 and 3 (see Figure 5.10).

The Grand Gulch region is bounded on the north by Utah Highway 95, on the east by Comb Ridge, and on the south by the Navajo Reservation boundary line, which follows the San Juan River and Lake Powell. The western part of the region lies within Glen Canyon National Recreation Area.

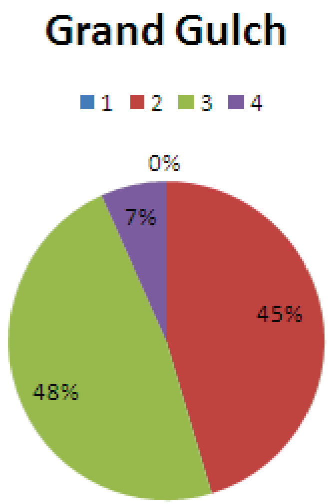
5.3.6 Henry Mountains

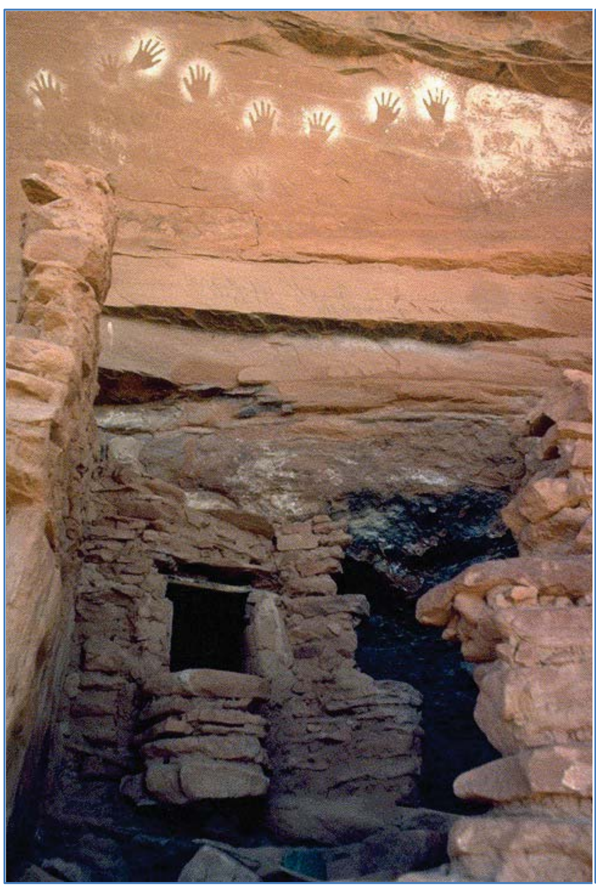
The Henry Mountains were among the last-named mountain ranges in the lower 48 states. The 1869 Powell Expedition simply dubbed them the Unknown Mountains. During Powell's second survey in 1872, they were named after Joseph Henry, then Secretary of the Smithsonian Institution (Van Cott, 1990). The range is divided into two groups. The northern group of three peaks consists of Mount Ellen (11,506 feet above sea level), Mount Pennell, and Mount Hillers. The southern group is known as the "Little Rockies," and includes Mount Ellsworth and Mount Holmes. The mountain cores are igneous intrusions known as laccoliths, which have upended the overlying sedimentary rock layers and become exposed through erosion.

The Henry Mountains are in Garfield and Wayne Counties, Utah.

This region includes the southern part of Capitol Reef National Park. The center is a cluster of BLM WSAs, including Mount Ellen, Mount Pennell, and Mount Hillers. These are surrounded by roadless BLM lands that have been incorporated in agency inventories and citizens' wilderness proposals. GAP analysis indicates this region is about half GAP status 2, and 41 % GAP status 3 (see Figure 5.11).

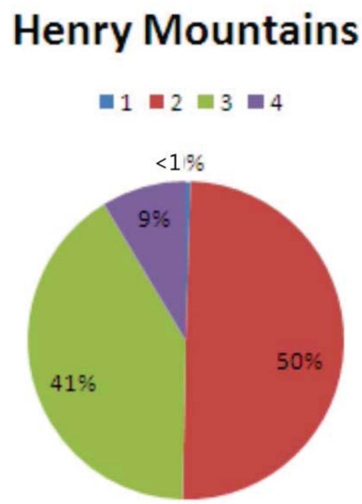
The region definition starts on the west with the portion of Capitol Reef National Park south of Utah Highway 24. Then there is the Mount Ellen-Blue Hills WSA and adjacent roadless lands. On the east and south, the edge of the region follows the boundary of Glen Canyon National Recreation Area, and includes Mount Pennell, Mount Hillers and the Little Rockies.

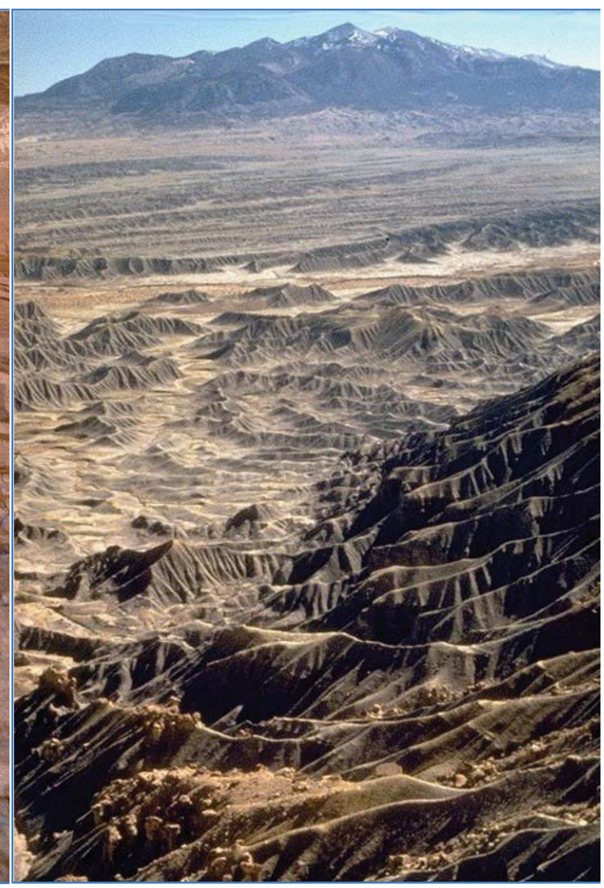




Fish Creek Canyon WSA.

Figure 5.10 Grand Gulch Region GAP status.





Mount Ellen-Blue Hills WSA.

Figure 5.11 Henry Mountains Region GAP status.

5.3.7 High Plateaus

The High Plateaus of Utah is a name coined in 1880 by Clarence Dutton of the U.S. Geological Survey (Van Cott, 1990). It has been applied with some flexibility, but is generally understood to encompass a series of plateaus in central Utah, most of which are part of the Dixie, Fishlake, and Manti-La Sal National Forests: the Paunsagunt Plateau, the Markagunt Plateau, the Tushar Mountains, the Pavant Range, the Wasatch Plateau, the Sevier Plateau, the Fish Lake Plateau, and the Aquarius Plateau. Large sections of these plateaus have been identified as national forest IRAs.

The High Plateaus region extends across 11 Utah counties: Garfield, Wayne, Piute, Sevier, Sanpete, Emery, Millard, Beaver, Iron, Carbon, and Kane Counties.

This region includes the Ashdown Gorge Wilderness, designated by the Utah Wilderness Act of 1984, and adjacent Cedar Breaks NM. There are no other designated protected areas except for a small BLM WSA, Fremont Gorge (adjacent to Capitol Reef National Park).

Nearly the entire region is made up of inventoried roadless areas, with some additional roadless areas proposed for wilderness by conservation groups. GAP analysis indicates this region is nearly all GAP status 3 (see Figure 5.12).

The region definition begins in the northwest with the Pavant Range and Canyon Range, and extends eastward to the Wasatch Plateau. Southward are the Fish Lake Plateau and the Aquarius Plateau, where the region extent follows the western boundary of Capitol Reef NP. The south end of the region includes parts of the Aquarius Plateau, the Paunsagunt Plateau, and the Markagunt Plateau. On the southwestern corner are Ashdown Gorge and Cedar Breaks NM. The western edge of this region follows the eastern limit of the Basin and Range, including the Tushar Mountains, and the Pavant Range.

5.3.8 High Uintas

The core of the massive Uinta mountain range contains the premier wilderness in the State of Utah, and an important component of the National Wilderness Preservation System. The High Uintas are the tallest mountains in Utah, and the most prominent east-west trending range in the contiguous United States. Hundreds of picturesque lakes and meadows are nestled within spectacular glacial basins. Cold, clear streams plunge from the basins into deep canyons to form river tributaries. At 13,528 feet above sea level, Kings Peak is the highest point in Utah. Most of the High Uintas Wilderness lies above 10,000 feet. The name derives from the Uintats, early relatives of the modern Ute Tribe (Van Cott, 1990).

The High Uintas region includes parts of the following counties: Duchesne, Summit, Uintah, Daggett, and Utah Counties.

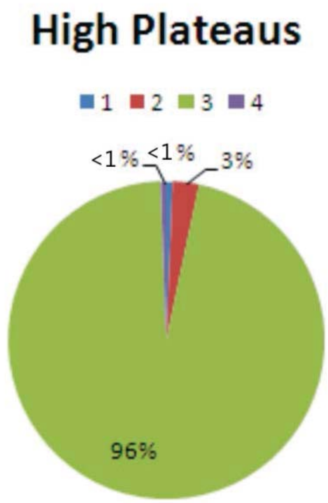
The High Uintas Primitive Area was administratively designated by the U.S. Forest Service in 1931. Pursuant to the Wilderness Act of 1964, the Forest Service studied the area and produced the first wilderness proposal for this region (USDA Forest Service, 1967). After much additional study and debate, the High Uintas Wilderness was designated by the Utah Wilderness Act of 1984. The High Uintas region also includes Dinosaur National Monument, which spans the Utah-Colorado border.

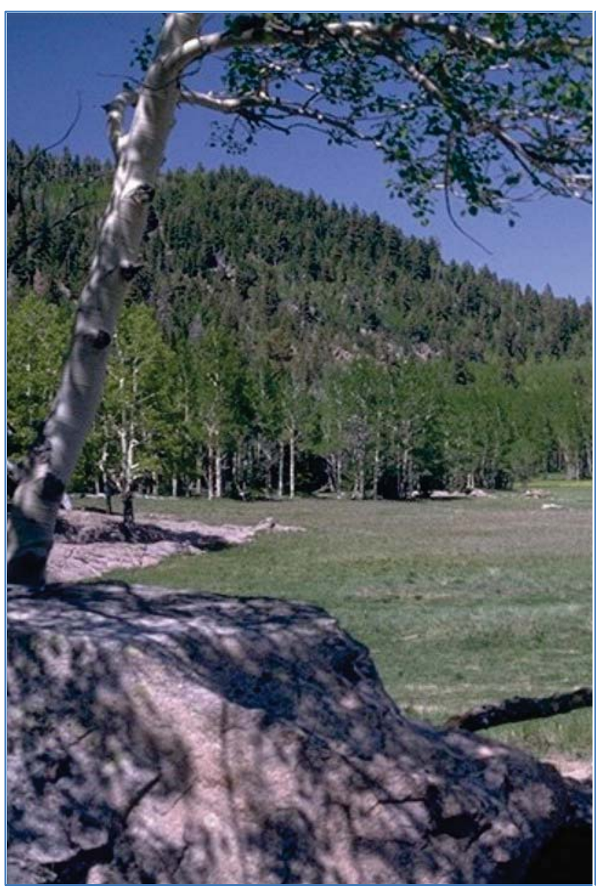
The High Uintas Wilderness is the center of a large cluster of national forest IRAs. Similarly, there are BLM WSAs and roadless areas adjacent to Dinosaur National Monument in both Utah and Colorado. This region also includes a half-dozen roadless areas in Wyoming. GAP analysis indicates this region is almost half GAP status 3, and more than a third GAP 2 (36%), with a large component (15%) of GAP status 1 due to the High Uintas Wilderness (Figure 5.13).

The region definition begins with the 100,000 acre Lakes Roadless Area west of the Mirror Lake Highway (Utah Highway 150). East of the highway lies the High Uintas Wilderness, and a series of national forest IRAs on the north slope of the Uintas, part of the Uinta-Wasatch-Cache National Forest. Beyond the eastern wilderness boundary is another large cluster of IRAs. In Wyoming, the region includes more IRAs and some BLM land. In the northeastern corner of Utah, and the northwestern corner of Colorado, there are more BLM roadless areas and WSAs. Dinosaur National Monument and some adjacent BLM lands in Utah and Colorado are included. Finally, the region incorporates all the national forest IRAs on the south slope of the Uintas, on the Ashley National Forest.

5.3.9 Hovenweep

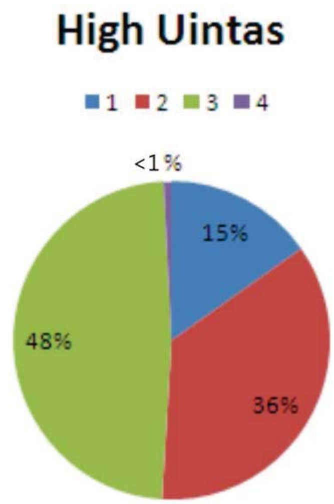
Hovenweep is a Native American name meaning “deserted valley” (Van Cott, 1990). Like Grand Gulch, this region is rich in archaeological resources left behind by the Ancestral Puebloan and earlier cultures. These include some of the largest and most significant cliff dwellings and mesa-top prehistoric sites in the Southwest.

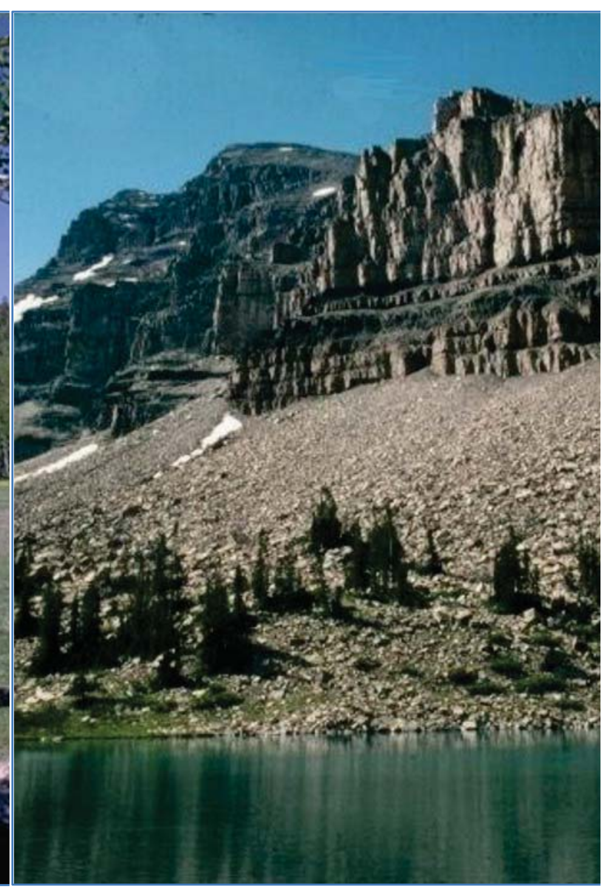




Wasatch Plateau, Manti-La Sal NF.

Figure 5.12 High Plateaus Region GAP status.





Ostler Peak, High Uintas Wilderness.

Figure 5.13 High Uintas Region GAP status.

Hovenweep was originally defined as part of the Grand Gulch region. This became a separate region because it extends into Colorado, and there is a 25-mile GAP between it and the Grand Gulch region to the west. The focus of this region, unlike Grand Gulch, is on legislatively protected areas including Mesa Verde National Park, Hovenweep NM, and Canyons of the Ancients NM. Hovenweep also lies within the San Juan River basin.

The Hovenweep region lies mostly in Montezuma and Dolores Counties, Colorado. A significant portion of the region is in San Juan County, Utah.

Hovenweep National Monument in Utah and Colorado, Colorado's Mesa Verde National Park (including the Mesa Verde Wilderness), and Canyons of the Ancients NM make up the bulk of this region.

In addition, there is a cluster of BLM WSAs and BLM land that is included in conservation group wilderness proposals. GAP analysis indicates the majority of this region to be GAP status 2, with a large component (18%) of GAP status 1 (see Figure 5.14). This is the region with the second-highest proportion of GAP 1 wildlands.

The region definition begins with a cluster of BLM land in Utah, and the Utah units belonging to Hovenweep NM. Canyons of the Ancients NM occupies the center of the region. Mesa Verde NP and some adjacent BLM WSAs make up the eastern part. The Ute Mountain Tribal Park and reservation lands adjacent to Mesa Verde are excluded from this region, because they are not public lands subject to the Wilderness Act.

5.3.10 Kaiparowits

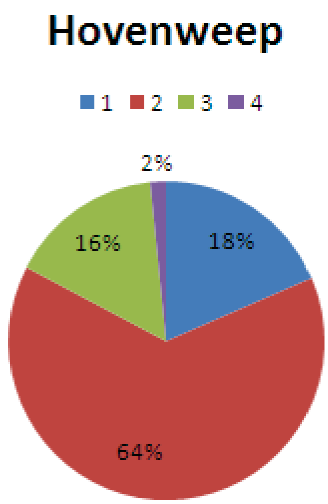
This region is centered on the 60-mile-long Kaiparowits Plateau in Kane County, southern Utah. There are various interpretations of the Native American name “Kaiparowits,” one of which is “big mountain’s little brother” (Van Cott, 1990).

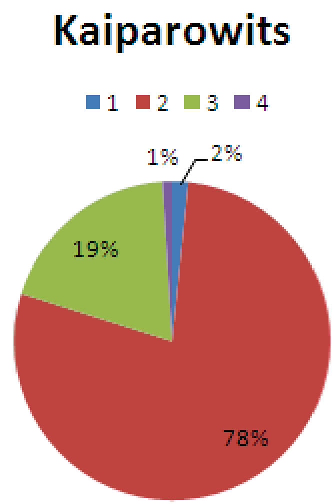
The Kaiparowits region includes the Paria Canyon-Vermilion Cliffs Wilderness in Utah and Arizona, Bryce Canyon National Park, the western part of Grand Staircase-Escalante NM, the Vermilion Cliffs NM in Arizona, and part of Glen Canyon NRA in Utah. The region is characterized by dissected table lands, including the Paria River drainage, and the spectacular escarpment of Fifty-Mile Mountain.

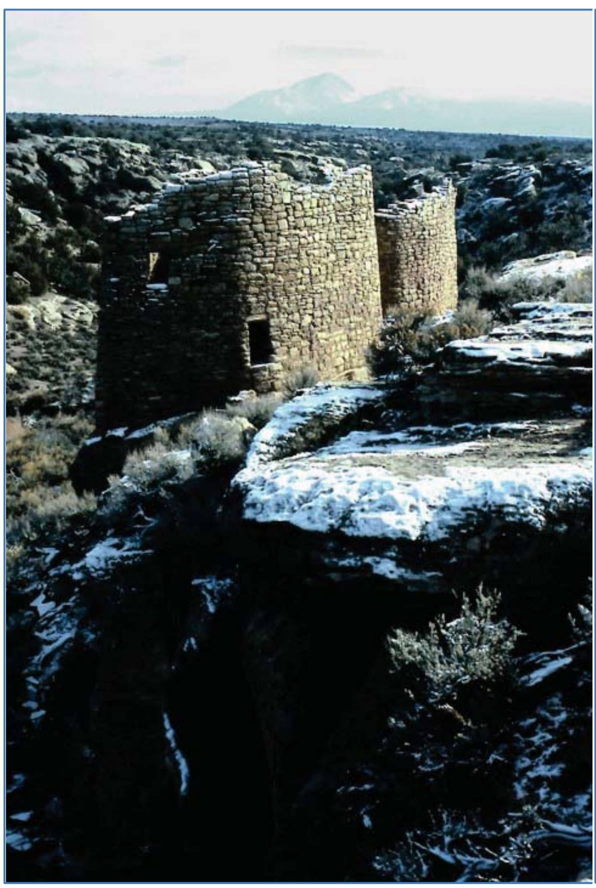
This region lies mainly within Garfield and Kane Counties, Utah. It also extends south into Coconino County in Arizona.

The region includes some major BLM WSAs within the Grand Staircase-Escalante NM, such as Fifty-Mile Mountain and Paria-Hackberry. West of the national monument, the region extends out to the Moquith Mountain WSA and adjacent BLM roadless areas. GAP analysis indicates the majority of this region to be GAP status 2 (see Figure 5.15).

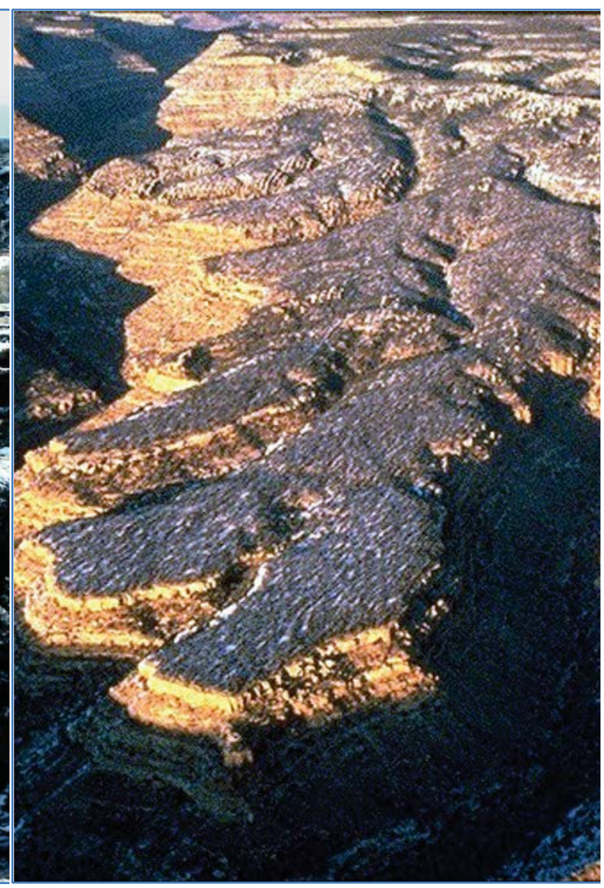
Starting with Bryce Canyon National Park (the high-elevation northwest extent of the Grand Staircase), the region definition continues to Grand Staircase-Escalante NM and included BLM WSAs and adjacent roadless areas. The eastern edge of the region follows the Hole-in-the-Rock Road at the base of the Straight Cliffs to Lake Powell. On the south, the region boundary continues along the north shore of Lake Powell and includes the entire Paria Plateau within the Vermilion Cliffs NM.







Hovenweep National Monument.



Paria-Hackberry WSA.

Figure 5.14 Hovenweep Region GAP status.

Figure 5.15 Kaiparowits Region GAP status.

5.3.11 San Rafael

The San Rafael Swell is a vast 75-mile-long dome-shaped anticline of sandstone, shale, and limestone that has been proposed for designation as a national park or a national monument. It contains a cluster of particularly scenic BLM wilderness study areas. It is bisected by the San Rafael River, named after Saint Raphael the Archangel by early travelers on the Old Spanish Trail. Interstate 70 divides the Swell into northern and southern sections, and provides the only paved road access to the region.

The San Rafael region lies mostly in Emery and Wayne Counties, with a portion in Sevier County.

This region is centered on the San Rafael Swell, and also includes the northern part of Capitol Reef National Park, known as Cathedral Valley. The six BLM WSAs are surrounded by large additional areas of roadless public lands proposed for wilderness by conservation groups. GAP analysis indicates most of this region to be GAP status 3 (see Figure 5.16).

The region definition starts with BLM land west of the Sids Mountain WSA, and continues north to areas along the Price River that extend almost to U.S. Highway 6. Mexican Mountain WSA and adjacent roadless lands are included. South of Interstate 70, the region incorporates the San Rafael Reef and Crack Canyon WSAs, plus a large addition in the Factory Butte area that is part of a citizens' wilderness proposal. To the west, the section of Capitol Reef NP north of Utah Highway 24 is included. North of Capitol Reef NP is Muddy Creek WSA, and a large area of roadless land to the west.

5.3.12 Wasatch Mountains

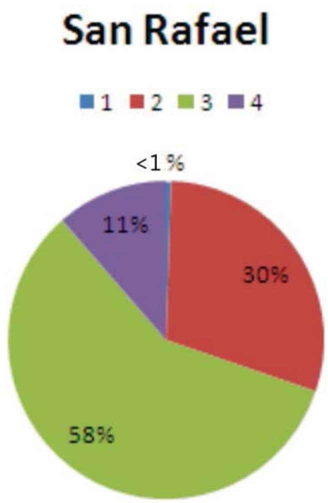
Wasatch is a Ute word for a mountain pass, generally believed to refer to where the Weber River cuts through the Wasatch Range (Van Cott, 1990). The Wasatch Front forms the eastern edge of the Basin and Range. Mountain peaks at elevations of 10,000 to 11,000 feet overlook Utah's major population centers of Salt Lake City and Provo. This region is mostly within the Uinta-Wasatch-Cache National Forest, and partly on the Ashley National Forest. The Wasatch Mountains receive heavy recreation visitation, and Utah's premiere ski resorts are located in this region.

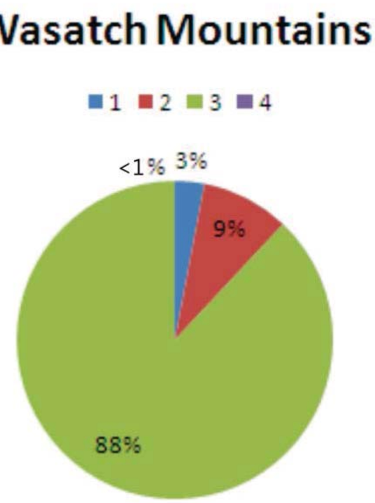
The Wasatch Mountains region includes part of seven Utah counties: Utah, Salt Lake, Duchesne, Wasatch, Juab, Sanpete, and Carbon Counties.

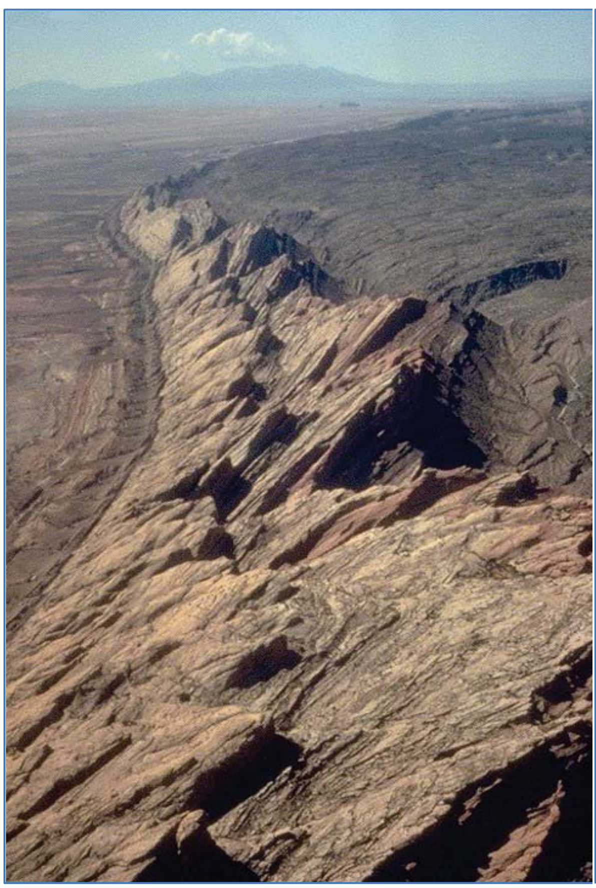
There are five wilderness areas in this region. Lone Peak Wilderness became Utah's first designated wilderness when the Endangered American Wilderness Act was signed into law in 1978. The Mount Nebo Wilderness, Mount Olympus Wilderness, Mount Timpanogos Wilderness, and Twin Peaks Wilderness were designated by the Utah Wilderness Act of 1984. Timpanogos Cave National Monument is just south of the Lone Peak Wilderness in American Fork Canyon.

Most of the Wasatch Mountains region is composed of national forest IRAs. GAP analysis indicates the majority of this region to be GAP status 3 (see Figure 5.17).

The region definition begins with a cluster of four wilderness areas and adjacent roadless areas just east of the Salt Lake Valley. It includes a large cluster of IRAs south of U.S. Highway 40 and north of U.S. Highway 6. Lastly, there are three other IRA clusters south of Highway 6, one of which includes the Mount Nebo Wilderness.

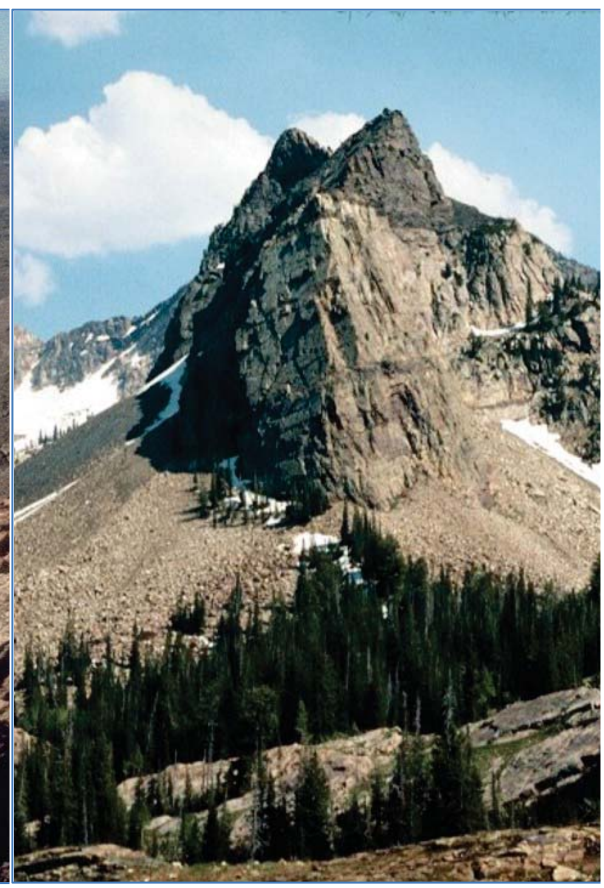






San Rafael Reef WSA.

Figure 5.16 San Rafael Region GAP status.



Twin Peaks Wilderness.

Figure 5.17 Wasatch Mountains Region GAP status.

5.3.13 West Desert

The Basin and Range vastness of Utah's West Desert is composed of a series of ecologically diverse mountain ranges separated by wide valleys. The West Desert region includes Great Basin National Park just over the state line in Nevada.

The most extensive of the 14 regions, the West Desert extends from the Snake River Plain in the north to Lake Mead in the south. Although the desert landscape is characterized by wide expanses of shrub steppe, the wilderness values lie primarily in the isolated mountain ranges. Notch Peak, in the House Range, is remarkable for its sheer 2,700-foot cliff (El Capitan in Yosemite National Park is only 300 feet higher).

The West Desert includes areas in seven Utah counties and two Nevada counties. Parts of Box Elder, Tooele, Juab, Millard, Beaver, Iron, and Washington Counties are in this region.

Besides Great Basin National Park, this region includes nine designated wilderness areas, four of them in Utah. The Deseret Peak Wilderness was designated in the Utah Wilderness Act of 1984. The Cedar Mountain Wilderness was designated by the 2006 National Defense Authorization Act. Cougar Canyon and Doc's Pass Wilderness were included in the Omnibus Public Land Management Act of 2009. In Nevada, the region includes the Highland Ridge Wilderness, Mt. Moriah Wilderness, Slaughter Creek Wilderness, Tunnel Spring Wilderness, and White Rock Range Wilderness.

The region includes a series of BLM WSAs, the largest of which encompass mountainous areas from the Deep Creek Mountains south to the House Range. On the Stansbury Mountains, adjacent to the Deseret Peak Wilderness, there are some national forest IRAs and another BLM WSA. Another cluster of national forest IRAs is located in western Washington and Iron Counties. In this region, there are also large expanses of roadless BLM land proposed for wilderness by conservation organizations. GAP analysis indicates the majority of this region to be GAP status 3 (see Figure 5.18).

The West Desert region definition encompasses roadless areas west and north of the Great Salt Lake, including national forest IRAs on the Raft River Mountains. South of the Great Salt Lake, it includes wilderness areas and associated wildlands on the Cedar Mountains and Stansbury Mountains. Southward, there are national forest IRAs on the Sheeprock Mountains, the BLM's Little Sahara, and more IRAs on the Canyon Mountains. Further south, there are conservationist-identified roadless BLM lands and another cluster of national forest IRAs on the Dixie National Forest in southwestern Utah. The west side of the region includes additional conservation-group proposals and a series of wilderness areas in Nevada on the White Rock Range, Highland Ridge adjacent to Great Basin National Park, and Mount Moriah north of the park. In Utah, there are BLM WSAs such as the Deep Creek Mountains, plus additional roadless lands.

5.3.14 Zion

This region is dominated by Zion National Park, originally established as Mukuntuweap National Monument in 1909. The name Zion was first applied to the upper Virgin River canyon by pioneer settler Isaac Behunin (Van Cott, 1990).

The Zion region is centered on Washington County, Utah. It extends into Kane and Iron Counties. A few areas are in Mohave County, Arizona.

The Utah Wilderness Act of 1984 established the Pine Valley Mountain Wilderness in the center of the Zion region. The Beaver Dam Mountains Wilderness and Cottonwood Point Wilderness on the Arizona-Utah border were both designated by the Arizona Wilderness Act of 1984.

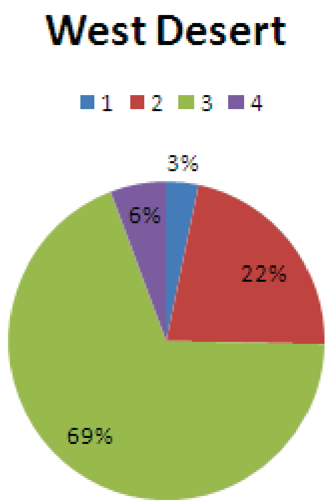
In recent years, a regional wilderness bill for Zion was developed by local government officials and stakeholders under the leadership of former Senator Bob Bennett. This was first introduced as the proposed Washington County Growth and Conservation Act of 2006.

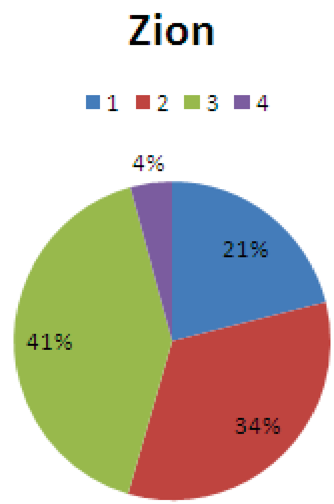
After lengthy negotiations, the Omnibus Public Land Management Act of 2009 added nearly all of the Zion National Park back country to the National Wilderness Preservation System. This law also designated 170 miles of segments of the Virgin River within the park as Utah's first wild and scenic river. The Act designated the Canaan Mountain Wilderness and several smaller BLM areas adjacent to the national park.

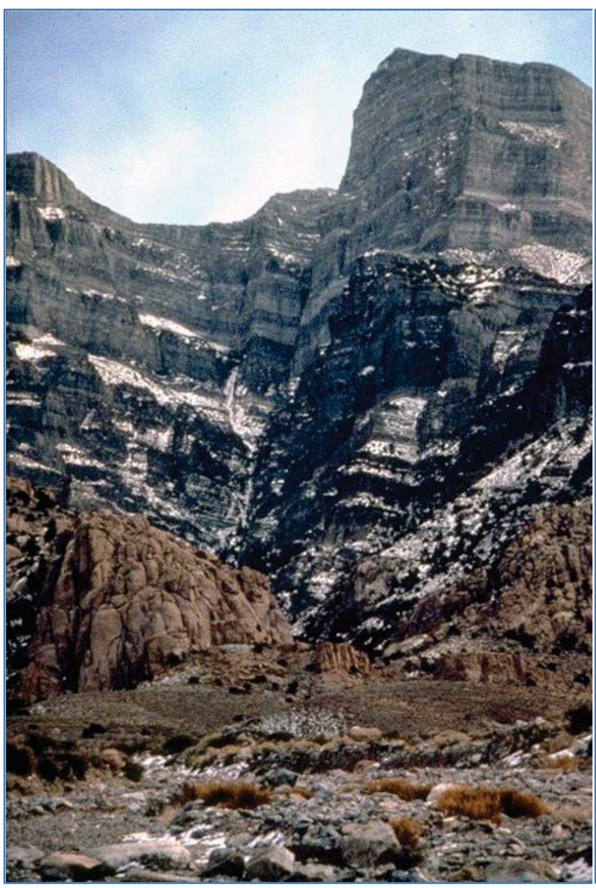
Six BLM wilderness areas and a national forest wilderness were added elsewhere in the county.

The Washington County legislation also designated two national conservation areas: the Red Cliffs NCA (which includes parts of the Red Canyon Wilderness and Snow Canyon State Park, and the entire Cottonwood Canyon Wilderness), and Beaver Dam Wash NCA in the extreme southwest corner of Utah.

See Figure 5.19 for this region's GAP status. The remaining undesignated wildlands in the Zion region consist primarily of national forest IRAs and UWC-proposed wilderness on BLM lands. The 2009 legislation released all the BLM WSAs in

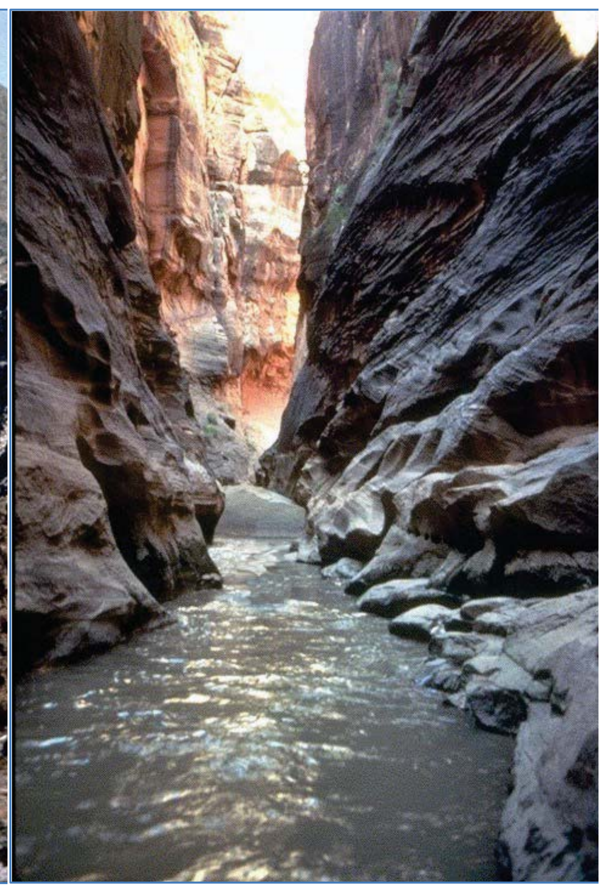






Notch Peak WSA.

Figure 5.18 West Desert Region GAP status.



Parunuweap Canyon WSA.

Figure 5.19 Zion Region GAP status.

Washington County, with the exception of the Joshua Tree ISA. The remaining BLM WSAs in this region include Parunuweap Canyon. This region has the largest component of GAP status 1 (21%) due to the 2009 wilderness bill. The remainder of the region is largely divided between GAP status 2 and 3.

The region definition includes most of Washington County, excluding the northwest corner that lies within the Great Basin shrub steppe ecoregion. It does not extend into Nevada due to a lack of identified wilderness-eligible land. Two wilderness areas on the Arizona-Utah border, Beaver Dam Mountains and Cottonwood Point, are included. The region also extends into Kane County to encompass Parunuweap Canyon WSA and other areas adjacent to Zion NP on the east.

CHAPTER 6

CONCLUSIONS AND FUTURE DIRECTION

The *Utah Wilderness Atlas* demonstrates a prototype of a simple and low-cost geographic information system (GIS) using an open-source approach and freely distributable datasets.

Such a GIS can be useful for educational institutions seeking to enhance the Geography curriculum, related natural resources studies, or to explore public land issues. This same approach is suited to small nonprofit groups, especially those lacking in GIS knowledge and operating on a limited budget. Many conservation organizations in the USA and throughout the world fit this description.

Scalable vector graphics (SVG) is used for Atlas web maps. SVG is an open standard published by the World Wide Web Consortium (W3C). Compared to proprietary application programming interfaces, it represents a low cost solution. The main drawback for SVG until 2011 was the lack of support in Microsoft Internet Explorer (IE), the most popular web browser. With IE9, SVG can be viewed without installing a plug-in.

The Atlas covers Utah, but unlike most previous atlases it expands the extent beyond the boundaries of the state in order to capture the spatial relationships among protected areas in neighboring states. This required integrating GIS datasets from different sources, often a difficult task.

For the first time, the Atlas makes an effort to integrate protected area datasets for national forests and BLM lands in a single system of regions. These are usually dealt with separately by different organizations. The Utah wilderness regions created for the Atlas aggregate all wilderness-eligible public lands across administrative boundaries.

The *Utah Wilderness Atlas* will continue to grow, adding content and incorporating land status changes as they occur. The library of datasets can be used for analysis and GIS modeling, adding to our understanding of protected lands issues.

There are a couple of broad future directions worth mentioning. In the area of technology, a paradigm shift is taking place with the advent of cloud computing. Internet virtual machines have the potential to reduce costs for schools and nonprofit groups.

In wilderness policy, a regional or county-based approach seems to be taking the place of advocacy for statewide legislation. Dealing with issues on a regional basis creates opportunities to take a close look at the maps, to resolve land use conflicts on a site-specific basis that often turns out to be less ideologically polarized.

APPENDIX A

GLOSSARY OF TERMS AND ABBREVIATIONS

abiotic environment
Pertaining to the non-living components of an ecosystem, e.g. minerals and climatic conditions.

ACEC
Area of Critical Environmental Concern (BLM).

AGRC
The Utah Automated Geographic Reference Center. Utah's principal GIS data clearinghouse (http://agrc.its.state.ut.us/).

allotment (grazing)
Area designated for the use of a certain number and kind of livestock for a prescribed grazing season; may also be designated as non-use.

ALRIS
Arizona Land Resource Information System. Arizona's principal GIS data clearinghouse (http://www.land.state.az.us/alris/).

annotation
Descriptive text used to label geographic features for display and hardcopy maps.

API
Application programming interface. An interface that enables different software programs to interact.

ArcCatalog™
ArcGIS desktop application for organizing and maintaining geospatial data.

ArcExplorer™
A free data browser or "thin client" software program distributed by ESRI.

ArcGIS™
ESRI's system to integrate desktop applications (ArcMap, ArcCatalog, ArcToolbox) with the ArcSDE geodatabase and ArcGIS Server map server software.

ArcIMS™
ESRI's Internet map server application.

ArcInfo™
Full-featured GIS software license from ESRI.

ArcMap™
The most commonly used ArcGIS Desktop application, and the lowest licensing level for ArcGIS.

ArcView™
Older, less expensive and less-capable GIS software from ESRI. ArcView 3.x was a standalone program that pre-dated ArcGIS desktop.

band
One segment of the electromagnetic spectrum that is recorded by a sensor. Multispectral images contain more than one band. A standard color monitor can display three bands of a multispectral image as red, green and blue.

bequest value
The value of protecting wilderness areas for future generations.

biodiversity
The variety of life on Earth and the interconnections among living things.

Biogeography
The study of living systems and their distribution. Biogeography is important to the study of biodiversity because we need to know where animals and plants live, where they don't, and why.

biotic environment
Pertaining to the living components of an ecosystem, plants and animals including microorganisms.

BLM
Bureau of Land Management, U.S. Department of the Interior.

CBI
Conservation Biology Institute, Corvallis, Oregon. A non-profit research and education organization formed in 1997 to study and promote biodiversity.

corridor (landscape)
Landscape elements that connect similar patches of habitat through an area with different characteristics.

***de facto* wilderness**
Lands that are wilderness in the general sense of the term, roadless and undeveloped, that are not protected by law and potentially available for wilderness designation.
DEIS
Draft environmental impact statement.

DEM
Digital elevation model. A raster file with a series of point elevations at regular intervals, it can be displayed in a GIS as digital shaded relief. File extensions vary according to format and application.

desert
A region of sparse vegetation, dominated by sand and rock.

DOQ
Digital orthophoto quadrangle, a scanned, georeferenced aerial photograph clipped to a USGS 7.5 minute quadrangle. Digital orthophoto quarter quads (DOQQs) cover one-fourth of a quadrangle.

ecoregion
A geographic region that is characterized by distinctive climate, soils, ecological features, and plant and animal communities.

ecosystem
A community of plants, animals, and microorganisms linked by energy and nutrient flows to interact with each other and with the physical environment.

ecosystem services
Economically valuable environmental services provided by functioning ecosystems. Examples of ecosystem services include water pollution and flood control, air purification, and climate modification.

ECW
Enhanced Wavelet Compression, a compressed raster file format developed by Earth Resources Mapping of West Perth, Western Australia. File extension **.ecw**.

EIS
Environmental impact statement. A document required by NEPA for federal actions significantly impacting the human environment.

endangered species
A species threatened with extinction.

endemic species
A species that naturally occurs in only one area or region. For example, the Joshua tree is a plant endemic to the Mojave Desert.

ENVI™
The Environment for Visualizing Images, image processing software developed by Research Systems, Inc. of Boulder, Colorado.

EOS
NASA Earth Observing System.

ERDAS Imagine™
Image processing software from ERDAS, Inc. of Atlanta, Georgia.

ER Mapper™
Geographic image processing software by Earth Resource Mapping, West Perth, Western Australia.

ESRI
Environmental Systems Research Institute, Redlands, California. Founded in 1969, ESRI is a leading provider of GIS software and services.

ETM+
Landsat Enhanced Thematic Mapper Plus.

existence value
The value of protecting wilderness just to know that such places exist, relatively untrammeled.

FGDC
Federal Geographic Data Committee, the body that sets GIS standards for the federal government (http://www.fgdc.gov).

fire regime
The characteristics of fire in a given ecosystem, such as the frequency, predictability, intensity, and seasonality of recorded wildfires.

FLPMA
The Federal Land Policy and Management Act of 1976. Also known as the “BLM Organic Act.” Section 603 of FLPMA mandated a 15-year inventory and study of BLM wilderness that was completed in 1991.

forest
Open or closed vegetation principally consisting of trees averaging more than five meters in height.

fragmentation
The breaking up of large habitats into smaller, isolated pieces. Most fragmentation is anthropogenic. Landscape and particularly forest fragmentation contributes to declining biodiversity.

FRAGSTATS
Geostatistical software program designed to compute a wide variety of landscape metrics for both raster and vector datasets. Developed by the USFS in 1995.

FWS
U.S. Fish & Wildlife Service, U.S. Department of the Interior.

GAP
Gap Analysis Program, FWS and NBS. The objective of GAP is to map unprotected areas important for preserving biodiversity in the USA.

Geography
The science of space and place that brings together Earth's physical and human dimensions in the integrated study of people, places and environments.

GeoTIFF
Geo-referenced Tagged Image File Format. A TIFF file that includes geographic coordinate system information.

GIS
Geographic Information System, a relational database in which properties are assigned to spatial entities such as points, lines, polygons and cells.

habitat
The area within which a given animal or plant lives and finds the nutrients, water, sunlight, shelter, living space and other essentials it needs to survive.

HDF-EOS
Hierarchical Data Format – Earth Observing System. File format used by NASA to distribute satellite imagery. File extension **.hdf**.

HTML
Hypertext Markup Language. A text-based format for Web pages. File extension usually **.html** or **.htm**.

HUC
Hydrologic Unit Code. A coding system developed by the USGS to map geographic boundaries of watersheds.

HUPC
High Uintas Preservation Council.

hydrology
The study of the properties, distribution, and circulation of water on the earth's surface, in the soil and rocks, and in the atmosphere.

ICBEMP
Interior Columbia Basin Ecosystem Management Project, USFS and BLM.

indigenous species
A species that has evolved within and adapted to a particular ecosystem (see native species).

instream flow
Allocation of water for seasonal stream flows to preserve aquatic ecosystems and provide recreational opportunities.

IRA
Inventoried Roadless Area (USFS).

IUCN
World Conservation Union, an international body based in Gland, Switzerland.

JPEG
Compressed raster file format developed by the Joint Photographic Experts Group. File extension **.jpg**. A separate **.jgw** file is needed for georeferencing.

KB
Kilobyte, one thousand bytes.

Landsat TM
Landsat Thematic Mapper sensor carried onboard the Landsat 5 satellite. A newer instrument, the Enhanced Thematic Mapper Plus (ETM+), is on Landsat 7.

latitude
Parallels of latitude are imaginary circles drawn around the globe parallel to the equator. The parallels are numbered according to the angle in degrees formed between a line from the line of latitude to the center of the earth and a line from the center of the earth to the equator. The distance between degrees of latitude is approximately 111 km.

LAC
Limits of Acceptable Change. A wilderness area management strategy that uses mapped zones to establish desired resource and social conditions.

longitude
A meridian of longitude is the position of a point on the globe in terms of degrees east or west of the Prime Meridian, which has a value of 0 degrees and runs between the North and South Pole through Greenwich, England. The length of a degree of longitude varies according to latitude.

Mappetizer
In 2010, the latest version of the MapViewSVG ArcGIS extension was renamed Mappetizer.

MapViewSVG
Armin Mueller of uismedia in Germany developed MapViewSVG as an extension to ArcMap.

minimum mapping unit
The smallest area that is depicted on a thematic map layer.

MODIS
Moderate Resolution Imaging Spectroradiometer, a sensor aboard the NASA Terra (EOS AM-1) satellite.

MOSS
Map Overlay and Statistical System, a public domain GIS software package.

MRLC
Multi-Resolution Land Characteristics, a consortium of federal agencies formed in 1992 to jointly acquire satellite-based remote sensing data for land-cover mapping. MRLC data is the basis of the NLCD.

MrSID™
Multiresolution Seamless Image Database. Highly compressed raster file format developed by LizardTech. File extension **.sid**.

NAD
North American Datum. There are two widely-used versions: NAD 27 is based on the Clarke 1866 spheroid, and NAD 83 on the GRS 1980 spheroid.

NAIP
National Agricultural Imagery Program.

NASA
National Aeronautics and Space Administration.

native species
A species living and reproducing in a given ecosystem. Native species may or may not be indigenous.

NBS
National Biological Survey, U.S. Department of the Interior.

NCA
National Conservation Area, a legislative designation.

NED
National Elevation Dataset.

NEPA
The National Environmental Policy Act of 1970. This law requires all federal agencies to disclose and consider the environmental impacts of their proposed actions.

NDVI
Normalized Difference Vegetation Index, used in remote sensing to highlight green vegetation. NDVI uses the difference between the red and near infrared bands to produce an index ranging from –1 to 1, with values above zero indicating the presence of vegetation.

NF
National forest.

NFMA
National Forest Management Act of 1976.

NLCD
National Land Cover Database, U.S. Geological Survey.

NLCS
National Landscape Conservation System. A system to coordinate management of BLM national monuments, NCAs, WSAs and other protected lands.

non-indigenous species
A species that has been introduced into an area where it does not occur naturally.

NPS
National Park Service, U.S. Department of the Interior, or National Park System.

NRCS
Natural Resources Conservation Service, U.S. Department of Agriculture.

NRI
Nationwide Rivers Inventory. A listing of free-flowing rivers in the United States that are believed to possess one or more “outstandingly remarkable” natural or cultural values.

NWPS
National Wilderness Preservation System. All designated wilderness areas are part of the NWPS, managed by the USFS, BLM, NPS and FWS.

OGC
Open Geospatial Consortium. A non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services.

PDF
Adobe Portable Document Format.™ A PostScript-based cross-platform format that preserves the appearance of documents. PDF can be read by leading web browsers as well as the freeware Adobe Acrobat Reader.™ (http://www.adobe.com)

plug-in
A set of software components that adds specific capabilities to a larger application, such as a web browser. Viewing SVG maps with Internet Explorer requires a plug-in.

PNG
Portable Network Graphics. A bitmapped image format that employs lossless data compression.

potential natural vegetation
The vegetation that would exist in a given location subsequent to the removal of human influences and the resulting plant succession.

prescribed fire
Fire ignited by management actions to meet specific ecological objectives, in accordance with an approved fire plan.

protected area
An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means.

range
The natural geographic distribution of a particular wildlife species.

RARE
Roadless Area Review and Evaluation. Several USFS initiatives conducted in the late 1970s and early 1980s to identify national forest roadless areas and assess their wilderness and development potential. There were three separate efforts: RARE I, RARE II, and the RARE II re-evaluation (often dubbed "RARE III"). See also Roadless Area Conservation Initiative.

region
An area of land or grouping of features that is separate and distinguishable from adjoining areas.

reintroduction
Returning members of a species to their historical range. This is a management action sometimes used when a species has become locally extinct. For example, desert bighorn sheep, bison and moose have been reintroduced in several areas in Utah.

relict species
A species that ha survived while other related ones have become extinct, or which now remains in isolated areas within its former range.

research natural area
An area in as near a natural condition as possible that is set aside to preserve a representative sample of an ecological community, primarily for scientific and educational purposes.

restoration
The repair of ecological damage to an ecosystem, so that it is close to a natural condition and can function as a self-regulating system. Restoration can include revegetation and reintroduction of indigenous species.

riparian
Pertaining to the banks of a river, stream or other body of fresh water.

RMP
Resource management plan (BLM).

Roadless Area Conservation Initiative
A USFS rulemaking procedure initiated by the Clinton administration in 2000 to protect national forest inventoried roadless areas from development. This effort was a follow-up to the RARE initiatives.

RS 2477
Revised Statute 2477, part of the Mining Law of 1866 that granted an implicit right-of-way for highways across federal land. This law was repealed by FLPMA in 1976, but controversy continues over RS 2477 rights-of-way that may have been established prior to FLPMA.

semidesert
An area of xerophytic shrubby vegetation with a poorly developed herbaceous lower layer, e.g. sagebrush.

SGID
State Geographic Information Database for Utah, maintained by the Utah AGRC.

shrub
A woody plant less than five meters high.

SITLA
Utah School and Institutional Trust Lands Administration.

species
(1) A group of organisms that have a unique set of characteristics that distinguished them from other organisms. If they reproduce, individuals within the same species can produce fertile offspring. (2) The basic unit of biological classification. Scientists refer to species in Latin using both their genus and species name.

steppe
Open herbaceous vegetation, less than one meter high, with tufts or plants discrete, yet sufficiently close together to dominate the landscape. Also called shortgrass prairie.

sustainable
Making use of natural resources in the present without diminishing the capacity of an ecosystem to provide resources in the future.

SUWA
Southern Utah Wilderness Alliance.

SVG
Scalable Vector Graphics text-based file format developed by the World Wide Web Consortium (W3C) using an XML specification. File extension **.svg**.

SVGMapper™
An extension for ArcView 3.x that exports a view into SVG format. Developed by Uros Preloznik in 2001.

threatened species
A species listed as threatened is considered at risk of becoming endangered in the near future.

TIFF
Tagged Image File Format, a lossless raster file format originally developed by the Aldus Corp. in 1986. File extension **.tif** or **.tiff**

TM
Landsat Thematic Mapper.

TWS
The Wilderness Society, Washington DC. Founded in 1935 by Aldo Leopold, Bob Marshall and Howard Zahniser to establish the NWPS.

UDWR
Utah Division of Wildlife Resources.

UGS
Utah Geological Survey.

untrammeled
Not subject to human controls and manipulations that hamper the free play of natural forces. A word describing desired wilderness conditions found in the Wilderness Act of 1964.

USFS
U.S. Forest Service, U.S. Department of Agriculture.

USGS
U.S. Geological Survey, U.S. Department of the Interior.

UNEP/GRID
United Nations Environment Programme Global Resource Information Database.

UTM
Universal Transverse Mercator projection. The world is divided longitudinally into UTM zones six degrees wide, each with its own standard projection. Utah lies entirely within UTM Zone 12 North.

UWA
Utah Wilderness Association. A statewide wilderness advocacy group that was active from 1979 to 1996.

UWC
Utah Wilderness Coalition. An alliance (formed in 1985) of national groups concerned about Utah wilderness, including the Sierra Club, TWS and SUWA.

W3C
The World Wide Web Consortium. An international community that develops standards to ensure the long-term growth of the Web.

WCMC
World Conservation Monitoring Centre, United Nations Environment Programme.

wetlands
Areas that, at least periodically, have waterlogged soils or are covered with shallow water.

wilderness-dependent wildlife
Species that thrive in conditions of naturalness, relatively intolerant of human intrusion into their habitat.

wilderness inventory area (WIA)
Similar to a wilderness study area, except it was inventoried by the BLM in the late 1990s after the completion of the wilderness inventory mandated by the Federal Land Management and Policy Act of 1976 (FLPMA).

wilderness study area (WSA)
A roadless area, usually on BLM land, that has been inventoried and found to have wilderness characteristics as described in Section 603 of the Federal Land Policy and Management Act (FLPMA) and Section 2(c) of the Wilderness Act of 1964.

wildland fire use
Using naturally ignited wildland fires to accomplish pre-stated resource management objectives in predefined geographic areas outlined in a fire management plan.

WRS
Worldwide Reference System for Landsat scenes.

WSA
Wilderness Study Area.

WSR
Wild and Scenic River.

WWF
World Wildlife Fund

XML
Extensible Markup Language, an extension of HTML that expands the functionality of Web applications. There are many variations on XML. ESRI's ArcXML and a standard developed by ------ called GeoXML are two types of XML customized for geographic applications.

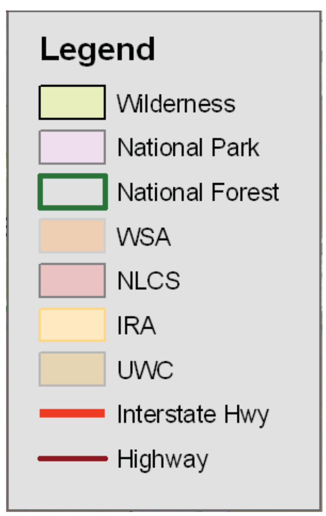
APPENDIX B

MAP APPENDIX

This appendix presents example maps from the Utah Wilderness Atlas. These maps illustrate the regions discussed in Chapter 5. The maps are all at the same scale. Shaded-out areas on the maps belong to other regions.

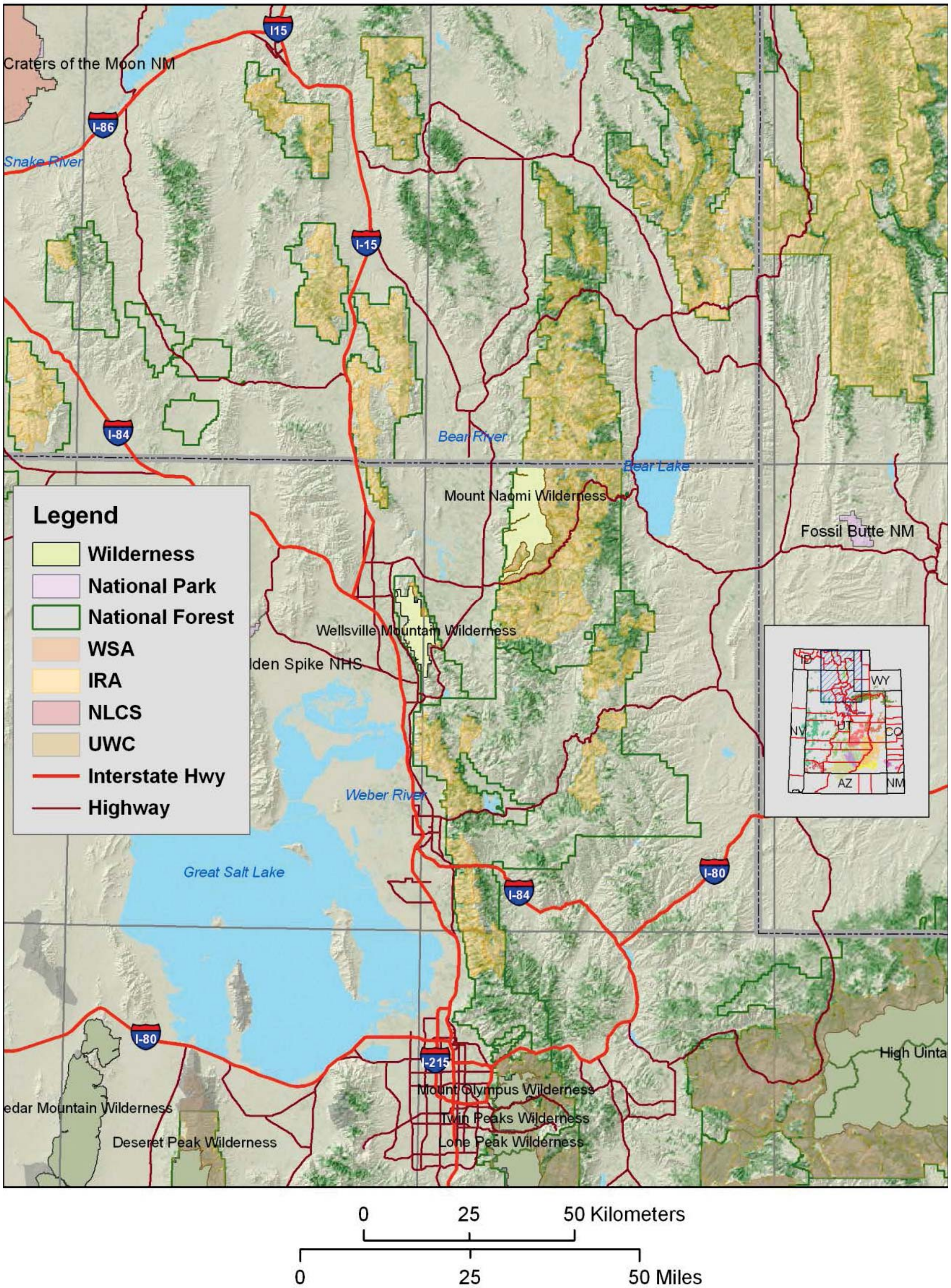
The complete Atlas can be found on the World Wide Web: http://www.utahwildernessatlas.net

Sample map legend for the maps in this appendix:



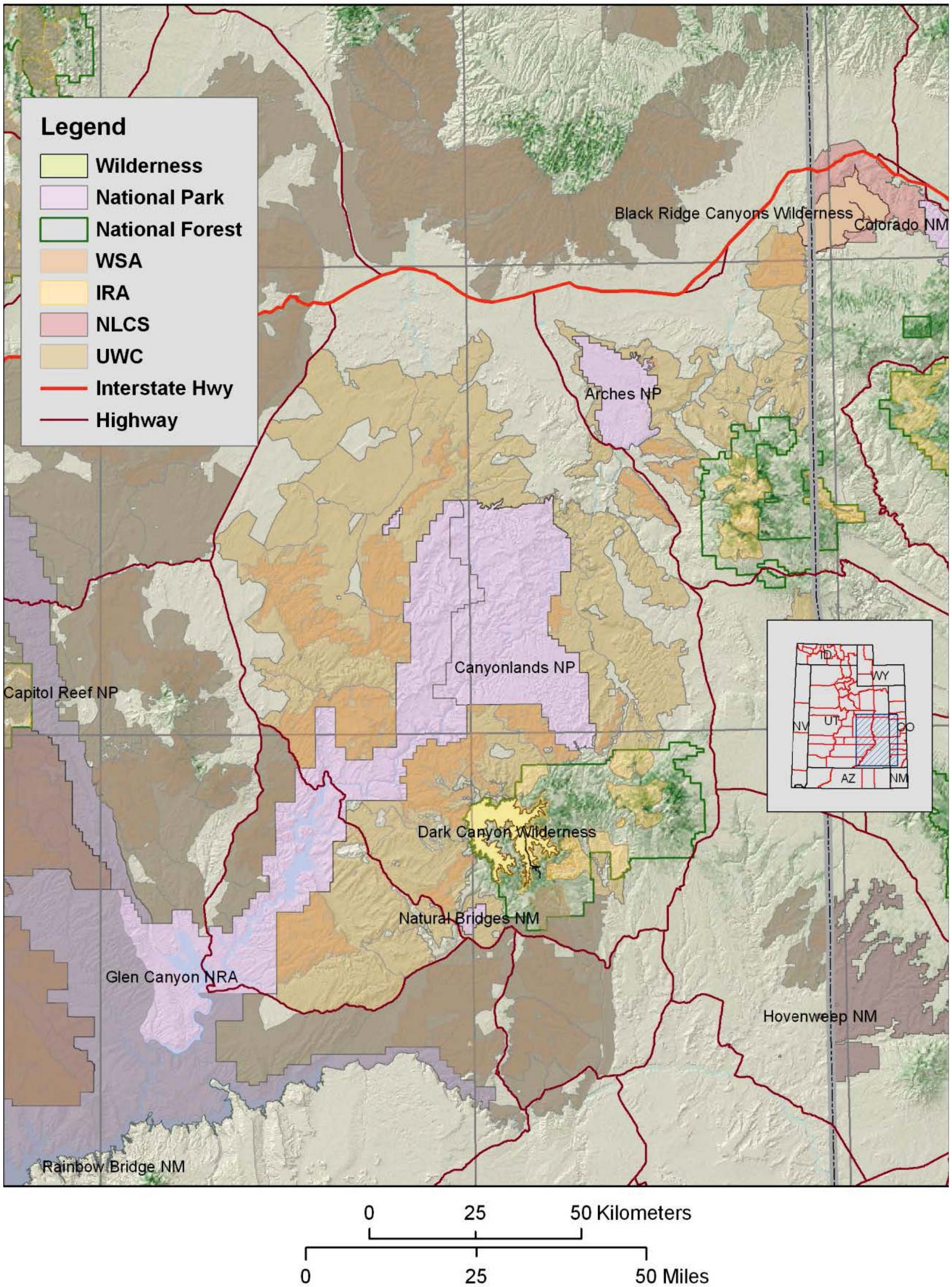
WSA	BLM Wilderness Study Area
NLCS	National Landscape Conservation System (BLM)
IRA	National forest Inventoried Roadless Area
UWC	Roadless areas inventoried by Utah Wilderness Coalition

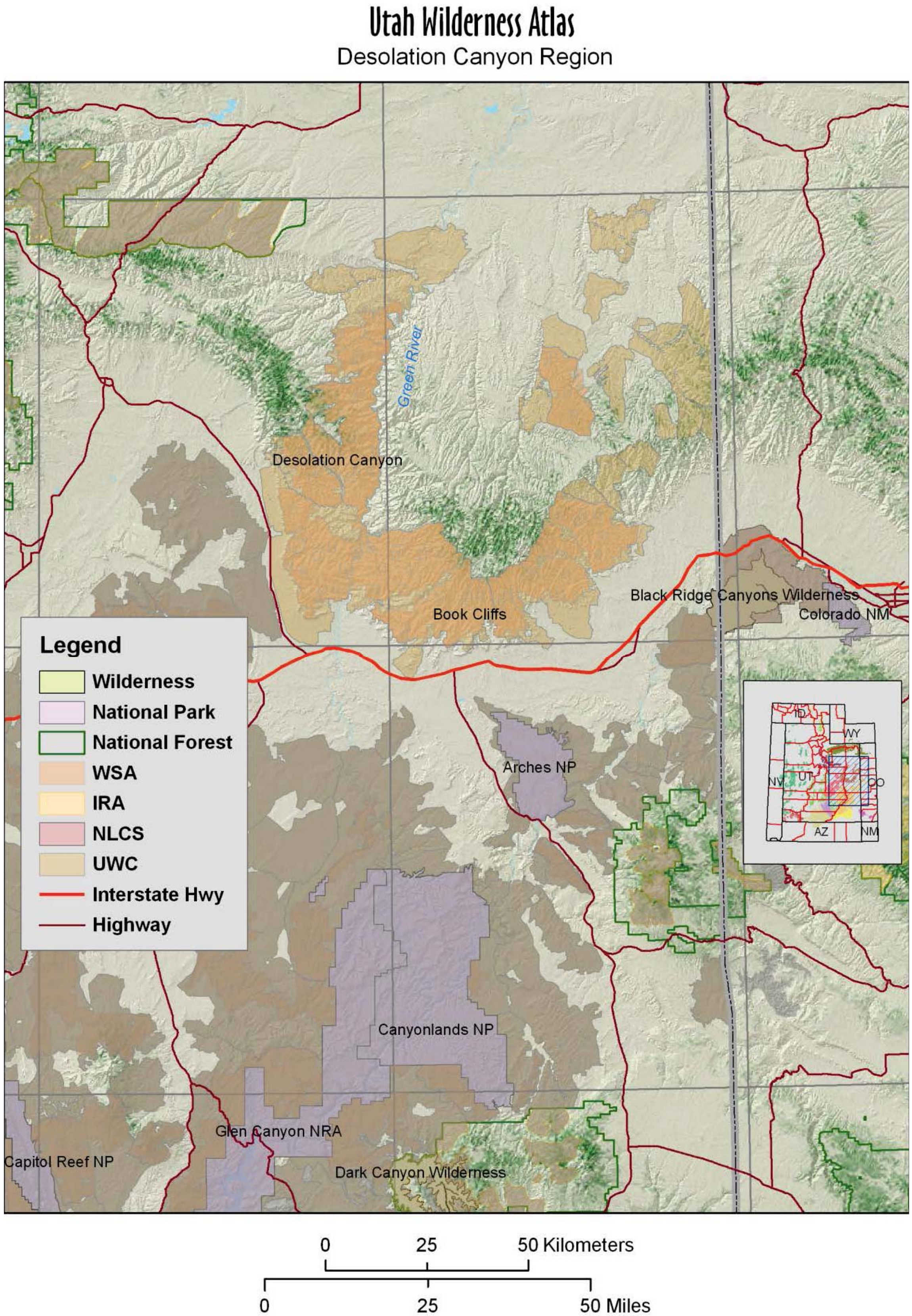
Utah Wilderness Atlas
Bear River Region

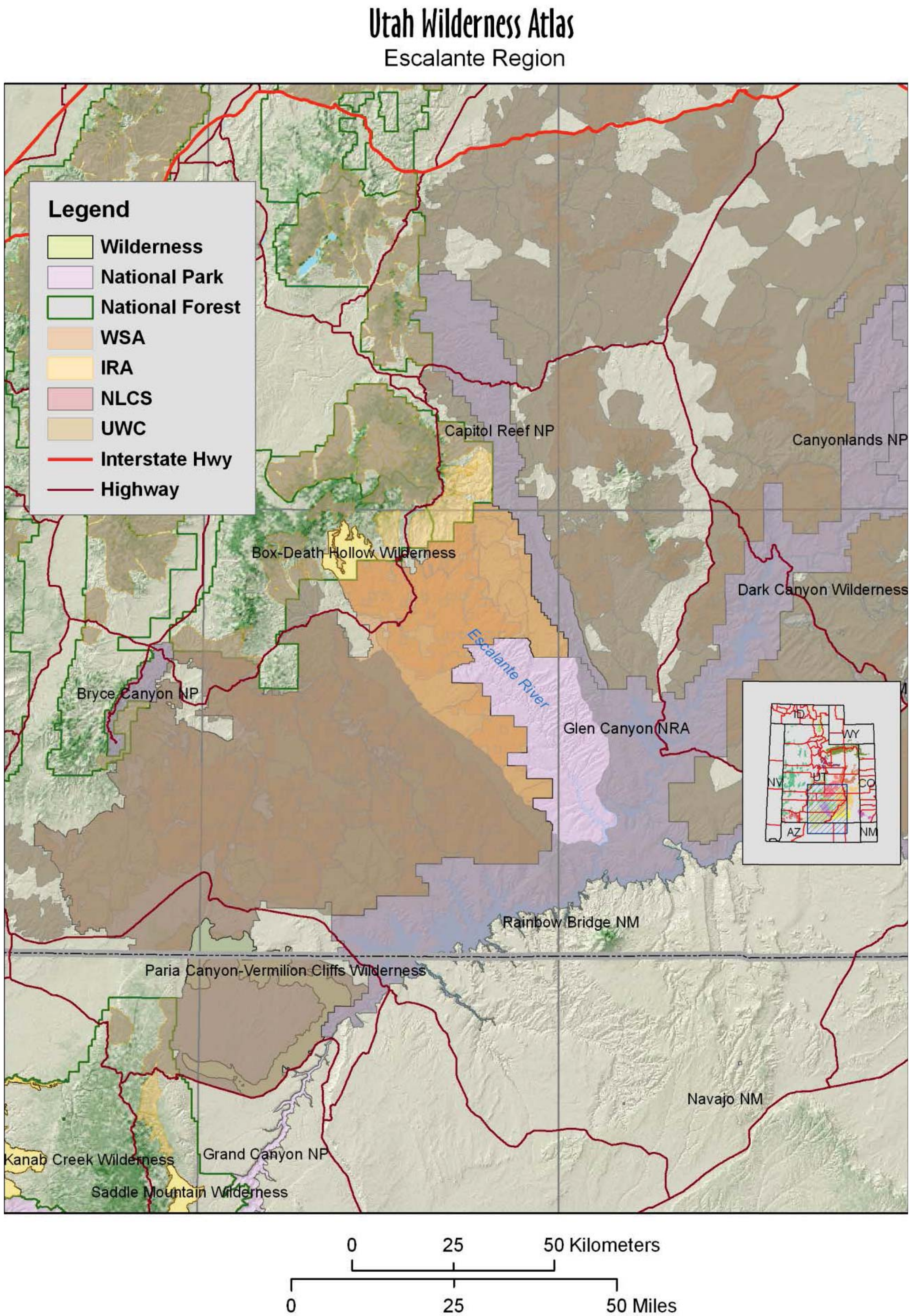


Utah Wilderness Atlas

Canyonlands Region

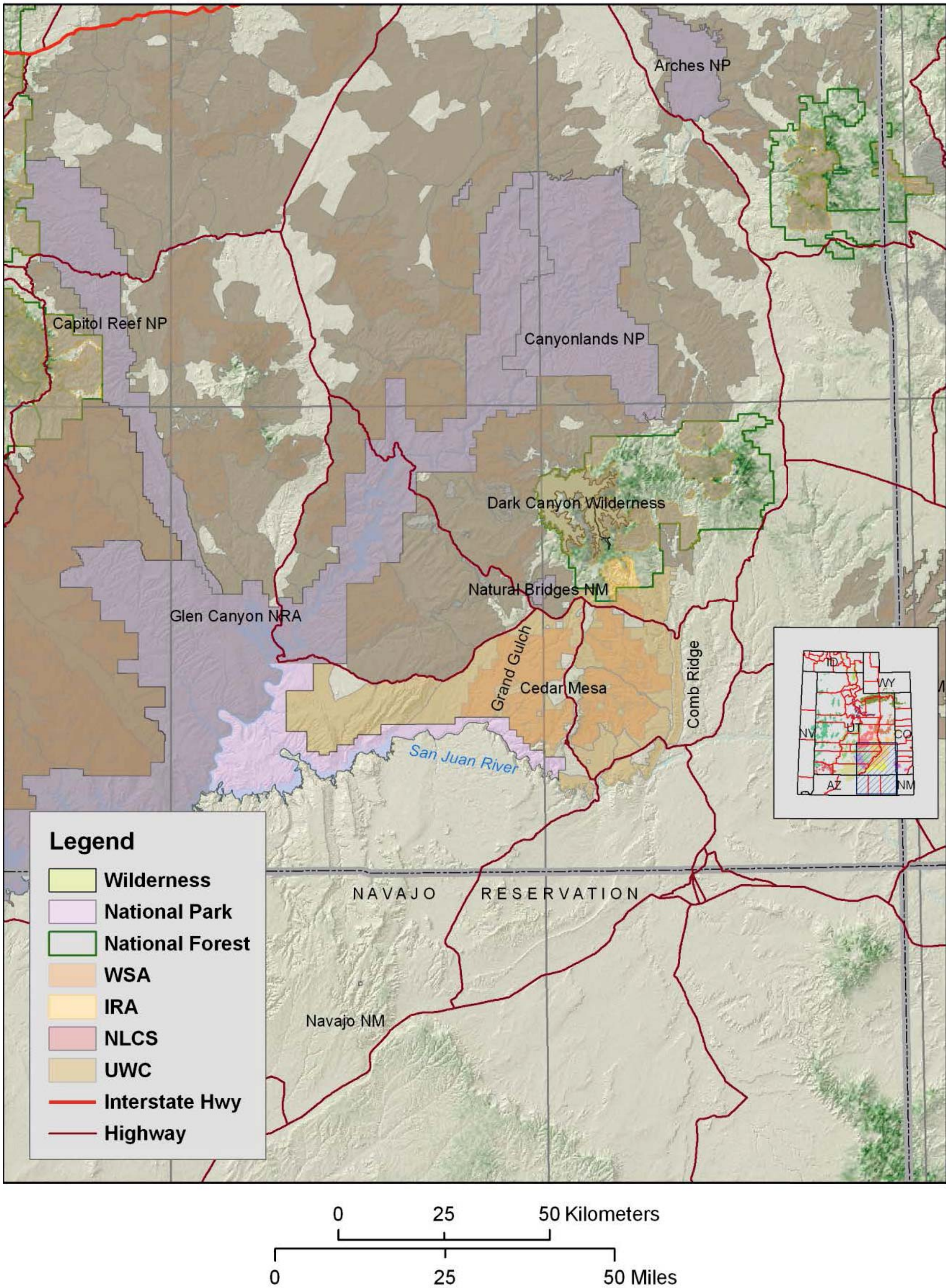



Utah Wilderness Atlas
Desolation Canyon Region
Green River
Desolation Canyon
Book Cliffs
Black Ridge Canyons Wilderness
Colorado NM
Arches NP
Canyonlands NP
Glen Canyon NRA
Capitol Reef NP
Dark Canyon Wilderness
Legend
Wilderness
National Park
National Forest
WSA
IRA
NLCS
UWC
Interstate Hwy
Highway
ID
WY
NV
UT
CO
AZ
NM
0
25
50 Kilometers
0
25
50 Miles


Utah Wilderness Atlas
Escalante Region
Legend
Wilderness
National Park
National Forest
WSA
IRA
NLCS
UWC
Interstate Hwy
Highway
Capitol Reef NP
Canyonlands NP
Box-Death Hollow Wilderness
Dark Canyon Wilderness
Escalante River
Bryce Canyon NP
Glen Canyon NRA
Rainbow Bridge NM
Paria Canyon-Vermilion Cliffs Wilderness
Navajo NM
Kanab Creek Wilderness
Grand Canyon NP
Saddle Mountain Wilderness
ID
WY
NV
UT
CO
AZ
NM
0
25
50 Kilometers
0
25
50 Miles

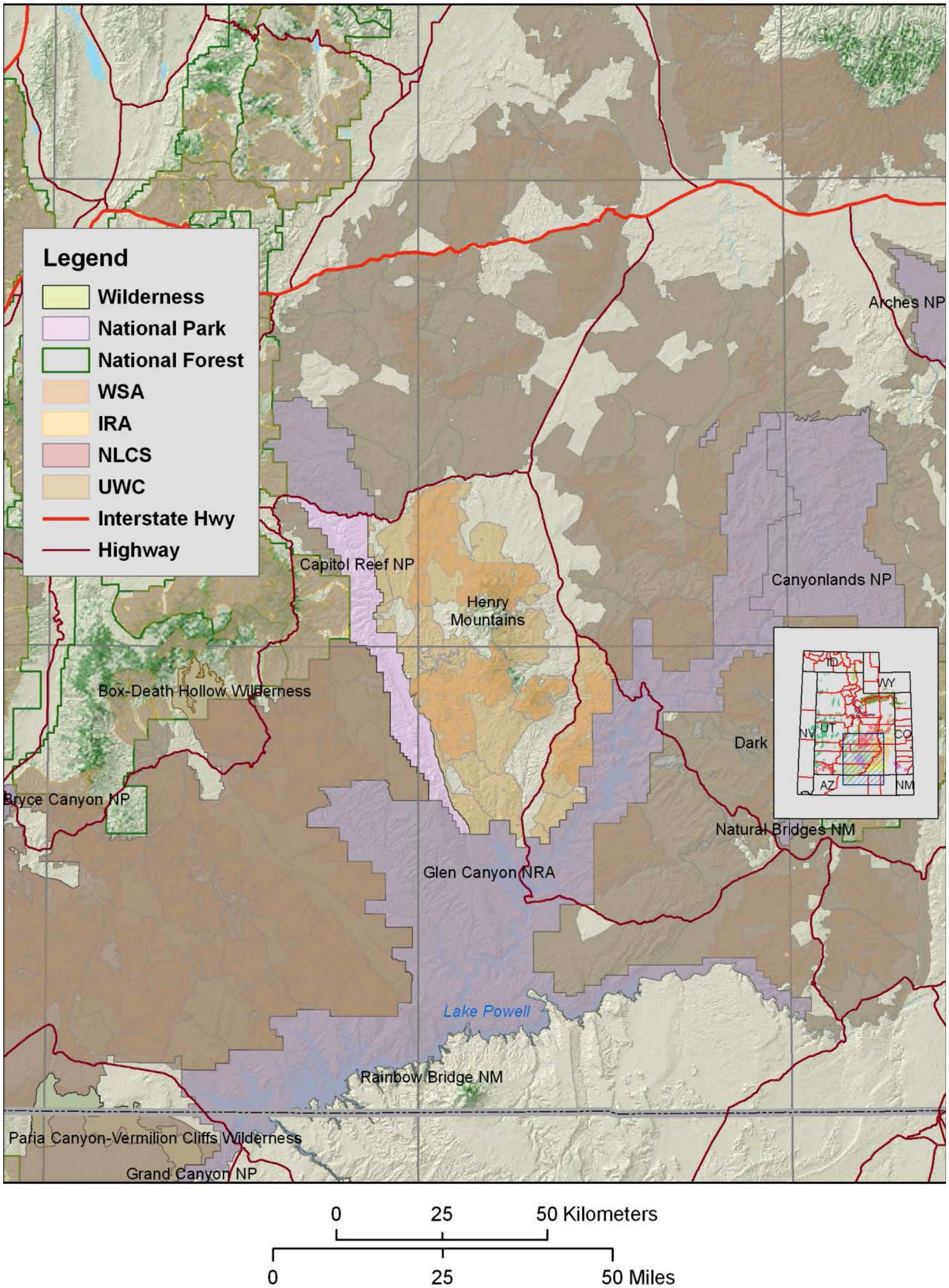
Utah Wilderness Atlas

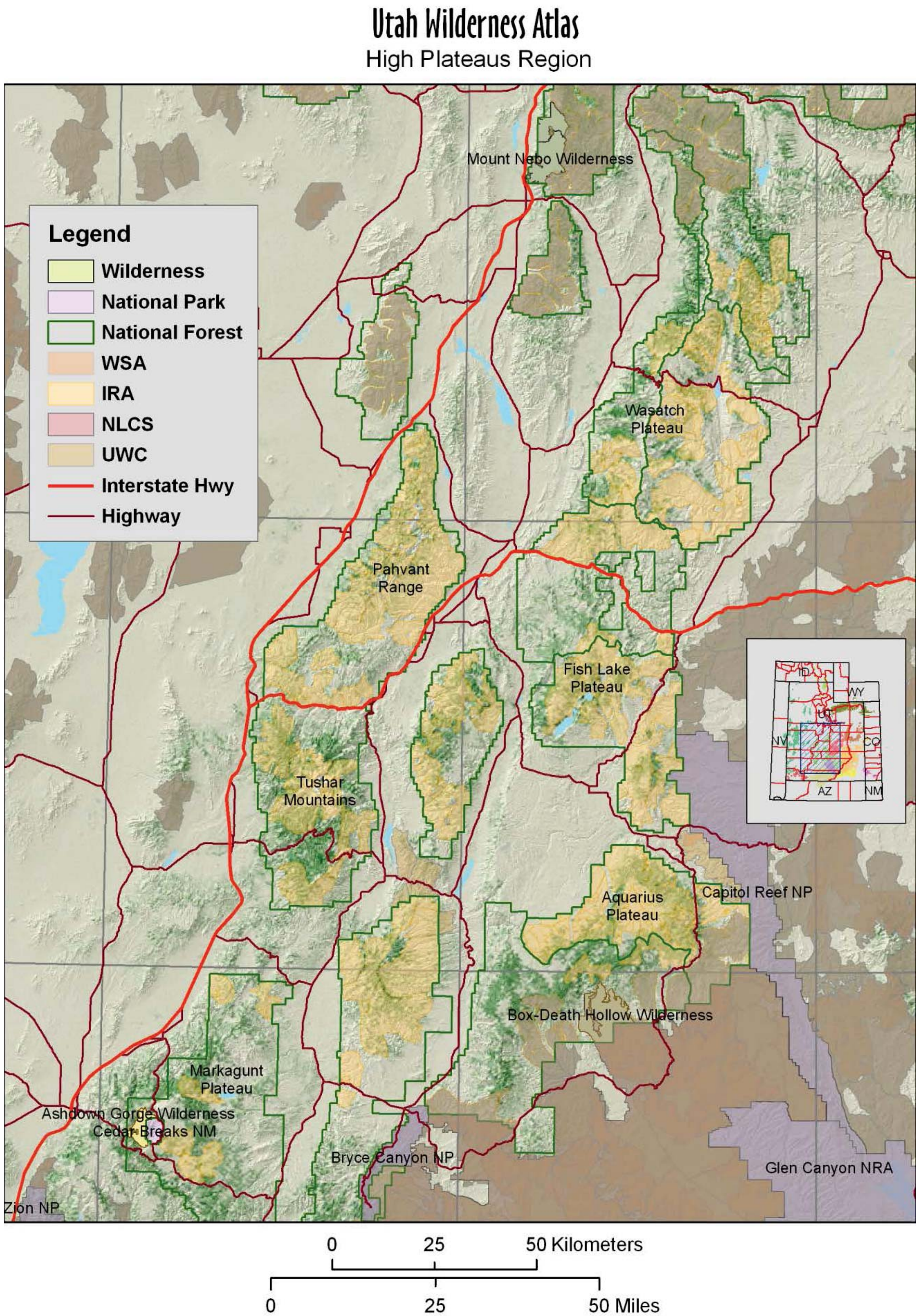
Grand Gulch Region



Utah Wilderness Atlas

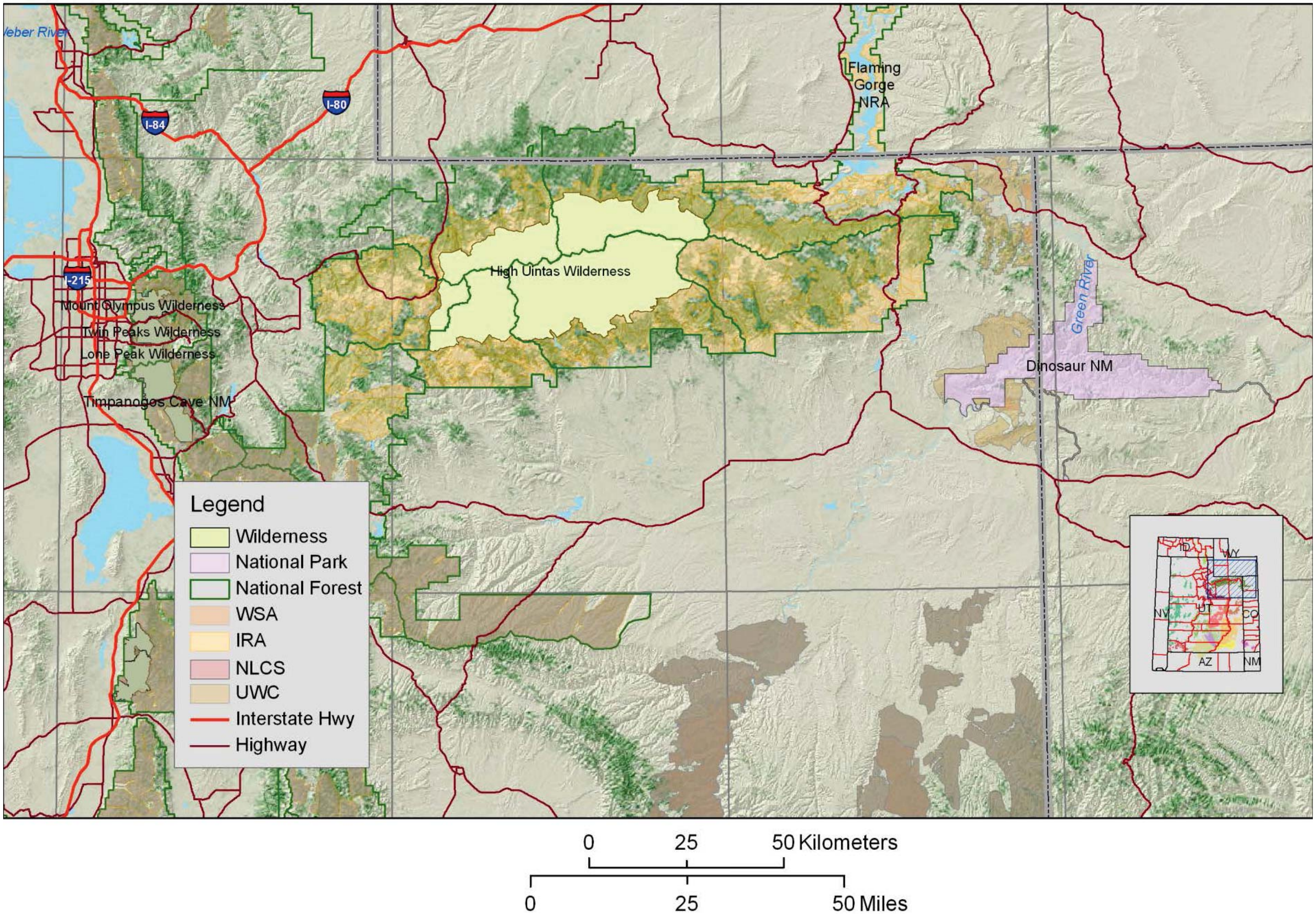
Henry Mountains Region




Utah Wilderness Atlas
High Plateaus Region
Legend
Wilderness
National Park
National Forest
WSA
IRA
NLCS
UWC
Interstate Hwy
Highway
Mount Nebo Wilderness
Wasatch Plateau
Pahvant Range
Fish Lake Plateau
Tushar Mountains
Aquarius Plateau
Capitol Reef NP
Box-Death Hollow Wilderness
Markagunt Plateau
Ashdown Gorge Wilderness
Cedar Breaks NM
Bryce Canyon NP
Glen Canyon NRA
Zion NP
ID
WY
UT
NV
CO
AZ
NM
0
25
50 Kilometers
0
25
50 Miles

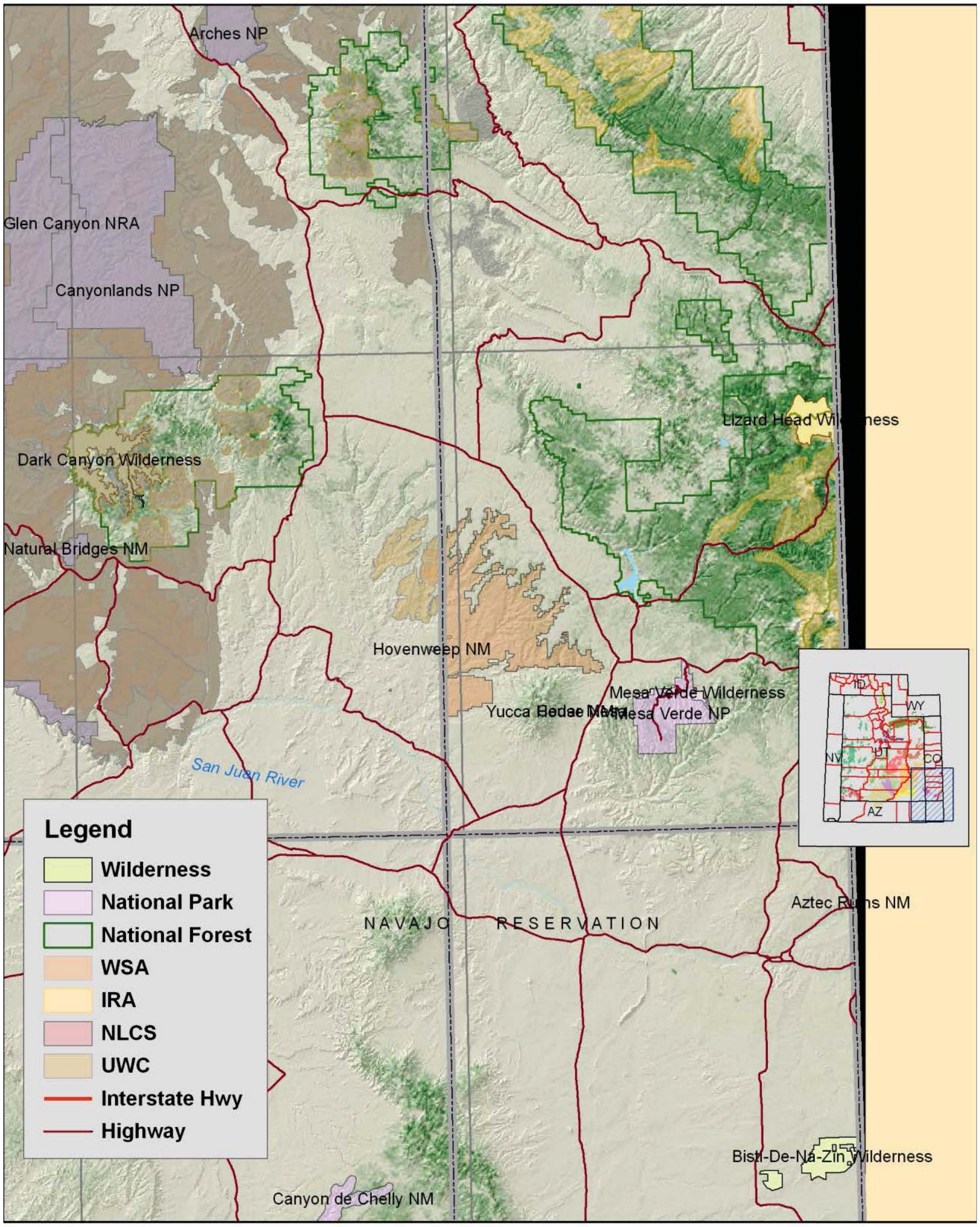
Utah Wilderness Atlas

High Uintas Region



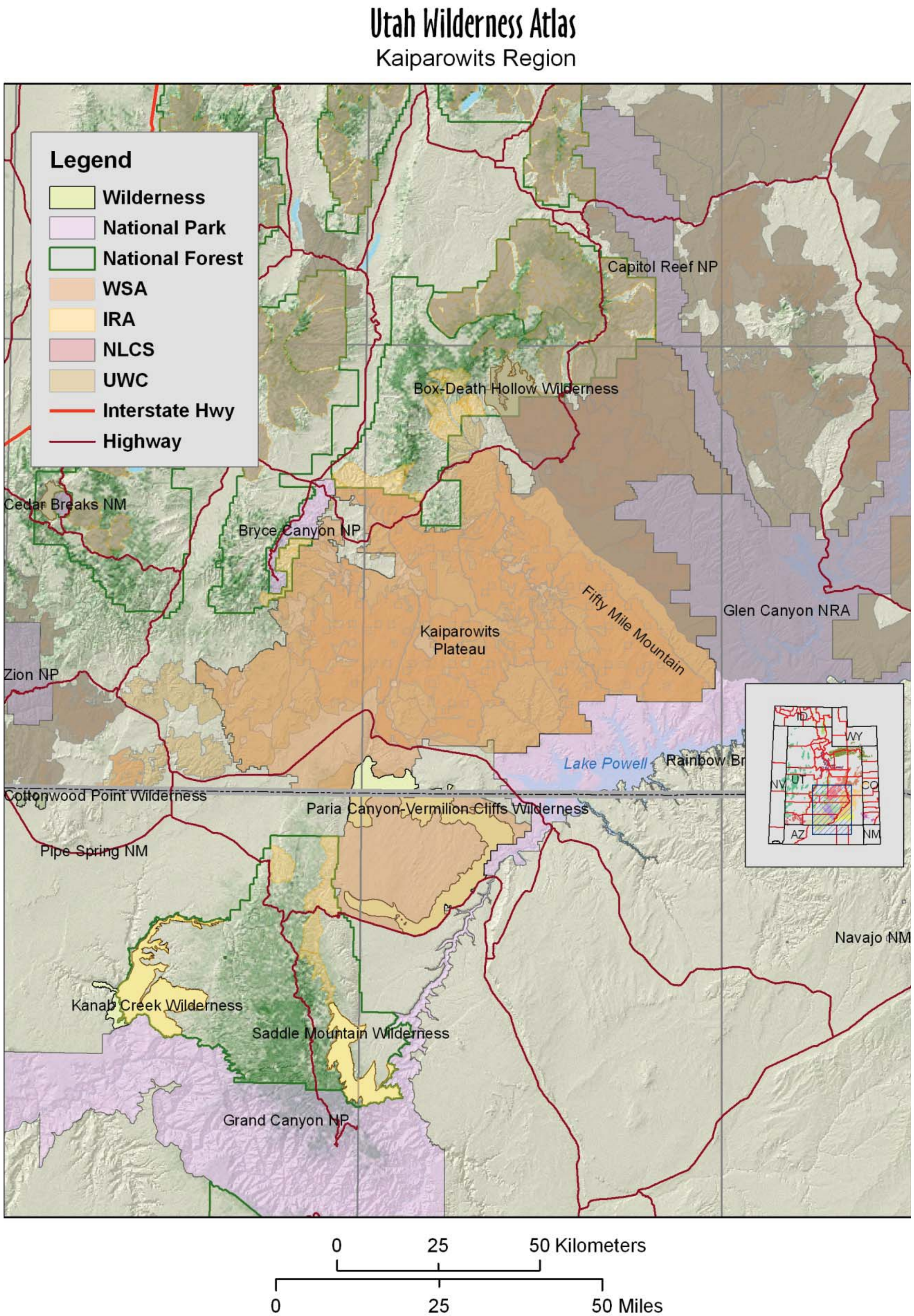
Utah Wilderness Atlas

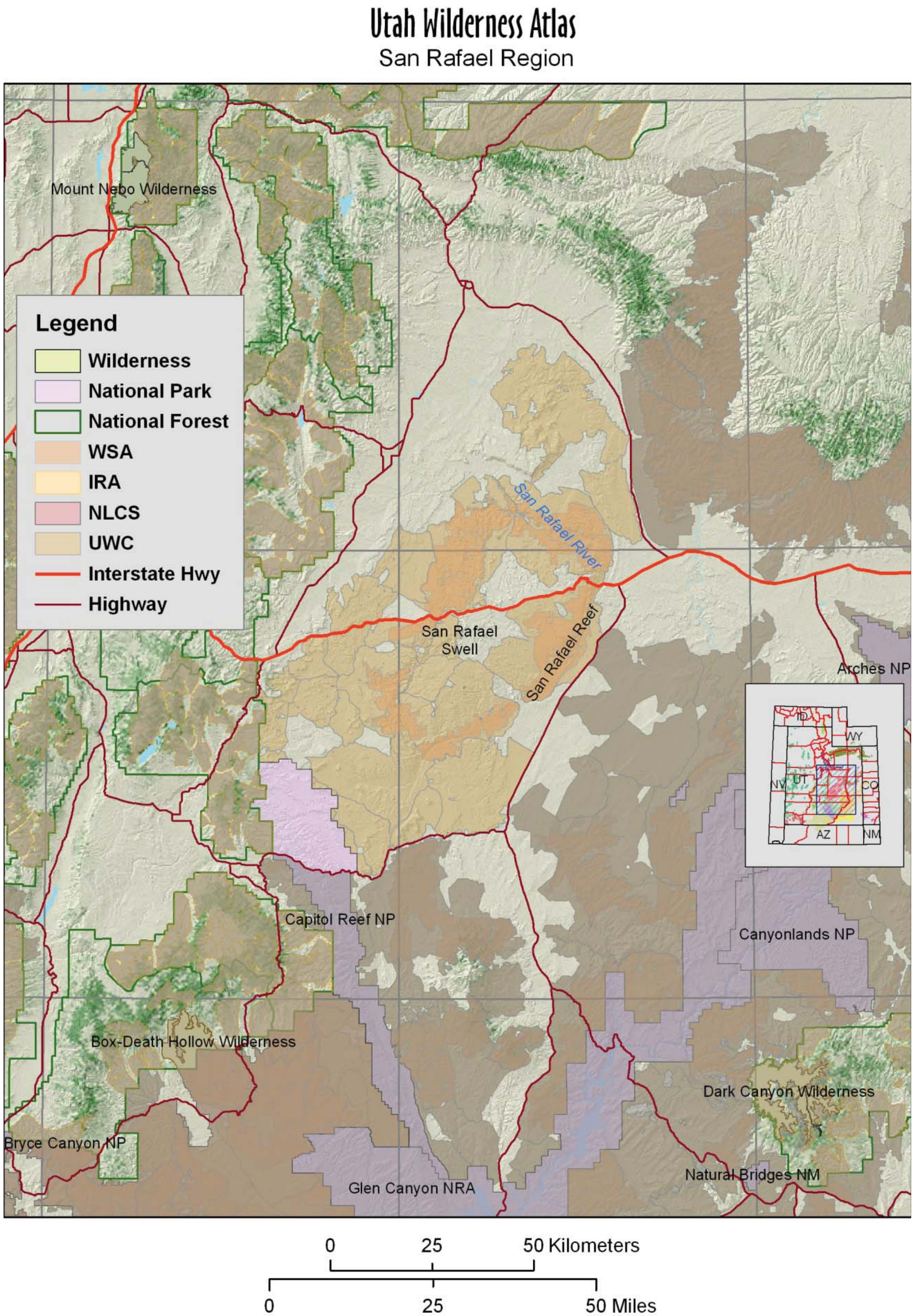
Hovenweep Region



0 25 50 Kilometers

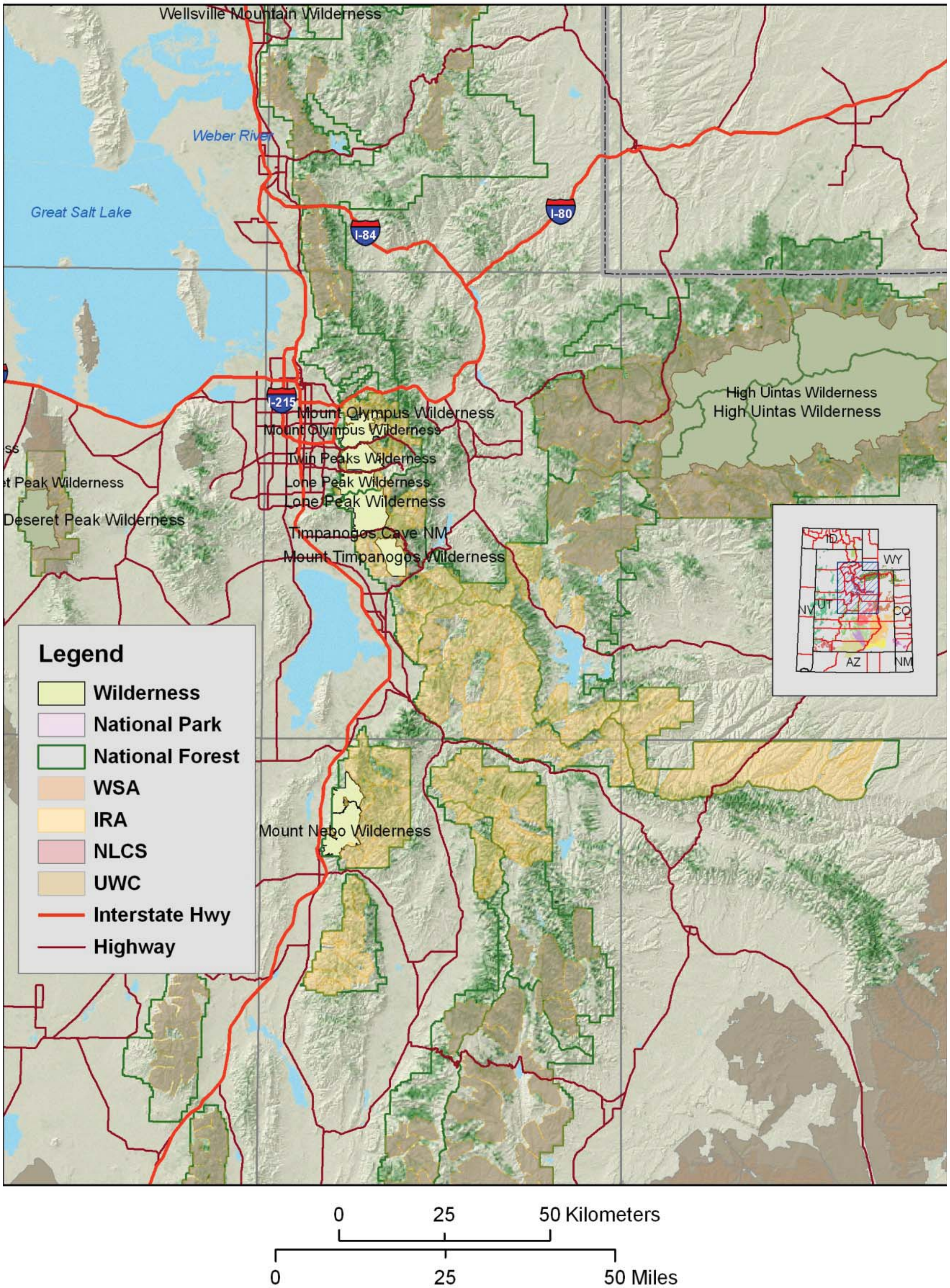
0 25 50 Miles


Utah Wilderness Atlas
Kaiparowits Region
Legend
Wilderness
National Park
National Forest
WSA
IRA
NLCS
UWC
Interstate Hwy
Highway
Capitol Reef NP
Box-Death Hollow Wilderness
Cedar Breaks NM
Bryce Canyon NP
Fifty Mile Mountain
Glen Canyon NRA
Kaiparowits Plateau
Zion NP
Lake Powell
Rainbow Br
Cottonwood Point Wilderness
Paria Canyon-Vermilion Cliffs Wilderness
Pipe Spring NM
Navajo NM
Kanab Creek Wilderness
Saddle Mountain Wilderness
Grand Canyon NP
ID
WY
NV
UT
CO
AZ
NM
0 25 50 Kilometers
0 25 50 Miles


Utah Wilderness Atlas
San Rafael Region
Mount Nebo Wilderness
Legend
Wilderness
National Park
National Forest
WSA
IRA
NLCS
UWC
Interstate Hwy
Highway
San Rafael River
San Rafael
Swell
San Rafael Reef
Arches NP
ID
WY
NV
UT
CO
AZ
NM
Capitol Reef NP
Canyonlands NP
Box-Death Hollow Wilderness
Dark Canyon Wilderness
Bryce Canyon NP
Natural Bridges NM
Glen Canyon NRA
0
25
50 Kilometers
0
25
50 Miles

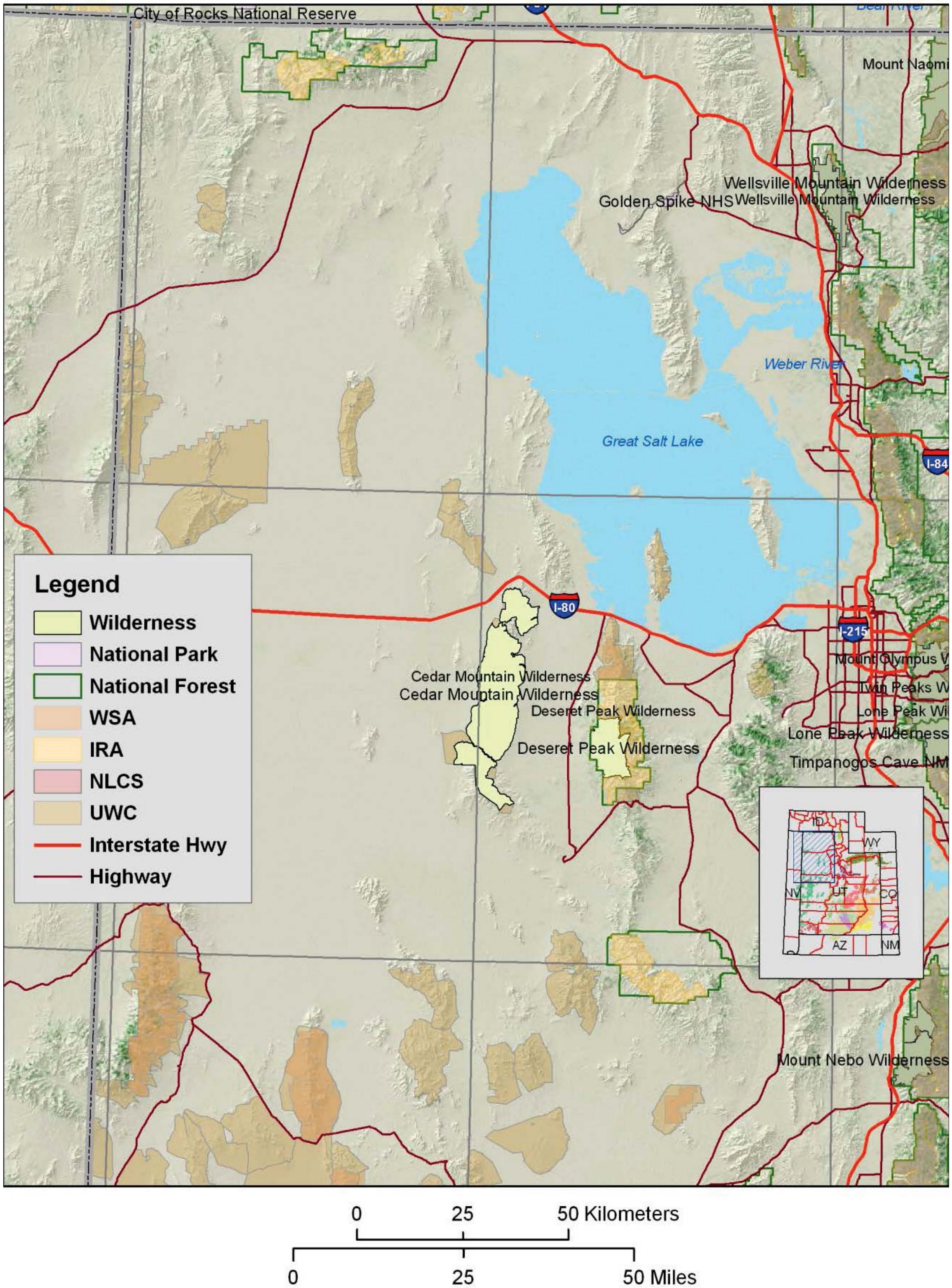
Utah Wilderness Atlas

Wasatch Mountains Region



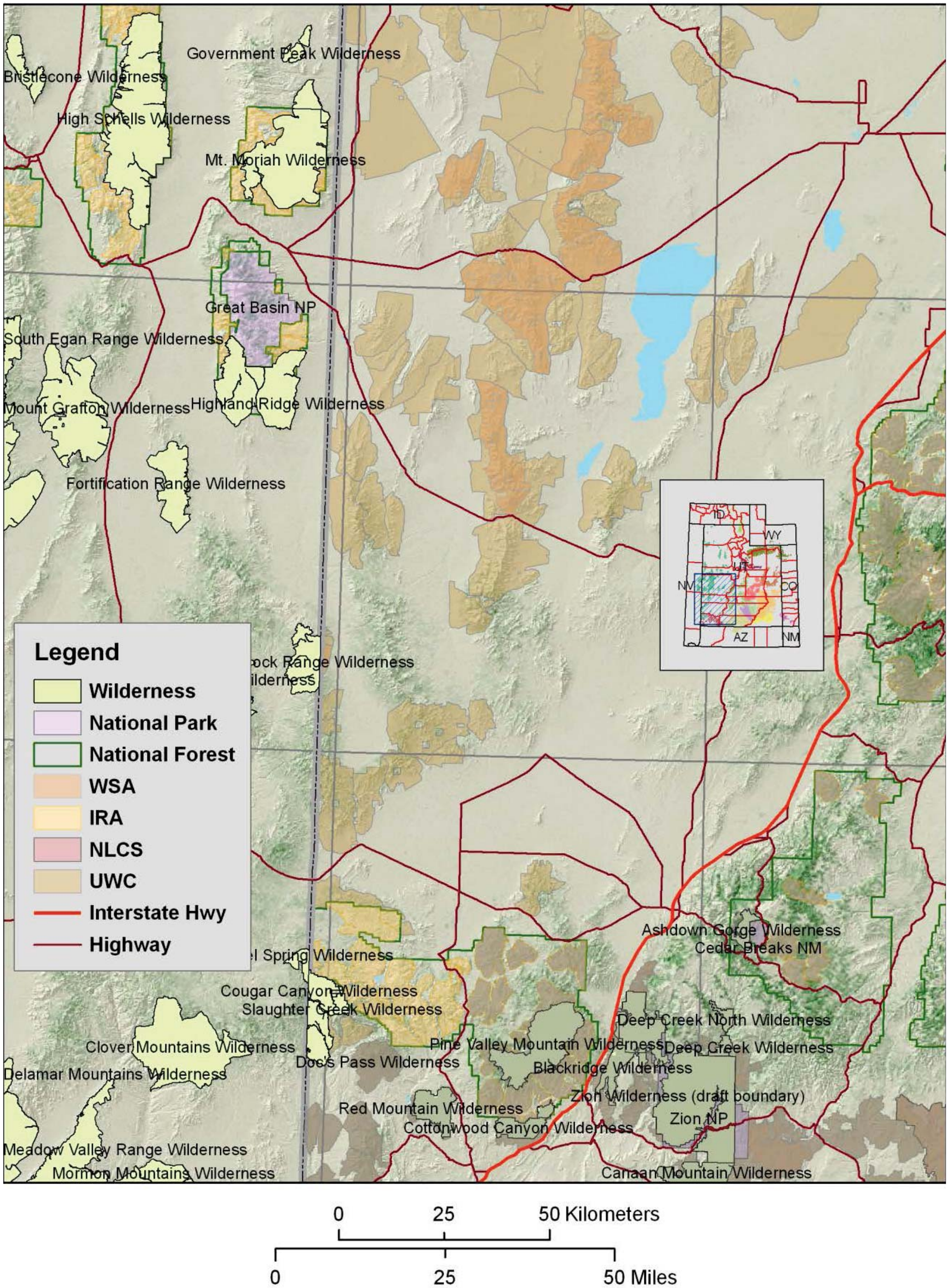
Utah Wilderness Atlas

West Desert Region (North)



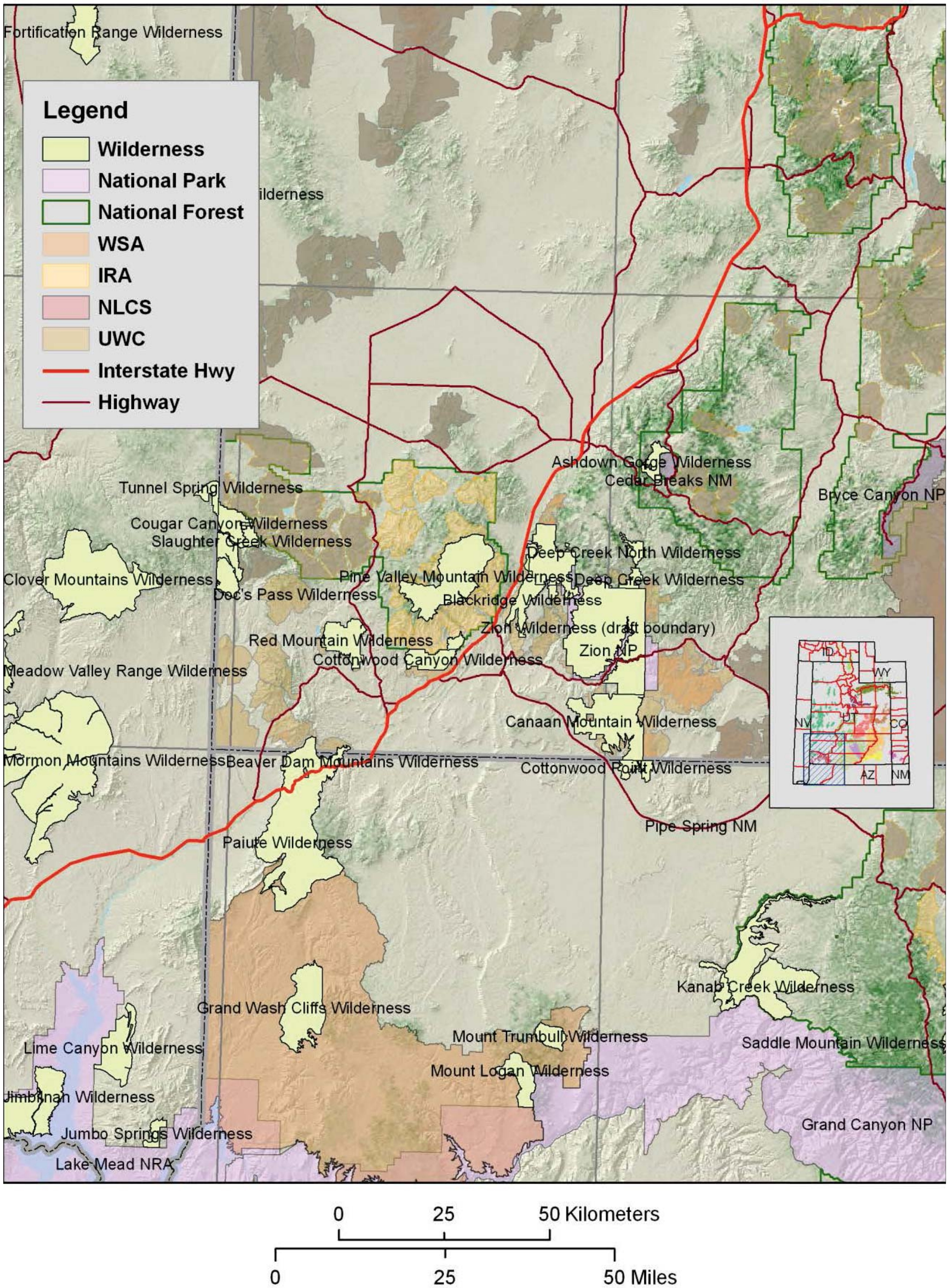
Utah Wilderness Atlas

West Desert Region (South)



Utah Wilderness Atlas

Zion Region



REFERENCES

Aitchison, S. (1987). *Utah wildlands*. Salt Lake City: Utah Geographic Series.

American Geographical Society. (2001). *AGS map catalog subject entries*. Retrieved February 2002 from: http://leardo.lib.uwm.edu/maptops.html

Anderson, J. R., Hardy, E.E., Roach, J.T., & Witmer, R.E. (1976). *A land use and land cover classification system for use with remote sensor data*. (U.S. Geological Survey Professional Paper 964). Washington, DC: U.S. Government Printing Office.

Aplet, G., Morton, P., Thomson, J., & Hartley, D. (1999). *Crown of the canyons: An atlas of the ecology, economy, and future of the greater Grand Staircase-Escalante ecosystem.* Washington, D.C.: The Wilderness Society**.** Retrieved November 2002 from: http://www.wilderness.org/standbylands/utah/atlas/

Aplet, G., Thomson, J., & Wilbert, M. (2000). Indicators of wildness: Using attributes of the land to assess the context of wilderness. In S.F. McCool, D.N. Cole, W.T. Borrie, & J. O'Loughlin (Eds.), *Proceedings: Wilderness Science in a Time of Change conference— Volume 2: Wilderness within the context of larger systems*. (Proceedings RMRS-P-15-VOL-2). Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Arizona Wilderness Act of 1984. Pub. L. No. 98-406, 98 Stat. 1485 (1984, August 28).

Atwood, W.W. (1940). *The physiographic provinces of North America*. Boston, MA: Ginn and Company.

Bailey, R.G. (1976). *Ecoregions of the United States*. [Map]. Ogden, UT: USDA Forest Service Intermountain Region.

Bailey, R.G. (1995). *Description of the ecoregions of the United States*. [With map]. (2nd edition revised and expanded. Misc. Publication No. 1391 (rev.)). Washington, DC: USDA Forest Service.

Bailey, R.G. (1996). *Ecosystem geography*. New York, NY: Springer-Verlag.

Blackett, R.E, & Wakefield, S. (2004). *A digital atlas of Utah's resources.* [CD-ROM]. (Open File Report 431 CD). Salt Lake City, UT: Utah Geological Survey.

Boehm, R. (1994). *Geography for life: National Geography standards.* Washington, DC: National Council for Geographic Education.

Brennan, A.E. (1998). *Grassroots of the desert: An analysis of the roles of the Utah Wilderness Association and the Southern Utah Wilderness Alliance in the debate over wilderness designation of Bureau of Land Management lands in southern Utah*. (M.S. thesis, Utah State University, 1998).

Bureau of Land Management. (1986). *Draft Utah statewide wilderness environmental impact statement*. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Land Management.

Bureau of Land Management. (1991). *Utah statewide wilderness study report*. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Land Management**.**

Bureau of Land Management. (1992). *State of Utah wilderness status map*. [Map]. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Land Management.

Bureau of Land Management. (1999). *Utah wilderness inventory report*. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Land Management.

Buyya, R., Broberg, J., & Goscinski, A.M., (Eds.). (2011). *Cloud computing: Principles and paradigms.* Hoboken, NJ: John Wiley & Sons.

Cartwright, W., Peterson, M.P., & Gartner, G., (Eds). (1999). *Multimedia cartography*. Berlin, Germany: Springer-Verlag.

Clinton, W.J. (1996). *Establishment of the Grand Staircase-Escalante National Monument by the President of the United States of America: A proclamation*. Washington, DC: The White House, Office of the Press Secretary.

Coalition for Utah's Future/Project 2000. (1994). *Community and wild lands futures: A pilot project in Emery County, Utah*. Salt Lake City, UT: Coalition for Utah's Future/Project 2000.

Colorado Canyons National Conservation Area and Black Ridge Canyons Wilderness Act of 2000. Pub. L. No. 106-353, 114 Stat. 1374 (2000, October 24).

Conservation Biology Institute. (2001). *CBI/WWF protected areas database* (2nd ed.). [CD-ROM]. Corvallis, OR: Conservation Biology Institute.

Convis, C. (2010). Personal communication (2010, December 7).

Craig, W.J., & Kandell, S.J. (2000). Monumental steps: GIS and the planning process for the Grand Staircase-Escalante National Monument. *GeoInfo Systems*, February, 22-30.

Crampton, C.G. (2000). *Standing up country: The canyon lands of Utah and Arizona* (Rev. ed.). Tucson, AZ: Rio Nuevo Publishers.

Crist, P.J. (2000). *Mapping and categorizing land stewardship: A handbook for conducting gap analysis* (Version 2.1.0). Retrieved July 2011 from GAP Website: http://www.gap.uidaho.edu/handbook/CompleteHandbook.pdf Moscow, ID: Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho.

Cronon, W. (1995). The trouble with wilderness; or, getting back to the wrong nature. In W. Cronon (Ed.), *Uncommon ground: Rethinking the human place in nature* (pp. 69-90). New York, NY: W.W. Norton & Company.

Davidson, D.W., Newmark, W.D., Sites, J.W., Shiozawa, D.K., Rickart, E.A., Harper, K.T., & Keiter, R.B. (1996). Selecting wilderness areas to conserve Utah's biological diversity. *The Great Basin Naturalist*, *56*(2), 95-118.

Dawson, C.P., & Hendee, J.C. (2009). *Wilderness management: Stewardship and protection of resources and values* (4th ed.). Golden, CO: Fulcrum Publishing.

Delaney, D. (2001). Making nature/marking humans: Law as a site of (cultural) production. *Annals of the Association of American Geographers, 91*(3), 487-503.

Earth Resource Mapping. 2001. *Using and distributing ECW V 2.0 wavelet compressed imagery*. West Perth, Western Australia: Earth Resource Mapping Pty, Ltd. Retrieved January 2002 from: http://ermapper.com

Edwards, K., & Batson, R.M. (1990). *Experimental digital shaded-relief maps of Utah*. (Miscellaneous Investigations Series, Map I-1847). Denver, CO: U.S. Geological Survey, Map Division.

Edwards, T. C., Homer, C., & Bassett, S. (1997). *Utah gap analysis: An environmental information system*. [CD-ROM]. Logan, UT: U.S.D.I. National Biological Service and Utah State University.

Endangered American Wilderness Act of 1978. Pub. L. No. 95-237, 92 Stat. 40 (1978, February 24).

ESRI. (1998). *ESRI shapefile technical description*. (ESRI White Paper). Redlands, CA: Environmental Systems Research Institute.

ESRI. (2001). *ESRI profile of the content standard for digital geospatial metadata*. (ESRI Technical Paper). Redlands, CA: Environmental Systems Research Institute.

Federal Geographic Data Committee. (1998). *Content standard for digital geospatial metadata.* (FGDC-STD-001-1998). Washington, DC: Federal Geographic Data Committee.

Fell, P.H., & Hansen, D.T. (1997). Construction of a theme keyword thesaurus for indexing search and retrieval across networks. *ESRI User Conference 1997 Proceedings*. Retrieved December 2001 from: http://www.esri.com/library/userconf/proc97/proc97/to200/pap187/p187.htm

Fenneman, N.M. (1931). *Physiography of the western United States*. New York, NY: McGraw Hill.

Fradkin, P.L. (1989). *Sagebrush country: Land and the American West*. Tucson, AZ: University of Arizona Press.

Fritz, S., McCallum, I., Schill, C., Perger, C., Grillmayer, R. Achard, F., et al. (2009). Geo-Wiki.Org: The use of crowdsourcing to improve global land cover. *Remote Sensing, 1*(3), 345-354.

Frost, K., & Goldman, R. (1998). *My Canyonlands* (2nd ed.). Moab, UT, Canyon Country Publications.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., & Tyler, D. (2002). The National Elevation Dataset. *Photogrammetric Engineering & Remote Sensing*, *68*(1), 5-11.

Getty Research Institute. 2001. *Getty thesaurus of geographic names*. Retrieved February 2002 from: http://www.getty.edu/research/tools/vocabulary/tgn/index.html

Goodman, D., & McCool, D. (Eds.). (1999). *Contested landscape: The politics of wilderness in Utah and the west*. Salt Lake City, UT: University of Utah Press.

Greer, D.C., Gurgel, K.D., Wahlquist, W.C., Christy, H.A., & Peterson, G.B. (1981). *Atlas of Utah*. Provo, UT: Brigham Young University Press.

Hall, C.M., & Page, S. (2006). *The geography of tourism and recreation: Environment, place and space* (3rd ed.). London, UK: Routledge.

Hemphill, L.S. (Ed.). (1998). *The Utah water atla*s. Logan, UT: Utah Water Research Laboratory, Utah State University. Retreived February 2011 from: http://www.neng.usu.edu/uwrl/atlas/

Howard, L. (2005). *Utah's wilderness areas: The complete guide.* Boulder, CO: Westcliffe Publishers.

Huete, A., Justice, C., & Leeuwen, W. (1999). *MODIS vegetation index (MOD13) algorithm theoretical basis document*. (Version 3). Greenbelt, MD: NASA Goddard Space Flight Center. Retrieved September 2001 from: http://modis.gsfc.nasa.gov/MODIS/ATBD/atbd-mod13.pdf

IUCN-WCPA & UNEP-WCMC. (1994). *Guidelines for protected areas management categories*. Gland, Switzerland: World Conservation Union, World Commission on Protected Areas and United Nations Environment Programme, World Conservation Monitoring Centre.

Jensen, J.R. (2000). *Remote sensing of the environment: An earth resource perspective*. Upper Saddle River, NJ: Prentice-Hall.

Johnson, J., & Greenfield, P. (1999). *MrSID image compression*. (RSAC-LSP 1900/5100-TIP1). Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, Remote Sensing Applications Center.

Justice, C.O., Vermote, E., Townshend, J.R.G., Defries, R., Roy, D.P., Hall, D.K., et al. (1998). The Moderate Resolution Imaging Spectroradiometer (MODIS): Land remote sensing for global change research. *IEEE Transactions on Geoscience and Remote Sensing*, *36*(4), 1228-1249.

Keiter, R.B., George, S.B., & Walker, J. (Eds.). (1998). *Visions of the Grand Staircase-Escalante: Examining Utah's newest national monument*. Salt Lake City, UT: Utah Museum of Natural History and Wallace Stegner Center.

Kennedy, M., & Kopp, S. (2000). *Understanding map projections*. Redlands, CA: Environmental Systems Research Institute, Inc.

Kilbourne, P. (2001). Interview by the author with Resource Information Manager for the Manti-La Sal National Forest. Price, Utah (2001, November 30).

Kraak, M., & Brown, A. (Eds.). (2001). *Web cartography: Developments and prospects*. London, UK: Taylor & Francis.

Lukez, R., & Wheeler, R. (1991). Mapping the wilderness: Environmentalists use AutoCAD to map Utah's treasures. *Cadence*, October, 75-79.

McDonald, J.R. (1972). *A geography of regions*. Dubuque, IA: William C. Brown.

McGhie, R.G. (1996). *Creation of a comprehensive managed areas spatial database for the conterminous United States*. (Summary Project Technical Report NASA-NAGW-1743. NCGIA Technical Report 96-4). Santa Barbara, CA: NCGIA, University of California.

McHarg, I.L. (1969). *Design with nature*. Garden City, NY: Natural History Press.

Meyer, S., & Landres, P. (2000). A National Wilderness Preservation System Database: Benefits, limitations, and future needs. *International Journal of Wildernes*s, *6*(1), 13-18.

NASA. (2000). *MODIS Land Surface Reflectance Science Computing Facility.* Retrieved September 2001 from: http://modis-land.gsfc.nasa.gov/mod09/ Greenbelt, MD: National Aeronautics and Space Administration, Goddard Space Flight Center.

NASA. (2001). *Global change master directory: A directory of earth science data*. Retrieved September 2001 from: http://gcmd.gsfc.nasa.gov/ Greenbelt, MD: National Aeronautics and Space Administration, Goddard Space Flight Center.

Nash, R.F. (2001). *Wilderness and the American mind* (4th ed.). New Haven, CT: Yale Univ. Press.

National Biological Service. (1995). *State of Utah: Land ownership and administration*. [Map]. United States Department of the Interior Gap Analysis Program. Reston, VA: U.S. Geological Survey.

National Defense Authorization Act for Fiscal Year 2006. Pub. No. 109-163, [Division A-Title III-Subtitle H—Utah Test and Training Range - Sec. 384, Designation and management of Cedar Mountain Wilderness, Utah], 119 Stat. 3217 (2006, January 6).

National Gap Analysis Program. (2010). *Standards and methods manual for state data stewards.* Moscow, ID: National Gap Analysis Program. Retrieved February 2011 from: http://www.gap.uidaho.edu/padus/state_standard2010_Nov14.

National Park Service. (1997). *Nationwide Rivers Inventory*. [CD-ROM]. Washington, DC: National Park Service, Rivers, Trails and Conservation Assistance Program.

NetMarketShare. (2011). *Browser market share news.* Retrieved March 2011 from: http://marketshare.hitslink.com/browser-market-share.aspx?qprid=0

Neumann, A., & Winter, A.M. (2001). *Time for SVG- Towards high quality interactive Web-maps*. Retrieved December 2001 from: http://www.carto.net/papers/svg/

Norton, C., & Catlin, J. (2001). *America's Redrock Wilderness Act: Utah Wilderness Coalition citizens' Utah BLM wilderness proposal*. [Map]. Salt Lake City, UT: Wild Utah Project.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Allnutt, T.F., et al. (2001). Terrestrial ecoregions of the world: A new map of life on Earth. *BioScience*, *51*(11), 933-938. Retrieved February 2011 from: http://www.bio-nica.info/biblioteca/Olson2001NewMapEcoregions.pdf

Omernik, J.M. (1987). Ecoregions of the conterminous United States. *Annals of the Association of American Geographers*, 77(1):118-125.

Omnibus Public Land Management Act of 2009. Pub. L. No. 111-11, [Title I- Subtitle O—Washington County, Utah]. 123 Stat. 1075 (2009, March 30).

Openshaw, S. (1984). *The modifiable areal unit problem*. (Concepts and Techniques in Modern Geography No. 38). Norwich, England: Geo Books, Regency House.

Peterson, M.P. (2001). Maps and the Internet. In R.B. Parry & C.R. Perkins (Eds.), *The map library in the new millennium*. Chicago, IL: American Library Association.

Plewe, B. (1997). *GIS online: Information retrieval, mapping and the Internet*. Albany, NY: OnWord Press.

Plewe, B. (2002). *Utah and Nevada atlas of historical county boundaries*. Provo, UT: Brigham Young University. Retrieved November 2002 from: http://webmap.geog.byu.edu/webmap/atlas.svg

Prior-Magee, J.S., Boykin, K.G., Bradford, D.F., Kepner, W.G., Lowry, J.H., Schrupp, et al. (Eds.). (2007). *Southwest Regional Gap Analysis Project final report.* Moscow, ID: U.S. Geological Survey, Gap Analysis Program.

Protected Areas Database (PAD-US) Technical Working Group. (2009). *PAD-US Technical Report.* San Francisco, CA: PAD-US Partnership. Retrieved February 2011 from: http://www.protectedlands.net/images/PADUSTechnical_Report_Oct_2009.pdf

Ramachandran, V.S. (1988). Perceiving shape from shading. *Scientific American*, August, 76-83.

Richardson, E.R. (1965). Federal park policy in Utah: The Escalante National Monument controversy of 1935-1940. *Utah Historical Quarterly, 33*(2), 109-133.

Ricketts, T.H., Dinerstein, E., Olson, D.M., & Loucks, C.J. (1999). *Terrestrial ecoregions of North America: A conservation assessment.* Washington, DC: Island Press.

Ridd, M.K. (1963). Landforms of Utah in proportional relief. (Map Supplement No. 3). *Annals of the Association of American Geographers, 53*(4) [Map].

Ridd, M.K. (1976). Multiple use. In R. Nash (Ed.), *The American environment: Readings in the history of conservation* (2nd ed., pp. 176-182). Reading, MA: Addison-Wesley Publishing Company.

Riebsame, W.E., & J.J. Robb (Eds.). (1997). *Atlas of the new west: Portrait of a changing region*. New York, NY: W.W. Norton & Company.

Roggenbuck, J.W., Stankey, G.H., & Roth, D.M. (1990). The wilderness classification process. In J.C. Hendee, G.H. Stankey, & R.C. Lucas (Eds.), *Wilderness management* (2nd ed., revised, pp. 123-156). Golden, CO: North American Press.

Rossum, S., & Lavin, S. (2000). Where are the Great Plains? A cartographic analysis. *Professional Geographer, 52*(3), 543-552.

Rudzitis, G. (1996). *Wilderness and the changing American West*. New York: John Wiley & Sons.

Salazar, K. (2010). *Protecting wilderness characteristics on lands managed by the Bureau of Land Management*. Secretarial Order 3310. (2010, December 22). Retrieved March 2011 from: http://www.blm.gov/pgdata/etc/medialib/blm/wo/Communications_Directorate/public_affairs/news_release_attachments.Par.26564.File.dat/sec_order_3310.pdf

Seaber, P.R., Kapinos, F.P., & Knapp, G.L. (1987). *Hydrologic unit maps: U.S. Geological Survey water-supply paper 2294.* Washington, DC: U.S. Geological Survey.

Snyder, J.P. (1987). *Map projections – a working manual*. (U.S. Geological Survey Professional Paper 1395). Washington, DC: U.S. Government Printing Office.

Southern Utah Wilderness Alliance. (2010). Utah wilderness. Our heritage. Worth protecting. Salt Lake City, UT: Southern Utah Wilderness Alliance. Retrieved January 2011 from: http://www.utahwilderness.org

Sprinkel, D.A. (1999). *Digital geologic resources atlas of Utah*. [CD-ROM]. (Bulletin 129DF). Salt Lake City, UT: Utah Geological Survey.

Stokes, W.L. (1977). *Physiographic subdivisions of Utah* [Map]. Salt Lake City, UT, Utah Geological Survey.

Svensson, P. (2008). Creator of Web spots a flaw in Internet Explorer. Associated Press (MSNBC). Retrieved March 2011 from:http://www.msnbc.msn.com/id/26646919

Swanson, F. (1999). *America's redrock wilderness: Protecting a national treasure*. Salt Lake City, UT: Southern Utah Wilderness Alliance.

Switalski, T. Adam, T.S., Duncan, S.L., Chavez, A.S., & Schmidt, R.H. (2002). *Wolves in Utah: An analysis of potential impacts and recommendations for management.* Natural Resources and Environmental Issues Volume X. Logan, UT: Utah State University College of Natural Resources.

Thomson, J.L., Hartley, D.A., Aplet, G.H., & Morton, P.A. (2000). Assessing interconnections between wilderness and adjacent lands: The Grand Staircase-Escalante National Monument, Utah. In S.F. McCool, D.N. Cole, W.T. Borrie, & J. O'Loughlin (Eds.), *Proceedings: Wilderness Science in a Time of Change conference— Volume 2: Wilderness within the context of larger systems*. (RMRS-P-15-VOL-2). Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Tucker, C.J., Grant, D.M, & Dykstra, J.D. (2004). NASA's global orthorectified Landsat data set. *Photogrammetric Engineering & Remote Sensing*, *70*(3), 313–322.

USDA Forest Service. (1967). *A proposal: High Uintas Wilderness, Ashley & Wasatch National Forests, Utah*. Washington, DC: USDA Forest Service.

USDA Forest Service. (1993). *National hierarchical framework of ecological units*. ECOMAP. Washington, DC: USDA Forest Service.

USDA Forest Service. (1997). High Uintas Wilderness management plan and forest plan amendment. Vernal, UT: Ashley National Forest. Retrieved May 2011 from: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5270268.pdf

U.S. Department of Commerce, National Telecommunications and Information Administration. (2011). *Digital nation: Expanding Internet usage.* NTIA Research Preview. Retrieved May 2011 from: http://www.ntia.doc.gov/reports/2011/NTIA_Internet_Use_Report_February_2011.pdf

U.S. District Court, District of Utah. (2003). *State of Utah v. Gale Norton: Stipulation and joint motion to enter order approving settlement.* (2003, April 11) . Retrieved March 2011 from: http://www.utahwildernessatlas.net/documents/docs/apr_2003_settlement.pdf

USGS. (2000). *USGS EROS Data Center Distributed Active Archive Center*. Retrieved September 2001 from: http://edcdaac.usgs.gov/modis/mod09a1.html Sioux Falls, SD: EDC DAAC User Services, U.S. Geological Survey EROS Data Center.

USGS. (2001). *Accuracy assessment of 1992 National Land Cover Data: Methods and results*. Retrieved March 2011 from: http://landcover.usgs.gov/accuracy/ Washington, DC: U.S. Department of the Interior, U.S. Geological Survey.

Utah Geographic Alliance. (1997). *Utah GAP Education Project: Ecoregions, wilderness, wildlife and habitats*. [CD-ROM]. Utah Geographic Alliance Education CD-ROM Series. Logan, UT: Utah Geographic Alliance and Utah State University.

Utah AGRC. (1995). *Utah State Geographic Information Database* [CD-ROM]. Salt Lake City, UT: Utah Information Technology Services, Automated Geographic Reference Center.

Utah AGRC. (2010a). *Utah GIS Portal*. Retrieved October 2010 from: http://agrc.its.state.ut.us/ Salt Lake City, UT: Utah Information Technology Services, Automated Geographic Reference Center.

Utah AGRC. (2010b). *Maps.utah.gov Utah map access portal*. Retrieved October 2010 from: http://maps.utah.gov/ Salt Lake City, UT: Utah Information Technology Services, Automated Geographic Reference Center.

Utah School and Institutional Trust Lands Administration. (2001). *Land ownership: January, 2001*. [Map]. Salt Lake City, UT: State of Utah School and Institutional Trust Lands Administration.

Utah Wilderness Act of 1984. Pub. L. No. 98-428, 98 Stat. 1657 (1984, September 28).

Utah Wilderness Association. (1985). *Defend the desert: Wilderness proposals for Utah's BLM lands.* Salt Lake City, UT: Utah Wilderness Association.

Utah Wilderness Coalition. (1985). *Utah citizens' BLM wilderness proposal*. Salt Lake City, UT: Utah Wilderness Coalition.

Utah Wilderness Coalition. (1990). *Wilderness at the edge: A citizen proposal to protect Utah's canyons and deserts*. Salt Lake City, UT: The Utah Wilderness Coalition**.**

Van Cott, J.W. (1990). *Utah place names*. Salt Lake City, UT: University of Utah Press.

Van Elzakker, C.P.J.M. (2001). Users of maps on the Web. In M. Kraak & A. Brown (Eds.), *Web cartography: Developments and prospects*. London, UK: Taylor & Francis.

Vaughn, D., & Wight, D.W. (1995). *Utah State Geographic Information Database*. Salt Lake City, UT: Utah Automated Geographic Reference Center.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., & Van Driel, N. (2001). Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources. *Photogrammetric Engineering and Remote Sensing,* 67(6):650-652.

Watkins, T. H. (2000). *The redrock chronicles: Saving wild Utah*. Baltimore, MD: The Johns Hopkins University Press.

Wertz, W.A., & Arnold, J.F. (1972). *Land systems inventory*. Ogden, UT: USDA Forest Service, Intermountain Region.

Wharton, T. (1997, January 14). Can Utah move from square one on wilderness? *Salt Lake Tribune*.

Wilderness Act. (1964). Pub. L. No. 88-577, 78 Stat 890 (1964, September 3).

Wilkison, B. (2006, April 17). Enviros wary of 'Nevada-style' wilderness bill. *High Country News*. Retrieved March 2011 from: http://www.hcn.org/issues/320/16231