

CHANGE DETECTION OF LAND COVER IN A MEADOW LANDSCAPE: THE
“RANCHES” MEADOW, SILVER FALLS STATE PARK, OREGON

By

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**CHANGE DETECTION OF LAND COVER IN A MEADOW
LANDSCAPE: THE “RANCHES” MEADOW, SILVER FALLS
STATE PARK, OREGON**

ABSTRACT

From a landscape ecology perspective, meadows are often seen as landscapes in transition. Succession and change in meadows may be investigated by considering the physical and anthropogenic factors that influence the landscape through time. What is often unknown is how changes occur and how physical and anthropogenic factors contribute to these changes. The purpose of this study was to investigate land cover changes between 1947 and 2003 in the “Ranches” meadow, located within Silver Falls State Park, Oregon, and examine what physical and anthropogenic factors played a role in these changes. The analysis was conducted by interpreting land cover patterns from historical information, aerial photographs, and GIS data. The basic land cover changes observed were that forest cover doubled in size, grassland and shrub cover were reduced by half, and wetland cover grew by 9% between 1947 and 2003. The factors of slope, historic vegetation, and land ownership all strongly influenced the nature and distribution of these land cover changes. These results will provide land managers with information useful for future restoration efforts and researchers with additional findings to consider related to the landscape ecology of meadows.

1 INTRODUCTION

Meadows are areas of “closed herbaceous vegetation, in stands of limited extent (Alaska Geobotany Center 2007).” Meadows favor specific ecological and topographical conditions, such as ridgetops, where soils are too thin to support trees, or poorly drained depressions, where soils tend to be saturated (USDA 2007). However, they may also exist on moist slopes where trees are normally abundant (USDA 2007). Meadows may form due to human- or lightning-caused fires, logging, and agriculture, in conjunction with other factors, such as topography, climate, and soil conditions (Lepofsky et al. 2003; Bai et al. 2004). They play multiple roles in natural landscapes, as they promote the proliferation of a wide variety of plant species, including rare species, offer habitat for wildlife, and supply wildlife viewing and hiking opportunities in a unique ecosystem (Halpren 1999; USDA 2007).

Meadows are often seen as being transitory, but Benedict (1982) indicated that meadows might instead be “as stable over time as the surrounding vegetation (148).” A meadow might be “biologically” stable if its particular species composition doesn’t change over time, or “geologically” stable if its geologic conditions are likely to persist (i.e. a more stable bedrock dam versus less stable moraine dam) (Benedict 1982). Still, vegetation succession in meadows may be part of “natural migrations, demographic responses to climate, or prehistoric human impacts” that are indicative of a recovering landscape (Swetnam, Allen, and Betancourt 1999: 1196).

Land cover succession and change in meadows may be investigated by considering the physical and anthropogenic factors that influence a landscape through

time, which could be considered a study into the ecology of the landscape. Landscape ecology is the study of how spatial variations in the landscape affect ecological processes (Turner, Gardner, and O'Neill 2001). Studies in the field of landscape ecology analyze heterogeneous areas through time to determine what drives ecological processes within these environments (Turner and Gardner 1991). German biogeographer Carl Troll first introduced the term “landscape ecology” in 1939 to describe vegetation changes on a regional scale (Turner, Gardner, and O'Neill 2001). A central idea to landscape ecology is the examination of landscape on a holistic scale, accounting for both the physical processes and human activities that combine to alter ecosystems.

Meadows located in parks and natural areas are ideal places to study land cover change, since they are often managed to protect and promote natural vegetation conditions (US DOI 1992). This study will examine land cover changes in the “Ranches” meadow¹, a historically significant area in the central region of Silver Falls State Park, Oregon. The planning division of the Oregon Parks and Recreation Department is currently undergoing a master plan update for Silver Falls State Park, located in the foothills of the Cascades on the eastern edge of the Willamette Valley (**Figure 1.1**). Information regarding land cover conditions in the Ranches meadow is required in order to manage the ecosystem for the benefit of native flora and fauna as well as the enjoyment of visitors. The Department’s goal for the meadow is to protect native vegetation communities, provide browse for wildlife, and maintain this uniquely open area. The management steps required in order to fulfill these goals

¹ Hereafter referred to as “Ranches meadow”

include the eradication of invasive species, replanting of native grasses, and removal of encroaching vegetation such as *Psuedotsuga menzesii* (Douglas fir) and *Spiraea douglasii* (Douglas spiraea).

In this research paper, the dynamics of land cover change within the Ranches meadow and surrounding section² were explored. The dual purpose of the study was to investigate patterns of land cover change within the section between 1947 and 2003, and to understand how physical and anthropogenic factors contributed to these land cover changes. The analysis was conducted by interpreting land cover patterns from historical information and a time series of aerial photographs. The results will provide managers with information useful for future restoration efforts and researchers with additional findings to consider related to the landscape ecology of meadows.

² The section referred to throughout this study is Township 8 South, Range 1 East, Section 13, Willamette Meridian.

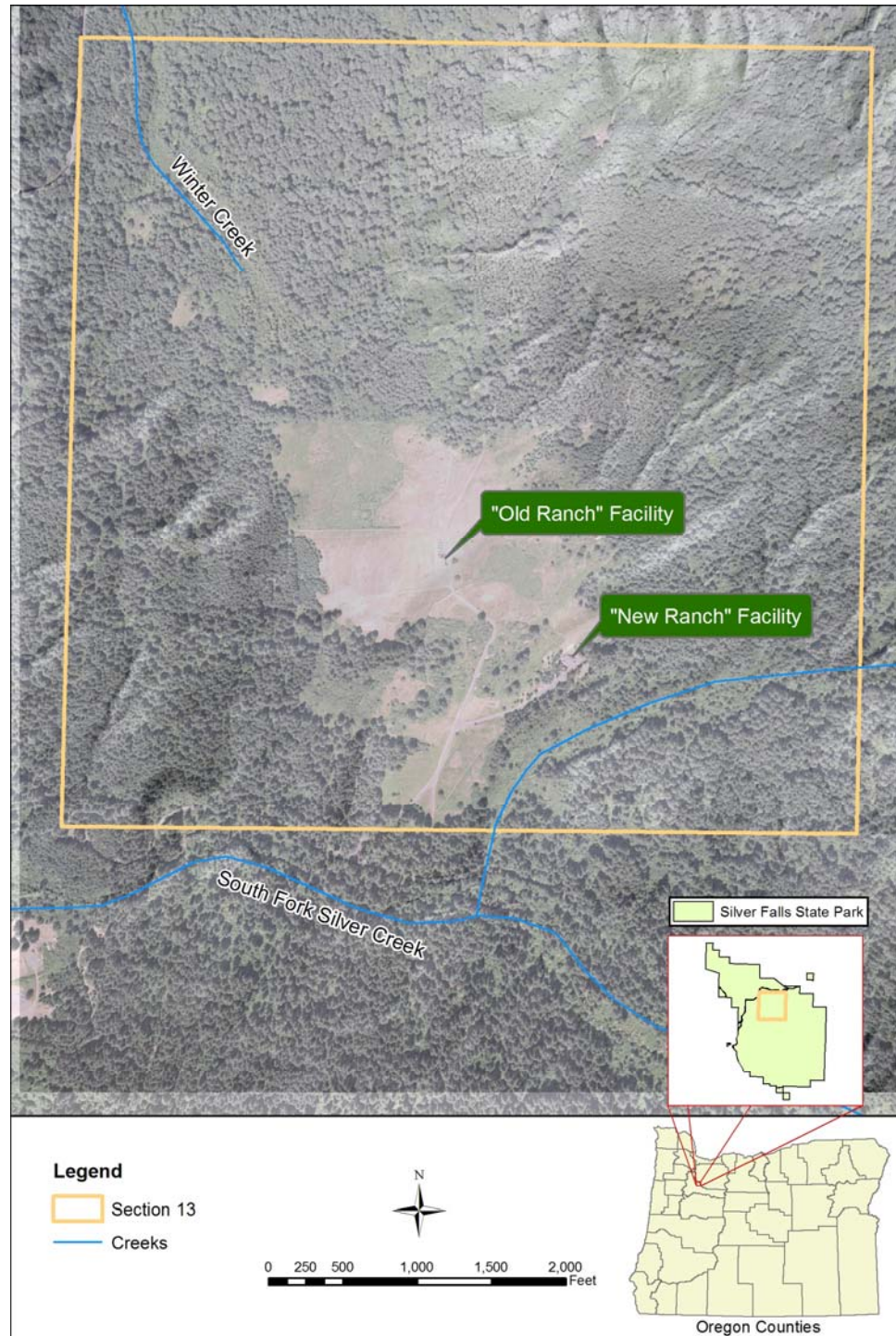


Figure 1.1 - Study Location: T8S R1E Section 13, Willamette Meridian
 Sources: Oregon Geospatial Enterprise Office (OGEO) 2007; Oregon Parks and Recreation Department (OPRD) 2007, Bureau of Land Management (BLM) 2003
 Map Author: Carl Anderson 2007

2 Meadows as Changing Landscapes

In order to analyze land cover changes in a meadow, it is necessary to consider the original conditions of the meadow, the physical and anthropogenic factors that have influenced land cover changes within it, and the pathways that these changes have taken through time (Lepofsky et al. 2003). This type of analysis can help to determine what key factors influence land cover change within meadows. Without knowledge of these baseline conditions and subsequent patterns of change, land managers lack the information needed to complete organizational objectives, such as restoring native species, eliminating invasive species, or improving habitat (Helms and Johnson 1996). Change detection techniques can be used to understand the characteristics of land cover change in meadows (Dyer and Moffet 1999; Hadley 1999; Lepofsky et al 2003; Bai et al 2004.)

2.1 Vegetation Change

“Natural” vegetation conditions within meadows exist and change because of localized physical factors such as topography, soil composition, climate, naturally-caused fire, vegetation history, as well as anthropogenic actions such as prescribed fire, grazing patterns, timber extraction, and vegetation management (Arno and Gruel 1986; Lepofsky et al. 2003). Natural vegetation is “perceived as the structure and composition of vegetation at the time of European contact and settlement (Taylor 1990: 457).” Two types of changes to natural vegetation that have been documented in meadows and/or grasslands include conifer encroachment (Franklin et al. 1971; Dunwiddie 1977; Vale 1977; Vale 1981; Agee and Smith 1984; Arno and Gruell

1986; Butler 1986; Taylor 1990; Magee and Antos 1992; Dyer and Moffett 1999; Hadley 1999; Lepofsky et al. 2003) and the introduction of invasive species (Hoshovsky 1986; Halpren 1999; Clark and Wilson 2001; Parker 2001; Ciesla 2002; Gray 2002).

2.1.1 Physical Factors Influencing Vegetation Change Within Meadows

Many meadows had historically existed apart from anthropogenic activities, indicating that there are physical factors that help explain why meadows originally existed and continue to persist today (Morris 1934; Stewart 1951; Lepofsky et al. 2003). Among these factors are topography, soils, climate, fire history and vegetation. As noted previously, meadows tend to favor ridgetops and depressions, and typically form in broad and flat valley bottoms (Harker et al. 1999), but also may exist in places where trees normally flourish (USDA 2007). High-elevation meadows are less likely to experience vegetation change if they are above treeline (Harker et al. 1999). Dry meadows often occur on soils with poor profile development, while wet meadow soils may range from “poorly drained hydric to dry, gravelly soils (Harker et al. 1999).” Changes in climate can create barriers to or accelerate vegetation changes within and surrounding meadows (Franklin et al. 1971; Vale 1981; Agee and Smith 1984; Butler 1986; Taylor 1990; Magee and Antos 1992; Dyer and Moffett 1999). Frequent fires in meadows can help grasses and forbs thrive and reduce the establishment of trees into meadows, while declines in fire frequency may promote vegetation succession (Habeck 1961; Arno and Gruel 1986; Hadley 1999; Boyd 1999). Existing vegetation

will tend to influence the future vegetation of a meadow unless acted upon by an outside natural or human-caused disturbance or condition (Benedict 1982).

2.1.2 Anthropogenic Actions Influencing Vegetation Change in Meadows in the Western United States

Native Americans had been burning Willamette Valley prairie for centuries prior to European settlement. With the influx of settlers into the American West, meadows and surrounding forestlands in western Oregon began to be utilized for resource extraction and economic production, which included timber harvesting, agriculture, and ranching. More recently, meadows included within local, state, or national parks and preserves may have undergone vegetation management treatments, the goal of which is to restore an ecosystem to a “natural” or desired state. Often, historic vegetation communities within meadows have been altered as a result of these anthropogenic actions.

2.1.2.1 Prescribed Fire

It is well documented that Native Americans utilized prescribed burning in meadow and grassland environments to assist with hunting and to improve food-gathering conditions (Habeck 1961; Arno and Gruel 1986; Hadley 1999; Boyd 1999). This included improving food sources in forest clearings, where berry crops such as “wild blackberry (*Rubus ursinus*)..., species of huckleberry (*Vaccinium* spp.), salal (*Gaultheria shallon*), blackcaps (*Rubus leucodermis*), thimbleberry (*Rubus parviflorus*), and salmonberry (*Rubus spectabilis*)” thrived after fire (Boyd 1999: 121).

The fires were generally set during the late summer and early fall (Boyd 1999). Fires in the Willamette Valley were more frequent between 1650 and 1850, because after 1850, these annual burns ceased (Sprague and Hansen 1946, as quoted in Habeck 1961; Boyd 1999). A result of the decrease in these annual burns is that, within the valley proper, forest cover has increased and now covers most areas not cultivated or grazed (Boyd 1999).

2.1.2.2 Timber Harvesting

Meadows in forested landscapes have often been enlarged due to forest clearing, either to obtain lumber or to clear land for agricultural use or both (Hadley 1999). This, in turn, would allow for sun-tolerant species to thrive, particularly if the cut was replanted after harvest. For instance, Douglas fir (*Pseudotsuga menziesii*) regenerates quickly on dry, exposed sites, which are readily available after clear-cutting (Cole 1977). Clear-cut logging promotes the growth of Douglas fir over other pre-European fire-adapted Willamette Valley tree species such as ponderosa pine (*Pinus Ponderosa*) and Oregon white oak (*Quercus garryana*) as well as shade-tolerant species such as grand fir (*Abies grandis*) and Pacific dogwood (*Cornus nuttallii*) (Cole 1977: 11). The result of clear-cut logging and replanting of monoculture stands is a decrease in forest specimen diversity, which may impact adjacent meadows.

2.1.2.3 Grazing

Meadow ecosystems used for grazing may be altered in many ways. As the animals graze, they rework native vegetation communities by reducing preferred grazing plant populations, compacting soils, redistributing nutrients, modifying drainage networks and landforms, and changing the behaviors of wild grazing ungulates (Cole and Landres 1996). The introduction of these characteristics can lead to changes in the vegetation structure of a meadow as opportunities are created for different species to establish themselves due to less competition (Hobbs and Huenneke 1992). Even tree establishment rates can be increased due to grazing (Madany and West 1983). However, with the improvement of grazing management practices, meadows have the ability to regenerate. For example, it was found that after sheep grazing was reduced within the Wallowa Mountains between 1938 and 1978 to 60% of 1938 capacity, a Green Fescue meadow was brought back to a “climax” condition in which “the climax grass species occurs in an almost pure stand (Reid, Strickler and Hall 1980: 9).”

2.1.2.4 Vegetation Management

Due to fire suppression policies over the past century and continued climate warming trends, meadows are at risk because of the encroachment of sun-tolerant trees (Franklin et al 1971; Vale 1981; Agee and Smith 1984; Magee and Antos 1992; Hadley 1999; Lepofsky et al. 2003). Consequently, land managers may attempt meadow restoration by removing trees from the fringes of the meadow (Dewald and

Springer 2001). Removing trees allows other desirable species greater access to sunlight and water resources, reduces the area of seed dispersal and maintains wildlife habitat.

Vegetation within meadows may also be managed to retain or restore specific ecosystem functions, vegetation communities, or endangered species. A major focus of restoration efforts is to eradicate a particular invasive alien species. The typical methods used to remove unwanted vegetation include mechanical (mowing, grinding, or hand-pulling), chemical (herbicides), biological (insects), burning and thinning. For example, hand pulling, mowing, and herbicide application are methods used to remove woody invasive species (Huckins and Soll 2004; Clark and Wilson 2001).

2.1.2.5 Introduction of Invasive Species

Timber harvesting, grazing and vegetation management are ways that humans have purposely changed meadow vegetation patterns. An unintended consequence of these actions has been the introduction of invasive species. As settlers came to the western United States in the mid-19th century, they brought along seeds of non-native plants, either purposefully for ornamental or agricultural purposes, or unknowingly by means of themselves and their possessions (Pojar and MacKinnon 1994; Pauchard and Shea 2006). To call a plant an invasive species is to give it an anthropocentric label indicating that it is out of place in an ecosystem. The Invasive Species Advisory Committee defines an invasive species as “a non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human, animal,

or plant health. (ISAC 2006).” Some of the effects of invasive species include reductions in biodiversity, exclusion of native species, decreases in the variety and vitality of grazing and forage species for wildlife and domestic animals, and the depletion of soil and water resources (Randall 2000).

Invasive species are generally first invaders and thrive in disturbed landscapes. When a forest is thinned, for example, the landscape is opened up to sun-tolerant invasive species (USDA Forest Service 2005). Another example is the spread of spotted knapweed (*Centaurea maculosa*) as a contaminant in alfalfa seeds brought to the Pacific Northwest in the 1800s (USDA Forest Service 2005). Logging and agricultural technologies are both catalysts for the establishment of invasive species to new areas.

2.1.3 Tree Encroachment as a Type of Vegetation Change in Meadows

An occurrence that has become a relatively recent concern of researchers and resource managers aiming to protect and restore natural vegetation conditions is the encroachment of trees into meadows. A combination of factors is usually responsible for this phenomenon, including climate variation, fire history, and grazing intensities (Dyer and Moffett 1999). It is often difficult to isolate the significance of each of these factors, because implementation of fire suppression policies and the allotment of grazing rights occurred nearly simultaneously in the American West in the late 19th and early 20th centuries (Dyer and Moffett 1999).

Climate variations between warm and cold or wet and dry types have impacted different meadow ecosystems in different ways. A warm climate promoted conifer

establishment due to extended growing seasons in Mt. Rainier National Park (Franklin et al. 1971), the Lemhi Mountains of Idaho (Butler 1986), and in southwest British Columbia (Lepofsky et al. 2003). A wet climate contributed to conifer establishment in the western Cascades of Oregon (Vale 1981), Lassen Volcanic National Park, California (Taylor 1990), Mary's Peak, Oregon (Magee and Antos 1992), and the White Mountains of New Mexico (Dyer and Moffett 1999). Increased levels of precipitation during the growing season contributed to rapid tree establishment in a meadow in the Oregon Coast Range (Magee and Antos 1992: 492). A dry climate allowed for tree invasion due to extended growing seasons in Olympic National Park (Agee and Smith 1984).

The fire regime of a landscape can play a crucial role in determining the establishment of tree seedlings in an open meadow. As mentioned above, effective fire suppression was established in much of the United States near the end of the 19th century and beginning of the 20th century, which allowed for the “establishment of tree seedlings and survival of saplings (Dyer and Moffett 1999: 450).” Natural- and human-started fires played a role in preventing tree establishment in six Oregon montane meadows and in Lassen Volcanic National Park, particularly prior to the 1930's, when fire sizes started decreasing dramatically (Vale 1981; Taylor 1990). Fire succession, which is the establishment of trees as the result of a fire, can also happen in meadows. For example, rates of tree establishment increased after a fire in one meadow in the Lemhi Mountains of Idaho (Butler 1986).

Finally, livestock grazing has played an important role in affecting the rates of tree establishment in meadows. The intensity of grazing is the main variable that influences conifer encroachments, but various studies have found different relationships between grazing intensities and encroachment patterns. Tree establishment peaked due to the denuding of competing vegetation in the Warner Mountains, California, and in the Galena Gulch Demonstration Area when grazing intensity was at a high level (Vale 1977; Arno and Gruell 1986). In the Wind River Mountains, Wyoming, tree establishment occurred more frequently when grazing levels were moderate, and virtually ceased once grazing ceased (Dunwiddie 1977). In the western Cascades of Oregon, tree invasions started only after the cessation of sheep grazing (Vale 1981; Hadley 1999). In Lassen Volcanic National Park, tree establishment rates increased when sheep grazing ceased but cattle grazing remained and increased again when all grazing had ceased (Taylor 1990). The initial introduction of grazing between 1925 and 1945 in the Lemhi Mountains, Idaho, increased tree establishment rates, but continued heavy grazing reduced the rates of encroachment (Butler 1986).

The studies cited above illustrate the uncertainty regarding the most important factors influencing tree encroachment into meadows. Several factors proved to be common between some studies, but each study had site-specific variations (**Table 2.1**). For example, warmer climates may promote meadow invasion in high elevation meadows, because this provides a longer growing season. Specifically, a drought period in the Pacific Northwest from approximately 1920 to 1940 allowed for

increased tree invasion in wet subalpine meadows (Franklin et al. 1971; Agee and Smith 1984; Butler 1986). However, this might have inhibited invasion in lower elevation meadows as seedlings fought to acquire sufficient moisture and fire frequency increased, endangering the establishment of smaller trees (Hadley 1999).

Table 2.1 - Tree Encroachment Studies and Factors Influencing Encroachment

Study	Meadow Location	Factors Influencing Encroachment
Franklin et al. (1971)	Mt. Rainier National Park, WA	Warm climate extends growing season
Dunwiddie (1977)	Wind River Mountains, WY	Moderate grazing levels promote invasion, cessation of grazing stops tree invasion
Vale (1977)	Warner Mountains, CA	Heavy grazing promotes high level of invasion
Vale (1981)	Western Cascades, OR	Tree invasion occurs only after the cessation of grazing; Decrease in large fires promotes invasion; Wet climate promotes rapid tree establishment
Agee and Smith (1984)	Olympic Mountains, WA	Dry Climate extends growing season
Arno and Gruell (1986)	Galena Gulch, MT	Heavy grazing promotes high level of invasion
Butler (1986)	Lemhi Mountains, ID	Warm climate extends growing season; Fire event promotes increased tree establishment; Introduction of grazing and a warmer climate combined to increase rates of establishment in one meadow
Taylor (1990)	Lassen Volcanic National Park, CA	Decreases in grazing promote tree establishment; Decreases in large fires promote invasion; Wet climate promotes rapid tree establishment
Magee and Antos (1992)	Mary's Peak, OR	Wet climate promotes rapid tree establishment
Dyer and Moffett (1999)	White Mountains, NM	Wet climate promotes rapid tree establishment
Hadley (1999)	Western Cascades, OR	Tree invasion occurs only after the cessation of grazing
Lepofsky et al. (2003)	Southwest British Columbia	Warm climate extends growing season

2.2 Protected Areas

In some instances, native meadow landscapes have been modified substantially by humans, but may subsequently be included in protected areas, such as local, state, and national parks, federal lands managed by the Department of the Interior or Department of Agriculture, and lands owned by private non-profit organizations. The International Union of Nature Conservation (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, managed through legal or other effective means (United Nations 2000).” Therefore, management of protected areas depends on the goals and mandates of the managing agency or organization. Management techniques in protected areas within the United States range from light-handed to heavy-handed. Legally declared wilderness areas require the use of non-motorized vehicles and tools (Wilderness Act of 1964), National Parks allow for slightly more landscape modification (United States of America 1872), and state and local parks may use the most intrusive landscape management techniques (Oregon Parks and Recreation Department Natural Resource Management Objectives 2007). Some types of protected areas may also be managed under a “multiple-use” paradigm, where resource extraction is allowed and maintaining natural conditions may be a secondary goal (Multiple-Use Sustained-Yield Act of 1960).

A primary goal of protected area managers is to enhance the native biodiversity of the terrain they are charged with protecting (US DOI 1992; OPRD 2007). This enhancement includes the “retention, restoration, or improvement of

specific habitats to benefit wildlife and botanical species (US DOI 1992: 3).”

According to a handbook designed for “forest vegetation management in recreation and historic parks,” produced by the Virginia Cooperative Extension (1996), “Control of exotic species can be justified when they threaten to alter natural ecosystems; seriously restrict, prey on, or compete with native populations; cause a major scenic or aesthetic intrusion; or disrupt the integrity of an historic site (4).” In order to accomplish these goals, it is useful for managers to understand which historic conditions of the vegetation are desired and how the vegetation regime has been altered since these “primitive” conditions.

2.3 Change Detection

Land cover change detection is a subject of study that can help land managers better understand how, when and where plants have encroached upon native meadow habitats. Various techniques have been used to reconstruct past landscapes and translate these conditions through time to determine why particular land cover types invade specific portions of a meadow. A combination of remote sensing imagery, aerial photography, vegetation measurements (such as tree coring, diameter at breast height, fire scars), soil samples (horizon types), fire history, and cultural history may be used to estimate when and how the meadow was established, and how its land cover has changed over time (Lepofsky et al. 2003).

Change detection is “the process of comparing spatially explicit databases from two different time periods to determine the location and nature of changes over

time (Johnston 1998: 119).” The use of remote sensing imagery or aerial photographs versus traditional vegetation field methodologies provides an advantage in that they show absolute change for a population instead of statistically significant change derived from a sample (Johnston 1998). When comparing two or more land cover classes, a matrix approach may be used to distinguish transitions between land cover classes across two time periods (Simpson et al. 1994; Johnston 1998; Jones 1998; Kennedy and Spies 2004). Analysis of tree invasions into meadows can be accomplished using aerial photographs and change detection techniques, including geographic information systems (GIS) (Dyer and Moffet 1999; Hadley 1999; Lepofsky et al 2003; Bai et al 2004). A geographic information system (GIS) is an information system that describes objects and events in relationship to an explicit geographic location (Longley et al. 2001).

3 RESEARCH QUESTIONS

The Ranches meadow is a landscape that has been affected by physical and anthropogenic factors through time. What is unknown is exactly how the meadow has changed and how important each of the previously discussed factors has contributed to this change. The following questions will be examined in this study:

1. How has the land cover of the Ranches meadow and the surrounding section changed through time?
2. How has the land cover in the historic meadow³ of 1874 changed, and how do these changes compare to changes in the surrounding section?
3. What role and to what magnitude did physical factors play in contributing to land cover change in the meadow?
4. How did anthropogenic factors impact the land cover of the meadow?

The following steps were taken in order to answer these research questions: (1) relevant aerial photographs and historical data sources were gathered, (2) a geographic information system (GIS) database was compiled, and (3) a GIS analysis was completed. This enabled a change detection analysis of land cover between 1947 and 2003 to be conducted within Township 8 South, Range 1 East, Section 13 and the historic meadow. The change detection results of the section were then compared with those of the historic meadow. Finally, a GIS-based approach was used to determine how physical and/or anthropogenic factors were associated with land cover changes within the section.

³ As delineated from Simpson, B. 1874. Township 8 South Range 1 East Willamette Meridian Oregon. US Surveyor Generals Office. Map.

4 METHODS

4.1 Site Description

4.1.1 *Topography, Climate, and Soils*

Silver Falls State Park is located in the western-most reaches of the Cascades and on the eastern fringe of the Willamette Valley, at elevations ranging between 700 and 3000 feet (Armstrong 1965: 192). The elevation range of the study section is 1380 to 1909 feet (**Figure 4.1**). The Willamette Valley receives approximately 40 inches of rainfall per year, most of which arrives in the form of rain from December to March (Habeck 1961). Based upon data from the USDA National Resource Conservation Service (NRCS) (2002), between 1961 and 1990, the meadow averaged an estimated 81.75 inches of precipitation per year, with the highest amount being 12.5 inches in December and the lowest amount being 1.25 inches in July. The average daily temperature ranges from 37.5° F in January to 61.9° F in August, (USDA NRCS 2002) (**Figure 4.2**). There are four soil map unit types in the study section (**Figure 4.3**): Horeb, Kinney, McCully, and Minniece (USDA NRCS 2006). The following soil descriptions are from the USDA NRCS:

The Horeb soil, gravelly substratum phase, is over 60 inches deep to bedrock, gravel and sand are below 40 inches. It is loamy, well drained and occurs on terraces and mountains. Permeability is rapid. Water erosion is a potential hazard. The Kinney soil, bedrock substratum phase, is 40 to 60 inches deep to bedrock. It is loamy, well drained and occurs on mountains. Water erosion is a potential hazard. The McCully soil, bedrock substratum phase, is 40 to 60 inches deep to bedrock. It is clayey, well drained and occurs on mountains. Water erosion is a potential hazard. The Minniece soil is over 60 inches deep to bedrock. It is clayey, somewhat poorly and poorly drained, and occurs on

terraces. Permeability is very slow. This soil is subject to flooding. A water table is present during late fall, winter and early spring. This is a hydric soil.

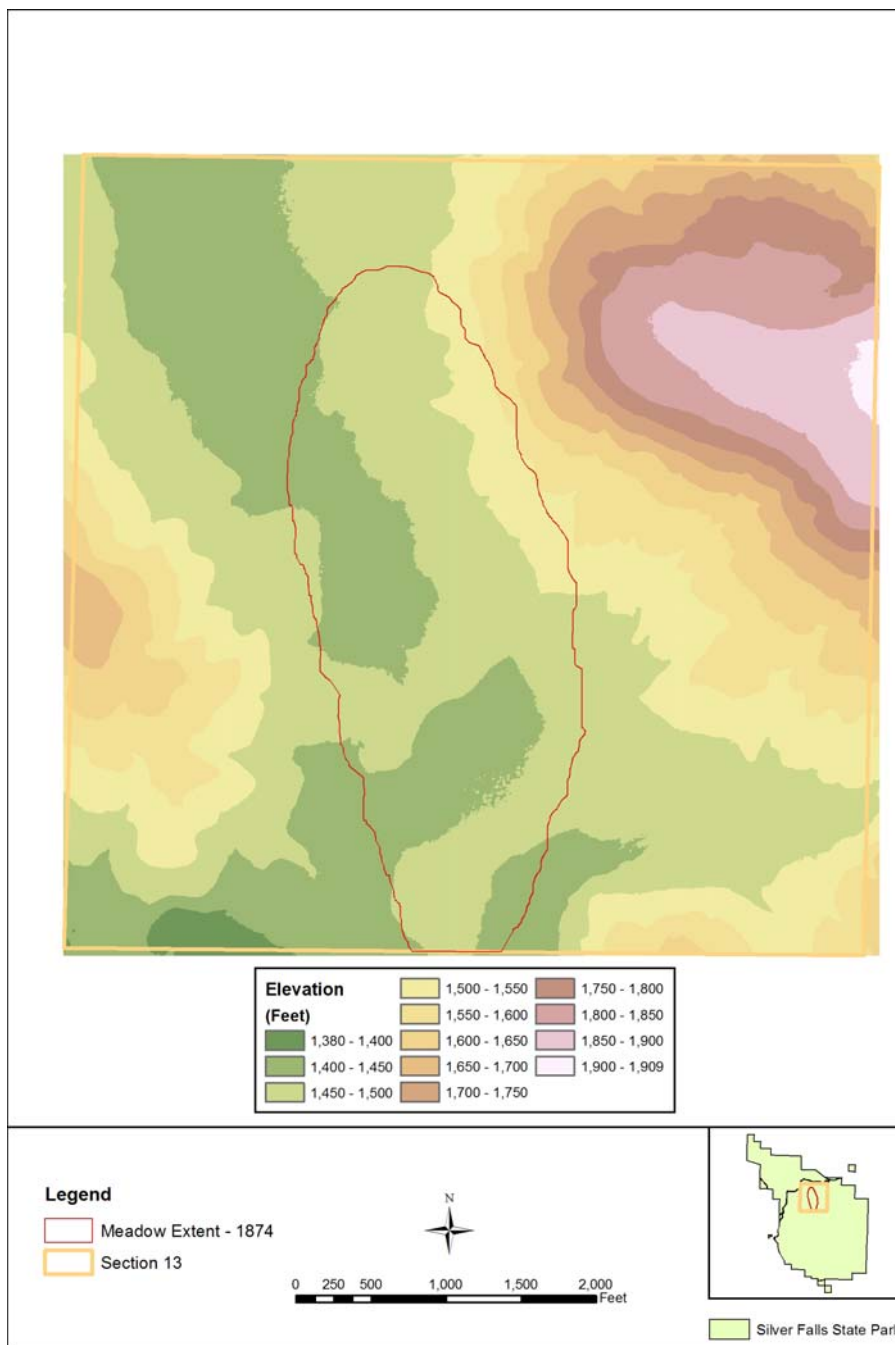


Figure 4.1 – Elevation: T8S R1E Section 13 Willamette Meridian
 Sources: Oregon Parks and Recreation Department (OPRD) 2007; Simpson 1874
 Map Author: Carl Anderson 2007

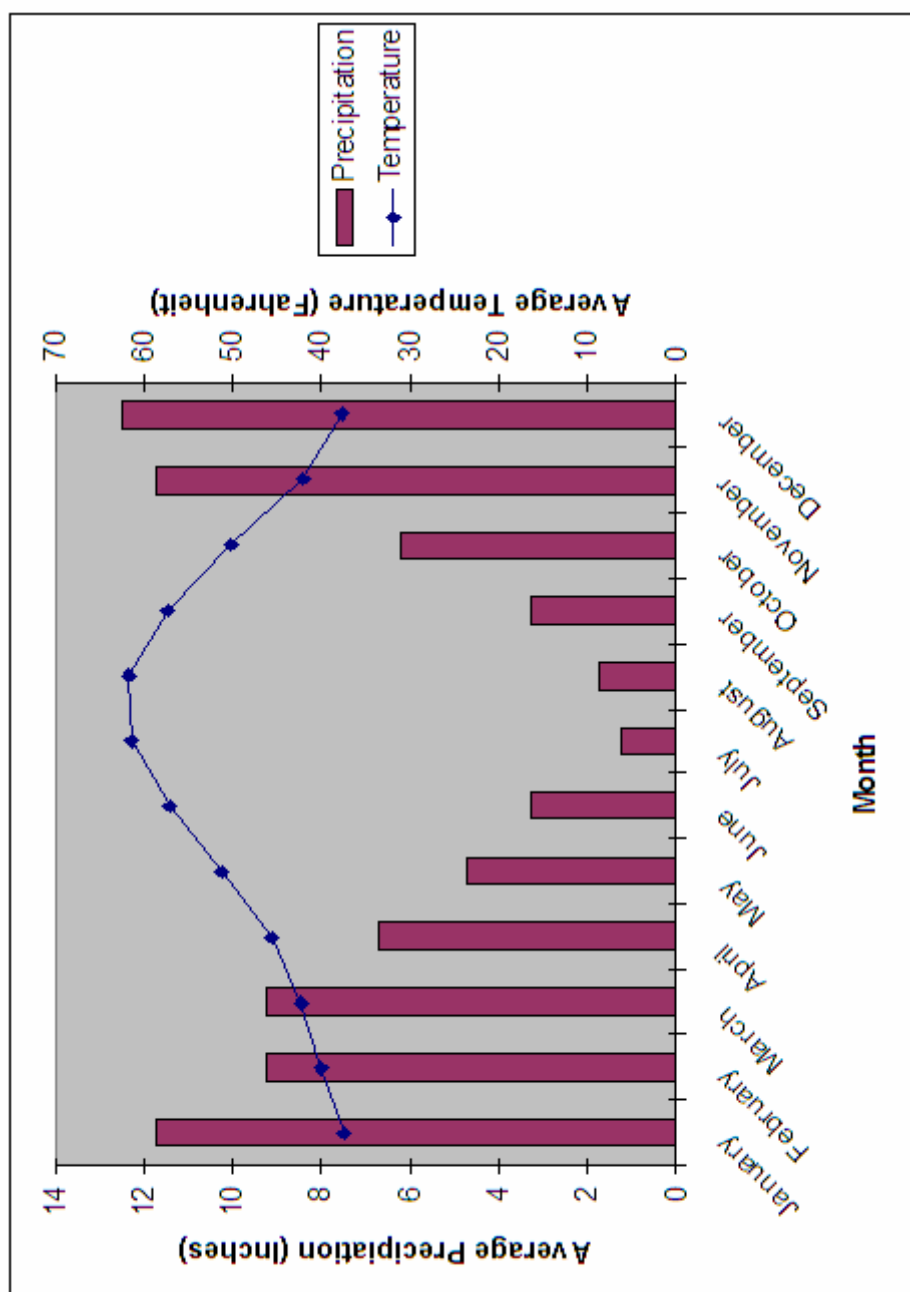


Figure 4.2 - Climograph for T8S R1E Section 13 Willamette Meridian between 1961 and 1990
Source: USDA NRCS 2002

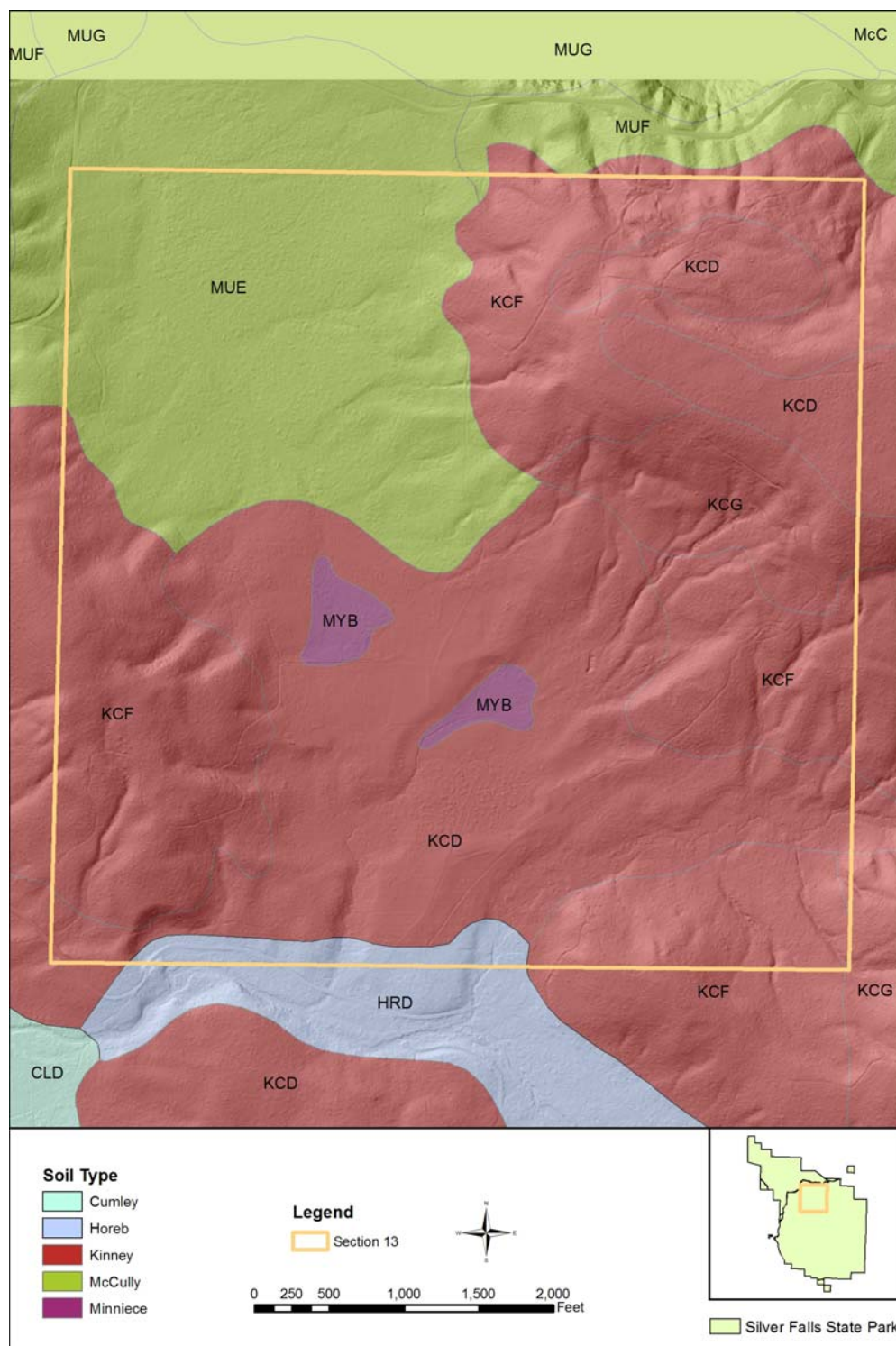


Figure 4.3 - Marion County Soil Data: T8S R1E Section 13 Willamette Meridian

Source: USDA NRCS 2006

Map Author: Carl Anderson 2007

4.1.2 Current Vegetation

The Ranches meadow currently contains a range of vegetation types (**Figure 4.4**). There are three wetland areas in the meadow proper, which are dominated by herbs such as *Gentiana sceptrum* (king gentian), shrubs such as *Spiraea douglasii* (Douglas spiraea), *Rhamnus purshiana* (cascara), and *Amelanchier alnifolia* (serviceberry), and small trees including *Malus fusca* (Pacific crab apple), *Salix lucida ssp. lasiandra* (Pacific willow). These wetlands may be classified generally as shrub swamps, which are “wetlands dominated by shrubs (occurring) at all elevations throughout northwestern Oregon. They occur on floodplains and basins, and most tolerate a variable water regime (Christy 2004).” The community structure may consist of “impenetrable stands of... *Spiraea douglasii*,” which is the case in the wetlands of the Ranches meadow (Christy 2004: 8). Surrounding the wetlands are belts of wet prairie, which include species such as *Festuca romeri* (Roemer’s fescue), *Deschampsia cespitosa* (tufted hairgrass), and *Danthonia californica* (California oatgrass). The upland prairie portions of the meadow are dominated by *Pteridium aquilinum* (bracken fern), *Festuca romeri*, (Roemer’s fescue), *Festuca rubra* (red fescue), *Agrostis spp.* (bentgrass), and the invasive species *Cytisus scoparius* (Scotch broom). The Scotch broom is an extensive problem for park management in some areas (**Figure 4.5**).

The surrounding forest largely consists of *Psuedotsuga menzesii* (Douglas fir), with lesser amounts of *Tsuga heterophylla* (western hemlock) and, in wet areas, *Populus trichocarpa* (black cottonwood). A stand of *Populus tremuloides* (quaking

aspen) is located at the northern edge of the wetland that drains into Winter Falls in the northern portion of the meadow. In addition, there are cultivated apple trees (*Malus sp.*) and a pear tree (*Pyrus communis*) arranged in a circular pattern throughout the eastern portion of the meadow (**Figure 4.6**).

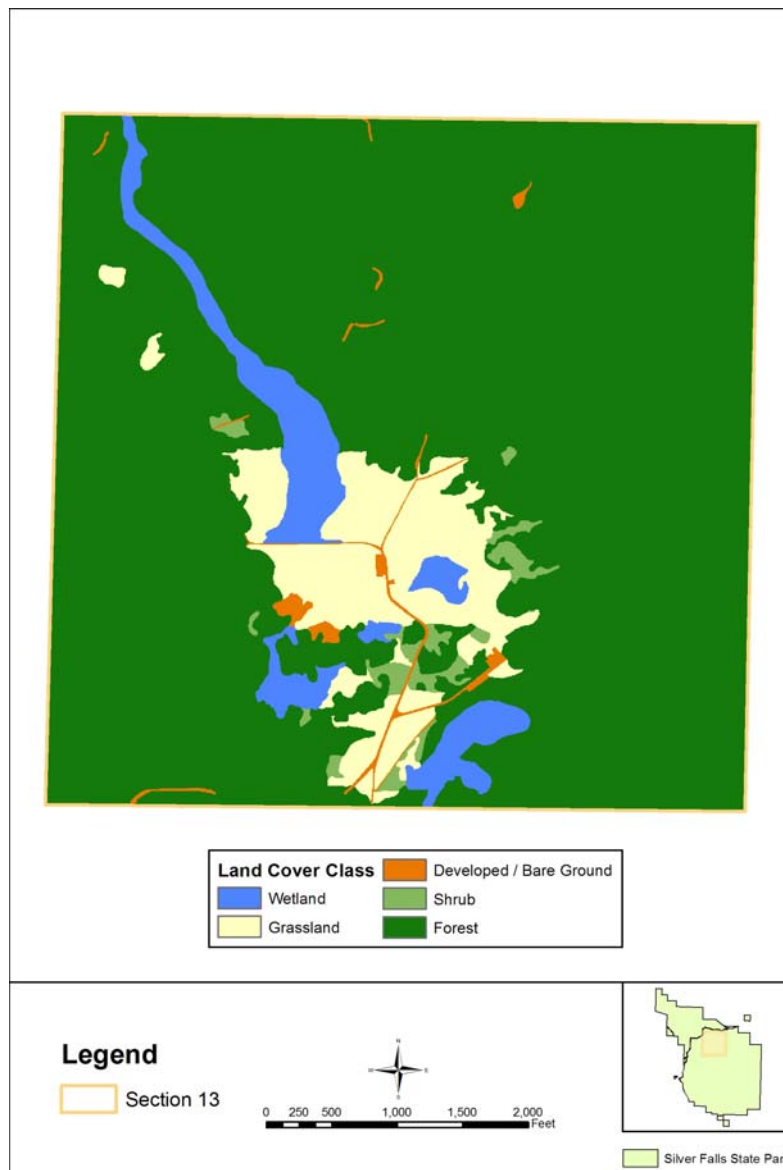


Figure 4.4 - Land Cover Classes as of 2003: T8S R1E Section 13 Willamette Meridian

Source: Unpublished Data, Carl Anderson 2007

Map Author: Carl Anderson 2007

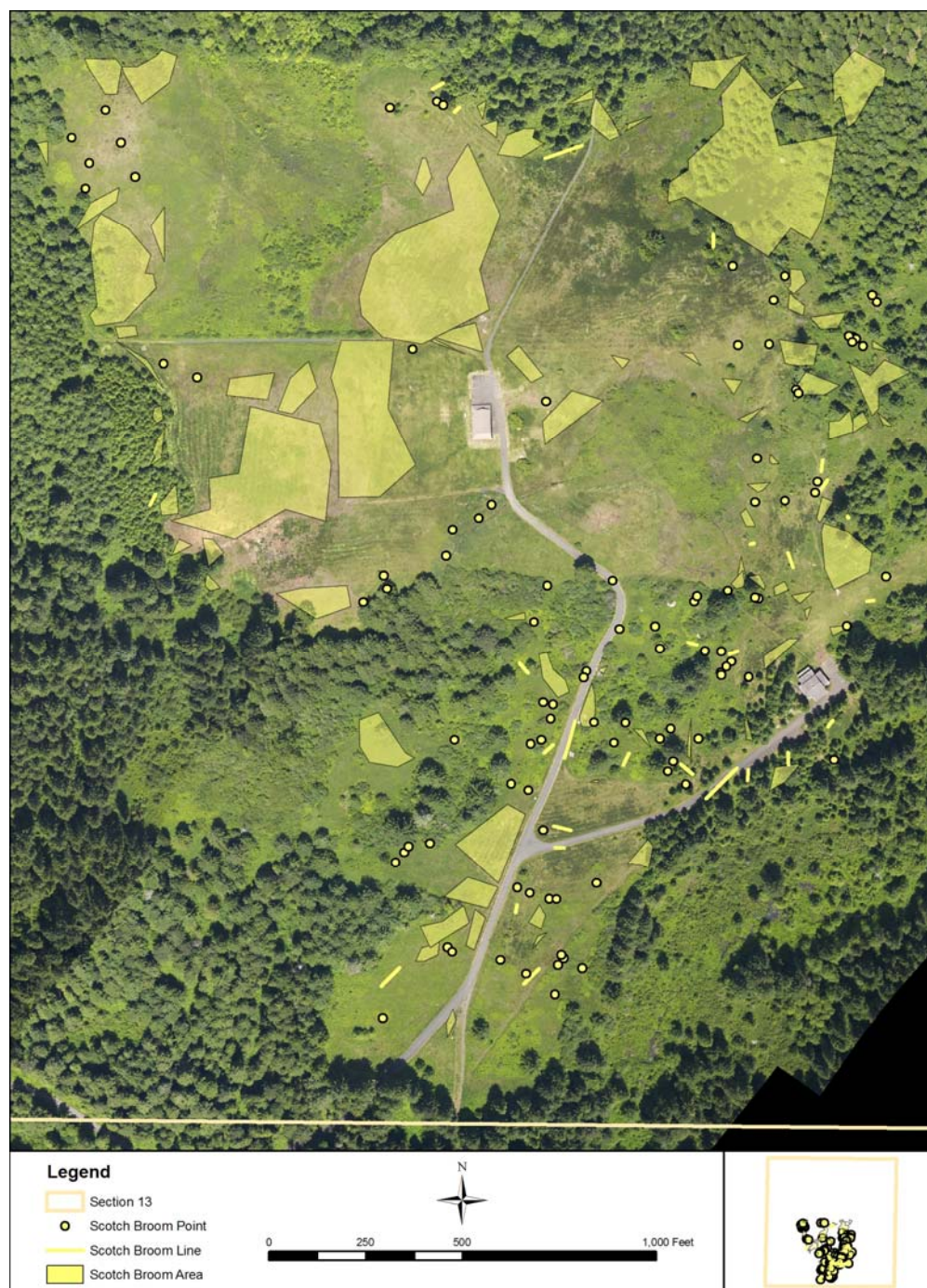


Figure 4.5 – Scotch Broom Extent as of 2006, Ranches Meadow

Sources: Unpublished Data, Carl Anderson 2006; OPRD 2005

Map Author: Carl Anderson 2007

*Note: Areas depicted in this figure represent partial Scotch broom coverage



Figure 4.6 – Apple, Pear and Aspen Trees, Ranches Meadow
 Sources: Unpublished Data, Carl Anderson 2006; OPRD 2005
 Map Author: Carl Anderson 2007

4.1.3 Landscape Chronology of the Ranches Meadow

The city of Independence, located in the Willamette River floodplain, approximately 27.5 miles due west of present-day Silver Falls State Park, was the end of the line for some Oregon Trail pioneers in the 1840's. The area that would become Silver Falls State Park was settled slightly later, between 1860 and 1874 (Habeck 1961; Chapman 1860; Simpson 1874). As of 1854, much of the park had been declared to be "rough and mountainous land unfit for settlement and unsurveyed" by the Surveyor General of the Oregon Territory (**Figure 4.7**) (Gardner 1854). According to Habeck (1961), the township (T8S R1E Willamette Meridian) that is now Silver Falls State Park was historically dominated by *Psuedotsuga menzesii* (Douglas fir) forest; however, this was based upon the 1854 surveyor's maps cited above, which did not cover the park's interior.

At the time of pioneer contact, much of the Willamette Valley was covered by tallgrass prairie, which was maintained by widespread burning practiced by Native Americans (Kirkwood 1902; Habeck 1961; Johannessen et al 1971; Pojar and Mackinnon 1994). It is unknown whether or not the Ranches meadow was maintained by Native American prescribed fire prior to European settlement. (Sprague and Hansen 1946, as quoted in Habeck 1961; Boyd 1999). The 1860 Oregon Surveyor's Map of T8S R1E Willamette Meridian indicates that the section within which the present day meadow exists had not been surveyed or settled as of this date (Chapman 1860). The Silverton Fire of 1865 covered 990,000 acres near and within present-day Silver Falls State Park, including much of the study section. The burned, dead nature

of the forest was so commonplace that the area was known as “snag country” in the late 19th century (Humphreys 1998; Oregon Department of Forestry 2007).

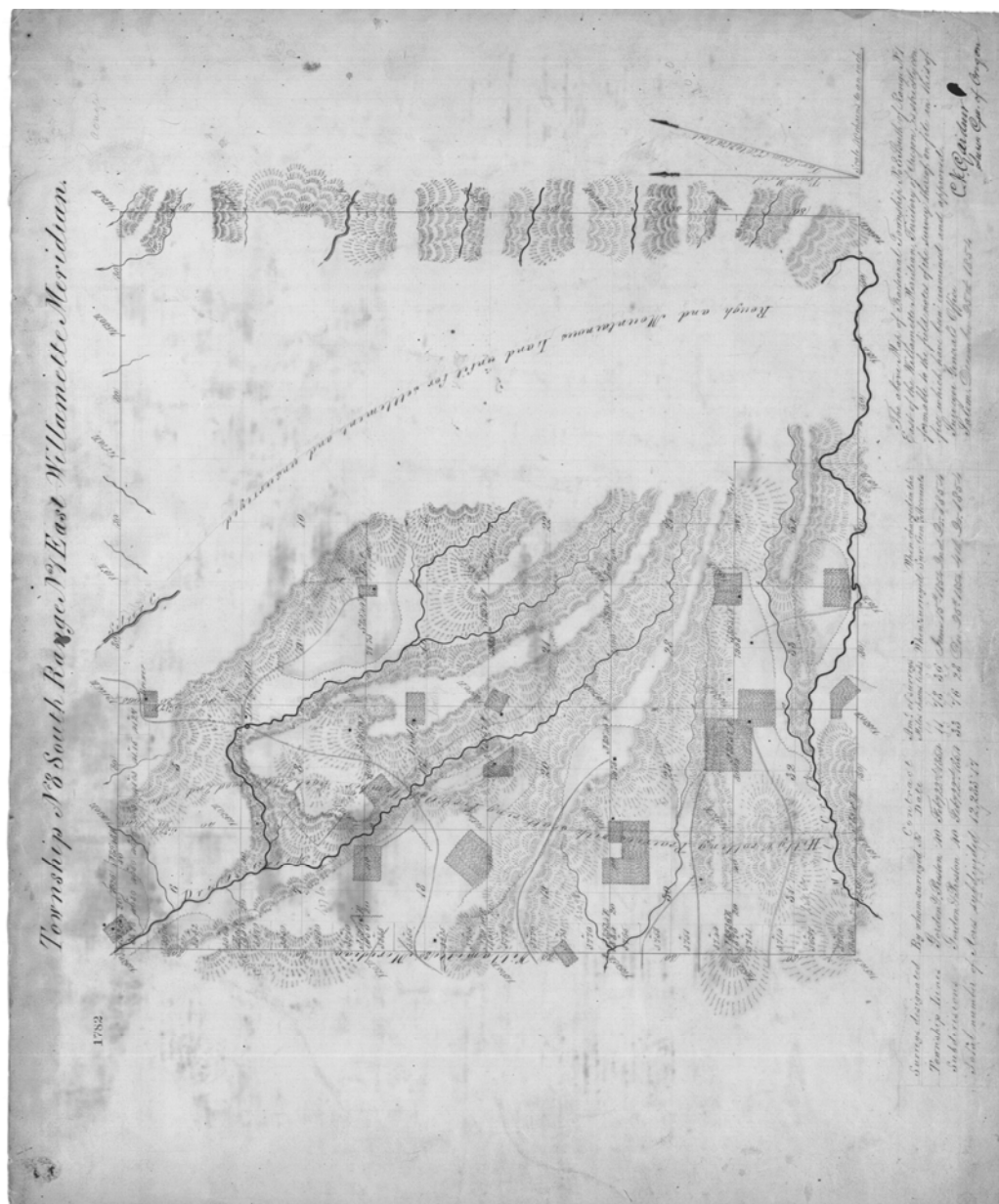


Figure 4.7 – 1854 Map of T8S R1E Willamette Meridian
Source: Gardner 1854

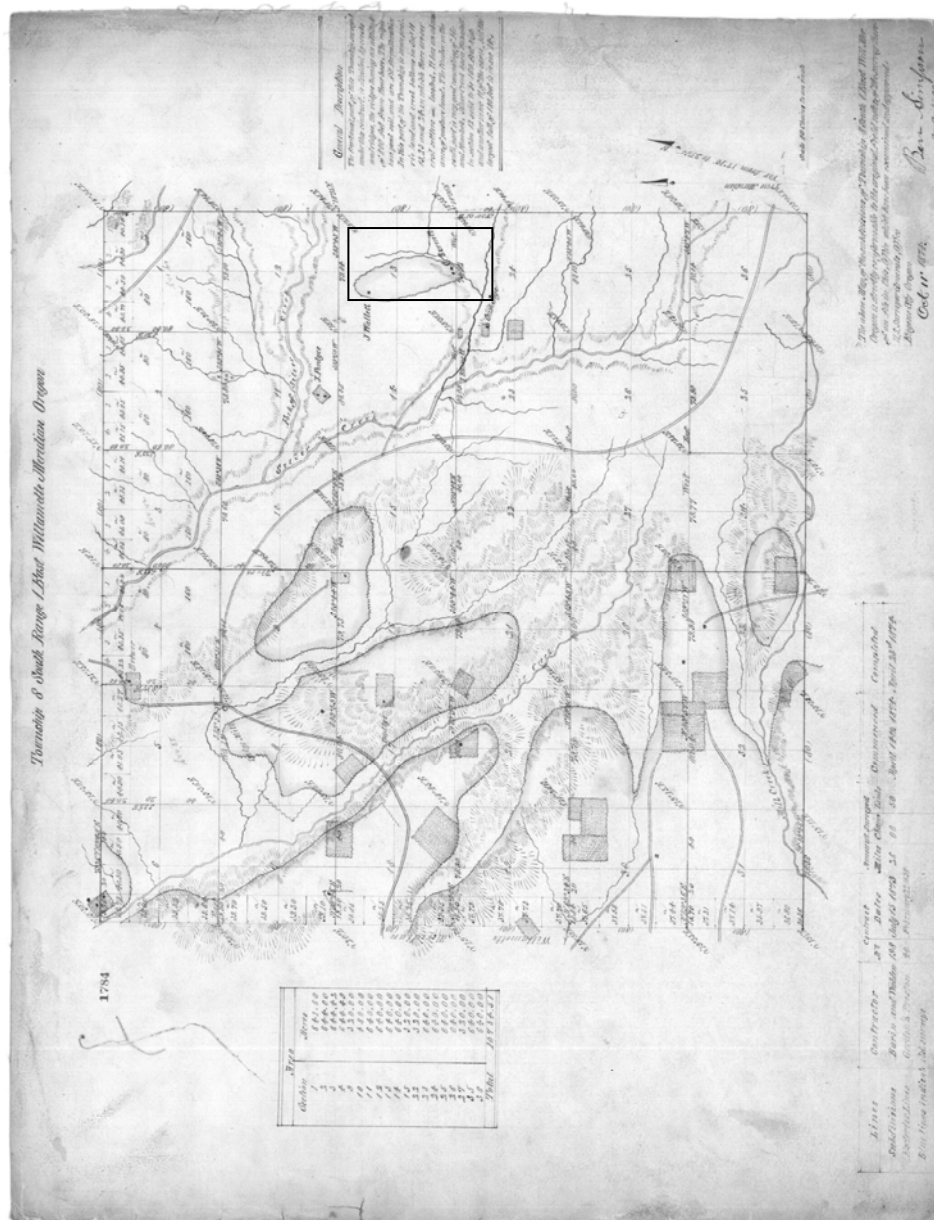


Figure 4.8 – 1874 Map of T8S R1E Willamette Meridian

Source: Simpson 1874

Box denotes Historic Meadow Area

According to the Oregon Natural Heritage Program (2002), a small area of roemer's fescue (*Festuca romeri*) meadow existed in the southern portion of the Ranches meadow prior to settlement. The 1874 Surveyor's map denotes an open meadow area in Section 13, which is similar to where the present day meadow is (Figure 4.8) (Simpson 1874). The Douglas fir forest type was found at these distinctly

higher elevations than the oak forests and prairies that were common on the valley floor (Habeck 1961: 74). The historical size of the Ranches meadow, based on the 1874 US Surveyor General's Map, is estimated to be 143.36 acres (**Figure 4.9**) (Simpson 1874). There are two settlements depicted on the map, one at the south end and one at the north end of the meadow, although ownership parcels are not depicted.



Figure 4.9 - Study Site Acreage: T8S R1E Section 13 Willamette Meridian and Historic Ranches Meadow Extent as of 1874

Source: Simpson 1874

Map Author: Carl Anderson 2007

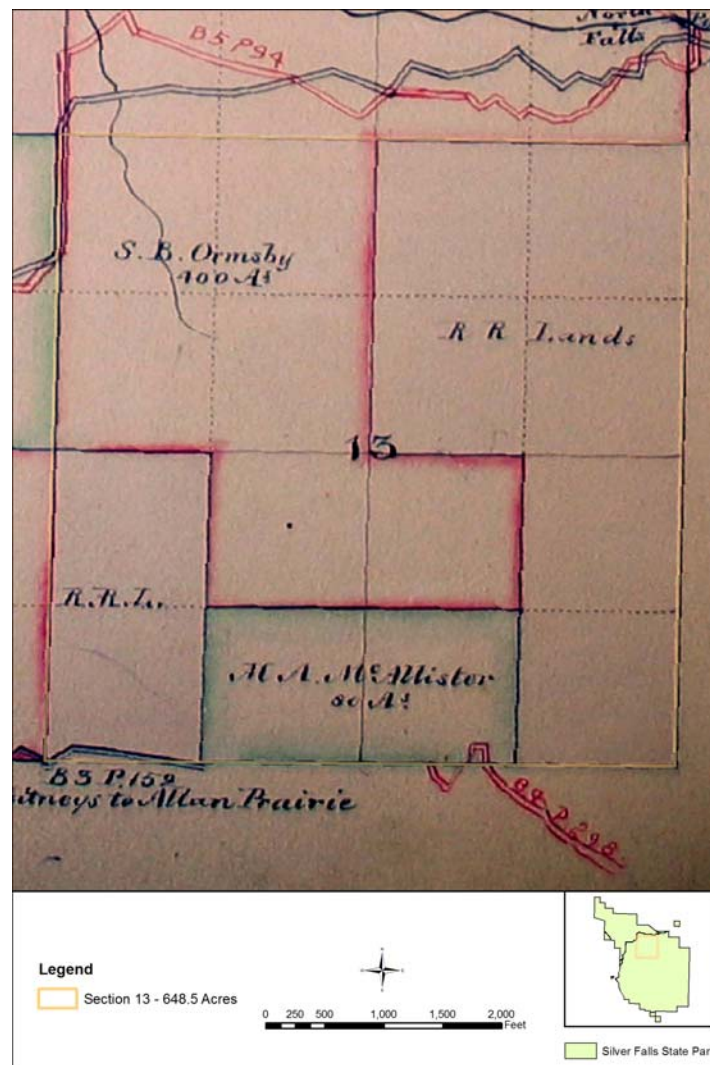


Figure 4.10 – 1889 Land Ownership: T8S R1E Section 13 Willamette Meridian
 Source: Marion County, Oregon (Shaw, Grimm, and Cornelius 1889)
 Map Author: Carl Anderson 2007

By 1889, half of the area surrounding the present-day meadow was in private ownership, and half remained in public ownership (**Figure 4.10**) (Shaw, Grimm, and Cornelius 1889). Much of the park was logged in the 1880's and 1890's, with most operations winding down before the establishment of the park in the 1930's (Tetra Tech 2006). Hence, much of the forest in the park is under 100 years old, although scattered groves of old growth forest remain (Tetra Tech 2006). The period of the late

1800's was the "boom" time of settlement in Silver Falls, as Silver Falls City was platted in 1888, and reached a peak of 200 residents (Friends of Silver Falls 2006). By 1914, the town church was one of the last remaining structures in the small town (Benson 1978). Even as timber harvesting occurred, the area near the falls was a popular tourist destination for the people of the county during the years prior to the first purchase of land by the state in 1931 (Friends of Silver Falls 2006).

Both the Silverton Fire of 1865 and subsequent logging and replanting activities promoted the rapid development of a second-growth Douglas fir – dominated forest throughout much of the park (Kirkwood 1902; Cole 1977). The exact date of timber harvesting in and near the meadow itself is unknown, but based on visual evidence from 1947 aerial photography and the 1951 USGS Topographic Map, it is likely that a significant portion of the area was logged prior to these dates. Approximately one million acres in the vicinity of the entire park was replanted in the 1930's with the help of the Civilian Conservation Corps (CCC), but it is unclear where this occurred near the Ranches meadow (Friends of Silver Falls 2006; Davison 2007).

Silver Falls State Park was dedicated on July 23, 1933 (Friends of Silver Falls 2006). The land surrounding the ten major waterfalls (1268 acres) was acquired by the state by 1933, but adjacent properties continued to be purchased in subsequent years, as the area of the park currently exceeds 9000 acres (Armstrong 1965; OPRD 2007). According to the 1941 Metsker's Atlas of Marion County, much of the land in the study section was still in private ownership, but some land was in public ownership (**Figure 4.11**). Based on the 1941 Metsker's land ownership map and

information from Silver Falls State Park employees, it is known that a 100-acre portion of the section, owned by L.L. Davidson, was a working sheep ranch between 1941 and 1952 (Metsker 1941; Janiszewski 2007). An aerial photograph from 1947 shows the rectangular pattern of the fenceline of this ranch as well as large amounts of non-forest vegetation throughout the area (see **Appendix A.1**). This area was one of the last to be purchased for inclusion into Silver Falls State Park. Eventually, the state of Oregon took ownership of all of the private lands in this area, including the acquisition of the “Ranches” meadow from L.L. Davidson in 1952 (Friends of Silver Falls 2006). The acquisition of this 100-acre parcel completed the purchase of the remaining private in-holdings near the meadow.

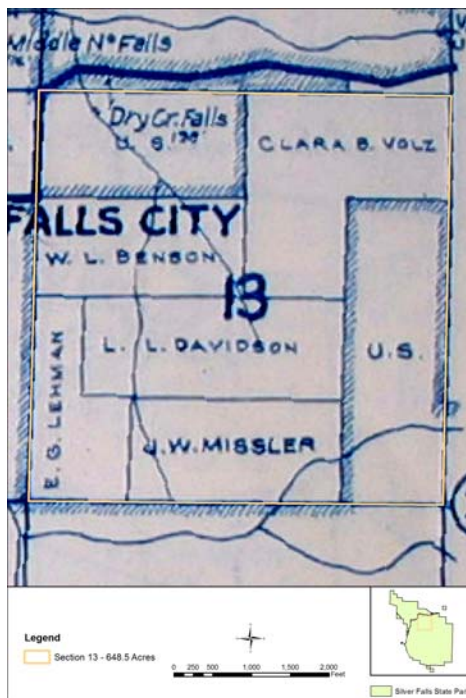


Figure 4.11 – 1941 Land Ownership: T8S R1E Section 13 Willamette Meridian
 Source: 1941 Metsker’s Atlas of Marion County, Oregon (Metsker 1941)
 Map Author: Carl Anderson 2007

After the purchase of the remaining parts of section 13, the park started managing the area for the purpose of encouraging visitor use. The park changed the old sheep barn into a group facility by adding a kitchen, restroom, and sleeping accommodations at least 1962, when camper night totals for the Old Ranch facility totaled 2212 (Armstrong 1963: 60). By 2006, combined annual usage for the Old and New Ranches had increased to 7166 visitors (Janiszewski 2007).

Several buildings were removed between 1972 and 1976, including a machine shed and chicken coop, based on evidence from aerial photographs and information from a former park employee (Lacompt 2007). A small sawmill was also torn out of the wetland to the north of the Old Ranch building prior to these dates, and a dirt access road leading away to the northwest has not been maintained since that time. The so-called “New Ranch” group facility was built in the southeast portion of the meadow in the mid-1970’s (Janiszewski 2007) (refer to **Figure 1.1**).

Active vegetation management of the meadow began in the 1980’s, when a grove of Douglas fir was planted on the western edge of the Old Ranch field. In the 1990’s, a flail mower was used annually in two areas north and west of the Old Ranch building to cut vegetation deemed to be a fire risk. Mowing for a stargazing party near the Old Ranch began in 1996 and continues annually to the present. Also during this decade, some topsoil was scraped off the western portions of the meadow, and smaller Douglas fir trees in the meadow were removed in 1999 or 2000 (Shepherd 2007).

Thinning treatments of ten acres and thirteen acres as well as one five acre “Chip Unit” Douglas fir removal were conducted in the vicinity of the Ranches in the

summer of 2001 (Smogor 2007). For the two thinning treatments, horses were used to remove the logs on gentler slopes, while a caterpillar was used on steep slopes. The five-acre removal was done in the meadow and involved removing a small stand of planted Douglas fir and chipping the debris.

The 21st century brought intensive efforts to eradicate the Scotch broom (*Cytisus scoparius*) problem along the edge of the meadow (Janiszewski 2007; Shepherd 2007). First, hand-pulling efforts were used, but these proved unsuccessful. In 2002, some areas were broadcast sprayed, and some of the killed plants were mechanically pulled. In 2005, additional broadcast spraying was implemented. Mechanical grinding, along with plantings of blue wildrye (*Elymus glaucus*) and California brome (*Bromus carinatus*), were conducted in the spring of 2006. Refer to **Figure 4.12** to see a depiction of the vegetation management areas between 1980 and 2006.

In summary, impacts to the Ranches meadow have been fire, logging, tree planting, grazing, development, and vegetation management efforts. The extent of the impact of the Silverton Fire of 1865 is difficult to determine, but most likely played an important role in the maintenance of meadow during the late 1800's. Similarly, the timing and location of logging activities in the area are unknown, but they likely occurred in the area due to the presence of the mill in the northern wetland of the meadow. Tree planting occurred in the park in the 1930's, but since at least 100 acres of the meadow was most likely grazed during this time, it is likely that this planting

did not occur in this well-defined area. Once the meadow was purchased by the state, the focus has been on restoring the meadow to more natural conditions.



Figure 4.12 - 1980 – 2006 Vegetation Treatments – Ranches Meadow
T8S R1E Section 13 Willamette Meridian
Sources: Oregon Parks and Recreation Department (OPRD), Carl Anderson 2007
Map Author: Carl Anderson 2007

4.2 Analysis Methodology

4.2.1 Aerial Photograph Georeferencing

Four aerial photos were chosen for use within the change detection analysis. The earliest usable photo was from 1947, which was 5 years before the park owned the L.L. Davidson ranch. The next photo (1970) used was from 18 years after the parcel was acquired, the third was from 1988 after further development in the area, and the final photo was from 2003 after more active vegetation management (**Table 4.1**) (See **Appendix A** for aerial photographs).

Table 4.1 - Aerial Photograph Descriptions

Imagery Date	Scale	Source	Project Number
2003	1:12000	Bureau of Land Management	O-03-SAL
1988	1:12000	Bureau of Land Management	O-88-ASC
1970	1:20000	American Soil Conservation Service	DFN-4LL-171
1947	1:37000	United States Geological Survey	GS-CK

The 1947, 1970, and 1988 photos were scanned with the following settings: reflective document type, photo auto exposure type, and 8-bit grayscale at 600 dots per inch (dpi), which gave these photos pixel sizes of 5.13, 2.78, and 1.67 feet, respectively. The equipment used was an Epson scanner, in professional mode, at the University of Oregon MAPS Library GIS lab. The 2003 photo was obtained from the Oregon Parks and Recreation Department in digital format; none of the settings used to scan the image into digital format are known. However, upon examination of the

file in ArcGIS, the pixel size was determined to be approximately 3 feet, so the image was most likely scanned at 300 dpi.

In order to georeference the images, a previously georeferenced 2005 aerial photograph was acquired from the Bureau of Land Management. This image was in the NAD 1983 Oregon Statewide Lambert Feet International projection. Selection of the ground control points was attempted at the scale of 1:1000 using the ArcMap 9.1 georeferencing toolbar. These exact points were first determined using the georeferenced photo. A minimum of seven points were used to georeference each aerial photo. Using a first-order polynomial transformation, each photo was transformed to match the georeferenced base photo. **Appendix B** shows the detailed RMSE (in feet) information for each of the photos.

The 1947 photo has the smallest scale (1:37000) of any of the photos used, which consequently required the analysis to be performed at this scale. The 1947 revised National Map Accuracy Standards indicate that for mapping at scales smaller than 1:20000, 90% of points must have an error of less than 1/30th of an inch. This means that errors must be less than 1.64 RMSE (Root Mean Square Error). In order to calculate the allowable RMSE at this scale, the following calculation is used:

$$\text{Allowable RMSE} = \text{Acceptable error on the ground} / 1.64$$

$$\text{Acceptable error on the ground} = \text{Map error} * \text{scale conversion} * \text{units conversion}$$

$$\begin{aligned} &= 1/30 \text{ inch} * 37000 * 1/12 \text{ foot/ inch} \\ &= 102.77 \text{ feet} \end{aligned}$$

$$\begin{aligned} \text{Allowable RMSE} &= \text{Acceptable error on the ground} / 1.64 \\ &= 102.78 \text{ feet} / 1.64 \end{aligned}$$

= 62.67 feet

The ground accuracies obtained in the georeferencing process for all of the images easily met the National Map Accuracy Standards.

4.2.2 *Land Cover Classification*

Once the aerial photographs were georegistered, the next step was to digitize land cover polygons. The land cover classification system used was adapted from the “USGS Land Use and Land Cover Classification System for Use With Remote Sensor Data” (Anderson et al. 1976). This classification system breaks land cover types into 9 broad categories: Urban or Built-up Land, Agricultural Land, Rangeland, Forest Land, Water, Wetland, Barren Land, Tundra, and Perennial Snow or Ice. In order to adapt these categories to the study site, relevant classes were selected and others were added for additional detail. The classes used are displayed in **Table 4.2**.

Table 4.2 - Adapted Land Cover Classification

ID	Land Cover Class	Label	Age	Grouped Class
1	Wet Grassland	WG		A - Grassland
2	Dry Grassland	DG		
3	Forested Wetland	FW		B - Wetland
4	Non-Forested Wetland	NW		
5	Young Forest	YF	<50 years	C - Forest
6	Mature Forest	MF	50-100	
7	Old Forest	OF	>100	
8	Stream	ST		D - Stream
9	Developed	DE		E – Developed / Bare Ground
10	Bare Ground	BG		
11	Shrub	SH		F - Shrub

The classes were developed to generalize vegetation classes into groups and provide categories for other land cover types not included in the USGS system.

The Wet Grassland land cover class is characterized by herbaceous species such as *Deschampsia cespitosa* (tufted hairgrass), *Danthonia californica* (California oatgrass) and *Festuca romeri* (Roemer's fescue) and occurs on low-lying, low gradient land adjacent to wetlands. The Dry Grassland land cover class consists of *Festuca romeri* (Roemer's fescue), *Agrostis sp.* (Bentgrass), *Pteridium aquilinum* (bracken fern), and some shrubs, including the invasive species *Cytisus scoparius* (Scotch broom). Shrub cover could not exceed 50% if an area was classified as Dry Grassland. Dry Grassland is generally at slightly higher elevations than Wet Grassland, and on low to moderate gradient slopes.

The Forested Wetland class is characterized by deciduous trees including *Populus trichocarpa* (black cottonwood), *Rhamnus purshiana* (cascara), *Malus fusca* (Pacific crab apple), *Populus tremuloides* (quaking aspen), and *Acer circinatum* (vine maple). These areas are generally downstream of the next land cover class type: Non-Forested Wetland. The meadow contains two prominent non-forested wetlands largely dominated by the shrub *Spiraea douglasii* (Douglas spiraea).

The fifth, sixth and seventh land cover classes are Young, Mature, and Old Forest, respectively. These classes were chosen in order to estimate the time of establishment of the forests surrounding the meadow and were based on visual inspections, using aerial photographs, of the changes within the study site since 1947, the date of the first photo used in the analysis. As has been noted previously, 990,000

acres surrounding and including the study area burned in the Silverton Fire of 1865, so the maximum age of forest stands as of 2003 would be 138 years old. Much of the Old Forest is located near water or on steeper slopes of generally 10 degrees or greater. The other two classes are spread throughout the study area.

The three land cover classes of Stream, Developed, and Bare Ground are visible on at least one aerial photo, although all of these classes cover a relatively small portion of the overall area. Stream areas were visible in the southwest corner of the section, while Developed areas stayed relatively stable. A large area of bare ground changed to forest in the northeast part of the section. The final land cover class used in the analysis was the Shrub category. This category includes shrubs, grasses, and even some small trees, and is typically found on dry sites. Shrubby vegetation comprised at least 50% of these areas.

A second classification grouping was used to combine the eleven land cover types into 6 broader categories, which were: A) Grassland, B) Wetland, C) Forest, D) Water, E) Developed / Bare Ground, and F) Shrub (refer to **Table 4.2**, Grouped Class column). This classification was used to show broader changes in the land cover of the study site.

The existing areas of the original eleven and six grouped land cover classes at the time of each photo were digitized using ArcGIS 9.1. The acreages were then calculated and summarized using the Field Calculator. The result of these calculations provided the absolute changes in land cover, but did not indicate the relationships

between these changes. Thus, a change detection analysis was required to show the specific change transitions from one land cover class to another.

4.3 Change Detection

The change detection analysis was performed using ArcGIS 9.1. First, each land cover classification feature class was exported to shapefile format so that the ArcGIS Toolbox conversion tools could be utilized. Next, each shapefile was converted into a raster file using the Feature to Raster tool in the ArcGIS Toolbox Conversion tools. The pixel resolution was set at 5.139 feet, since this was the pixel size of the smallest scale, 1:37000 1947 aerial photograph.

Two separate raster files were made from each land cover class shapefile for each year. The first file was a raster file containing pixel values that corresponded with the original eleven classes in the land cover classification. The second was a raster file that assigned pixel values based upon the six grouped classes as noted in **Table 4.2**. These eight files covered T8S, R1E, Section 13, Willamette Meridian. Eight more raster files were created for the historic meadow extent by clipping the original land cover class files to the historic meadow extent shapefile, which was previously digitized from the 1874 surveyor's map (Simpson 1874).

A total of sixteen change detection iterations were performed, as displayed in **Table 4.3**. These were grouped into four sets, based upon the time period analyzed. The four interval groupings were 1947 to 1970, 1970 to 1988, 1988 to 2003, and 1947 to 2003. The original land cover class change detections produced an eleven by eleven

change detection matrix, which displayed the area of land cover classes in all possible combinations of each two of the eleven input layers, as shown in **Table 4.4** (Johnston 1998). The grouped land cover class change detections produced six by six detection matrices (**Table 4.5**). Each cell indicates a change or no change value. For example, in **Table 4.4**, cell 25 would indicate a change from forested wetland to forested wetland; i.e., no change, while cell 16 would indicate a change from dry grassland to young forest. It should be noted that not all matrix values are likely or able to occur, but may occur due to georeferencing errors or inconsistencies in interpreting the land cover classification (Johnston 1998: 121).

Table 4.3 – Change Detection Permutations

Iteration	Number of Classes	Year 1	Year 2	Study Area
1	11	1947	1970	Section
2	11	1947	1970	Historic Meadow
3	6	1947	1970	Section
4	6	1947	1970	Historic Meadow
5	11	1970	1988	Section
6	11	1970	1988	Historic Meadow
7	6	1970	1988	Section
8	6	1970	1988	Historic Meadow
9	11	1988	2003	Section
10	11	1988	2003	Historic Meadow
11	6	1988	2003	Section
12	6	1988	2003	Historic Meadow
13	11	1947	2003	Section
14	11	1947	2003	Historic Meadow
15	6	1947	2003	Section
16	6	1947	2003	Historic Meadow

Table 4.4 – Complete Land Cover Class Matrix Diagram

		Second Year Land Cover Classes										
		1	2	3	4	5	6	7	8	9	10	11
First Year Land Cover Classes	1	1	2	3	4	5	6	7	8	9	10	11
	2	12	13	14	15	16	17	18	19	20	21	22
	3	23	24	25	26	27	28	29	30	31	32	33
	4	34	35	36	37	38	39	40	41	42	43	44
	5	45	46	47	48	49	50	51	52	53	54	55
	6	56	57	58	59	60	61	62	63	64	65	66
	7	67	68	69	70	71	72	73	74	75	76	77
	8	78	79	80	81	82	83	84	85	86	87	88
	9	89	90	91	92	93	94	95	96	97	98	99
	10	100	101	102	103	104	105	106	107	108	109	110
	11	111	112	113	114	115	116	117	118	119	120	121

Table 4.5 – Grouped Land Cover Class Matrix Diagram

		Second Year Land Cover Classes					
		A	B	C	D	E	F
First Year Land Cover Classes	A	1	2	3	4	5	6
	B	7	8	9	10	11	12
	C	13	14	15	16	17	18
	D	19	20	21	22	23	24
	E	25	26	27	28	29	30
	F	31	32	33	34	35	36

For each of the change detections, results were compared between the section and the historic meadow. Because the data obtained from the change detections cover the entire “population,” no statistical tests were required. Descriptive statistics are adequate to distinguish land cover change patterns at these two scales.

4.4 GIS Analysis of Physical and Anthropogenic Change Factors

The second primary methodology of the study was to analyze the land cover changes against available anthropogenic and physical data that may have influenced these changes. The variables chosen for inclusion in this analysis were slope, aspect, soil map units, historic vegetation, vegetation management, historic timber extent, and land ownership (Data not depicted elsewhere is shown in **Appendix C**). LIDAR data were obtained from the Oregon Parks and Recreation Department (OPRD) GIS staff to use for the slope and aspect factors (OPRD 2007). Soil map unit data (See **Figure 4.3**) for Marion County, Oregon were obtained from United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) through its Soil Data Mart website (USDA NRCS 2007). The historic vegetation shapefile, which depicts pre-settlement vegetation types, was obtained from the State of Oregon and was created by the Oregon Natural Heritage Program in June of 2002. Management data were obtained from various sources associated with Silver Falls State Park. Each treatment, development or management event was recorded and digitized (Janiszewski 2007; LaCompt 2007; Smogor 2007). Additionally, some of the management data

were obtained from fieldwork completed in the summer of 2006. Land ownership data were acquired from various maps (**Table 4.6**). Finally, the historic timber extent shapefile was obtained from the State of Oregon (Oregon Department of Forestry 2007). This file was created by the Oregon Department of Forestry, and depicts the timber resources in the state as of 1914.

Table 4.6 – Historic Ownership Maps - Township 8 South, Range 1 East, Willamette Meridian

Source	Author	Date
Oregon Surveyor General's Office	C.W. Gardner	12/25/1854
(Copy) Surveyor General's Office	W.W. Chapman	8/29/1860
Secondary Source: Public Survey Office	J.A. Gauong	1/11/1932
US Surveyor General's Office	Ben Simpson	10/11/1874
Supervisor's Maps of the Road Districts in Marion County	T.C. Shaw, W.T. Grimm, A.H. Cornelius	January, 1889
Oregon Department of Transportation	Unknown	1936
Metsker's Atlas of Marion County	C.F. Metsker	February, 1941
USGS 15' Topographic Map	Unknown	1951

4.5 Restraining Factors

The results of this change detection study must be considered in the light of several limiting factors. The first is subjectivity in the process of georeferencing and coregistration (Green and Hartley 2000). While efforts were made to register all aerial photographs to the same, defined aerial photograph, slight positional errors occurred. This was particularly of concern when digitizing more “static” features, such as roads and buildings.

A second limiting factor is error in the digitizing process (Green and Hartley 2000: 112). Two common digitizing errors are digitizing curved lines as a series of short, straight line segments and errors arising due to digitizing aerial photographs that are taken at different scales. This was a significant hindrance for the 1947 photograph at a scale of 1:37000, as progressions in land cover features were more difficult to interpret and digitize at the chosen digitizing scale of 1:1000.

A third error in interpreting the aerial photographs in this study arose from the subjectivity of the interpreter (Green and Hartley 2000: 113). It can be difficult for a less-experienced aerial photograph interpreter to have consistent classification interpretations of land cover observed at different scales, different times of day, times of the year, and in even in different color tones. It is very helpful if the interpreter has a working knowledge of the ecotype or even the specific site that is being interpreted so that they are able to recognize patterns and relate them to real world land cover classes. In this study, errors arising from interpreter subjectivity were reduced because an individual who is experienced with Silver Falls State Park and particularly with the Ranches meadow conducted the research.

An additional restraining factor in measuring the rates of change in this study was the irregular intervals between imagery acquisition dates. This may be significant as the interval length is the longest during the first study period (1947 - 1970) and shortest during the most recent period (1988 – 2003). In addition, vegetation changes may be accelerated by management practices, but these changes may not be perceptible given the intervals that have been studied.

5 RESULTS

5.1 Absolute Land Cover Change – Section 13

Across the section, grassland areas of the meadow decreased and forested areas increased greatly during the study period (**Figure 5.1, Table 5.1**). By area, the most significant changes occurred between 1947 and 1970, as dry grassland areas decreased from 202 to 80 acres, a 60.8% decline, shrub areas decreased from 110 to 53 acres, a decline of 52.0%, and young forest increased by 103.5% from 161 to 331 acres. Classes smaller in area, including the wet grassland (-19.6%), stream (-100.0%) and bare ground (-87%) categories experienced declines in area, while changes in non-forested wetland (-41.1%) and forested wetland (+38.6%) largely negated each other.

The changes in the grouped cover classes clearly display the shift of the area from a mixed grassland/shrub/forest land cover composition to a predominantly forested landscape. In 1947, the grassland and shrub classes comprised 37% and 18% of the section, respectively, while forest covered 43%. Reforestation occurred rapidly as 73% of the section was made up of forest in 1970 (an increase of 71.1% between 1947 and 1970), with grassland and shrub cover declining by 56% and 52%, respectively. Between 1947 and 2003, overall grassland and shrub coverage in the section fell by 77.3% and 92.5%, respectively. By 2003, forest covered 84% of the section, with no other grouped land cover category covering more than 8.2% (refer to **Figure 5.1**).

Other changes occurred in the wetland and developed land cover classes. The wetland group remained relatively steady in area, with a net gain between 1947 and

2003 of approximately 3.7 acres, an increase of 9.0%. Developed areas also increased by 77.5%, though the area that they composed during the study period remained quite small (0.6% of total land cover).. The developed / bare ground and stream categories were virtually invisible on the 2003 aerial photograph. See **Appendix D** for original and grouped land cover class maps for each study period.

Figure 5.1 – Area of Grouped Land Cover Types for 1947, 1970, 1988, and 2003; Township 8 South, Range 1 East, Section 13, Willamette Meridian

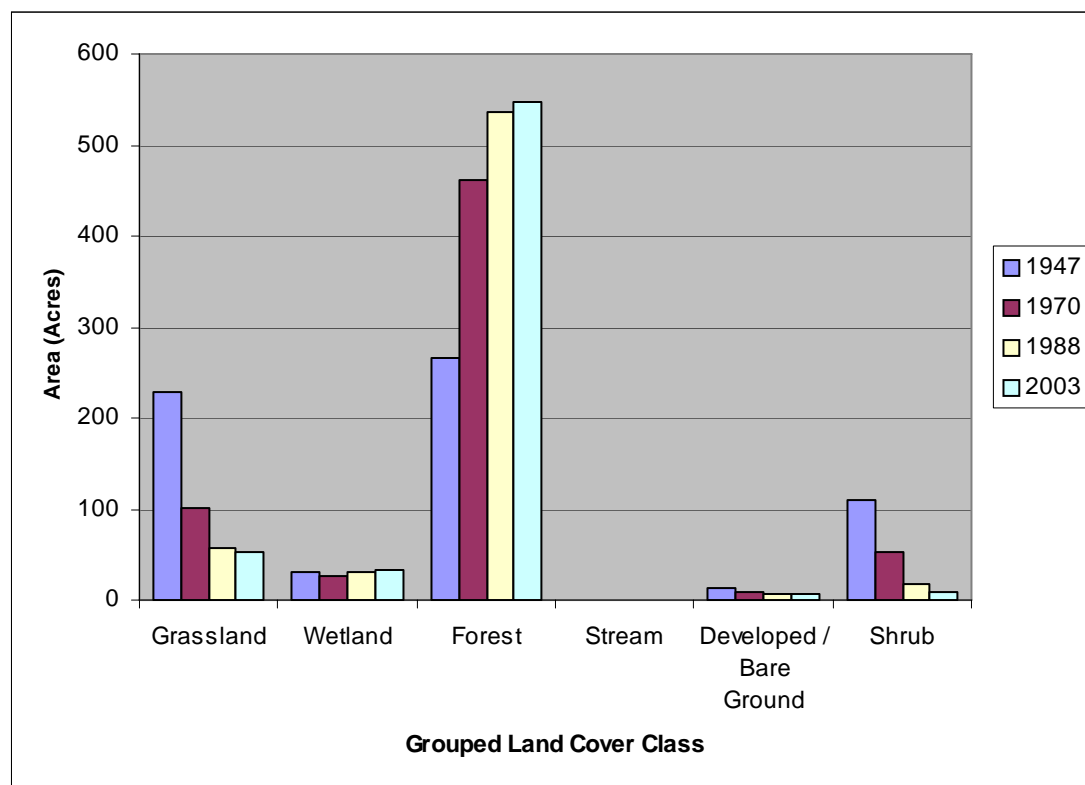


Table 5.1 – Original Land Cover and Grouped Land Cover Class Changes, 1947 to 1970, 1970 to 1988, 1988 to 2003, and 1947 to 2003, Township 8 South, Range 1 East, Section 13, Willamette Meridian

	1947	1970	Change from 1947 to 1970
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	4.2%	3.4%	-19.6%
Dry Grassland	32.4%	12.7%	-60.8%
Forested Wetland	1.6%	2.2%	38.6%
Non-Forested Wetland	3.3%	1.9%	-41.1%
Young Forest	25.8%	52.5%	103.5%
Mature Forest	17.1%	20.8%	22.0%
Old Forest	0.0%	0.0%	0.0%
Stream	0.1%	0.0%	-100.0%
Developed	0.4%	1.1%	216.1%
Bare Ground	1.7%	0.2%	-87.0%
Shrub	17.7%	8.5%	-52.0%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	36.6%	16.1%	-56.1%
Wetland	4.8%	4.1%	-15.4%
Forest	42.9%	73.4%	71.1%
Stream	0.1%	0.0%	-100.0%
Developed / Bare Ground	2.1%	1.4%	-35.1%
Shrub	17.7%	8.5%	-52.0%

	1970	1988	Change from 1970 to 1988
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	3.4%	1.7%	-49.7%
Dry Grassland	12.7%	7.4%	-41.9%
Forested Wetland	2.2%	2.1%	-0.4%
Non-Forested Wetland	1.9%	2.7%	40.6%
Young Forest	52.5%	43.0%	-18.1%
Mature Forest	20.8%	36.0%	72.8%
Old Forest	0.0%	5.0%	NA
Stream	0.0%	0.0%	0.0%
Developed	1.1%	0.6%	-46.3%
Bare Ground	0.2%	0.4%	91.6%
Shrub	8.5%	2.7%	-67.8%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	16.1%	9.1%	-43.6%
Wetland	4.1%	4.9%	19.0%
Forest	73.4%	84.0%	14.4%
Stream	0.0%	0.0%	0.0%
Developed / Bare Ground	1.4%	1.0%	-23.4%
Shrub	8.5%	2.7%	-67.8%

	1988	2003	Change from 1988 to 2003
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	1.7%	1.3%	-23.7%
Dry Grassland	7.4%	7.0%	-4.9%
Forested Wetland	2.1%	2.5%	18.5%
Non-Forested Wetland	2.7%	2.7%	0.3%
Young Forest	43.0%	44.2%	2.8%
Mature Forest	36.0%	22.8%	-36.7%
Old Forest	5.0%	18.5%	271.2%
Stream	0.0%	0.0%	-100.0%
Developed	0.6%	0.6%	4.6%
Bare Ground	0.4%	0.3%	-34.1%
Shrub	2.7%	1.3%	-51.6%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	9.1%	8.3%	-8.4%
Wetland	4.9%	5.3%	8.4%
Forest	84.0%	85.5%	1.8%
Stream	0.0%	0.0%	-100.0%
Developed / Bare Ground	1.0%	0.9%	-11.5%
Shrub	2.7%	1.3%	-51.6%

	1947	2003	Change from 1947 to 2003
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	4.2%	1.3%	-69.2%
Dry Grassland	32.4%	7.0%	-78.3%
Forested Wetland	1.6%	2.5%	63.7%
Non-Forested Wetland	3.3%	2.7%	-16.9%
Young Forest	25.8%	44.2%	71.3%
Mature Forest	17.1%	22.8%	33.4%
Old Forest	0.0%	18.5%	NA
Stream	0.1%	0.0%	-100.0%
Developed	0.4%	0.6%	77.5%
Bare Ground	1.7%	0.3%	-83.6%
Shrub	17.7%	1.3%	-92.5%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	36.6%	8.3%	-77.3%
Wetland	4.8%	5.3%	9.0%
Forest	42.9%	85.5%	99.3%
Stream	0.1%	0.0%	-100.0%
Developed / Bare Ground	2.1%	0.9%	-56.0%
Shrub	17.7%	1.3%	-92.5%

5.2 Absolute Land Cover Change – Historic Meadow

Absolute cover was also determined for the 143.36 acre historic meadow (**Table 5.2**). The most significant changes in area occurred between 1947 and 1970, as dry grassland areas declined by 52.5% from 66 acres to 31 acres and young forest increased by 177.7% from 24 acres to 65 acres. Within the grouped land cover classes, the forest group increased by 124.3% between 1947 and 2003, seeing an increase in total area from 32% to 73% of the historic meadow. The grassland and shrub classes declined by 71.7% and 73.9%, respectively, resulting in a final grassland area of 20.9 acres and shrub area of 2.88 acres.

Some increases also occurred within other land cover classes. The forested wetland class grew by 1221.3% between 1947 and 2003, but this may be because the initial forested wetland area in the meadow was close to zero, and a large portion of non-forested wetland in the southern portion of the meadow as of 1947 was reclassified as forested wetland in 1970. Another large increase occurred in the developed class between 1947 and 1970 as roads were built and/or paved. The grouped wetland class grew by 24% between 1947 and 2003, from 10.8 to 13.4 acres. Also, the developed / bare ground class increased by 71.7% between 1947 and 2003, but the class still only covered a relatively small area (2.0 acres) by 2003.

Table 5.2 – Original Land Cover and Grouped Land Cover Class Changes, 1947 to 1970, 1970 to 1988, 1988 to 2003, and 1947 to 2003, Township 8 South, Range 1 East, Section 13, Willamette Meridian, Historic Ranches Meadow

	1947	1970	Change from 1947 to 1970
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	5.7%	5.9%	3.1%
Dry Grassland	45.9%	21.8%	-52.5%
Forested Wetland	0.3%	4.2%	1101.3%
Non-Forested Wetland	7.2%	4.0%	-44.4%
Young Forest	16.4%	45.5%	177.7%
Mature Forest	16.0%	12.4%	-22.2%
Old Forest	0.0%	0.0%	NA
Stream	0.0%	0.0%	NA
Developed	0.6%	1.1%	94.4%
Bare Ground	0.3%	0.4%	69.4%
Shrub	7.7%	4.6%	-39.8%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	51.6%	27.6%	-46.4%
Wetland	7.5%	8.2%	8.7%
Forest	32.4%	58.0%	79.0%
Stream	0.0%	0.0%	NA
Developed / Bare Ground	0.8%	1.6%	86.8%
Shrub	7.7%	4.6%	-39.8%

	1970	1988	Change from 1970 to 1988
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	5.9%	3.1%	-47.3%
Dry Grassland	21.8%	13.3%	-39.1%
Forested Wetland	4.2%	4.1%	-1.8%
Non-Forested Wetland	4.0%	4.8%	20.4%
Young Forest	45.5%	41.4%	-9.1%
Mature Forest	12.4%	27.4%	120.4%
Old Forest	0.0%	0.0%	NA
Stream	0.0%	0.0%	NA
Developed	1.1%	1.0%	-8.2%
Bare Ground	0.4%	0.8%	89.3%
Shrub	4.6%	4.0%	-13.3%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	27.6%	16.4%	-40.8%
Wetland	8.2%	8.9%	9.0%
Forest	58.0%	68.8%	18.7%
Stream	0.0%	0.0%	NA
Developed / Bare Ground	1.6%	1.8%	18.5%
Shrub	4.6%	4.0%	-13.3%

	1988	2003	Change from 1988 to 2003
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	3.1%	2.3%	-24.5%
Dry Grassland	13.3%	12.2%	-7.6%
Forested Wetland	4.1%	4.6%	12.0%
Non-Forested Wetland	4.8%	4.7%	-1.8%
Young Forest	41.4%	43.5%	5.0%
Mature Forest	27.4%	18.2%	-33.5%
Old Forest	0.0%	10.9%	NA
Stream	0.0%	0.0%	-100.0%
Developed	1.0%	0.9%	-11.4%
Bare Ground	0.8%	0.5%	-36.7%
Shrub	4.0%	2.0%	-49.9%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	16.4%	14.6%	-10.8%
Wetland	8.9%	9.3%	4.5%
Forest	68.8%	72.6%	5.6%
Stream	0.0%	0.0%	-100.0%
Developed / Bare Ground	1.8%	1.4%	-22.4%
Shrub	4.0%	2.0%	-49.9%

	1947	2003	Change from 1947 to 2003
Land Cover Class	Percent Cover	Percent Cover	Percent Change
Wet Grassland	5.7%	2.3%	-59.0%
Dry Grassland	45.9%	12.2%	-73.3%
Forested Wetland	0.3%	4.6%	1221.3%
Non-Forested Wetland	7.2%	4.7%	-34.3%
Young Forest	16.4%	43.5%	165.1%
Mature Forest	16.0%	18.2%	14.0%
Old Forest	0.0%	10.9%	NA
Stream	0.0%	0.0%	NA
Developed	0.6%	0.9%	58.1%
Bare Ground	0.3%	0.5%	103.2%
Shrub	7.7%	2.0%	-73.9%
Grouped Cover Class	Percent Cover	Percent Cover	Percent Change
Grassland	51.6%	14.6%	-71.7%
Wetland	7.5%	9.3%	24.0%
Forest	32.4%	72.6%	124.3%
Stream	0.0%	0.0%	NA
Developed / Bare Ground	0.8%	1.4%	71.7%
Shrub	7.7%	2.0%	-73.9%

5.3 Change Detection

Land cover change detections were conducted for the periods from 1947 to 1970, 1970 to 1988, 1988 to 2003, and 1947 to 2003 for the section and historic meadow. The results of these change detections indicate how land cover types transitioned during each period. The results are grouped into four sections: Group A includes the results between 1947 and 1970, Group B the results between 1970 and 1988, Group C the results between 1988 and 2003, and Group D the results between 1947 and 2003. For each of the change detection groups, changes greater than 1% of total cover are discussed. Complete matrix diagrams displaying all 121 matrix values for the original eleven land cover classes and 36 matrix values for the grouped classes for each iteration can be found in **Appendix E**.

5.3.1 *Change Detection Group A: 1947 to 1970*

Between 1947 and 1970, the two most significant land cover changes occurred between the shrub to young forest (14.3%) and dry grassland to young forest (12.1%) categories (**Table 5.3**). Much of the shrub to young forest change occurred directly to the northeast of the Ranches meadow as well as in the north half of the northeast corner of the section. The dry grassland to young forest transition occurred along the western edge of the Ranches meadow as well as throughout the section, with the least amount of this type of change occurring in the southwest corner of the section. In addition, the young forest to young forest and mature forest to mature forest categories were sizeable, covering a combined 32.7% of the section. In contrast, dry grassland to

dry grassland occurred in only 11.2% of the section. This means that more forest remained forest than grassland remained grassland during this study period.

Additionally, the forest to forest grouped land cover class was greater than double any of the other classes in the grouped land cover class change detection for this time period (**Figure 5.2**). As noted previously, 73.4% of the section was comprised of forest in 1970. The group change detection provides the breakdown of most of this total: 38.7% of the section was forest in 1947 and 1970, while 14.6% was shrub, 14.4% was grassland, 1.8% was developed or bare ground, and 1.7% was wetland in 1947 and had changed to forest by 1970.

The historic meadow experienced less transition to forest than the section. Fifty-four and seven-tenths percent of the land cover changes within the historic meadow were changes between the same land cover class (**Table 5.4**). Only 7% of the area changed from dry grassland to forest, which was 52% less than this type of change in the section. Similarly, 7% of the meadow area changed from shrub to forest, which was 42% less than this type of change in the section. Forest to forest land cover change occurred less frequently in the historic meadow than in the section. Specifically, young forest to young forest land cover change comprised 13.7% of the meadow, 26% less than occurred in the section. Furthermore, mature forest to mature forest occurred 79% less in the historic meadow area than it did in the section. Some of the historic meadow grouped land cover classes that did not change were grassland (41% of the meadow), forest (18%), and wetland (7.7%), which compared to values of 14.4%, 38.7% and 2.6% of the area in the section for these classes, respectively.

Grassland to grassland occurred 64% less and forest to forest occurred 115% more in the section than it did in the historic meadow.

Table 5.3 1947 to 1970 Original Land Cover and Grouped Land Cover Class Changes - Values Covering Greater Than 1% of the Area of the Section

Original Eleven Land Cover Classes – Section 13			Grouped Land Cover Classes - Section 13		
47 to 70 Change	Percent of Area	Area in Acres	47 to 70 Change	Percent of Area	Area in Acres
YF to YF	18.51	120.27			
SH to YF	14.36	93.27	Forest to Forest	38.66	251.13
MF to MF	14.15	91.93	Shrub to Forest	14.60	94.87
DG to YF	12.1	78.59	Grassland to Grassland	14.41	93.59
DG to DG	11.24	73.01	Grassland to Forest	14.36	93.31
YF to MF	5.05	32.8	Grassland to Shrub	4.55	29.58
DG to SH	4.33	28.12	Wetland to Wetland	2.68	17.41
SH to SH	1.92	12.51	Shrub to Shrub	1.92	12.51
DG to WG	1.74	11.28	Developed / Bare Ground to Forest	1.81	11.76
WG to YF	1.61	10.47	Wetland to Forest	1.70	11.02
BG to YF	1.55	10.08	Forest to Shrub	1.40	9.12
NW to FW	1.51	9.83			
FW to YF	1.37	8.87			
WG to WG	1.21	7.87			

Table 5.4 1947 to 1970 Original Land Cover and Grouped Land Cover Class Changes - Values Covering Greater Than 1% of the Area of the Historic Meadow

Original Eleven Land Cover Classes - Historic Meadow			Grouped Land Cover Classes - Historic Meadow		
47 to 70 Change	Percent of Area	Area in Acres	47 to 70 Change	Percent of Area	Area in Acres
DG to DG	30.57	43.82	Grassland to Grassland	41.42	59.38
YF to YF	13.67	19.60	Forest to Forest	18.05	25.88
DG to WG	7.47	10.71	Grassland to Forest	9.25	13.26
DG to YF	7.02	10.06	Wetland to Wetland	7.68	11.02
SH to YF	7.01	10.05	Shrub to Forest	7.43	10.65
DG to SH	5.84	8.37	Grassland to Shrub	6.24	8.94
NW to NW	4.68	6.71	Grassland to Wetland	2.95	4.23
MF to MF	3.03	4.35	Grassland to Developed / Bare Ground	2.19	3.14
WG to WG	2.72	3.90	Wetland to Forest	1.13	1.63
NW to FW	2.66	3.81			
WG to YF	2.23	3.20			
WG to NW	1.65	2.37			
DG to DE	1.32	1.90			

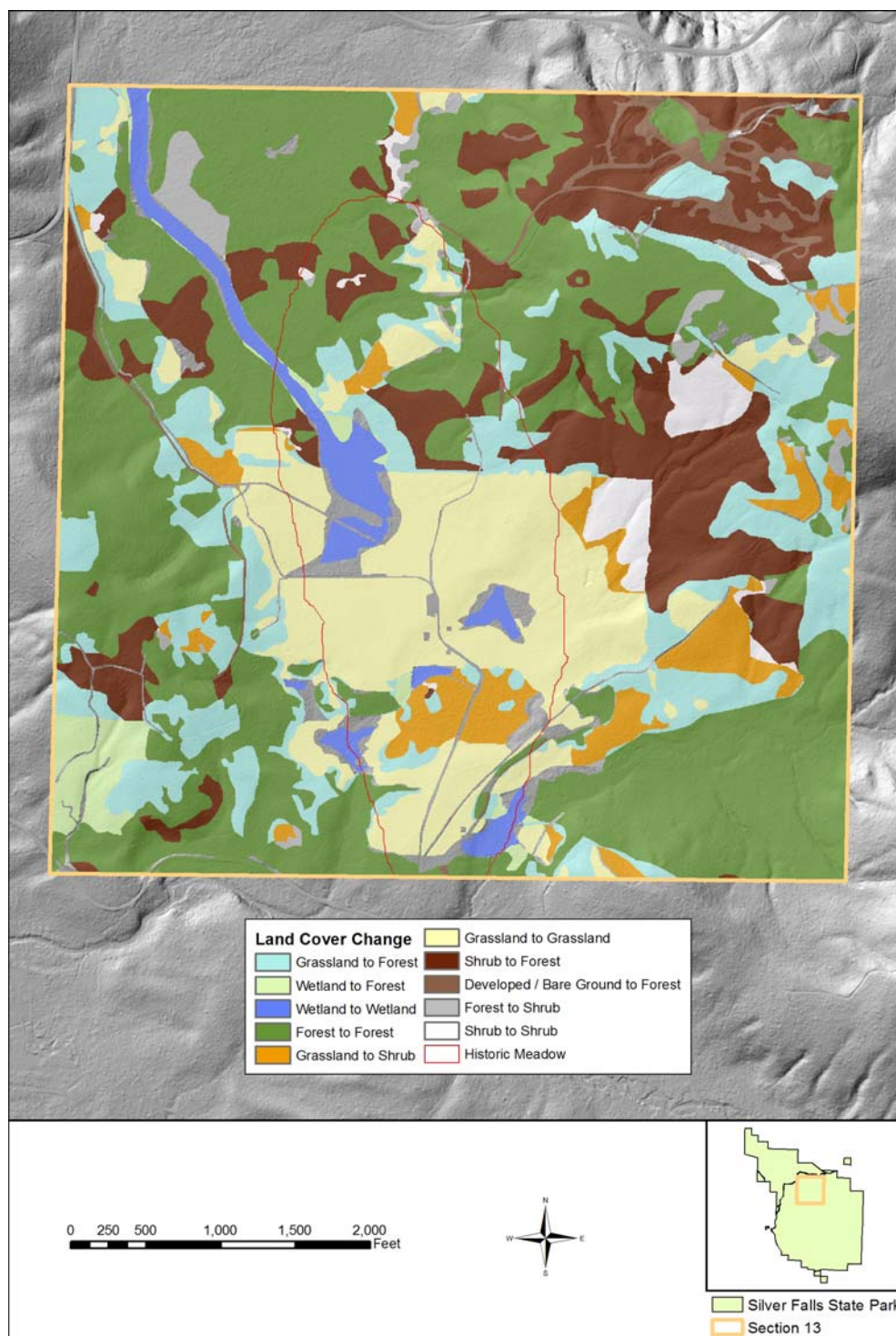


Figure 5.2 - Change Detection 1947 to 1970: Grouped Land Cover Class Changes
T8S R1E Section 13 Willamette Meridian

Sources: OPRD 2007, Unpublished Data, Carl Anderson 2007

Map Author: Carl Anderson 2007

5.3.2 Change Detection Group B: 1970 to 1988

The important land cover changes occurring between 1970 and 1988 were within the three forest to forest categories of young forest to young forest, young forest to mature forest, and mature forest to mature forest, which represented 64.4% of the section (**Table 5.5**). These changes were found in all areas surrounding the Ranches meadow. Mature forest to old forest also contributed 4.9% of the total and was found solely within the southeastern portion of the meadow on the south side of the South Fork of Silver Creek. Other substantial trends included the transition of shrub to young forest (5.6%) and dry grassland to young forest (3.0%), primarily along the immediate fringes of the Ranches meadow. The value of 1.4% for the shrub to mature forest category is an error and is most likely due to inaccuracies during the interpretation of the aerial photographs.

As a whole, the rate of land cover changes between classes decreased compared to the 1947 to 1970 time period. For example, the frequency of the shrub to young forest category decreased by 61% and the frequency of the dry grassland to young forest category decreased by 75% during the 1970 to 1988 period compared to the 1947 to 1970 period. What occurred instead was that more of the section remained within the forest grouped land cover class category (**Figure 5.3**). Forest to forest covered 70% of the section during the 1970 to 1988 time period, an increase of 81% over the 1947 to 1970 time period. In contrast, the amount of land in the grassland to grassland category decreased by 42% when comparing the 1970 to 1988 change detection with the 1947 to 1970 change detection. The wetland to wetland category

grew slightly between the two change detection groups, increasing by 14%, but still covered only 3.1% of the section.

Fifty and four-tenths percent of the land cover changes within the historic meadow were in “no change” categories (**Table 5.6**). The amount of change in the dry grassland to dry grassland category within the historic meadow decreased by 29.4% between the 1947 to 1970 period and the 1970 to 1988 period. However, during the 1970 to 1988 time period, this category covered 247% more in area within the historic meadow than within the section. The amount of dry grassland to dry grassland land cover change decreased in the historic meadow between the 1947 to 1970 period and the 1970 to 1988 period. However, the amount of this category within the historic meadow remained greater than the amount in the section between 1970 and 1988 as a percentage of area.

Among the historic meadow grouped classes, forest to forest overtook grassland to grassland as the largest category, with each class covering 34.3% and 31.0% of the historic meadow, respectively. When comparing the 1947 to 1970 change detection and the 1970 to 1988 change detection, this was an increase of 90% in the forest to forest category and a decrease of 25% in the grassland to grassland category. Wetland to wetland change comprised 9.1% of the historic meadow, an increase of 18% between 1947 to 1970 and 1970 to 1988. Finally, the grassland to forest and grassland to shrub classes covered 4.5% and 4.3% of the historic meadow, decreases from the 1947 to 1970 period of 52% and 31%, respectively.

Table 5.5 1970 to 1988 Original Land Cover and Grouped Land Cover Class Changes
- Values Covering More than 1% of the Area of the Section

Original Eleven Land Cover Classes - Section 13			Grouped Land Cover Classes - Section 13		
70 to 88 Change	Percent of Area	Area in Acres	70 to 88 Change	Percent of Area	Area in Acres
YF to YF	31.80	206.59	Forest to Forest	70.06	455.11
YF to MF	18.37	119.36	Grassland to Grassland	8.42	54.71
MF to MF	14.23	92.43	Shrub to Forest	6.97	45.25
DG to DG	6.23	40.48	Grassland to Forest	4.06	26.36
SH to YF	5.60	36.37	Wetland to Wetland	3.05	19.84
MF to OF	4.90	31.81	Grassland to Shrub	1.63	10.61
DG to YF	2.99	19.45			
NW to NW	1.66	10.78			
FW to FW	1.38	8.97			
SH to MF	1.37	8.88			
DG to SH	1.34	8.68			

Table 5.6 1970 to 1988 Original Land Cover and Grouped Land Cover Class Changes
- Values Covering More than 1% of the Area of the Historic Meadow

Original Eleven Land Cover Classes - Historic Meadow			Grouped Land Cover Classes - Historic Meadow		
70 to 88 Change	Percent of Area	Area in Acres	70 to 88 Change	Percent of Area	Area in Acres
DG to DG	21.62	31.00	Forest to Forest	34.25	49.10
YF to MF	16.00	22.94	Grassland to Grassland	30.97	44.40
YF to YF	14.39	20.62	Wetland to Wetland	9.15	13.12
NW to NW	6.61	9.47	Grassland to Forest	4.46	6.39
WG to WG	3.96	5.68	Grassland to Shrub	4.32	6.19
MF to MF	3.85	5.52	Shrub to Forest	3.34	4.79
WG to DG	3.48	4.99	Shrub to Shrub	2.66	3.81
SH to YF	3.03	4.34	Grassland to Developed / Bare Ground	2.06	2.95
DG to SH	2.97	4.26	Grassland to Wetland	1.80	2.58
SH to SH	2.66	3.81	Wetland to Forest	1.11	1.59
DG to YF	2.61	3.74	Developed / Bare Ground to Developed / Bare Ground	1.02	1.46
FW to FW	2.49	3.57			
DG to WG	1.90	2.73			
WG to NW	1.45	2.08			
WG to SH	1.35	1.93			
DG to BG	1.05	1.51			

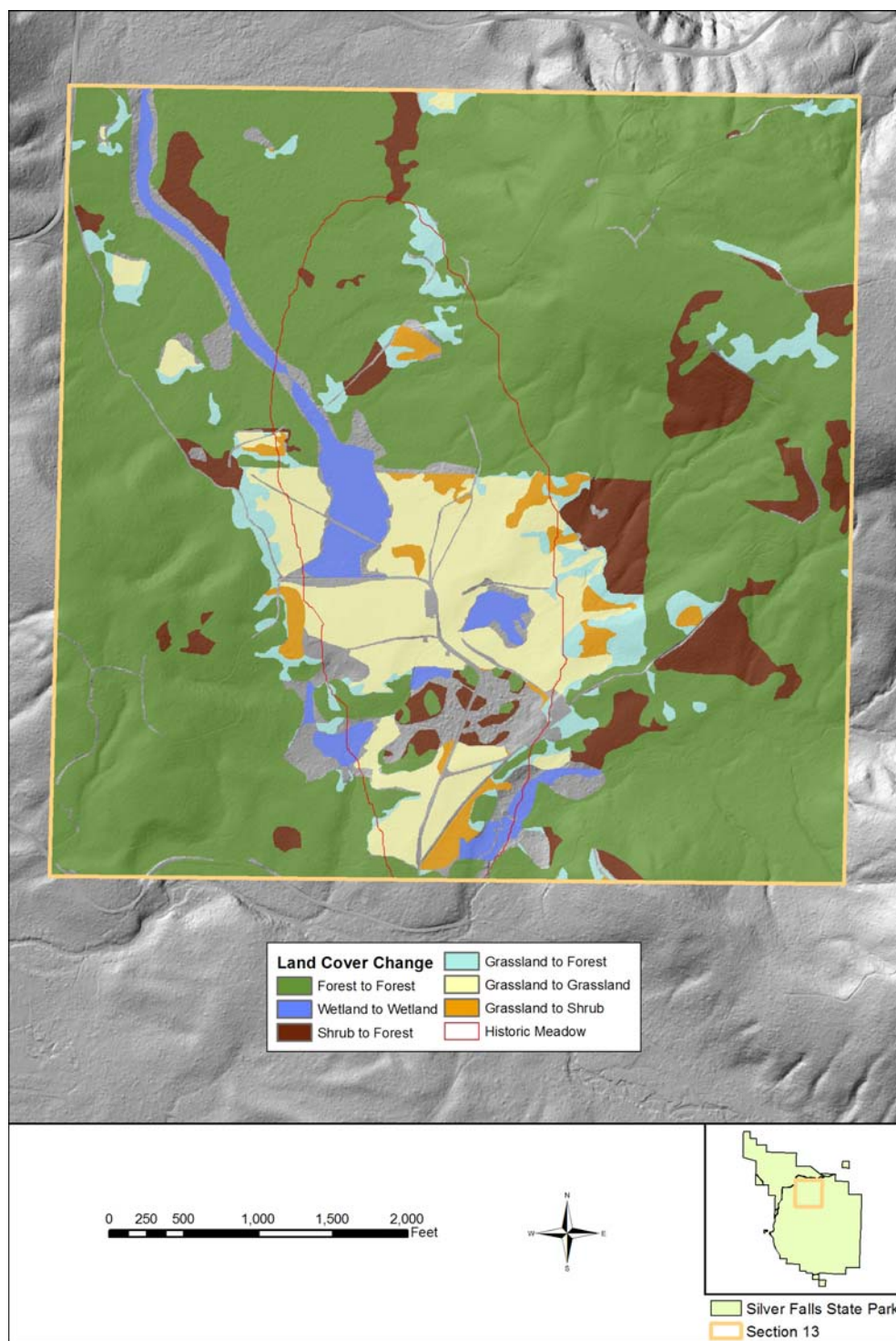


Figure 5.3 - Change Detection 1970 to 1988: Grouped Land Cover Class Changes
T8S R1E Section 13 Willamette Meridian

Sources: OPRD 2007; Unpublished Data, Carl Anderson 2007

Map Author: Carl Anderson 2007

5.3.3 Change Detection Group C: 1988 to 2003

Land cover changes during this time period were dominated by changes between “forest” categories or “no change” categories, while very little of the section maintained grassland cover. The essential changes occurring between 1988 and 2003 were within three forest to forest categories, but in this instance the categories were young forest to young forest, mature forest to mature forest, and mature forest to old forest, representing 67.4% of the section (**Table 5.7**). Young forest to mature forest and mature forest to young forest also contributed a combined 8.5% of the total. Obviously, the mature forest to young forest category should be zero, and this result should belong in either the young forest to young forest or mature forest to mature forest categories. The only other change category exceeding 1% of the total area was the shrub to young forest category at 1.4%. Only 5.6% of the section (36.5 acres) was in the dry grassland to dry grassland category, a decrease of 10% when compared to the 1970 to 1988 change detection period and 50% when compared to the 1947 to 1970 period.

The rate of land cover changes decreased even further during this time period. Only 1.5% of the section was in the shrub to forest category, and 1.0% was in the grassland to forest category. These were 78% and 74% declines for these respective categories between the 1970 to 1988 and 1988 to 2003 change detections (**Figure 5.4**). These “change” categories were located in close proximity to the Ranches meadow. Between the 1970 to 1988 and 1988 to 2003 periods, the amount of grassland to

grassland change declined by 15.4% and the amount of wetland to wetland change increased by 30.5%.

In the historic meadow, dry grassland to dry grassland remained the largest class within the original land cover class change detection at 22% of the total area (**Table 5.8**). This was an increase of 2% over the 1970 to 1988 change detection result. The non-forested wetland to non-forested wetland class comprised 7.5% of the historic meadow, an increase of 13.4% over the 1970 to 1988 change detection result. Overall, seven of the top nine categories (71.7% of the historic meadow area) were “no change” categories.

In the grouped land cover change detection analysis of the historic meadow, forest to forest, covering 39.9% of the meadow, increased its dominance over the grassland to grassland (28.6% of the meadow) land cover change category during this time period (**Figure 5.4**). The forest to forest category grew by 16.5% and the grassland to grassland category decreased by 7.6% between the 1970 to 1988 and 1988 to 2003 change detections. Still, the forest to forest category covered 51% less area as a percentage in the historic meadow than it did in the section in the 1988 to 2003 change detection.

Table 5.7 1988 to 2003 Original Land Cover and Grouped Land Cover Class Changes
- Values Covering More than 1% of the Area of the Section

Original Eleven Land Cover Classes - Section 13				Grouped Land Cover Classes - Section 13		
88 to 03 Change	Percent of Area	Area in Acres		88 to 03 Change	Percent of Area	Area in Acres
YF to YF	36.83	238.88		Forest to Forest	81.08	525.77
MF to MF	17.60	114.15		Grassland to Grassland	7.12	46.18
MF to OF	13.01	84.40		Wetland to Wetland	3.98	25.79
DG to DG	5.63	36.53		Shrub to Forest	1.52	9.88
OF to OF	4.75	30.79		Grassland to Forest	1.04	6.75
YF to MF	4.26	27.65				
MF to YF	4.24	27.52				
NW to NW	2.27	14.73				
FW to FW	1.67	10.85				
SH to YF	1.44	9.33				

Table 5.8 1988 to 2003 Original Land Cover and Grouped Land Cover Class Changes
- Values Covering More than 1% of the Area of the Historic Meadow

Original Eleven Land Cover Classes - Historic Meadow				Grouped Land Cover Classes - Historic Meadow		
88 to 03 Change	Percent of Area	Area in Acres		88 to 03 Change	Percent of Area	Area in Acres
DG to DG	22.04	31.60		Forest to Forest	39.90	57.20
YF to YF	17.47	25.04		Grassland to Grassland	28.61	41.01
MF to MF	15.52	22.26		Wetland to Wetland	10.53	15.09
NW to NW	7.50	10.75		Shrub to Forest	4.01	5.75
WG to WG	3.90	5.58		Forest to Wetland	2.46	3.53
SH to YF	3.65	5.24		Shrub to Shrub	2.33	3.34
MF to OF	3.52	5.05		Grassland to Forest	2.22	3.18
FW to FW	2.96	4.24		Shrub to Grassland	1.84	2.64
SH to SH	2.33	3.34		Developed / Bare Ground to Developed / Bare Ground	1.68	2.42
WG to DG	2.00	2.87		Developed / Bare Ground to Grassland	1.13	1.62
YF to MF	1.74	2.49				
MF to YF	1.64	2.35				
YF to FW	1.61	2.31				
DG to YF	1.51	2.17				
SH to WG	1.33	1.90				
DE to DE	1.20	1.72				

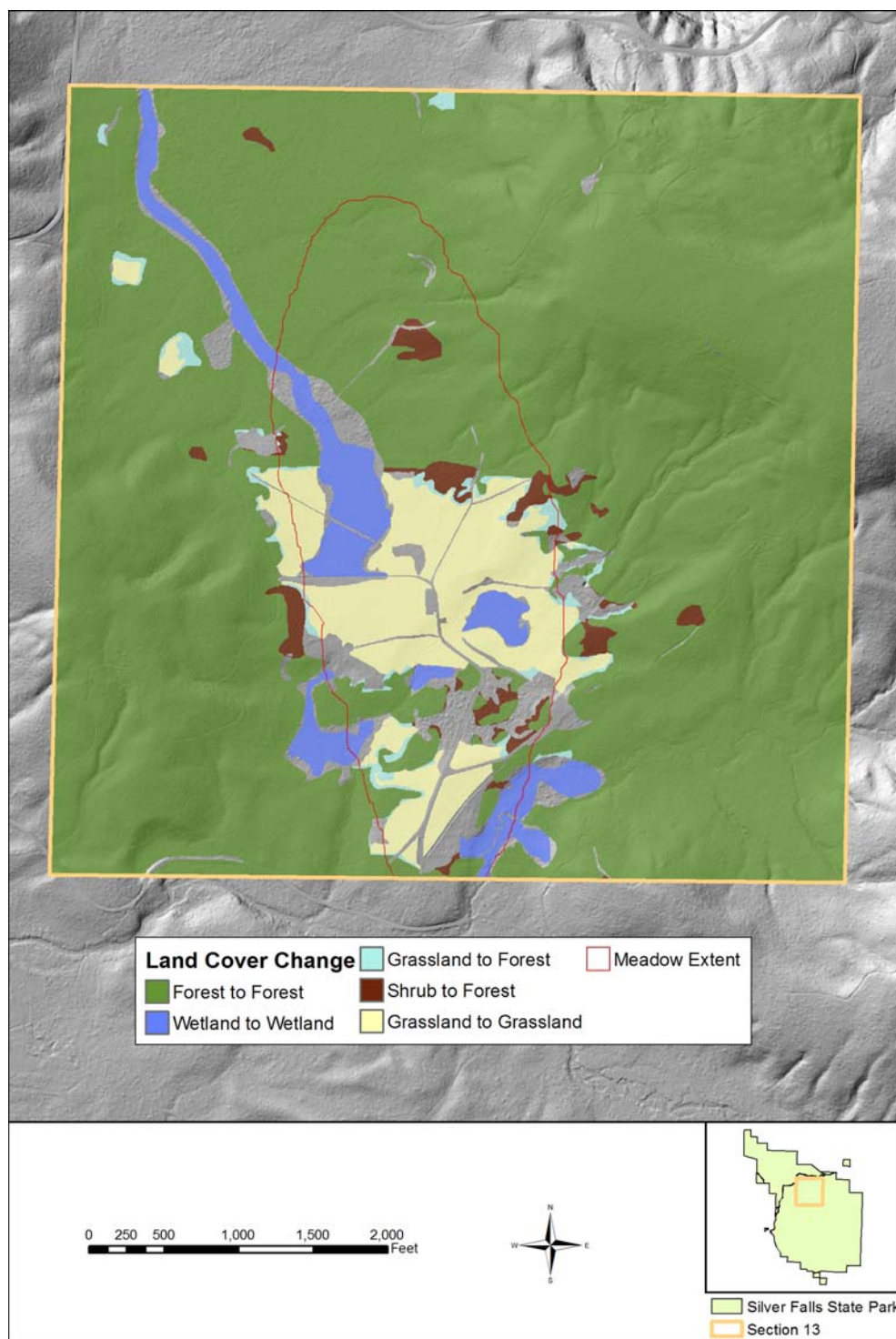


Figure 5.4 - Change Detection 1988 to 2003: Grouped Land Cover Class Changes
T8S R1E Section 13 Willamette Meridian

Sources: OPRD 2007; Unpublished Data, Carl Anderson 2007

Map Author: Carl Anderson 2007

5.3.4 Change Detection Group D: 1947 to 2003

The purpose of this iteration was to see what transitions occurred during the entire study period. The dominant changes occurring between 1947 and 2003 were split between four categories, each of which was greater than 13% of the area (**Table 5.9**). Combined, dry grassland to young forest and shrub to young forest comprised 32.2% of the area, while young forest to mature forest and mature forest to old forest contributed a combined 30.7%. The dry grassland to young forest and shrub to young forest classes occurred primarily to the east and east-northeast of the Ranches meadow out to the section boundary, along the Winter Creek drainage to the northwest, and on the western edge of the Ranches meadow. Most of the remaining changes shown in **Table 5.9** are from a non-forest class to a forest class.

The grouped land cover class change detection revealed how the forest land cover class became the most dominant land cover type in the section between 1947 and 2003. Greater than 40% of the area was within the forest to forest land cover category, while 23.6% changed from grassland to forest and 16.8% from shrub to forest. Other changes occurred in the grassland to wetland (1.6% of the section area) and grassland to shrub (1.3% of the section area) classes. Only 10.7% of the section area (69.09 acres) was comprised of the grassland to grassland or wetland to wetland categories. Most of the “change” categories occurred immediately to the east of the Ranches meadow, in the northeast corner of the section, and along the west side of the wetland feeding Winter Falls to the north (**Figure 5.5**).

The area of the dry grassland to dry grassland category within the historic meadow was 290% more by percent than it was in the section, but dry grassland changed to another land cover class 22% more in the historic meadow than in the section. This means that more of the historic meadow than the section started out as dry grassland as a percentage. However, more dry grassland in the historic meadow has changed to other land cover classes than in the section as a percentage. In addition, changes from any non-forest land cover class to any type of forest class occurred within 26.7% of the historic meadow area versus 38.1% of the section, which means that this type of change occurred 30% less in the historic meadow.

The grouped land cover class change detection provided similar results, as grassland to grassland was the single largest group (31.7%) and occurred 300% more in the historic meadow than the section (**Table 5.10**). Grassland to other grouped land cover types comprised 30.4% of the historic meadow, meaning that these types of land cover changes occurred 15% more in the historic meadow than in the section. Forest to forest occurred 55% less in the historic meadow than in the section. Finally, wetland to wetland occurred 217% more and shrub to forest occurred 53% less in the historic meadow than in the section.

Table 5.9 1947 to 2003 Original Land Cover and Grouped Land Cover Class Changes
- Values Covering More than 1% of the Area of the Section

Original Land Cover Classes - Section 13			Grouped Land Cover Classes - Section 13		
47 to 03 Change	Percent of Area	Area in Acres	47 to 03 Change	Percent of Area	Area in Acres
DG to YF	19.22	124.67	Forest to Forest	40.20	260.76
YF to MF	15.47	100.37	Grassland to Forest	23.60	153.08
MF to OF	15.23	98.79	Shrub to Forest	16.82	109.09
SH to YF	13.01	84.40	Grassland to Grassland	7.92	51.38
DG to DG	6.62	42.94	Wetland to Wetland	2.73	17.70
YF to YF	6.51	42.20	Developed / Bare Ground to Forest	1.89	12.23
SH to MF	3.35	21.73	Wetland to Forest	1.78	11.51
YF to OF	2.09	13.58	Grassland to Wetland	1.59	10.29
DG to MF	1.77	11.46	Grassland to Shrub	1.25	8.13
BG to YF	1.52	9.85			
NW to FW	1.46	9.46			
FW to YF	1.32	8.59			
WG to YF	1.30	8.45			
DG to SH	1.23	7.96			
NW to NW	1.18	7.66			

Table 5.10 1947 to 2003 Original Land Cover and Grouped Land Cover Class
Changes - Values Covering More than 1% of the Area of the Historic Meadow

Original Land Cover Classes - Historic Meadow			Grouped Land Cover Classes - Historic Meadow		
47 to 03 Change	Percent of Area	Area in Acres	47 to 03 Change	Percent of Area	Area in Acres
DG to DG	25.88	37.10	Grassland to Grassland	31.65	45.37
DG to YF	15.17	21.75	Grassland to Forest	20.13	28.86
YF to MF	11.56	16.57	Forest to Forest	18.07	25.91
NW to NW	5.11	7.32	Wetland to Wetland	8.65	12.40
SH to YF	4.47	6.41	Shrub to Forest	7.83	11.23
DG to WG	3.92	5.62	Grassland to Wetland	4.24	6.08
DG to SH	3.21	4.60	Grassland to Shrub	3.21	4.60
NW to FW	3.13	4.49	Grassland to Developed / Bare Ground	2.82	4.04
MF to OF	3.03	4.35			
SH to MF	2.85	4.09			
YF to YF	2.57	3.69			
WG to YF	2.26	3.24			
WG to NW	2.17	3.12			
DG to MF	1.99	2.86			
DG to DE	1.59	2.28			
DG to BG	1.09	1.56			

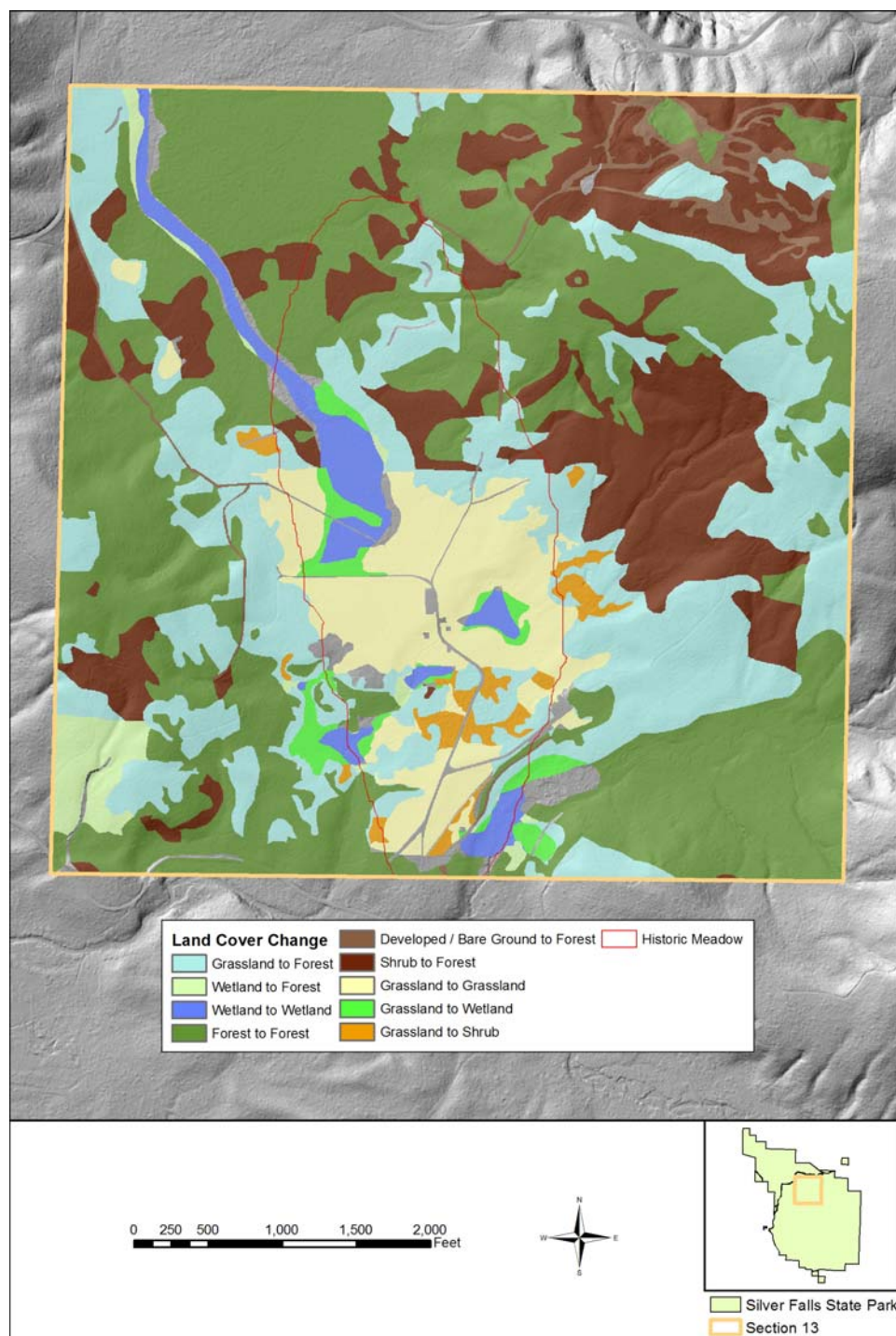


Figure 5.5 - Change Detection 1947 to 2003: Grouped Land Cover Class Changes
T8S R1E Section 13 Willamette Meridian

Sources: OPRD 2007; Unpublished Data, Carl Anderson 2007

Map Author: Carl Anderson 2007

5.4 GIS Analysis

The second portion of the study examined several physical and anthropogenic factors to determine how they affected land cover changes during the study period. The factors analyzed were slope, aspect, soil map units, historic vegetation, management, historic timber extent, and land ownership. Each of these factors were evaluated against the 1947 to 2003 grouped class change detection for the whole section (See **Appendix F** for Modelbuilder diagram). Each of the land cover changes highlighted in the “Grouped Land Cover Class” section of **Table 5.9** are included in this analysis. This land cover change detection contained a total of 26 different types of change or no change occurrences.

5.4.1 *Slope and Aspect*

The first model parameters tested were slope and aspect. Slope was split into three classes, which consisted of the following values: 0% – 10%, 10% – 30%, and > 30%. Aspect contained 3 classes, which consisted of Flat (0°), North (270° – 360°, >0° - 90°) and South (90° – 270°). **Figure 5.6** displays how these files were compared to land cover changes using Modelbuilder in ArcGIS 9.1.

These parameters indicate the most common land cover changes between 1947 and 2003 in the Section as a function of the slope and aspect. These groupings of land cover change in relation to slope and aspect are depicted in **Appendix G**.

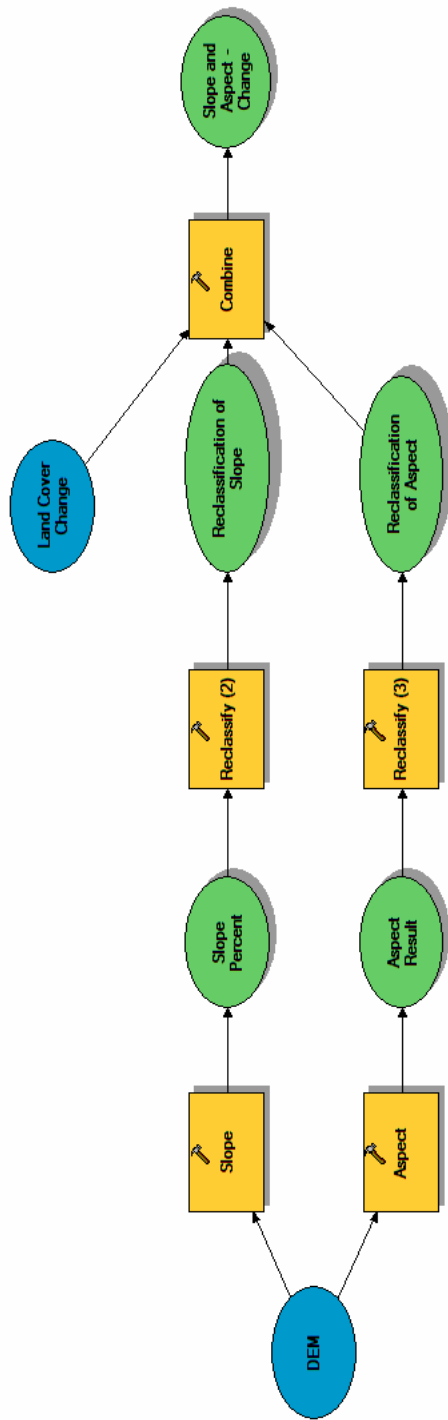


Figure 5.6 – Topography and Land Cover Comparison Model Diagram

Table 5.11 Percent of Each Grouped Land Cover Change Class Within Each Slope and Aspect Category: 1947 to 2003

Class	Slope 0% – 10%		Slope 10% - 30%		Slope >30%	
	North	South	North	South	North	South
Forest to Forest	15.47	18.31	22.45	25.45	10.12	8.17
Grassland to Forest	15.45	17.22	17	38.19	3.86	8.25
Shrub to Forest	11.12	11.6	19.43	32.73	12.67	12.42
Grassland to Grassland	41.85	40.97	4.61	12.42	0	0
Wetland to Wetland	42.61	44.1	5.1	7.85	0	0
Developed / Bare Ground to Forest	15.77	11.34	38.12	12.59	19.35	2.79
Wetland to Forest	8.06	14.83	7.67	57.66	2.93	8.84
Grassland to Wetland	37.91	41.38	7.72	12.55	0.19	0.2
Grassland to Shrub	36.19	38.04	9.97	15.24	0.18	0.28

The results for the land cover change classes covering more than 1% of the total section area are depicted in **Table 5.11**. Three aspect “groups” can be discerned from the data: first, the forest to forest, grassland to forest, shrub to forest, grassland to grassland, wetland to wetland, grassland to wetland, and grassland to shrub categories occurred slightly more often on south-facing slopes (an average of 55% of the time) than north facing slopes (45% of the time). In contrast, developed / bare ground to forest was the only class that occurred much more often on north-facing slopes than south facing slopes (73% versus 27%). This is likely due to logging activities and reforestation that occurred in the northeast portion on the section, which is on a

generally north-facing slope. Finally, wetland to forest occurred much more on south-facing slopes (81% of the time) than north-facing slopes.

Secondly, the results can be grouped by slope percent. The forest to forest, grassland to forest, shrub to forest, developed / bare ground to forest and wetland to forest occurred an average of 82% of the time on slopes less than 30%, while grassland to grassland, wetland to wetland, grassland to wetland and grassland to shrub occurred on slopes of 0% to 30% almost 100% of the time. These groupings indicate that changes from any land cover category to forest occur more frequently as a percentage on slopes greater than 30% than changes from grassland to grassland, wetland to wetland, grassland to wetland and grassland to shrub do.

5.4.2 Soils

The second portion of the GIS Analysis was a comparison of the land cover change classes to soil types. A total of four soil map unit types exist within the section: Kinney, McCully, Horeb, and Minniece. The most common soil in the section is Kinney (73.78%), followed by McCully (22.92%), Horeb (1.71%), and Minniece (1.60%). **Appendix H** displays complete results of land cover changes according to each soil type.

The three most common land cover change classes generally occurred in proportion to the soil composition of the Section (**Table 5.12**). Forest to forest occurred 35% more on McCully and 11% less on Kinney than would be expected based on percent soil coverage, while grassland to forest exhibited the opposite

tendency, occurring 19% more on McCully and 10% more on Kinney than would be expected based on percent soil coverage. Forest to forest occurred 75% more on Horeb soils than would be expected. All three of these groups occurred very infrequently on Minniece soils.

Table 5.12 Percent of Each Grouped Land Cover Change Class Within Each Soil Type: 1947 to 2003

Change	Soil Type			
	Kinney	McCully	Horeb	Minniece
Forest to Forest	65.36	31.61	3	0.03
Grassland to Forest	81.4	18.6	0	0
Shrub to Forest	78.64	21.08	0.14	0.14
Grassland to Grassland	90.91	2.41	0.07	6.61
Wetland to Wetland	55.04	30.59	4.03	10.34
Developed / Bare Ground to Forest	79.66	17.83	1.94	0.56
Wetland to Forest	81.4	17.47	1.13	0
Grassland to Wetland	61.5	8.1	1.43	28.96
Grassland to Shrub	97.96	0	0.51	1.53

Of the remaining six land cover change groups displayed in **Table 5.12**, four show distributions different than the percent soil cover. Grassland to grassland occurs 23% more on Kinney soils, 89% less on McCully soils and 313% more on Minniece soils than expected based on percent soil coverage. Wetland to wetland occurs 33% more on McCully soils, 25% less on Kinney, 546% more on Minniece and 136% more Horeb soil types than expected based on percent soil coverage. Grassland to wetland occurs 1710% more on Minniece soils but 65% less on McCully soils than expected

based on percent soil coverage. Finally, grassland to shrub occurs on Kinney soils 98% of the time.

5.4.3 Historic Vegetation

The next portion of the GIS analysis compared pre-settlement vegetation data, as compiled by the Oregon Natural Heritage Program (2002), with changes in land cover during the study period. Since the scale of this historic vegetation data for the study area is only 1:24000, only two types of pre-settlement vegetation existed in the GIS shapefile from ONHP for this section: Douglas fir and Roemer's fescue. Prior to settlement, Douglas fir occupied nearly all of the section (97.45%) while only 2.55% of the Section was covered by the Roemer's fescue vegetation type (See **Appendix C.2**). The complete results of the comparison of these two vegetation types to land cover changes between 1947 and 2003 within the section are displayed in **Appendix I**.

Five of the ten most common land cover change classes stand out because they differ from the historic vegetation distributions (**Table 5.13**). The first is the shrub to forest category, which took place entirely within the Douglas fir historic vegetation type. This signifies that there was most likely no shrub cover in the historic Roemer's fescue vegetation area in 1947. The next category is grassland to grassland. As a percentage, five times as much of this land cover change category occurred within the historic Roemer's fescue area compared to its occurrence in the whole section. This indicates that the grassland to grassland area within the historic Roemer's vegetation area comprised an important portion of the grassland to grassland land cover change

class in the whole section between 1947 and 2003. Similarly, the wetland to wetland land cover change class occurred four times more within the Roemer's fescue area than was expected based on percent historic vegetation coverage.

Grassland changed 188% more to wetland and 389% more to shrub within the historic Roemer's fescue area than expected based on percent historic vegetation coverage. However, these results might have been expected due to the fact that these land cover types are logical successors from the grassland land cover type and given the fact that they are in close proximity to the South Fork of Silver Creek.

Table 5.13 Percent of Each Grouped Land Cover Change Class Within Each Historic Vegetation Type: 1947 to 2003

Change	Historic Vegetation Type	
	Douglas fir	roemer's fescue
Forest to Forest	99.05	0.95
Grassland to Forest	98.78	1.22
Shrub to Forest	100	0
Grassland to Grassland	87.21	12.79
Wetland to Wetland	91.42	8.58
Developed / Bare Ground to Forest	97.38	2.62
Wetland to Forest	99.85	0.15
Grassland to Wetland	92.65	7.35
Grassland to Shrub	87.54	12.46

5.4.4 Vegetation Management

Four unique types of vegetation management occurred during the study period in the section, mostly within the Ranches meadow. These types were herbicide,

mowing, planting, and thinning. **Table 5.14** displays the amounts and acreages of each of these treatments within the section. Combined, these treatments account for less than 6.75% of the entire section, so the percent totals for this analysis (**Table 5.15**) only indicate what percent of each land cover change class that occurred in the vegetation management areas underwent each type of management action. The most frequent treatments occurred in the grassland to grassland land cover change class. Mowing consisted of 62% of the treatments in this class and herbicide application for most of the other 38%. The second most frequent land cover change class that experienced vegetation management was shrub to forest, which only experienced thinning treatments. The third most amount of management occurred in the grassland to forest land cover change class. Thinned treatments were the most common, covering 60% of this class, while Plantings covered 37%.

Table 5.14 – Vegetation Management Types, Acreages, and Percentage of Section

Type	Acreage	Percent of Section
Herbicide	9.55	1.47
Mowed	17.74	2.74
Planted	1.62	1.62
Thinned	15.49	2.39

Table 5.15 – Percent of Vegetation Management Type Within Each Land Cover Change Class that Experienced Vegetation Management Action(s): 1947 to 2003

Change	Vegetation Management Type			
	Herbicide	Mowing	Planting	Thinning
Developed / Bare Ground to Developed / Bare Ground	0	100	0	0
Developed / Bare Ground to Grassland	37.18	62.82	0	0
Forest to Forest	0	0	0	100
Grassland to Developed / Bare Ground	0.15	99.66	0.19	0
Grassland to Forest	0.53	2.52	36.79	60.16
Grassland to Grassland	37.53	62.04	0.08	0.35
Grassland to Shrub	0.39	0	0	99.61
Grassland to Wetland	0	100	0	0
Shrub to Forest	0	0	0	100
Wetland to Grassland	0	100	0	0

5.4.5 *Historic Timber*

According to the timber data (Oregon Department of Forestry 2007), most of the section was burned over as part of the Silverton Fire of 1865, after which these areas were restocked. As a result, the two timber categories as of 1914 were “Burned Areas re-stocking” and “Non-Timber Areas.” The non-timber areas covered 5.9% of the section, located completely in the southwest corner (see **Appendix C.3**). These non-timber areas are also situated where the southwestern part of the section drains into the South Fork of Silver Creek. Given these facts, the results in **Table 5.16** are mostly as expected based on the percent coverage of these two timber class types. The important exceptions were within the stream to forest and wetland to forest categories

within the non-timber areas, which occurred 1405% and 1108% more than expected based upon the percent coverage of timber classes for the section.

Table 5.16 Percent of Each Grouped Land Cover Change Class Within Each Historic Timber Type: 1947 to 2003

Change	Historic Timber Type	
	Burned Areas - Restocking	Non-Timber Areas
Developed / Bare Ground to Developed / Bare Ground	100	0
Developed / Bare Ground to Forest	100	0
Developed / Bare Ground to Grassland	100	0
Developed / Bare Ground to Shrub	100	0
Developed / Bare Ground to Wetland	100	0
Forest to Developed / Bare Ground	62.13	37.87
Forest to Forest	94.48	5.52
Forest to Grassland	100	0
Forest to Shrub	100	0
Forest to Wetland	100	0
Grassland to Developed / Bare Ground	100	0
Grassland to Forest	94.59	5.41
Grassland to Grassland	100	0
Grassland to Shrub	100	0
Grassland to Wetland	100	0
Shrub to Developed / Bare Ground	100	0
Shrub to Forest	94.64	5.36
Shrub to Grassland	100	0
Shrub to Shrub	100	0
Shrub to Wetland	100	0
Stream to Forest	11.19	88.81
Stream to Wetland	100	0
Wetland to Forest	24.48	75.52
Wetland to Grassland	100	0
Wetland to Shrub	100	0
Wetland to Wetland	100	0

5.4.6 Land Ownership

Land ownership was also examined in the GIS analysis in order to understand the relationship of ownership patterns to land cover change. Five patterns of ownership progression between public and private ownership occurred in the section between the dates of 1889, 1941, and 1951. These patterns were: 1) public – public – public, 2) private – public – public, 3) private – private – public, 4) public – private – private, and 5) private – private – private. The percent of each of the classes in the section is shown in **Table 5.16** and **Figure 5.7**. Approximately 56% of the section was in private ownership as of 1951, while 18% of the section remained in public ownership between 1889 and the present. By 1952, all of the land in the section was in public ownership. **Appendix J** displays the complete results of the ownership patterns versus the land cover change classes. In this analysis, only those land cover change classes that covered more than one percent of the section were examined (**Table 5.17**).

Table 5.16 Percent of Each Ownership Type in the Section

Ownership Year	1889	1941	1951	Percent of Section
Ownership Type	Public	Public	Public	18.73
	Private	Public	Public	12.49
	Private	Private	Public	12.51
	Public	Private	Private	28.11
	Private	Private	Private	28.16

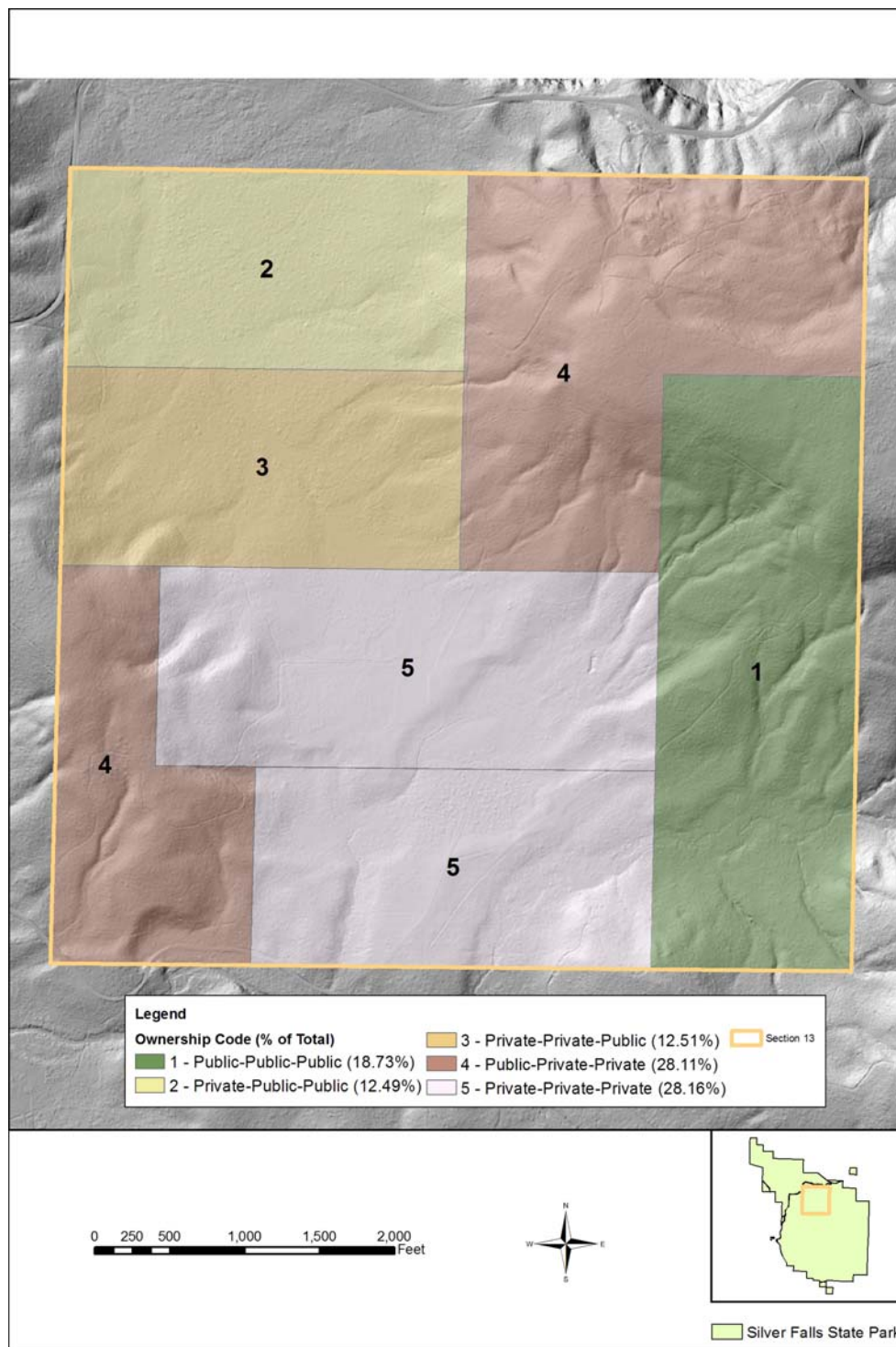


Figure 5.7 Land Ownership: 1889, 1941, and 1951;
T8S R1E Section 13 Willamette Meridian
Sources: Shaw, Grimm, and Cornelius 1889; Metsker 1941; USGS 1951
Map Author: Carl Anderson 2007

Table 5.17 Percent of Each Land Cover Change Class Within Each Land Ownership Type: 1947 to 2003

Change	Ownership Type					Ownership Year
	Public	Private	Private	Public	Private	1889
	Public	Public	Private	Private	Private	1941
	Public	Public	Public	Private	Private	1951
Forest to Forest	20.25	20.09	13.66	30.33	15.66	
Grassland to Forest	26.64	7.81	12.53	19.84	33.17	
Shrub to Forest	25.58	9.09	12.43	47.88	5.01	
Grassland to Grassland	0	1.18	3.18	0.51	95.13	
Wetland to Wetland	0	16.76	34.73	0	48.51	
Developed / Bare Ground to Forest	0	3.53	5.2	82.8	8.48	
Wetland to Forest	0	11.63	2.8	75.52	10.04	
Grassland to Wetland	0	0	11.51	0	88.49	
Grassland to Shrub	0	0	8.96	2.85	88.19	

Of particular interest is the private – private – private ownership pattern, as this area encompasses most of the grassland cover remaining in the section. Within the private-private-private land ownership pattern, the distributions of the land cover change classes are different than what would be expected if each land cover class were distributed among each ownership pattern according to the actual percent cover of ownership throughout the section. For example, of the most frequent land cover change class, forest to forest, 61% more than expected occurred within the private – public – public ownership type and 44% less than expected occurred within the private – private – private ownership type based on the percent coverage of these land ownership types throughout the section. The following land cover types occurred within the private-private-private ownership type more than expected based on the percent coverage of the private-private-private land ownership type throughout the

section: grassland to forest (18% more than expected), grassland to grassland (238% more than expected), grassland to wetland (214% more than expected), and grassland to shrub (213% more than expected). Additionally, the wetland to wetland land cover class occurred 83% of the time within private – private – private or private – private – public ownership types, which was 105% more than expected

Several land cover change categories consisting of changes from a non-forest land cover type to a forest land cover type occurred more than expected within public-private-private and/or public-public-public ownership areas based on the percent coverage of each of these land ownership areas within the section. Shrub to forest occurred 70% more than expected within the public – private – private type and 37% more than expected within the public – public – public type. Grassland to forest occurred 42% more than expected within the public-public-public type. Finally, the developed / bare ground to forest and wetland to forest classes occurred on the public – private – private ownership type 195% and 169% more than expected, respectively.

6 DISCUSSION

6.1 Land Cover Change - Overall

The first research question asked in this study was: How has the land cover of the Ranches meadow and the surrounding section changed through time? Overall land cover change trends provided some preliminary insight into the changes that took place across the section. The basic land cover changes in the section were that forest cover doubled in size, grassland and shrub cover were reduced by half, and wetland cover grew by 9% between 1947 and 2003.

Land cover changes occurred most rapidly within the 1947 to 1970 period as the landscape added significant amounts of forest cover. Changes from non-forest classes to forest classes declined between each study period. Specifically, changes from non-forest land cover classes to forest classes comprised only 11.3% of the section during the 1970 to 1988 period and 2.6% during the 1988 to 2003 period. So, the amount of change from non-forest to forest classes declined by 65% between the 1947 to 1970 and 1970 to 1988 periods and 77% between the 1970 to 1988 and 1988 to 2003 periods.

6.2 Land Cover Change – Historic Meadow

The second research question examined was: How has the land cover in the historic meadow of 1874 changed, and how do these changes compare to changes in the surrounding section? The change detection results were different for the historic meadow extent than for the section as a whole. A comparison between the grouped

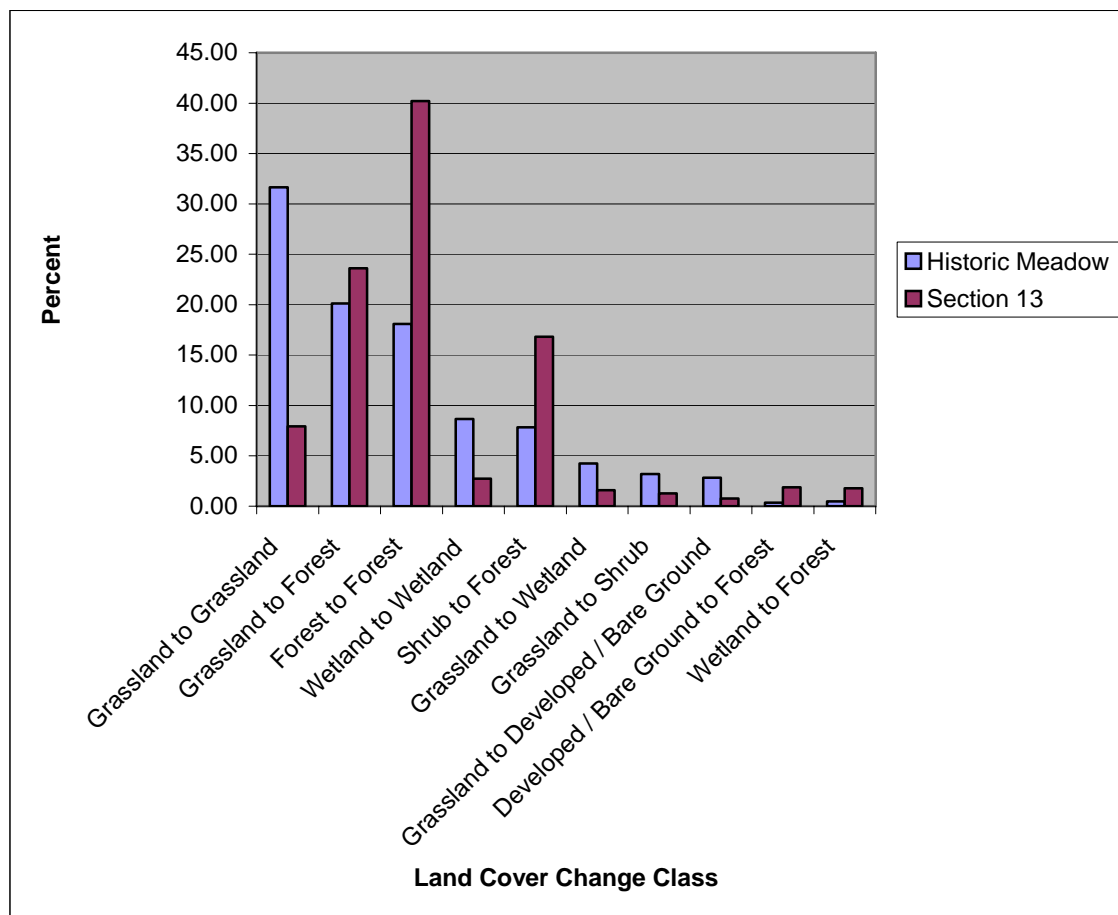
land cover categories covering more than 1% of the area at each scale is shown in

Figure 6.1. First, between 1947 and 2003, 32% of the historic meadow extent was within the grassland to grassland class, while only 8% of the section was in this class. Secondly, land cover changes from a non-forest land cover class to a forest class were important at both scales, but comprised a greater percentage of the area in the section (44.1%) than in the historic meadow (28.9%). In addition, slightly more of the historic meadow extent than the section changed from grassland to a different class (30.4% versus 26.4%) during the 1947 to 2003 time period. So, while a larger percentage of the historic meadow remained in grassland than the section as a whole, grassland cover declined a similar amount as a percentage at both scales.

The land cover of the historic meadow experienced declining rates of change during the study period. Sixty-seven percent of the grouped land cover classes did not change between 1947 and 1970 with 17.8% of the remainder changing to forest and 6% changing to shrub. During the 1970 to 1988 change detection only 8.9% and during the 1988 to 2003 change detection only 6.2% of the historic meadow area consisted of changes from non-forest classes to forest classes. So, the amount of change from non-forest to forest classes declined by 50% between the 1947 to 1970 and 1970 to 1988 periods and 44% between the 1970 to 1988 and 1988 to 2003 periods. The rates of change from non-forest to forest classes declined in the historic meadow, but these rates did not decline as quickly as in the section. Non-forest to forest changes comprised more area as a percentage in the section than in the historic

meadow, but changes from non-forest to forest classes have continued at a faster rate in the historic meadow than in the section.

Figure 6.1 Historic Meadow and Township 8 South, Range, 1 East, Section 13, Willamette Meridian; Grouped Land Cover Change Class as a Percentage of Area: 1947 to 2003



6.3 The Impact of Physical Factors on Land Cover Change

The third research question of the study was: What role and to what magnitude did physical factors play in contributing to land cover change in the meadow? Most of

the land cover changes between 1947 and 2003 occurred on south – facing slopes and on gradients of less than 30%. This is not particularly surprising, since south facing slopes received more sunlight than north facing slopes, and slopes of less than 30% were more common than those greater than 30%. However, grassland to grassland and wetland to wetland occurred on slopes of less than 30% virtually all of the time. Land cover classes changing to forest were less discriminating, occurring on slopes greater than 30% anywhere from 11% to 22% of the time. Clearly, steep slopes were not a barrier to forest expansion in this landscape. Another interesting facet of the slope and aspect analysis was that developed / bare ground to forest land cover change occurred primarily on north-facing slopes. This can likely be attributed to the logging activities that occurred in the early 1900's in the northeast part of the section, which created a substantial area of bare ground, but which was reforested by 2003.

Soils played a role in determining land cover change progressions for some of the land cover types. In particular, grassland to grassland occurred most frequently on Kinney soils, which is a loamy and well-drained soil with medium to very rapid runoff and moderate permeability. In addition, grassland to grassland and wetland to wetland occurred frequently on Minniece soils, which are deep and very deep, poorly and somewhat poorly drained soils and have a seasonal water table of 0 to 2 feet November through May. Grassland to wetland also frequently occurred on the hydric Minniece soils.

The historic roemer's fescue area stands out as an area that remained grassland from prior to settlement to the present. This area still contains significant amounts of

the native roemer's fescue species based on observations in the field. Additionally, because of the topography of the area, wetland and shrub cover also have remained present due to lower elevations and / or moderate slopes.

6.4 The Impact of Anthropogenic Factors on Land Cover Change

The final research question asked was: How did anthropogenic factors impact the land cover of the meadow? Although vegetation management practices were implemented in the meadow, these did not seem to impact the transition of land cover types within the treatment areas, with the exception of the planting area that resulted in grassland to forest land cover change. While these treatments did not impact large land cover areas, they most likely will impact the quality of the grassland in the meadow, particularly as Scotch broom treatments are implemented on the forest/grassland fringe along the edge of the meadow (Bossard 1991) (see **Figure 4.4** and **Figure 4.5**). The Historic timber coverage as of 1914 did little to influence land cover changes, with the exception of the stream to forest and wetland to forest categories in the non-timber areas. These changes occurred in the southwest corner of the section where a stream and wetland were reclassified as forest based on the 1970 aerial photograph.

Ownership patterns appear to have a strong relationship to land cover changes in the section. Most all of the grassland as it remains today is located in the private-private land ownership progression area. What is known about this land ownership area is that the northern 100 acres were used as a sheep ranch up until 1952,

and it is likely that similar activities were conducted in the southern 80 acres based on the openness of the area in the 1947 aerial photograph. Grazing activities kept the vegetation down, but perhaps just as significantly, these areas have mostly very gentle slopes. Although areas in this ownership type were more likely than usual to progress from grassland to forest, they were also much more likely to remain grassland, change to wetland, or change to shrub, which all favor modest slopes. Wetland land cover was also more likely to remain as wetland in this land ownership type.

The observed land cover progressions align with the findings of previous studies (Vale 1981; Taylor 1990; and Hadley 1999). Vale (1981) found that pentads with tree invasions were characterized by “no grazing” or cattle grazing only, but not sheep grazing. Taylor (1990) found that in Lassen Volcanic National Park, most of the tree invasions occurred after the reduction or cessation of grazing. Hadley (1999) also found that tree invasions occurred only after the cessation of sheep grazing. Sheep grazing is known to have occurred in at least one hundred acres of the Ranches meadow prior to 1952 (**Figure 6.2**), which may have reduced tree invasions in this area until after grazing ceased.

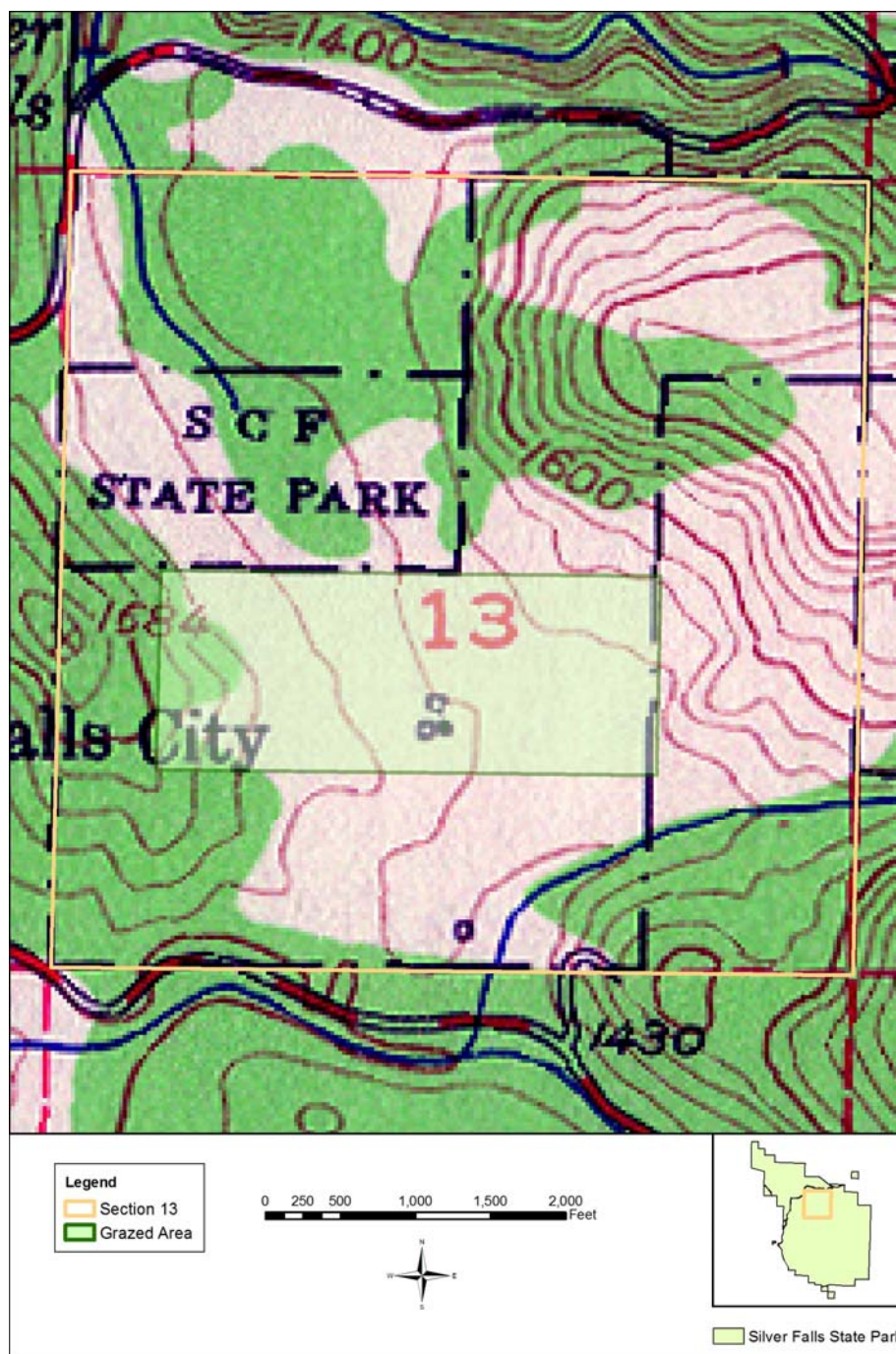


Figure 6.2 Area Grazed Prior to 1952 – Overlaid on 1951 USGS Topographic Map;
T8S R1E Section 13 Willamette Meridian
Sources: OPRD 2007; USGS 1951
Map Author: Carl Anderson 2007

7 CONCLUSIONS

This study researched land cover changes between 1947 and 2003 in the Ranches meadow, Silver Falls State Park, Oregon. Physical and anthropogenic factors were also examined to determine their influence on these land cover changes. The results reveal that the Ranches meadow and surrounding section have lost significant areas of grassland and gained forest cover between 1947 and 2003. Several key factors influenced how these changes occurred. First, low-gradient slopes correlated strongly with land cover changes to grassland and/or wetland, which occurred almost exclusively on slopes of less than 30%. In contrast, changes to forest types occurred across all gradients. Secondly, ownership patterns in the section between 1889 and 1951 played an important role. With the change of ownership of the lands in the study section from private to public by 1952, grazing and timber harvesting ceased and forestlands in the area expanded. However, grassland persisted more frequently on lands privately owned between 1889 and 1951 than on lands experiencing other land ownership patterns. Finally, the *Festuca roemerii* (Roemer's fescue) historic vegetation type likely helped maintain grassland areas in the southern portion of the meadow.

One implication of these findings is that much of the remaining meadow will transition to forest along the edge of the meadow where transitions between land cover types are most likely to occur (Bai et al. 2004: 74). However, the results also show that the rates of these land cover transitions have been declining both in the section and in the historic meadow. This means that these transitions may continue to occur,

but at slower rates. This is consistent with a study in the Wind River Mountains, Wyoming, that found that moderate grazing levels actually promoted tree invasion, but that once grazing ceased, the meadow was able to regain some ground cover, limiting the invasion of trees (Dunwiddie 1977: 398).

Unlike many of the background studies cited (Franklin et al 1971; Dunwiddie 1977; Vale 1977; Agee and Smith 1984; Taylor 1990; Dyer and Moffett 1999), the results of this study are properly framed within the context of a highly managed, lower elevation meadow. Therefore, the implications of the results should be looked at in light of a more complex set of variables; i.e. more human manipulation of the landscape occurs here than in “wilderness-type” protected areas. A useful study for comparison is a study of “forest history and meadow invasion” in the Ridgon Meadows, Oregon (Hadley 1999). This area is a Special Interest Area within the Willamette National Forest, and is not located in a legally-defined wilderness area. The site has “experienced selective and salvage logging, and blowdown,” seedlings and saplings have been removed, and prescribed and slash burning has occurred within the meadow (Hadley 1999). In this meadow, two areas cleared prior to 1944 changed to forest by 1990, and 25% of the historical meadow had been reforested. This is similar to the regrowth of forest in the northeast portions of the section in this study. However, much more reforestation occurred in the historic Ranches meadow than occurred in the Ridgon Meadows.

The Silverton fire of 1865 left a lasting mark on the Silver Falls area (Humphreys 1998), but the impact that this fire had upon the Ranches meadow was

not addressed in this study. Additionally, further specific details of post-fire logging practices in the area in the early 1900's could provide information useful for examining land cover change trends and the anthropogenic reasons influencing them. In order to address these issues, future research could include tree aging and soil composition studies to obtain a fire history for the site and research potential areas where trees were replanted (Franklin et al 1971; Dunwiddie 1977; Vale 1981; Agee and Smith 1984; Arno and Gruel 1986; Butler 1986; Taylor 1990; Hadley 1994; Miller and Halpren 1998; Dyer and Moffett 1999; Hadley 1999; Lepofsky et al. 2003; Moore and Huffman 2004).

Finally, the results of this study provide three potential hypotheses for future studies into landscape change in meadows. First, both physical and anthropogenic factors may play significant roles in land cover changes in meadows (Lepofsky et al. 2003), particularly in less pristine, highly developed landscapes (Reid, Strickler, and Hall 1980; Hadley 1999). Secondly, meadows may change at faster rates immediately after changes from private to public ownership than they do when they have been in public ownership for an extended period of time (Dunwiddie 1977). Lastly, change detection studies over multiple time intervals in meadows provide more complete information about rates of land cover change than studies that only examine one time period (Hadley 1999).

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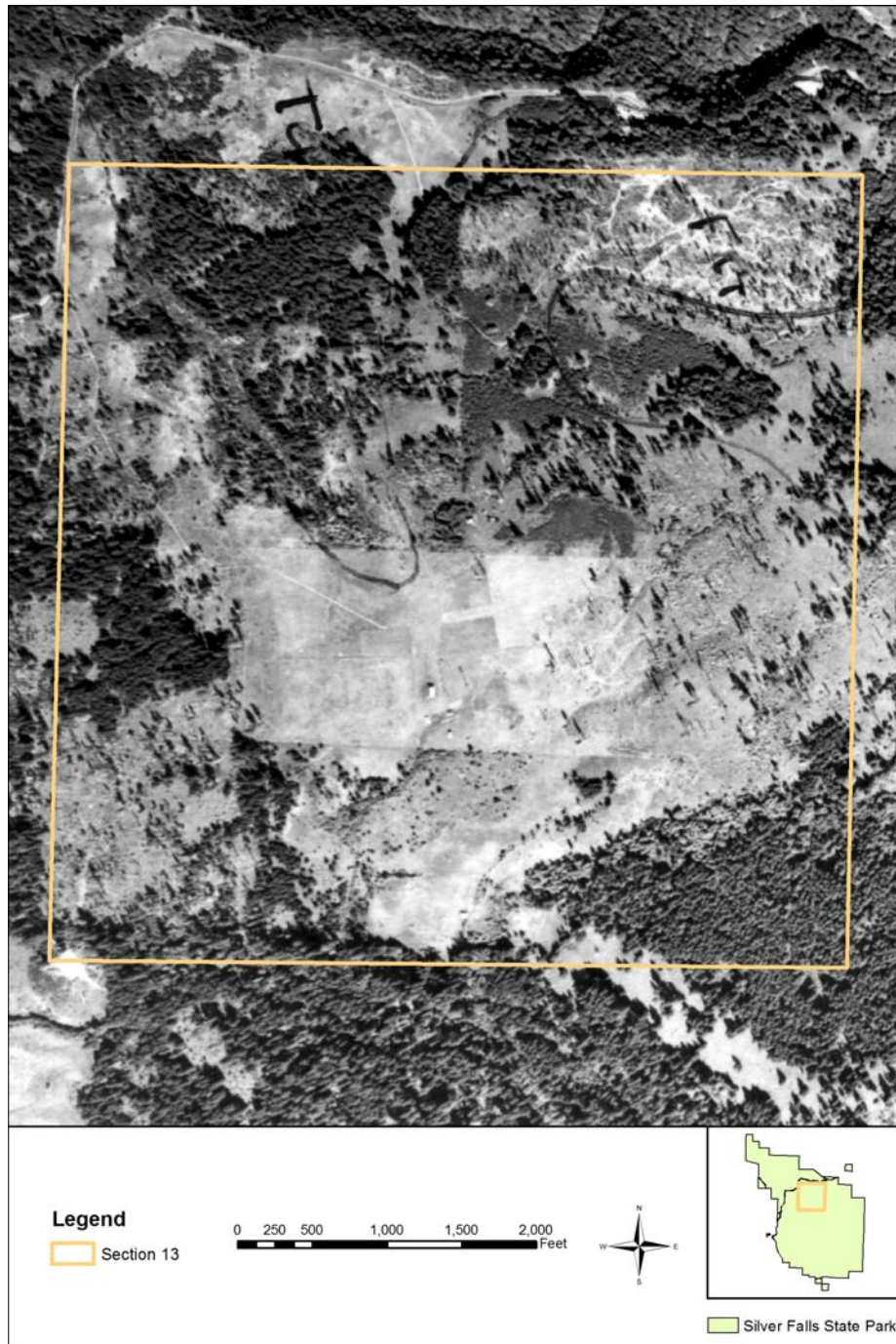
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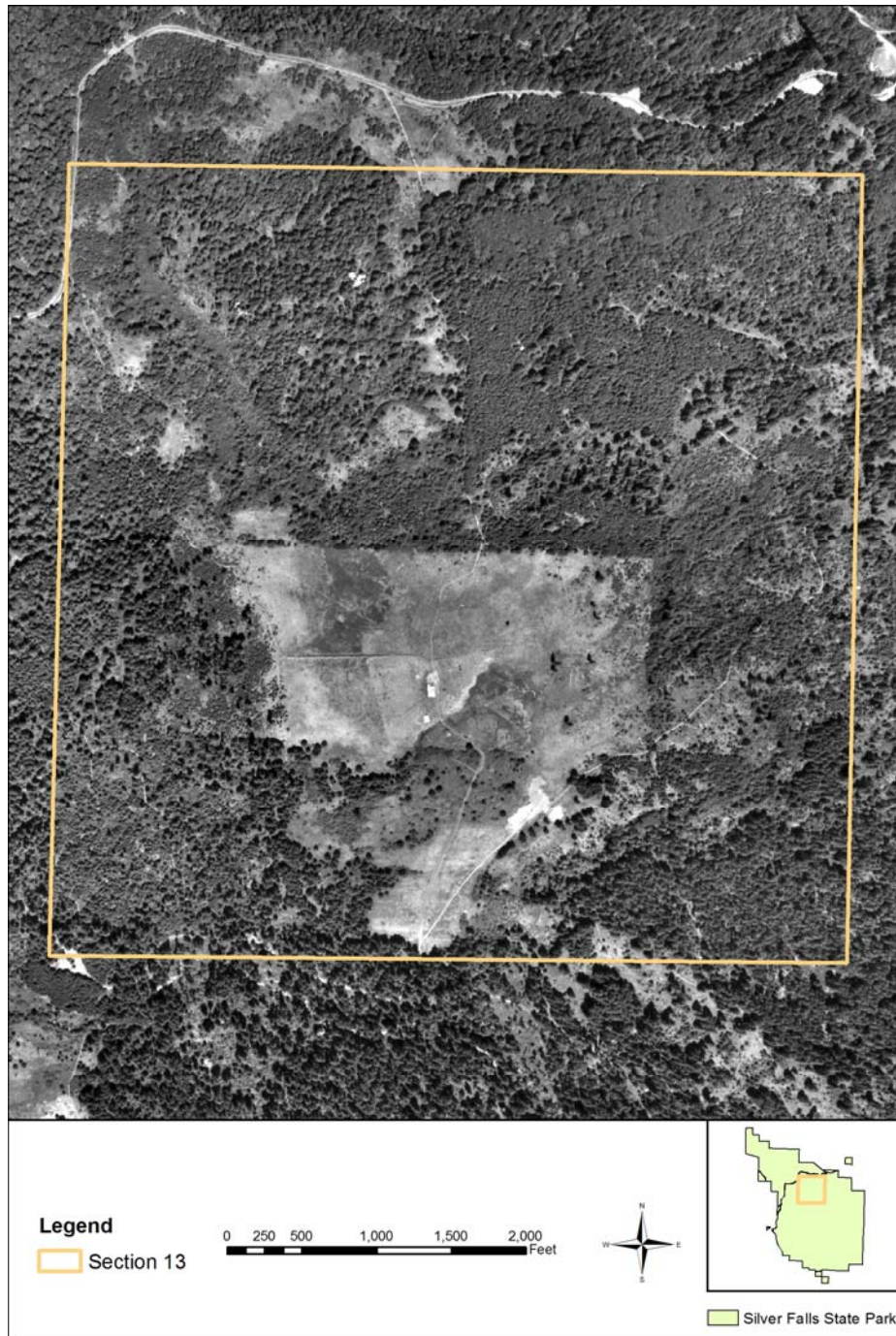
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APPENDICES

Appendix A – Aerial Photographs



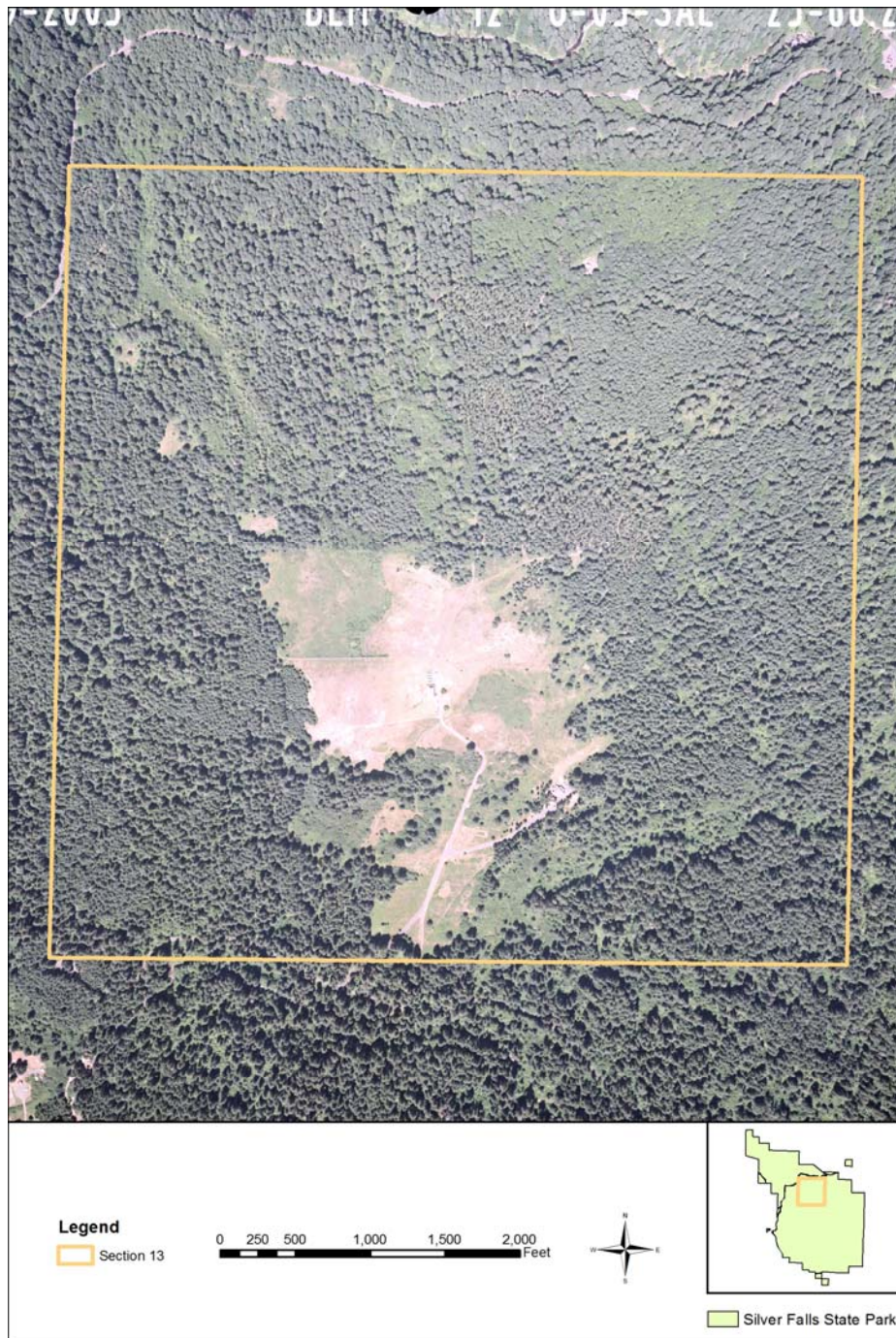
A.1 1947 Aerial Photograph - Scale 1:37000
T8S R1E Section 13 Willamette Meridian
Source: USGS Project: GS-CK
Map Author: Carl Anderson 2007

Appendix A – continued

A.2 1970 Aerial Photograph - Scale 1:20000
T8S R1E Section 13 Willamette Meridian
Source: ASCS Project: DFN-4LL-171
Map Author: Carl Anderson 2007

Appendix A – continued

A.3 1988 Aerial Photograph - Scale 1:12000
T8S R1E Section 13 Willamette Meridian
Source: BLM Project: O-88-ASC
Map Author: Carl Anderson 2007

Appendix A – continued

A.4 2003 Aerial Photograph - Scale 1:12000
T8S R1E Section 13 Willamette Meridian
Source: BLM Project: O-03-SAL
Map Author: Carl Anderson 2007

Appendix B – Aerial Photograph Georeferencing Link Tables

B.1 Link table – 2003 to 2005 georeferencing

Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	1472.888318	1391.168164	759851.311780	1145440.939555	12.04493
2	1548.985879	1259.460847	760093.499280	1145005.175666	5.75410
3	1153.052966	1445.706916	758840.895113	1145609.342332	9.44744
4	1498.622449	1012.252109	759940.835163	1144229.544069	9.18743
5	1384.264300	1127.303679	759571.338791	1144592.770160	3.15656
6	132.604437	1559.145608	755567.145604	1145974.805979	11.29336
7	2449.326437	2673.806656	762967.152067	1149492.762137	14.58979
8	1358.599424	2656.871881	759514.645515	1149439.195643	16.33136
9	609.330088	438.182965	757082.996811	1142397.746269	12.86237

☒ Auto Adjust Transformation: 1st Order Polynomial (Affine) Total RMS Error: 11.22682

Load... Save... OK

B.2 Link table – 1988 to 2005 georeferencing

Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	4.413493	4.058041	759851.125355	1145439.856473	8.87715
2	4.714735	3.641622	760096.720432	1145004.878077	1.20475
3	3.326529	4.136753	758831.609873	1145609.062660	5.14257
4	4.210320	4.871002	759737.051015	1146221.821872	6.05788
5	5.464731	4.307306	760867.147974	1145567.163499	8.92247
6	5.353730	3.430518	760686.677705	1144742.451523	5.35882
7	1.661458	0.412639	756864.203813	1142206.365871	3.45312
8	4.209265	3.162714	759570.575562	1144595.073292	3.83918

☒ Auto Adjust Transformation: 1st Order Polynomial (Affine) Total RMS Error: 5.89905

Load... Save... OK

Appendix B - Continued

B.3 Link table – 1970 to 2005 georeferencing

Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	6.297045	4.464017	759851.443136	1145439.856473	14.57813
2	6.449398	4.204768	760095.852376	1145002.167983	5.88233
3	5.664047	4.550615	758833.451911	1145610.036643	10.51276
4	2.907925	5.310206	754430.230935	1146992.905617	2.27259
5	6.301863	3.483651	759825.739890	1143819.861124	16.68033
6	6.009816	6.905472	759519.783992	1149396.369982	12.83534
7	6.865317	4.311278	760754.406679	1145156.172878	16.50939
8	6.098015	4.570976	759548.303257	1145611.719790	5.44415
9	8.139652	7.052909	762959.383462	1149533.299224	4.33404
10	6.710275	4.193995	760521.858654	1144954.145949	14.88123

☒ Auto Adjust Transformation: 1st Order Polynomial (Affine) Total RMS Error: 11.61129

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B.4 Link table – 1947 to 2005 georeferencing

Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	2.201017	4.253169	759851.337209	1145440.174253	16.15150
2	2.110133	5.647943	759511.927487	1149410.660364	6.85764
3	0.354289	4.848737	754446.823320	1146974.028420	5.46304
4	2.543528	4.004306	760858.281653	1144743.125642	4.40011
5	0.961762	3.275841	756316.614987	1142517.431198	6.91072
6	2.185544	4.227348	759804.106501	1145349.736448	4.40168
7	2.282390	4.109821	760096.651918	1145002.560569	17.64076

☒ Auto Adjust Transformation: 1st Order Polynomial (Affine) Total RMS Error: 10.24997

Load... Save... OK

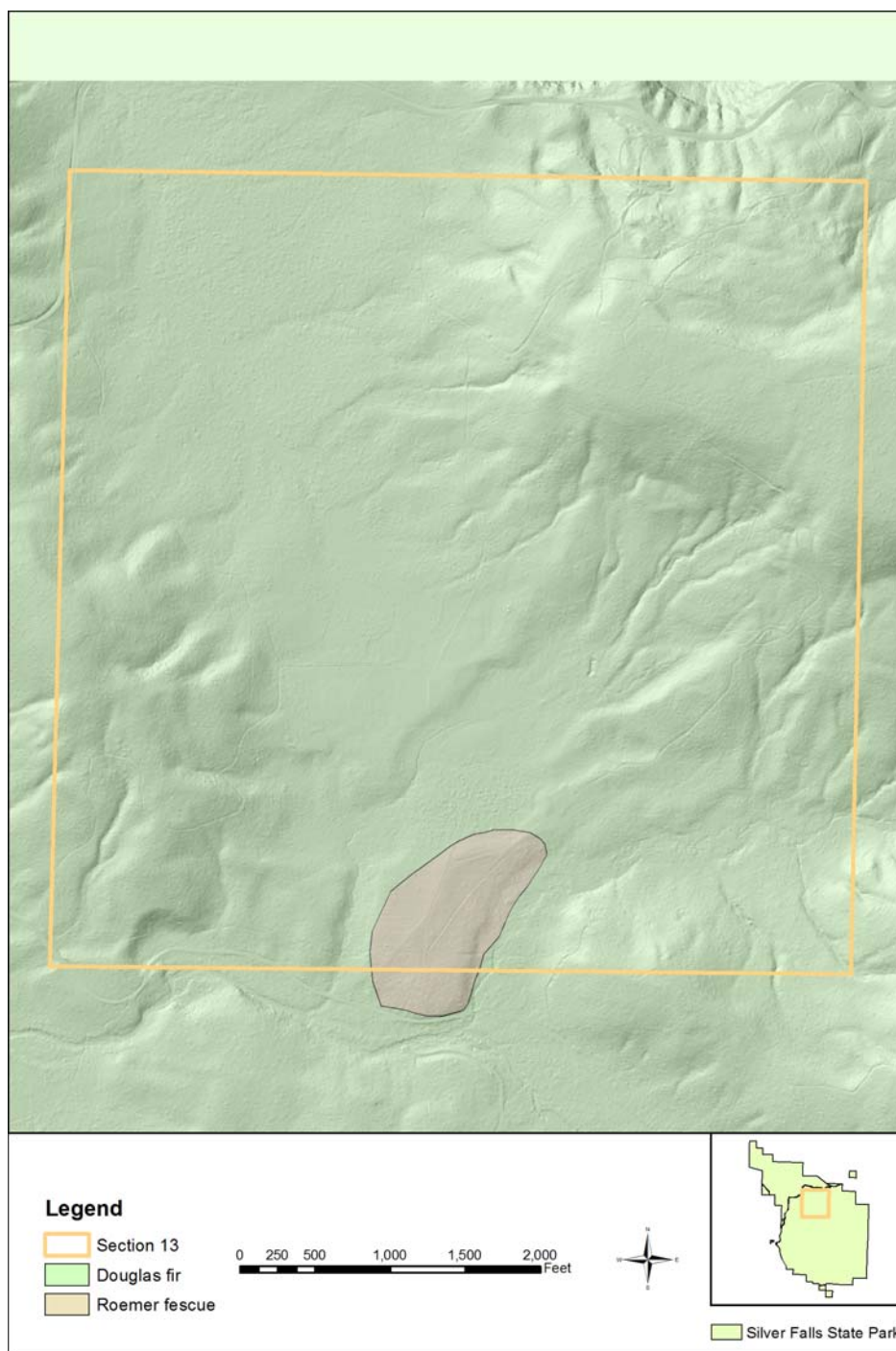
Appendix C –Data layers used in the GIS Analysis



C.1 2007 LIDAR Data - T8S R1E Section 13 Willamette Meridian

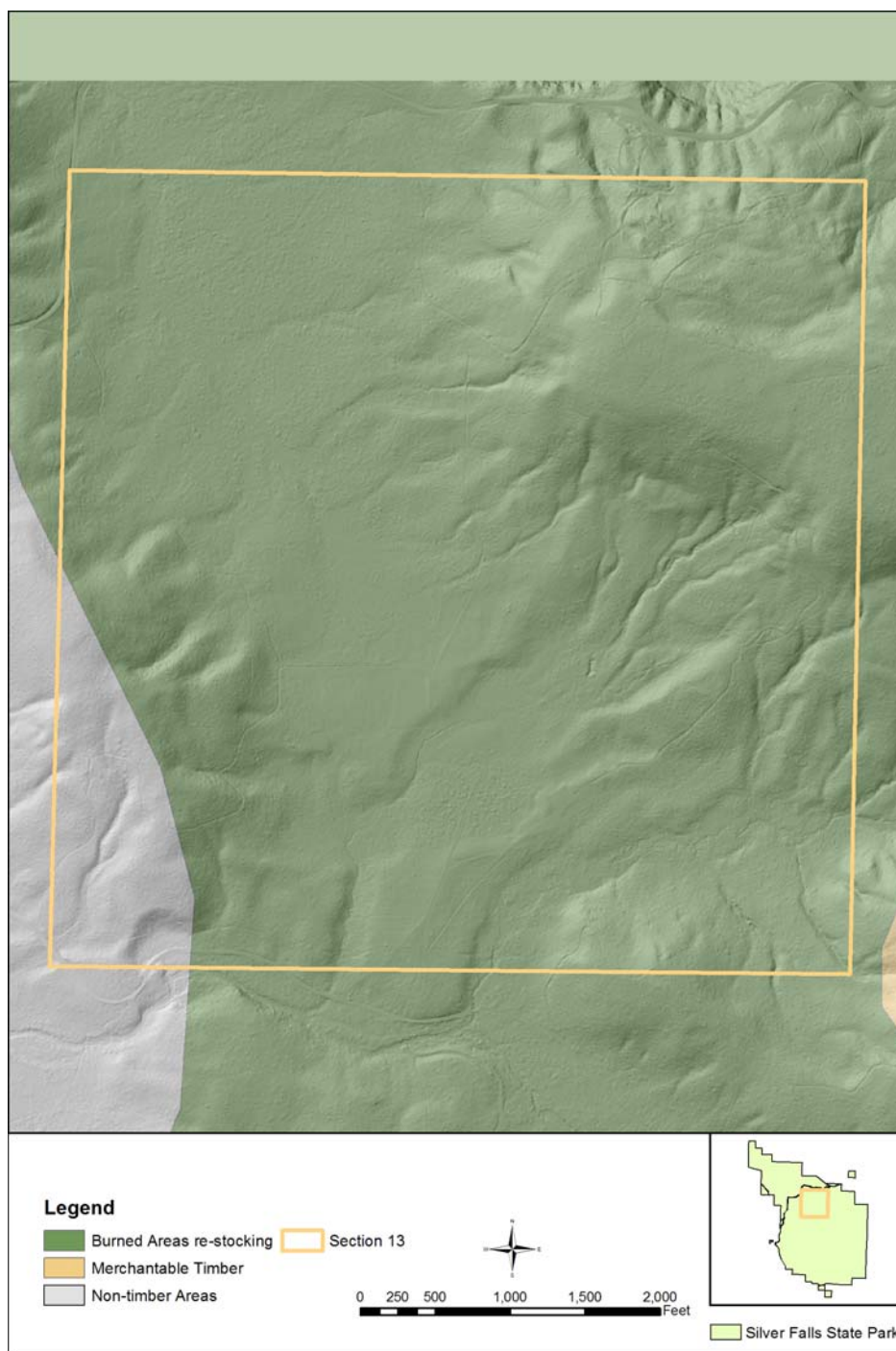
Source: Oregon Parks and Recreation Department

Map Author: Carl Anderson 2007

Appendix C – continued**C.2 Pre-Settlement Vegetation Data - T8S R1E Section 13 Willamette Meridian**

Source: Oregon Natural Heritage Program

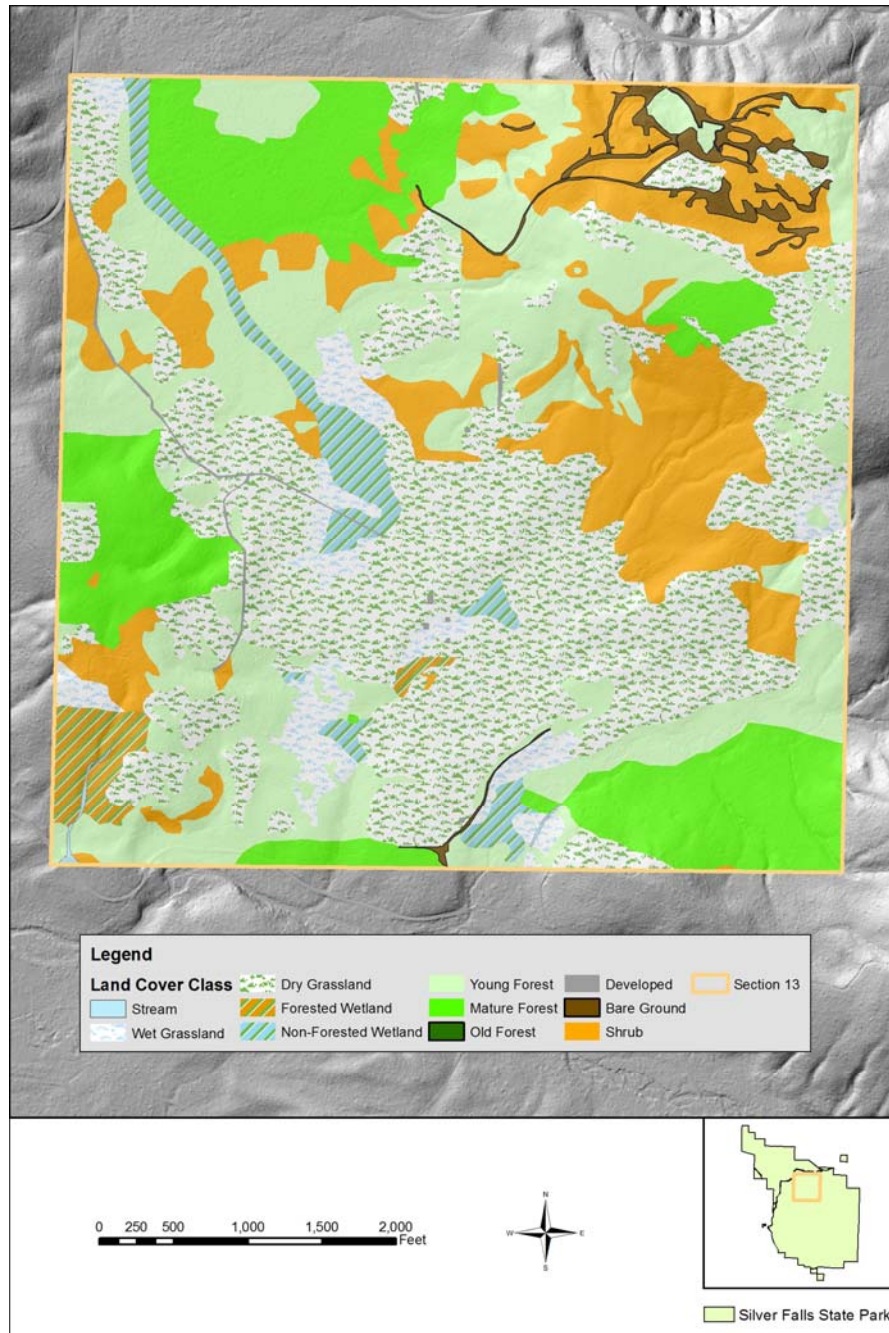
Map Author: Carl Anderson 2007

Appendix C – continued**C.3 1914 Timber Stand Data - T8S R1E Section 13 Willamette Meridian**

Source: Oregon Department of Forestry

Map Author: Carl Anderson 2007

Appendix D – Original and Grouped Land Cover Class Areas for 1947, 1970, 1988, and 2003

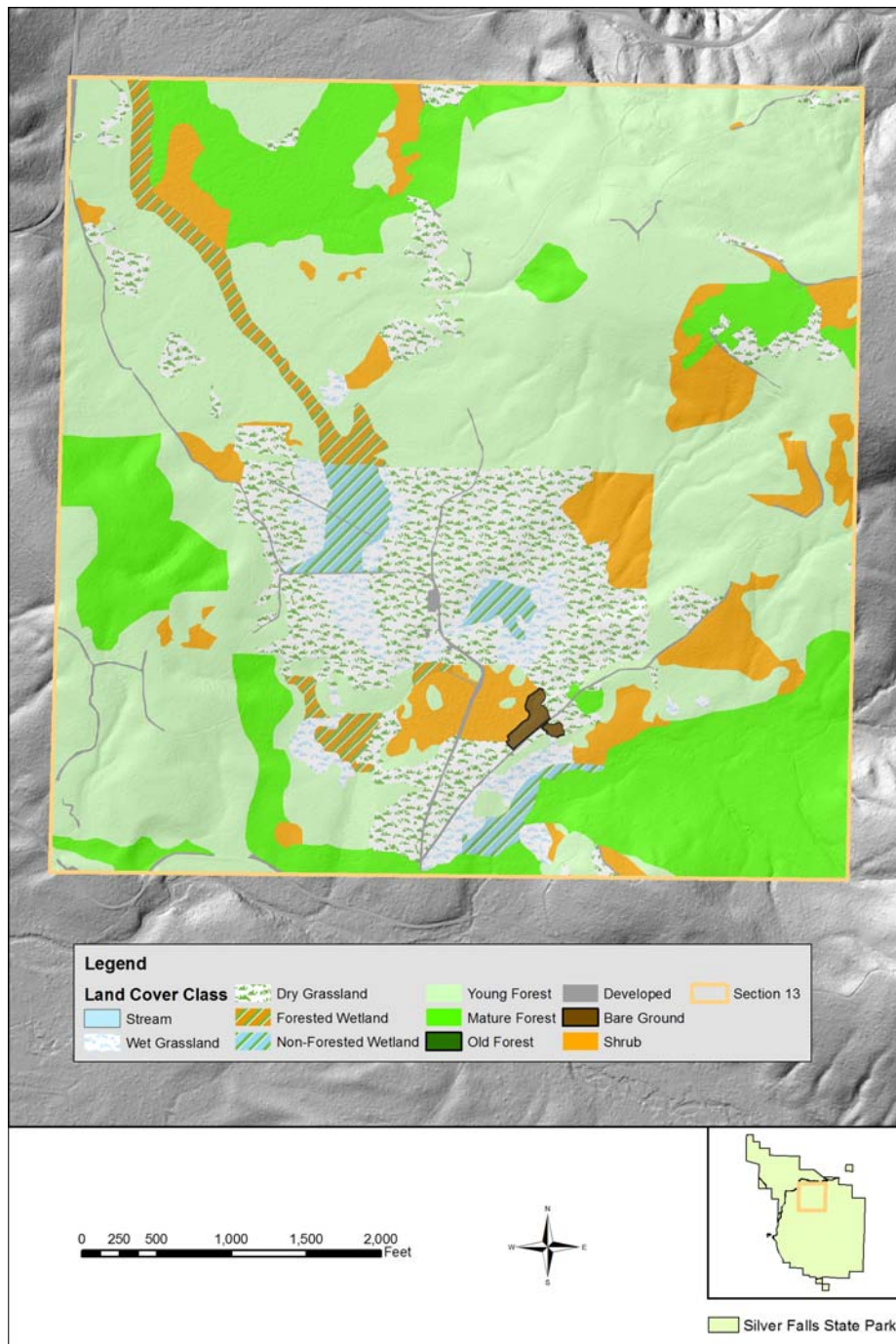


D.1 1947 Land Cover Classes Overlayed on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

Map Author: Carl Anderson 2007

Appendix D – continued

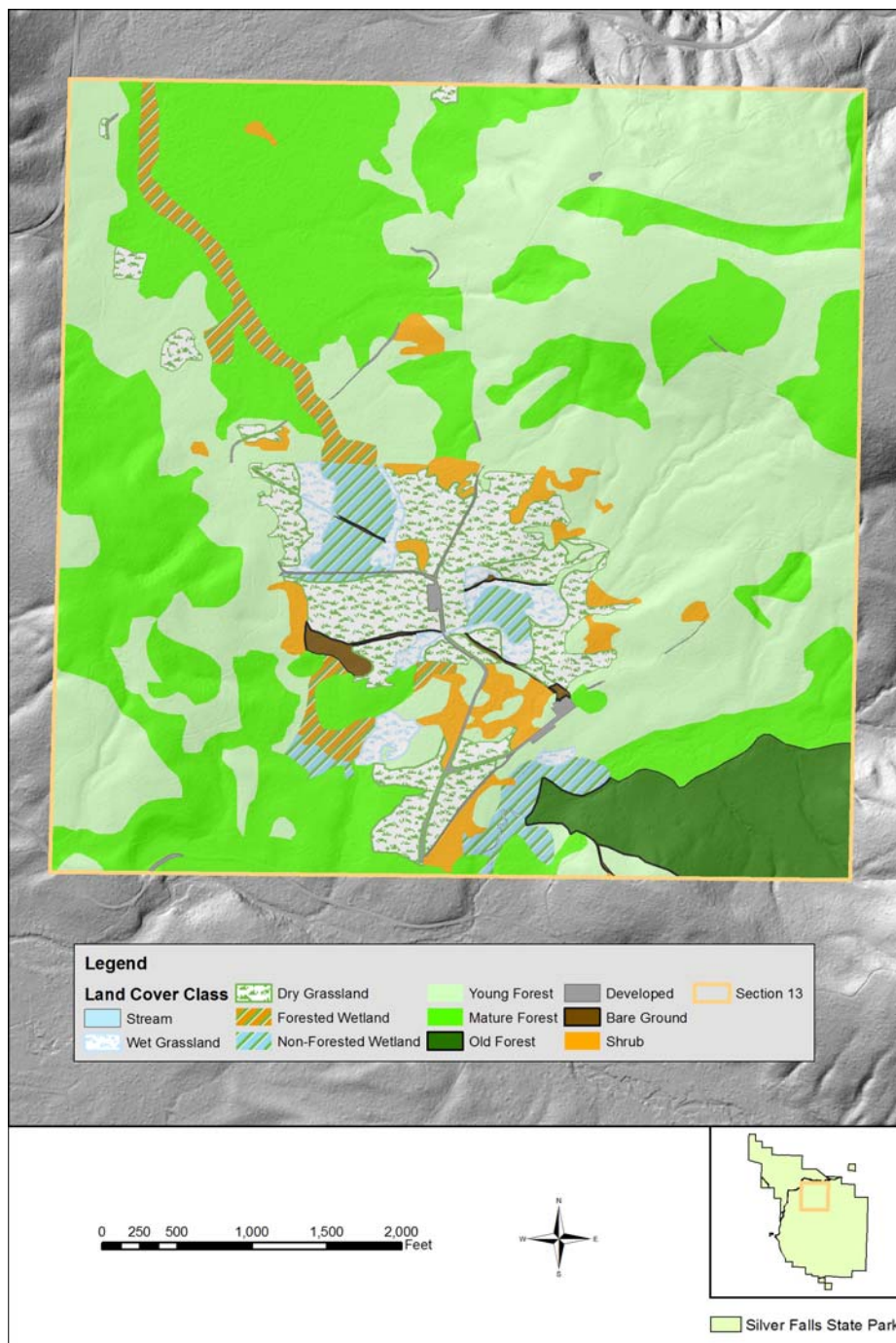


**D.2 1970 Land Cover Classes Overlayed on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian**

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

Map Author: Carl Anderson 2007

Appendix D – continued

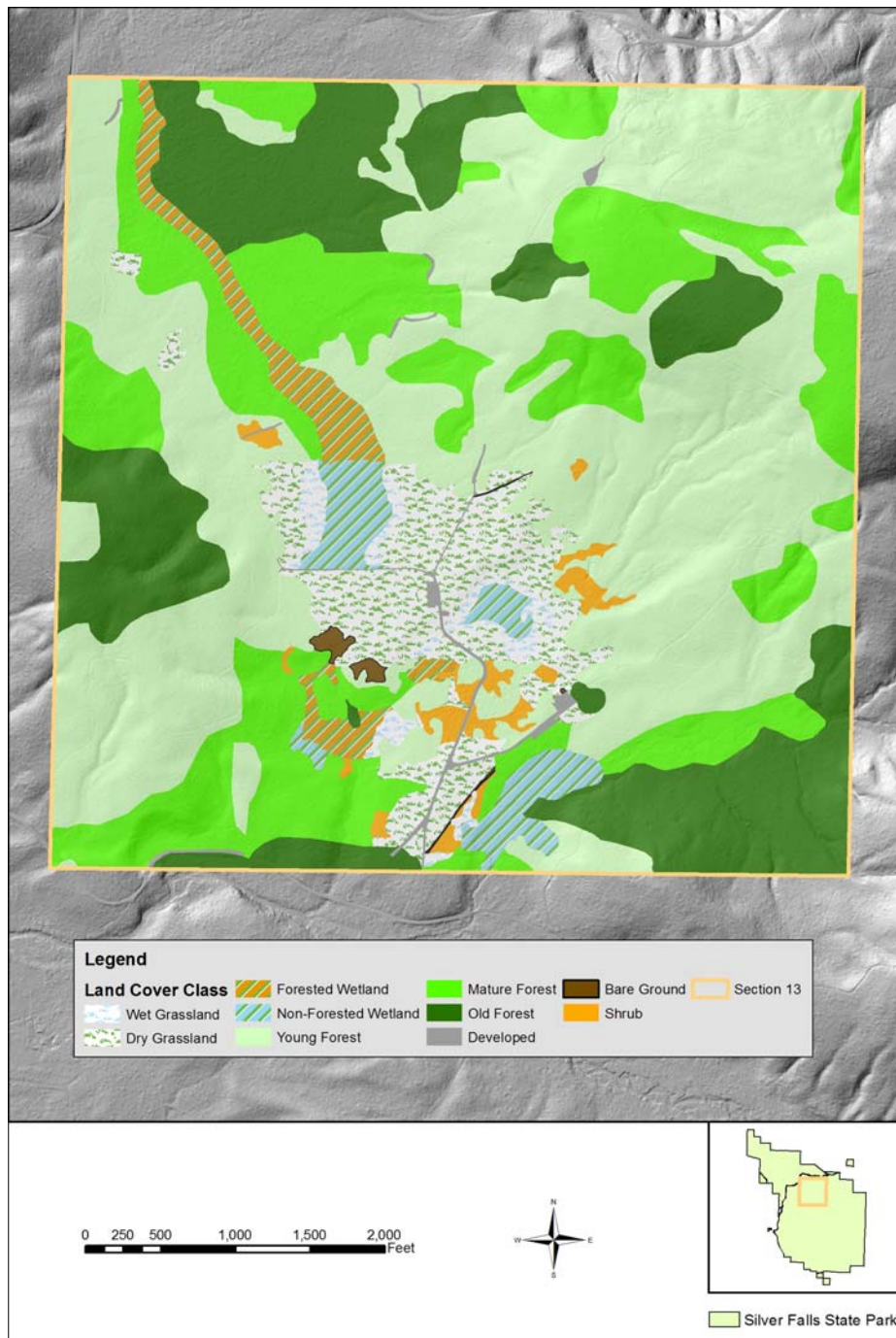


**D.3 1988 Land Cover Classes Overlayed on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian**

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

Map Author: Carl Anderson 2007

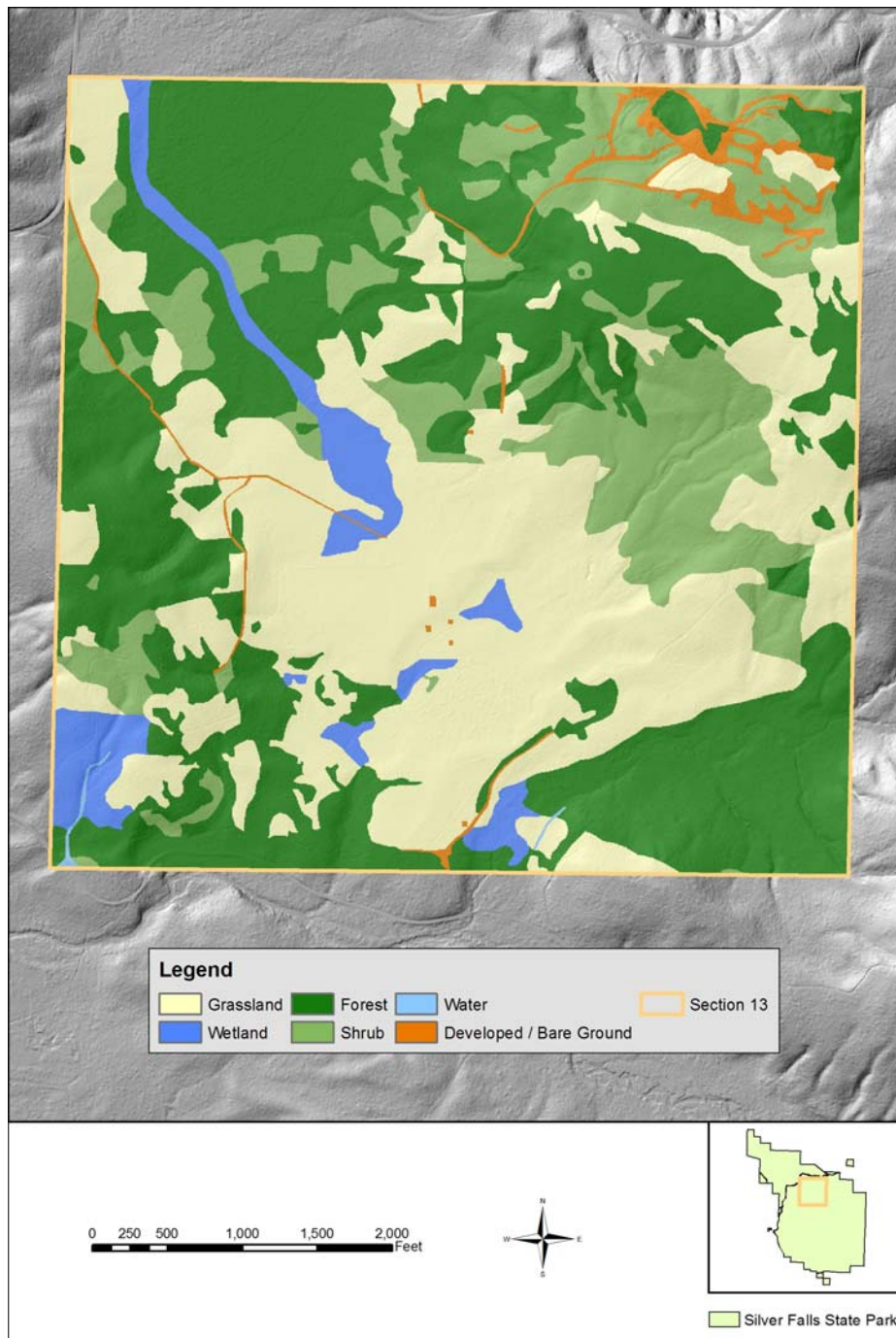
Appendix D – continued



D.4 2003 Land Cover Classes Overlayed on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

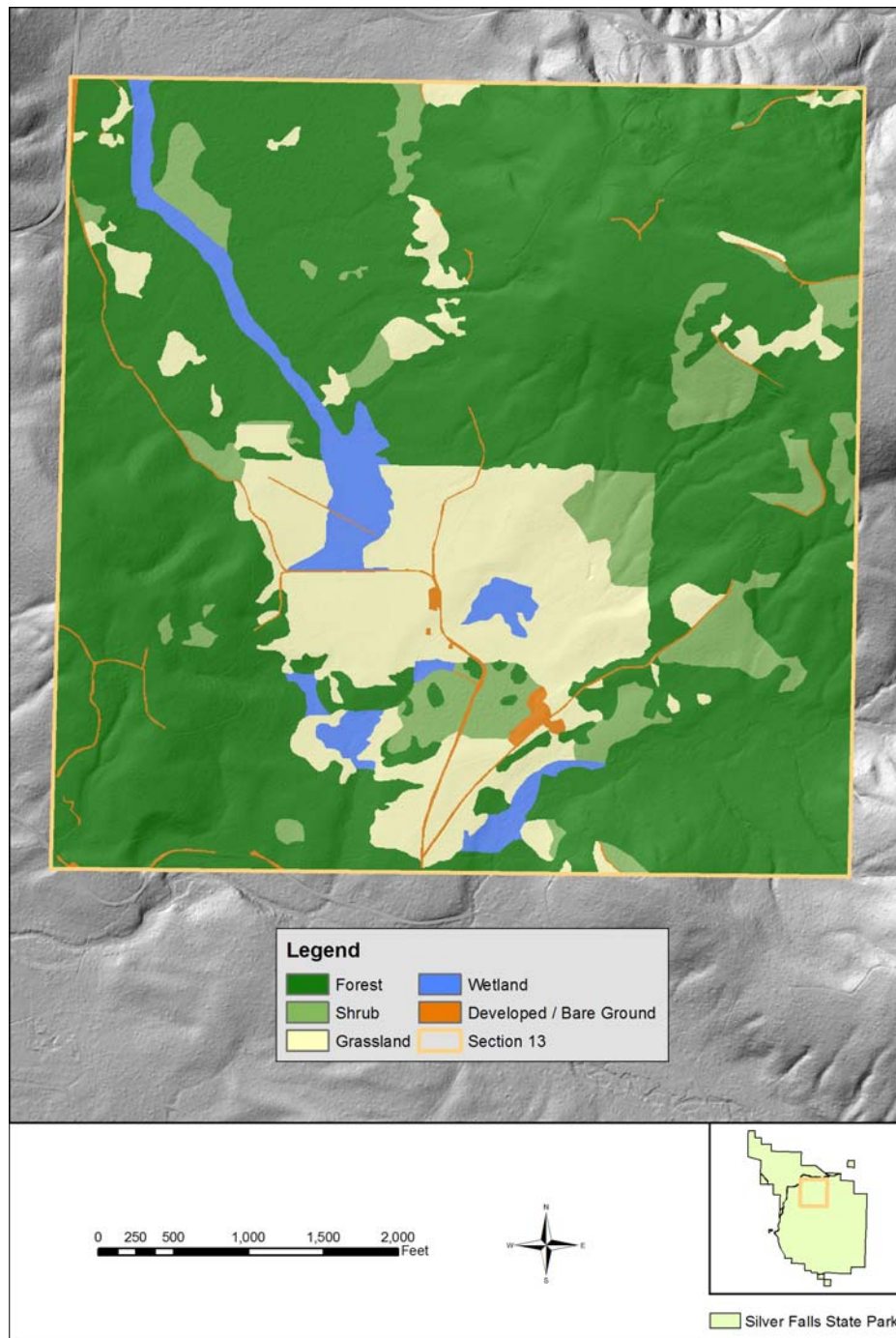
Map Author: Carl Anderson 2007

Appendix D – continued

D.5 1947 Grouped Land Cover Classes Overlaid on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

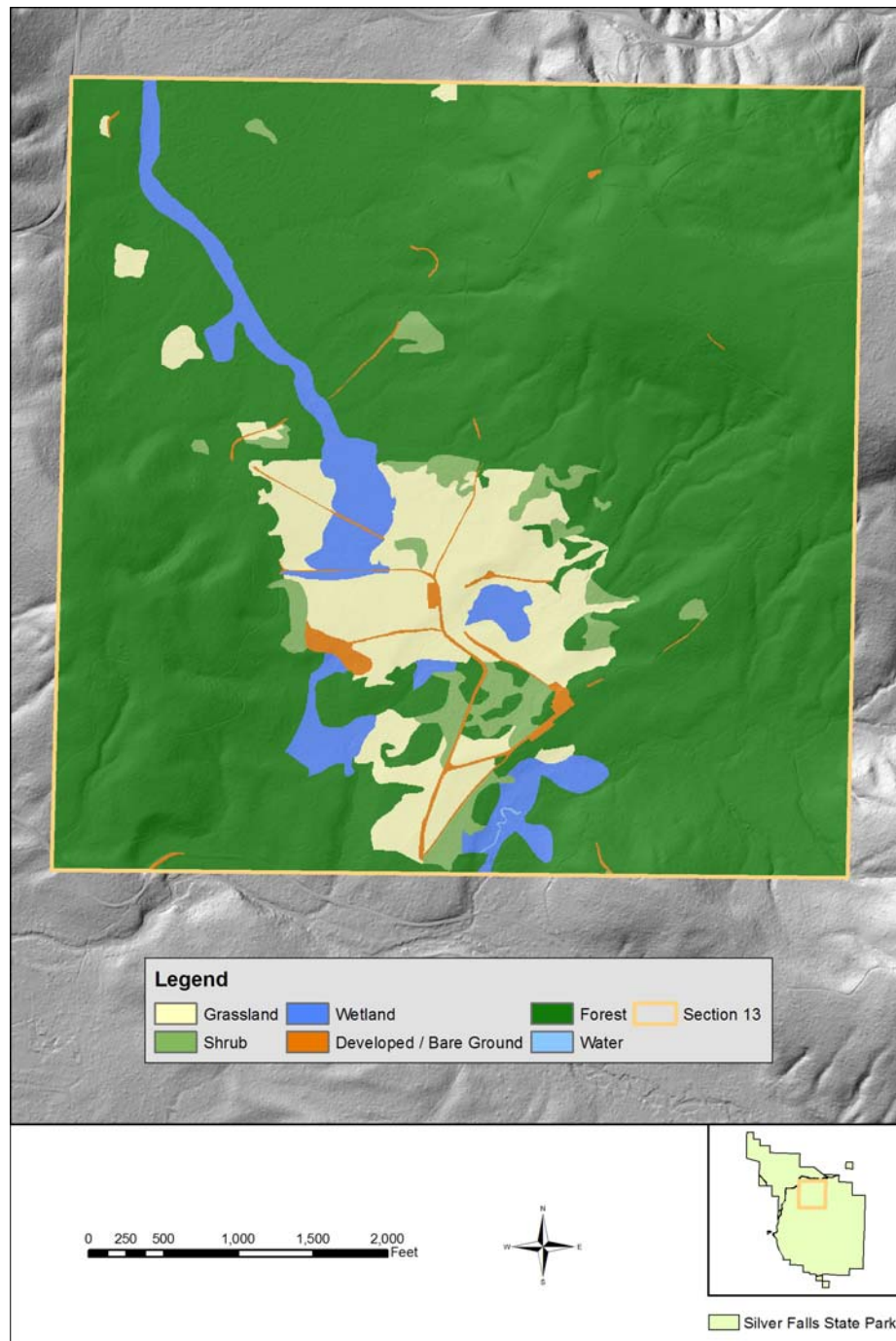
Map Author: Carl Anderson 2007

Appendix D – continued

**D.6 1970 Grouped Land Cover Classes Overlayed on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian**

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

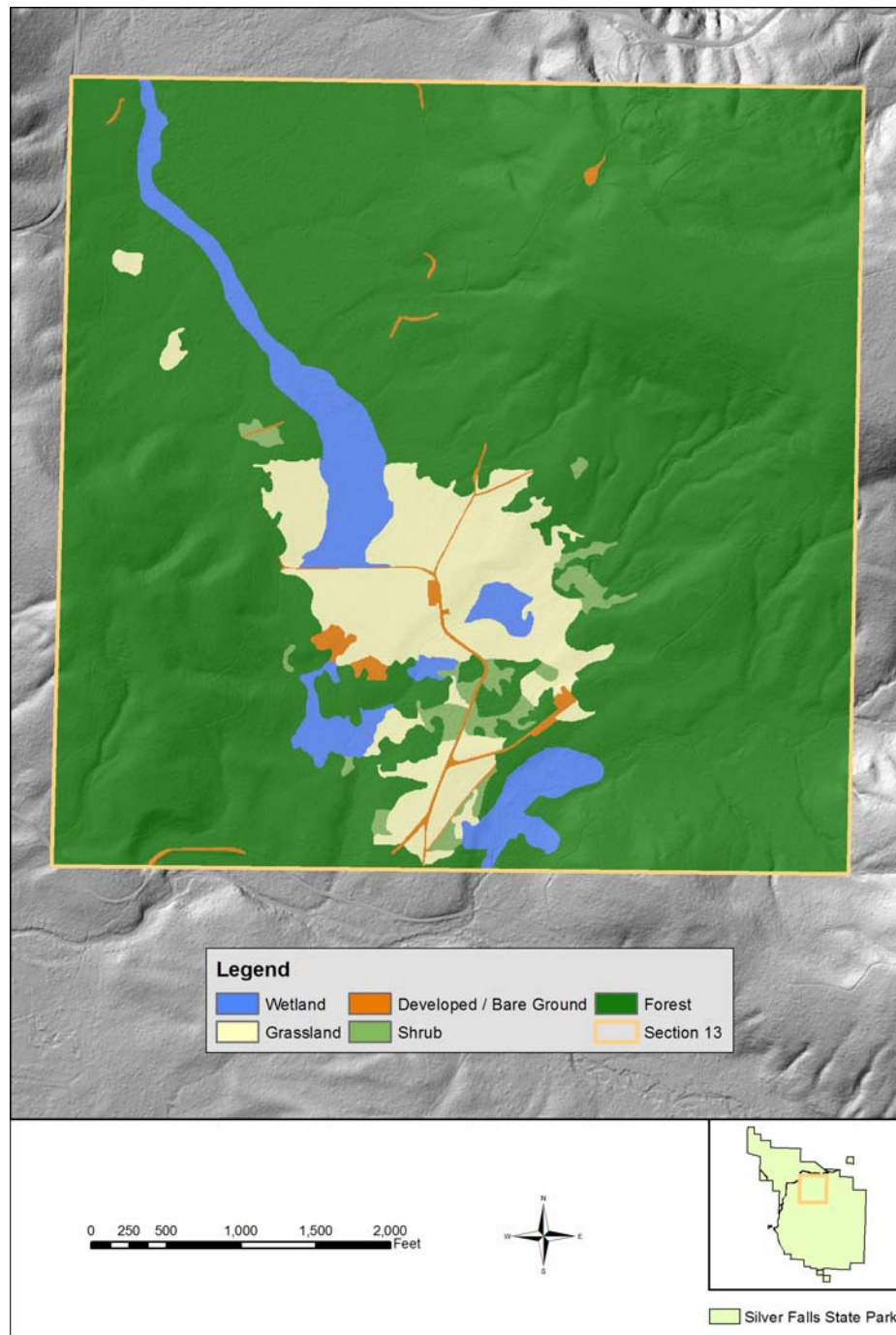
Map Author: Carl Anderson 2007

Appendix D – continued

D.7 1988 Grouped Land Cover Classes Overlaid on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

Map Author: Carl Anderson 2007

Appendix D – continued

D.8 2003 Grouped Land Cover Classes Overlaid on LIDAR-derived DEM Hillshade
T8S R1E Section 13 Willamette Meridian

Source: OPRD 2007; Unpublished Data, Carl Anderson, 2007

Map Author: Carl Anderson 2007

Appendix E – Matrix Tables

E.1 Iteration 1 1947 to 1970 – Eleven Land Cover Class Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	47 to 70 Change	Area in Acres
1	12961	1.21	1	1	No change	7.87
2	2351	0.22	1	2	WG to DG	1.43
3	2064	0.19	1	3	WG to FW	1.25
4	4765	0.45	1	4	WG to NW	2.89
5	17233	1.61	1	5	WG to YF	10.47
6	576	0.05	1	6	WG to MF	0.35
7	0	0.00	1	7	WG to OF	0.00
8	0	0.00	1	8	WG to ST	0.00
9	597	0.06	1	9	WG to DE	0.36
10	1	0.00	1	10	WG to BG	0.00
11	2417	0.23	1	11	WG to SH	1.47
12	18576	1.74	2	1	DG to WG	11.28
13	120209	11.24	2	2	No change	73.01
14	618	0.06	2	3	DG to FW	0.38
15	2154	0.20	2	4	DG to NW	1.31
16	129408	12.10	2	5	DG to YF	78.59
17	6425	0.60	2	6	DG to MF	3.90
18	0	0.00	2	7	DG to OF	0.00
19	0	0.00	2	8	DG to ST	0.00
20	7253	0.68	2	9	DG to DE	4.40
21	1907	0.18	2	10	DG to BG	1.16
22	46295	4.33	2	11	DG to SH	28.12
23	8	0.00	3	1	FW to DG	0.00
24	50	0.00	3	2	FW to WG	0.03
25	823	0.08	3	3	No change	0.50
26	0	0.00	3	4	FW to NW	0.00
27	14607	1.37	3	5	FW to YF	8.87
28	0	0.00	3	6	FW to MF	0.00
29	0	0.00	3	7	FW to OF	0.00
30	0	0.00	3	8	FW to ST	0.00
31	429	0.04	3	9	FW to DE	0.26
32	0	0.00	3	10	FW to BG	0.00
33	58	0.01	3	11	FW to SH	0.04
34	1765	0.17	4	1	NW to DG	1.07
35	289	0.03	4	2	NW to WG	0.18
36	16185	1.51	4	3	NW to FW	9.83
37	11661	1.09	4	4	No change	7.08
38	2729	0.26	4	5	NW to YF	1.66
39	805	0.08	4	6	NW to MF	0.49

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	47 to 70 Change	Area in Acres
40	0	0.00	4	7	NW to OF	0.00
41	0	0.00	4	8	NW to ST	0.00
42	93	0.01	4	9	NW to DE	0.06
43	0	0.00	4	10	NW to BG	0.00
44	129	0.01	4	11	NW to SH	0.08
45	485	0.05	5	1	YF to DG	0.29
46	3740	0.35	5	2	YF to WG	2.27
47	1571	0.15	5	3	YF to FW	0.95
48	1001	0.09	5	4	YF to NW	0.61
49	198024	18.51	5	5	No change	120.27
50	54005	5.05	5	6	YF to MF	32.80
51	0	0.00	5	7	YF to OF	0.00
52	0	0.00	5	8	YF to ST	0.00
53	1210	0.11	5	9	YF to DE	0.73
54	212	0.02	5	10	YF to BG	0.13
55	4878	0.46	5	11	YF to SH	2.96
56	301	0.03	6	1	MF to DG	0.18
57	2136	0.20	6	2	MF to WG	1.30
58	757	0.07	6	3	MF to FW	0.46
59	230	0.02	6	4	MF to NW	0.14
60	10102	0.94	6	5	MF to YF	6.14
61	151364	14.15	6	6	No change	91.93
62	0	0.00	6	7	MF to OF	0.00
63	0	0.00	6	8	MF to ST	0.00
64	317	0.03	6	9	MF to DE	0.19
65	0	0.00	6	10	MF to BG	0.00
66	10131	0.95	6	11	MF to SH	6.15
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	122	0.01	8	1	ST to DG	0.07
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	0	0.00	8	4	ST to NW	0.00
82	692	0.06	8	5	ST to YF	0.42

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	47 to 70 Change	Area in Acres
83	142	0.01	8	6	ST to MF	0.09
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	147	0.01	8	9	ST to DE	0.09
87	0	0.00	8	10	ST to BG	0.00
88	27	0.00	8	11	ST to SH	0.02
89	119	0.01	9	1	DE to DG	0.07
90	289	0.03	9	2	DE to WG	0.18
91	0	0.00	9	3	DE to FW	0.00
92	154	0.01	9	4	DE to NW	0.09
93	2597	0.24	9	5	DE to YF	1.58
94	4	0.00	9	6	DE to MF	0.00
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	397	0.04	9	9	DE to DE	0.24
98	0	0.00	9	10	DE to BG	0.00
99	144	0.01	9	11	DE to SH	0.09
100	593	0.06	10	1	BG to DG	0.36
101	196	0.02	10	2	BG to WG	0.12
102	0	0.00	10	3	BG to FW	0.00
103	32	0.00	10	4	BG to NW	0.02
104	16595	1.55	10	5	BG to YF	10.08
105	170	0.02	10	6	BG to MF	0.10
106	0	0.00	10	7	BG to OF	0.00
107	0	0.00	10	8	BG to ST	0.00
108	159	0.01	10	9	BG to DE	0.10
109	11	0.00	10	10	BG to BG	0.01
110	98	0.01	10	11	BG to SH	0.06
111	11	0.00	11	1	SH to DG	0.01
112	2737	0.26	11	2	SH to WG	1.66
113	356	0.03	11	3	SH to FW	0.22
114	2	0.00	11	4	SH to NW	0.00
115	153571	14.36	11	5	SH to YF	93.27
116	2642	0.25	11	6	SH to MF	1.60
117	0	0.00	11	7	SH to OF	0.00
118	0	0.00	11	8	SH to ST	0.00
119	1190	0.11	11	9	SH to DE	0.72
120	0	0.00	11	10	SH to BG	0.00
121	20590	1.92	11	11	SH to SH	12.51

Appendix E - continued

E.2 Iteration 2 – 1947 to 1970 – Grouped Land Cover Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	1947 to 1970 Change	Area in Acres
1	154097	14.41	A	A	No change	93.59
2	9601	0.90	A	B	Grassland to Wetland	5.83
3	153642	14.36	A	C	Grassland to Forest	93.31
4	0	0.00	A	D	Grassland to Stream	0.00
5	9758	0.91	A	E	Grassland to Developed / Bare Ground	5.93
6	48712	4.55	A	F	Grassland to Shrub	29.58
7	2112	0.20	B	A	Wetland to Grassland	1.28
8	28669	2.68	B	B	No change	17.41
9	18141	1.70	B	C	Wetland to Forest	11.02
10	0	0.00	B	D	Wetland to Stream	0.00
11	522	0.05	B	E	Wetland to Developed / Bare Ground	0.32
12	187	0.02	B	F	Wetland to Shrub	0.11
13	6662	0.62	C	A	Forest to Grassland	4.05
14	3559	0.33	C	B	Forest to Wetland	2.16
15	413495	38.66	C	C	No change	251.13
16	0	0.00	C	D	Forest to Stream	0.00
17	1739	0.16	C	E	Forest to Developed / Bare Ground	1.06
18	15009	1.40	C	F	Forest to Shrub	9.12
19	122	0.01	D	A	Stream to Grassland	0.07
20	0	0.00	D	B	Stream to Wetland	0.00
21	834	0.08	D	C	Stream to Forest	0.51
22	0	0.00	D	D	No change	0.00
23	147	0.01	D	E	Stream to Developed / Bare Ground	0.09
24	27	0.00	D	F	Stream to Shrub	0.02
25	1197	0.11	E	A	Developed / Bare Ground to Grassland	0.73
26	186	0.02	E	B	Developed / Bare Ground to Wetland	0.11
27	19366	1.81	E	C	Developed / Bare Ground to Forest	11.76
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	567	0.05	E	E	No change	0.34
30	242	0.02	E	F	Developed / Bare Ground to Shrub	0.15
31	2748	0.26	F	A	Shrub to Grassland	1.67
32	358	0.03	F	B	Shrub to Wetland	0.22
33	156213	14.60	F	C	Shrub to Forest	94.87
34	0	0.00	F	D	Shrub to Stream	0.00
35	1190	0.11	F	E	Shrub to Developed / Bare Ground	0.72
36	20590	1.92	F	F	No change	12.51

Appendix E – continued

E.3 Iteration 3 – 1947 to 1970 – Eleven Land Cover Class Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	47 to 70 Change	Area in Acres
1	6432	2.72	1	1	No change	3.90
2	1569	0.66	1	2	WG to DG	0.95
3	387	0.16	1	3	WG to FW	0.23
4	3904	1.65	1	4	WG to NW	2.37
5	5280	2.23	1	5	WG to YF	3.20
6	0	0.00	1	6	WG to MF	0.00
7	0	0.00	1	7	WG to OF	0.00
8	0	0.00	1	8	WG to ST	0.00
9	305	0.13	1	9	WG to DE	0.18
10	0	0.00	1	10	WG to BG	0.00
11	936	0.40	1	11	WG to SH	0.57
12	17670	7.47	2	1	DG to WG	10.71
13	72280	30.57	2	2	No change	43.82
14	548	0.23	2	3	DG to FW	0.33
15	2136	0.90	2	4	DG to NW	1.29
16	16594	7.02	2	5	DG to YF	10.06
17	0	0.00	2	6	DG to MF	0.00
18	0	0.00	2	7	DG to OF	0.00
19	0	0.00	2	8	DG to ST	0.00
20	3132	1.32	2	9	DG to DE	1.90
21	1743	0.74	2	10	DG to BG	1.06
22	13811	5.84	2	11	DG to SH	8.37
23	8	0.00	3	1	FW to DG	0.00
24	49	0.02	3	2	FW to WG	0.03
25	822	0.35	3	3	No change	0.50
26	0	0.00	3	4	FW to NW	0.00
27	686	0.29	3	5	FW to YF	0.42
28	0	0.00	3	6	FW to MF	0.00
29	0	0.00	3	7	FW to OF	0.00
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	0	0.00	3	10	FW to BG	0.00
33	57	0.02	3	11	FW to SH	0.03
34	1707	0.72	4	1	NW to DG	1.03
35	225	0.10	4	2	NW to WG	0.14
36	6287	2.66	4	3	NW to FW	3.81
37	11061	4.68	4	4	No change	6.71
38	1996	0.84	4	5	NW to YF	1.21
39	0	0.00	4	6	NW to MF	0.00

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	47 to 70 Change	Area in Acres
40	0	0.00	4	7	NW to OF	0.00
41	0	0.00	4	8	NW to ST	0.00
42	89	0.04	4	9	NW to DE	0.05
43	0	0.00	4	10	NW to BG	0.00
44	0	0.00	4	11	NW to SH	0.00
45	363	0.15	5	1	YF to DG	0.22
46	1062	0.45	5	2	YF to WG	0.64
47	524	0.22	5	3	YF to FW	0.32
48	123	0.05	5	4	YF to NW	0.07
49	32332	13.67	5	5	No change	19.60
50	1453	0.61	5	6	YF to MF	0.88
51	0	0.00	5	7	YF to OF	0.00
52	0	0.00	5	8	YF to ST	0.00
53	28	0.01	5	9	YF to DE	0.02
54	0	0.00	5	10	YF to BG	0.00
55	237	0.10	5	11	YF to SH	0.14
56	307	0.13	6	1	MF to DG	0.19
57	235	0.10	6	2	MF to WG	0.14
58	148	0.06	6	3	MF to FW	0.09
59	0	0.00	6	4	MF to NW	0.00
60	1737	0.73	6	5	MF to YF	1.05
61	7169	3.03	6	6	No change	4.35
62	0	0.00	6	7	MF to OF	0.00
63	0	0.00	6	8	MF to ST	0.00
64	76	0.03	6	9	MF to DE	0.05
65	0	0.00	6	10	MF to BG	0.00
66	28	0.01	6	11	MF to SH	0.02
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	0	0.00	8	4	ST to NW	0.00
82	0	0.00	8	5	ST to YF	0.00

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	47 to 70 Change	Area in Acres
83	0	0.00	8	6	ST to MF	0.00
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	125	0.05	9	1	DE to DG	0.08
90	75	0.03	9	2	DE to WG	0.05
91	0	0.00	9	3	DE to FW	0.00
92	153	0.06	9	4	DE to NW	0.09
93	299	0.13	9	5	DE to YF	0.18
94	0	0.00	9	6	DE to MF	0.00
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	249	0.11	9	9	DE to DE	0.15
98	0	0.00	9	10	DE to BG	0.00
99	0	0.00	9	11	DE to SH	0.00
100	577	0.24	10	1	BG to DG	0.35
101	57	0.02	10	2	BG to WG	0.03
102	0	0.00	10	3	BG to FW	0.00
103	31	0.01	10	4	BG to NW	0.02
104	266	0.11	10	5	BG to YF	0.16
105	112	0.05	10	6	BG to MF	0.07
106	0	0.00	10	7	BG to OF	0.00
107	0	0.00	10	8	BG to ST	0.00
108	17	0.01	10	9	BG to DE	0.01
109	0	0.00	10	10	BG to BG	0.00
110	0	0.00	10	11	BG to SH	0.00
111	10	0.00	11	1	SH to DG	0.01
112	365	0.15	11	2	SH to WG	0.22
113	164	0.07	11	3	SH to FW	0.10
114	2	0.00	11	4	SH to NW	0.00
115	16584	7.01	11	5	SH to YF	10.05
116	983	0.42	11	6	SH to MF	0.60
117	0	0.00	11	7	SH to OF	0.00
118	0	0.00	11	8	SH to ST	0.00
119	41	0.02	11	9	SH to DE	0.02
120	0	0.00	11	10	SH to BG	0.00
121	824	0.35	11	11	SH to SH	0.50

Appendix E - continued

E.4 Iteration 4 – 1947 to 1970 – Grouped Land Cover Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1947 Class	1970 Class	1947 to 1970 Change	Area in Acres
1	97951	41.42	A	A	No change	59.38
2	6975	2.95	A	B	Grassland to Wetland	4.23
3	21874	9.25	A	C	Grassland to Forest	13.26
4	0	0.00	A	D	Grassland to Stream	0.00
5	5180	2.19	A	E	Grassland to Developed / Bare Ground	3.14
6	14747	6.24	A	F	Grassland to Shrub	8.94
7	1989	0.84	B	A	Wetland to Grassland	1.21
8	18170	7.68	B	B	No change	11.02
9	2682	1.13	B	C	Wetland to Forest	1.63
10	0	0.00	B	D	Wetland to Stream	0.00
11	89	0.04	B	E	Wetland to Developed / Bare Ground	0.05
12	57	0.02	B	F	Wetland to Shrub	0.03
13	1967	0.83	C	A	Forest to Grassland	1.19
14	795	0.34	C	B	Forest to Wetland	0.48
15	42691	18.05	C	C	No change	25.88
16	0	0.00	C	D	Forest to Stream	0.00
17	104	0.04	C	E	Forest to Developed / Bare Ground	0.06
18	265	0.11	C	F	Forest to Shrub	0.16
19	0	0.00	D	A	Stream to Grassland	0.00
20	0	0.00	D	B	Stream to Wetland	0.00
21	0	0.00	D	C	Stream to Forest	0.00
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	834	0.35	E	A	Developed / Bare Ground to Grassland	0.51
26	184	0.08	E	B	Developed / Bare Ground to Wetland	0.11
27	677	0.29	E	C	Developed / Bare Ground to Forest	0.41
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	266	0.11	E	E	No change	0.16
30	0	0.00	E	F	Developed / Bare Ground to Shrub	0.00
31	375	0.16	F	A	Shrub to Grassland	0.23
32	166	0.07	F	B	Shrub to Wetland	0.10
33	17567	7.43	F	C	Shrub to Forest	10.65
34	0	0.00	F	D	Shrub to Stream	0.00
35	41	0.02	F	E	Shrub to Developed / Bare Ground	0.02
36	824	0.35	F	F	No change	0.50

Appendix E - continued

E.5 Iteration 5 – 1970 to 1988 – Eleven Land Cover Class Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	47 to 70 Change	Area in Acres
1	10350	0.97	1	1	No change	6.29
2	8511	0.80	1	2	WG to DG	5.17
3	1017	0.10	1	3	WG to FW	0.62
4	6968	0.65	1	4	WG to NW	4.23
5	3092	0.29	1	5	WG to YF	1.88
6	1148	0.11	1	6	WG to MF	0.70
7	0	0.00	1	7	WG to OF	0.00
8	0	0.00	1	8	WG to ST	0.00
9	200	0.02	1	9	WG to DE	0.12
10	478	0.04	1	10	WG to BG	0.29
11	3177	0.30	1	11	WG to SH	1.93
12	4568	0.43	2	1	DG to WG	2.77
13	66662	6.23	2	2	No change	40.48
14	771	0.07	2	3	DG to FW	0.47
15	365	0.03	2	4	DG to NW	0.22
16	32027	2.99	2	5	DG to YF	19.45
17	7133	0.67	2	6	DG to MF	4.33
18	0	0.00	2	7	DG to OF	0.00
19	0	0.00	2	8	DG to ST	0.00
20	2518	0.24	2	9	DG to DE	1.53
21	3661	0.34	2	10	DG to BG	2.22
22	14292	1.34	2	11	DG to SH	8.68
23	349	0.03	3	1	FW to DG	0.21
24	35	0.00	3	2	FW to WG	0.02
25	14776	1.38	3	3	No change	8.97
26	127	0.01	3	4	FW to NW	0.08
27	2156	0.20	3	5	FW to YF	1.31
28	4886	0.46	3	6	FW to MF	2.97
29	0	0.00	3	7	FW to OF	0.00
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	0	0.00	3	10	FW to BG	0.00
33	45	0.00	3	11	FW to SH	0.03
34	1298	0.12	4	1	NW to DG	0.79
35	56	0.01	4	2	NW to WG	0.03
36	9	0.00	4	3	NW to FW	0.01
37	17756	1.66	4	4	No change	10.78
38	47	0.00	4	5	NW to YF	0.03
39	310	0.03	4	6	NW to MF	0.19

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	47 to 70 Change	Area in Acres
40	0	0.00	4	7	NW to OF	0.00
41	201	0.02	4	8	NW to ST	0.12
42	133	0.01	4	9	NW to DE	0.08
43	131	0.01	4	10	NW to BG	0.08
44	58	0.01	4	11	NW to SH	0.04
45	105	0.01	5	1	YF to DG	0.06
46	1127	0.11	5	2	YF to WG	0.68
47	3896	0.36	5	3	YF to FW	2.37
48	667	0.06	5	4	YF to NW	0.41
49	340181	31.80	5	5	No change	206.59
50	196553	18.37	5	6	YF to MF	119.36
51	0	0.00	5	7	YF to OF	0.00
52	33	0.00	5	8	YF to ST	0.02
53	431	0.04	5	9	YF to DE	0.26
54	37	0.00	5	10	YF to BG	0.02
55	2519	0.24	5	11	YF to SH	1.53
56	0	0.00	6	1	MF to DG	0.00
57	97	0.01	6	2	MF to WG	0.06
58	959	0.09	6	3	MF to FW	0.58
59	2101	0.20	6	4	MF to NW	1.28
60	8104	0.76	6	5	MF to YF	4.92
61	152203	14.23	6	6	No change	92.43
62	52386	4.90	6	7	MF to OF	31.81
63	0	0.00	6	8	MF to ST	0.00
64	48	0.00	6	9	MF to DE	0.03
65	14	0.00	6	10	MF to BG	0.01
66	221	0.02	6	11	MF to SH	0.13
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	0	0.00	8	4	ST to NW	0.00
82	0	0.00	8	5	ST to YF	0.00

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	47 to 70 Change	Area in Acres
83	0	0.00	8	6	ST to MF	0.00
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	94	0.01	9	1	DE to DG	0.06
90	844	0.08	9	2	DE to WG	0.51
91	0	0.00	9	3	DE to FW	0.00
92	228	0.02	9	4	DE to NW	0.14
93	6228	0.58	9	5	DE to YF	3.78
94	1468	0.14	9	6	DE to MF	0.89
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	2503	0.23	9	9	DE to DE	1.52
98	223	0.02	9	10	DE to BG	0.14
99	204	0.02	9	11	DE to SH	0.12
100	0	0.00	10	1	BG to DG	0.00
101	27	0.00	10	2	BG to WG	0.02
102	0	0.00	10	3	BG to FW	0.00
103	0	0.00	10	4	BG to NW	0.00
104	659	0.06	10	5	BG to YF	0.40
105	0	0.00	10	6	BG to MF	0.00
106	0	0.00	10	7	BG to OF	0.00
107	0	0.00	10	8	BG to ST	0.00
108	112	0.01	10	9	BG to DE	0.07
109	0	0.00	10	10	BG to BG	0.00
110	1333	0.12	10	11	BG to SH	0.81
111	1037	0.10	11	1	SH to DG	0.63
112	361	0.03	11	2	SH to WG	0.22
113	1198	0.11	11	3	SH to FW	0.73
114	303	0.03	11	4	SH to NW	0.18
115	59893	5.60	11	5	SH to YF	36.37
116	14626	1.37	11	6	SH to MF	8.88
117	0	0.00	11	7	SH to OF	0.00
118	0	0.00	11	8	SH to ST	0.00
119	428	0.04	11	9	SH to DE	0.26
120	14	0.00	11	10	SH to BG	0.01
121	6907	0.65	11	11	SH to SH	4.19

Appendix E - continued

E.6 Iteration 6 – 1970 to 1988 – Grouped Land Cover Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	1970 to 1988 Change	Area in Acres
1	90091	8.42	A	A	No change	54.71
2	9121	0.85	A	B	Grassland to Wetland	5.54
3	43400	4.06	A	C	Grassland to Forest	26.36
4	0	0.00	A	D	Grassland to Stream	0.00
5	6857	0.64	A	E	Grassland to Developed / Bare Ground	4.16
6	17469	1.63	A	F	Grassland to Shrub	10.61
7	1738	0.16	B	A	Wetland to Grassland	1.06
8	32668	3.05	B	B	No change	19.84
9	7399	0.69	B	C	Wetland to Forest	4.49
10	201	0.02	B	D	Wetland to Stream	0.12
11	264	0.02	B	E	Wetland to Developed / Bare Ground	0.16
12	103	0.01	B	F	Wetland to Shrub	0.06
13	1329	0.12	C	A	Forest to Grassland	0.81
14	7623	0.71	C	B	Forest to Wetland	4.63
15	749427	70.06	C	C	No change	455.11
16	33	0.00	C	D	Forest to Stream	0.02
17	530	0.05	C	E	Forest to Developed / Bare Ground	0.32
18	2740	0.26	C	F	Forest to Shrub	1.66
19	0	0.00	D	A	Stream to Grassland	0.00
20	0	0.00	D	B	Stream to Wetland	0.00
21	0	0.00	D	C	Stream to Forest	0.00
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	965	0.09	E	A	Developed / Bare Ground to Grassland	0.59
26	228	0.02	E	B	Developed / Bare Ground to Wetland	0.14
27	8355	0.78	E	C	Developed / Bare Ground to Forest	5.07
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	2838	0.27	E	E	No change	1.72
30	1537	0.14	E	F	Developed / Bare Ground to Shrub	0.93
31	1398	0.13	F	A	Shrub to Grassland	0.85
32	1501	0.14	F	B	Shrub to Wetland	0.91
33	74519	6.97	F	C	Shrub to Forest	45.25
34	0	0.00	F	D	Shrub to Stream	0.00
35	442	0.04	F	E	Shrub to Developed / Bare Ground	0.27
36	6907	0.65	F	F	No change	4.19

Appendix E- continued

E.7 Iteration 7 – 1970 to 1988 – Eleven Land Cover Class Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	70 to 88 Change	Area in Acres
1	9368	3.96	1	1	No change	5.68
2	8238	3.48	1	2	WG to DG	4.99
3	93	0.04	1	3	WG to FW	0.06
4	3439	1.45	1	4	WG to NW	2.08
5	1991	0.84	1	5	WG to YF	1.21
6	193	0.08	1	6	WG to MF	0.12
7	0	0.00	1	7	WG to OF	0.00
8	0	0.00	1	8	WG to ST	0.00
9	207	0.09	1	9	WG to DE	0.13
10	483	0.20	1	10	WG to BG	0.29
11	3187	1.35	1	11	WG to SH	1.93
12	4502	1.90	2	1	DG to WG	2.73
13	51136	21.62	2	2	No change	31.00
14	492	0.21	2	3	DG to FW	0.30
15	225	0.10	2	4	DG to NW	0.14
16	6171	2.61	2	5	DG to YF	3.74
17	2186	0.92	2	6	DG to MF	1.33
18	0	0.00	2	7	DG to OF	0.00
19	0	0.00	2	8	DG to ST	0.00
20	1685	0.71	2	9	DG to DE	1.02
21	2491	1.05	2	10	DG to BG	1.51
22	7029	2.97	2	11	DG to SH	4.26
23	310	0.13	3	1	FW to DG	0.19
24	37	0.02	3	2	FW to WG	0.02
25	5885	2.49	3	3	No change	3.57
26	124	0.05	3	4	FW to NW	0.08
27	1626	0.69	3	5	FW to YF	0.99
28	853	0.36	3	6	FW to MF	0.52
29	0	0.00	3	7	FW to OF	0.00
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	0	0.00	3	10	FW to BG	0.00
33	45	0.02	3	11	FW to SH	0.03
34	1086	0.46	4	1	NW to DG	0.66
35	57	0.02	4	2	NW to WG	0.03
36	10	0.00	4	3	NW to FW	0.01
37	15621	6.61	4	4	No change	9.47
38	53	0.02	4	5	NW to YF	0.03
39	87	0.04	4	6	NW to MF	0.05

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	70 to 88 Change	Area in Acres
40	0	0.00	4	7	NW to OF	0.00
41	190	0.08	4	8	NW to ST	0.12
42	109	0.05	4	9	NW to DE	0.07
43	141	0.06	4	10	NW to BG	0.09
44	56	0.02	4	11	NW to SH	0.03
45	108	0.05	5	1	YF to DG	0.07
46	247	0.10	5	2	YF to WG	0.15
47	1127	0.48	5	3	YF to FW	0.68
48	299	0.13	5	4	YF to NW	0.18
49	34019	14.39	5	5	No change	20.62
50	37842	16.00	5	6	YF to MF	22.94
51	0	0.00	5	7	YF to OF	0.00
52	33	0.01	5	8	YF to ST	0.02
53	134	0.06	5	9	YF to DE	0.08
54	41	0.02	5	10	YF to BG	0.02
55	1924	0.81	5	11	YF to SH	1.17
56	0	0.00	6	1	MF to DG	0.00
57	68	0.03	6	2	MF to WG	0.04
58	0	0.00	6	3	MF to FW	0.00
59	299	0.13	6	4	MF to NW	0.18
60	26	0.01	6	5	MF to YF	0.02
61	9103	3.85	6	6	No change	5.52
62	0	0.00	6	7	MF to OF	0.00
63	0	0.00	6	8	MF to ST	0.00
64	0	0.00	6	9	MF to DE	0.00
65	0	0.00	6	10	MF to BG	0.00
66	221	0.09	6	11	MF to SH	0.13
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	0	0.00	8	4	ST to NW	0.00
82	0	0.00	8	5	ST to YF	0.00

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	70 to 88 Change	Area in Acres
83	0	0.00	8	6	ST to MF	0.00
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	80	0.03	9	1	DE to DG	0.05
90	754	0.32	9	2	DE to WG	0.46
91	1	0.00	9	3	DE to FW	0.00
92	169	0.07	9	4	DE to NW	0.10
93	325	0.14	9	5	DE to YF	0.20
94	58	0.02	9	6	DE to MF	0.04
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	2203	0.93	9	9	DE to DE	1.34
98	186	0.08	9	10	DE to BG	0.11
99	161	0.07	9	11	DE to SH	0.10
100	0	0.00	10	1	BG to DG	0.00
101	29	0.01	10	2	BG to WG	0.02
102	0	0.00	10	3	BG to FW	0.00
103	0	0.00	10	4	BG to NW	0.00
104	362	0.15	10	5	BG to YF	0.22
105	0	0.00	10	6	BG to MF	0.00
106	0	0.00	10	7	BG to OF	0.00
107	0	0.00	10	8	BG to ST	0.00
108	15	0.01	10	9	BG to DE	0.01
109	0	0.00	10	10	BG to BG	0.00
110	1337	0.57	10	11	BG to SH	0.81
111	1013	0.43	11	1	SH to DG	0.61
112	193	0.08	11	2	SH to WG	0.12
113	228	0.10	11	3	SH to FW	0.14
114	0	0.00	11	4	SH to NW	0.00
115	7159	3.03	11	5	SH to YF	4.34
116	750	0.32	11	6	SH to MF	0.45
117	0	0.00	11	7	SH to OF	0.00
118	0	0.00	11	8	SH to ST	0.00
119	247	0.10	11	9	SH to DE	0.15
120	16	0.01	11	10	SH to BG	0.01
121	6287	2.66	11	11	SH to SH	3.81

Appendix E - continued

E.8 Iteration 8 – 1970 to 1988 – Grouped Land Cover Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1970 Class	1988 Class	1970 to 1988 Change	Area in Acres
1	73244	30.97	A	A	No change	44.40
2	4249	1.80	A	B	Grassland to Wetland	2.58
3	10541	4.46	A	C	Grassland to Forest	6.39
4	0	0.00	A	D	Grassland to Stream	0.00
5	4866	2.06	A	E	Grassland to Developed / Bare Ground	2.95
6	10216	4.32	A	F	Grassland to Shrub	6.19
7	1490	0.63	B	A	Wetland to Grassland	0.90
8	21640	9.15	B	B	No change	13.12
9	2619	1.11	B	C	Wetland to Forest	1.59
10	190	0.08	B	D	Wetland to Stream	0.12
11	250	0.11	B	E	Wetland to Developed / Bare Ground	0.15
12	101	0.04	B	F	Wetland to Shrub	0.06
13	423	0.18	C	A	Forest to Grassland	0.26
14	1725	0.73	C	B	Forest to Wetland	1.05
15	80990	34.25	C	C	No change	49.10
16	33	0.01	C	D	Forest to Stream	0.02
17	175	0.07	C	E	Forest to Developed / Bare Ground	0.11
18	2145	0.91	C	F	Forest to Shrub	1.30
19	0	0.00	D	A	Stream to Grassland	0.00
20	0	0.00	D	B	Stream to Wetland	0.00
21	0	0.00	D	C	Stream to Forest	0.00
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	863	0.36	E	A	Developed / Bare Ground to Grassland	0.52
26	170	0.07	E	B	Developed / Bare Ground to Wetland	0.10
27	745	0.32	E	C	Developed / Bare Ground to Forest	0.45
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	2404	1.02	E	E	No change	1.46
30	1498	0.63	E	F	Developed / Bare Ground to Shrub	0.91
31	1206	0.51	F	A	Shrub to Grassland	0.73
32	228	0.10	F	B	Shrub to Wetland	0.14
33	7909	3.34	F	C	Shrub to Forest	4.79
34	0	0.00	F	D	Shrub to Stream	0.00
35	263	0.11	F	E	Shrub to Developed / Bare Ground	0.16
36	6287	2.66	F	F	No change	3.81

Appendix E - continued

E.9 Iteration 9 – 1988 to 2003 – Eleven Land Cover Class Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	88 to 03 Change	Area in Acres
1	9412	0.88	1	1	No change	5.71
2	4904	0.46	1	2	WG to DG	2.97
3	699	0.07	1	3	WG to FW	0.42
4	1534	0.14	1	4	WG to NW	0.93
5	937	0.09	1	5	WG to YF	0.57
6	313	0.03	1	6	WG to MF	0.19
7	0	0.00	1	7	WG to OF	0.00
8	0	0.00	1	8	WG to ST	0.00
9	0	0.00	1	9	WG to DE	0.00
10	0	0.00	1	10	WG to BG	0.00
11	0	0.00	1	11	WG to SH	0.00
12	1610	0.15	2	1	DG to WG	0.98
13	60254	5.63	2	2	No change	36.53
14	5	0.00	2	3	DG to FW	0.00
15	88	0.01	2	4	DG to NW	0.05
16	8662	0.81	2	5	DG to YF	5.25
17	966	0.09	2	6	DG to MF	0.59
18	258	0.02	2	7	DG to OF	0.16
19	0	0.00	2	8	DG to ST	0.00
20	776	0.07	2	9	DG to DE	0.47
21	1133	0.11	2	10	DG to BG	0.69
22	3968	0.37	2	11	DG to SH	2.41
23	15	0.00	3	1	FW to DG	0.01
24	135	0.01	3	2	FW to WG	0.08
25	17904	1.67	3	3	No change	10.85
26	214	0.02	3	4	FW to NW	0.13
27	198	0.02	3	5	FW to YF	0.12
28	2808	0.26	3	6	FW to MF	1.70
29	1247	0.12	3	7	FW to OF	0.76
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	105	0.01	3	10	FW to BG	0.06
33	0	0.00	3	11	FW to SH	0.00
34	1150	0.11	4	1	NW to DG	0.70
35	1090	0.10	4	2	NW to WG	0.66
36	122	0.01	4	3	NW to FW	0.07
37	24300	2.27	4	4	No change	14.73
38	199	0.02	4	5	NW to YF	0.12
39	1274	0.12	4	6	NW to MF	0.77

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	88 to 03 Change	Area in Acres
40	178	0.02	4	7	NW to OF	0.11
41	0	0.00	4	8	NW to ST	0.00
42	0	0.00	4	9	NW to DE	0.00
43	0	0.00	4	10	NW to BG	0.00
44	202	0.02	4	11	NW to SH	0.12
45	77	0.01	5	1	YF to DG	0.05
46	1676	0.16	5	2	YF to WG	1.02
47	3999	0.37	5	3	YF to FW	2.42
48	365	0.03	5	4	YF to NW	0.22
49	394007	36.83	5	5	No change	238.88
50	45606	4.26	5	6	YF to MF	27.65
51	3324	0.31	5	7	YF to OF	2.02
52	0	0.00	5	8	YF to ST	0.00
53	1005	0.09	5	9	YF to DE	0.61
54	8	0.00	5	10	YF to BG	0.00
55	2320	0.22	5	11	YF to SH	1.41
56	71	0.01	6	1	MF to DG	0.04
57	19	0.00	6	2	MF to WG	0.01
58	4040	0.38	6	3	MF to FW	2.45
59	460	0.04	6	4	MF to NW	0.28
60	45398	4.24	6	5	MF to YF	27.52
61	188271	17.60	6	6	No change	114.15
62	139213	13.01	6	7	MF to OF	84.40
63	0	0.00	6	8	MF to ST	0.00
64	633	0.06	6	9	MF to DE	0.38
65	22	0.00	6	10	MF to BG	0.01
66	200	0.02	6	11	MF to SH	0.12
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	961	0.09	7	4	OF to NW	0.58
71	475	0.04	7	5	OF to YF	0.29
72	165	0.02	7	6	OF to MF	0.10
73	50785	4.75	7	7	No change	30.79
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	234	0.02	8	4	ST to NW	0.14
82	0	0.00	8	5	ST to YF	0.00

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	88 to 03 Change	Area in Acres
83	0	0.00	8	6	ST to MF	0.00
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	0	0.00	9	1	DE to DG	0.00
90	806	0.08	9	2	DE to WG	0.49
91	31	0.00	9	3	DE to FW	0.02
92	0	0.00	9	4	DE to NW	0.00
93	995	0.09	9	5	DE to YF	0.60
94	147	0.01	9	6	DE to MF	0.09
95	134	0.01	9	7	DE to OF	0.08
96	0	0.00	9	8	DE to ST	0.00
97	4031	0.38	9	9	DE to DE	2.44
98	42	0.00	9	10	DE to BG	0.03
99	186	0.02	9	11	DE to SH	0.11
100	77	0.01	10	1	BG to DG	0.05
101	2036	0.19	10	2	BG to WG	1.23
102	0	0.00	10	3	BG to FW	0.00
103	225	0.02	10	4	BG to NW	0.14
104	719	0.07	10	5	BG to YF	0.44
105	12	0.00	10	6	BG to MF	0.01
106	0	0.00	10	7	BG to OF	0.00
107	0	0.00	10	8	BG to ST	0.00
108	10	0.00	10	9	BG to DE	0.01
109	1471	0.14	10	10	BG to BG	0.89
110	8	0.00	10	11	BG to SH	0.00
111	1202	0.11	11	1	SH to DG	0.73
112	3290	0.31	11	2	SH to WG	1.99
113	65	0.01	11	3	SH to FW	0.04
114	345	0.03	11	4	SH to NW	0.21
115	15386	1.44	11	5	SH to YF	9.33
116	904	0.08	11	6	SH to MF	0.55
117	0	0.00	11	7	SH to OF	0.00
118	0	0.00	11	8	SH to ST	0.00
119	231	0.02	11	9	SH to DE	0.14
120	237	0.02	11	10	SH to BG	0.14
121	7096	0.66	11	11	SH to SH	4.30

Appendix E - continued

E.10 Iteration 10 – 1988 to 2003 – Grouped Land Cover Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	1988 to 2003 Change	Area in Acres
1	76180	7.12	A	A	No change	46.18
2	2326	0.22	A	B	Grassland to Wetland	1.41
3	11136	1.04	A	C	Grassland to Forest	6.75
4	0	0.00	A	D	Grassland to Stream	0.00
5	1909	0.18	A	E	Grassland to Developed / Bare Ground	1.16
6	3968	0.37	A	F	Grassland to Shrub	2.41
7	2390	0.22	B	A	Wetland to Grassland	1.45
8	42540	3.98	B	B	No change	25.79
9	5904	0.55	B	C	Wetland to Forest	3.58
10	0	0.00	B	D	Wetland to Stream	0.00
11	105	0.01	B	E	Wetland to Developed / Bare Ground	0.06
12	202	0.02	B	F	Wetland to Shrub	0.12
13	1843	0.17	C	A	Forest to Grassland	1.12
14	9825	0.92	C	B	Forest to Wetland	5.96
15	867244	81.08	C	C	No change	525.77
16	0	0.00	C	D	Forest to Stream	0.00
17	1668	0.16	C	E	Forest to Developed / Bare Ground	1.01
18	2520	0.24	C	F	Forest to Shrub	1.53
19	0	0.00	D	A	Stream to Grassland	0.00
20	234	0.02	D	B	Stream to Wetland	0.14
21	0	0.00	D	C	Stream to Forest	0.00
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	2919	0.27	E	A	Developed / Bare Ground to Grassland	1.77
26	256	0.02	E	B	Developed / Bare Ground to Wetland	0.16
27	2007	0.19	E	C	Developed / Bare Ground to Forest	1.22
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	5554	0.52	E	E	No change	3.37
30	194	0.02	E	F	Developed / Bare Ground to Shrub	0.12
31	4492	0.42	F	A	Shrub to Grassland	2.72
32	410	0.04	F	B	Shrub to Wetland	0.25
33	16290	1.52	F	C	Shrub to Forest	9.88
34	0	0.00	F	D	Shrub to Stream	0.00
35	468	0.04	F	E	Shrub to Developed / Bare Ground	0.28
36	7096	0.66	F	F	No change	4.30

Appendix E - continued

E.11 Iteration 11 – 1988 to 2003 – Eleven Land Cover Class Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	88 to 03 Change	Area in Acres
1	9211	3.90	1	1	No change	5.58
2	4741	2.00	1	2	WG to DG	2.87
3	643	0.27	1	3	WG to FW	0.39
4	879	0.37	1	4	WG to NW	0.53
5	860	0.36	1	5	WG to YF	0.52
6	133	0.06	1	6	WG to MF	0.08
7	0	0.00	1	7	WG to OF	0.00
8	0	0.00	1	8	WG to ST	0.00
9	0	0.00	1	9	WG to DE	0.00
10	0	0.00	1	10	WG to BG	0.00
11	0	0.00	1	11	WG to SH	0.00
12	1567	0.66	2	1	DG to WG	0.95
13	52127	22.04	2	2	No change	31.60
14	4	0.00	2	3	DG to FW	0.00
15	93	0.04	2	4	DG to NW	0.06
16	3579	1.51	2	5	DG to YF	2.17
17	530	0.22	2	6	DG to MF	0.32
18	136	0.06	2	7	DG to OF	0.08
19	0	0.00	2	8	DG to ST	0.00
20	714	0.30	2	9	DG to DE	0.43
21	1127	0.48	2	10	DG to BG	0.68
22	882	0.37	2	11	DG to SH	0.53
23	17	0.01	3	1	FW to DG	0.01
24	133	0.06	3	2	FW to WG	0.08
25	6996	2.96	3	3	No change	4.24
26	80	0.03	3	4	FW to NW	0.05
27	138	0.06	3	5	FW to YF	0.08
28	194	0.08	3	6	FW to MF	0.12
29	174	0.07	3	7	FW to OF	0.11
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	102	0.04	3	10	FW to BG	0.06
33	2	0.00	3	11	FW to SH	0.00
34	1132	0.48	4	1	NW to DG	0.69
35	891	0.38	4	2	NW to WG	0.54
36	82	0.03	4	3	NW to FW	0.05
37	17731	7.50	4	4	No change	10.75
38	0	0.00	4	5	NW to YF	0.00

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	88 to 03 Change	Area in Acres
39	339	0.14	4	6	NW to MF	0.21
40	0	0.00	4	7	NW to OF	0.00
41	0	0.00	4	8	NW to ST	0.00
42	0	0.00	4	9	NW to DE	0.00
43	0	0.00	4	10	NW to BG	0.00
44		0.00	4	11	NW to SH	0.00
45	75	0.03	5	1	YF to DG	0.05
46	349	0.15	5	2	YF to WG	0.21
47	3804	1.61	5	3	YF to FW	2.31
48	117	0.05	5	4	YF to NW	0.07
49	41310	17.47	5	5	No change	25.04
50	4112	1.74	5	6	YF to MF	2.49
51	9	0.00	5	7	YF to OF	0.01
52	0	0.00	5	8	YF to ST	0.00
53	390	0.16	5	9	YF to DE	0.24
54	6	0.00	5	10	YF to BG	0.00
55	1560	0.66	5	11	YF to SH	0.95
56	71	0.03	6	1	MF to DG	0.04
57	11	0.00	6	2	MF to WG	0.01
58	1795	0.76	6	3	MF to FW	1.09
59	111	0.05	6	4	MF to NW	0.07
60	3880	1.64	6	5	MF to YF	2.35
61	36710	15.52	6	6	No change	22.26
62	8322	3.52	6	7	MF to OF	5.05
63	0	0.00	6	8	MF to ST	0.00
64	122	0.05	6	9	MF to DE	0.07
65	17	0.01	6	10	MF to BG	0.01
66	33	0.01	6	11	MF to SH	0.02
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	223	0.09	8	4	ST to NW	0.14

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	88 to 03 Change	Area in Acres
82	0	0.00	8	5	ST to YF	0.00
83	0	0.00	8	6	ST to MF	0.00
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	0	0.00	9	1	DE to DG	0.00
90	797	0.34	9	2	DE to WG	0.48
91	35	0.01	9	3	DE to FW	0.02
92	0	0.00	9	4	DE to NW	0.00
93	578	0.24	9	5	DE to YF	0.35
94	152	0.06	9	6	DE to MF	0.09
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	2837	1.20	9	9	DE to DE	1.72
98	47	0.02	9	10	DE to BG	0.03
99	154	0.07	9	11	DE to SH	0.09
100	83	0.04	10	1	BG to DG	0.05
101	1800	0.76	10	2	BG to WG	1.09
102	0	0.00	10	3	BG to FW	0.00
103	231	0.10	10	4	BG to NW	0.14
104	123	0.05	10	5	BG to YF	0.07
105	12	0.01	10	6	BG to MF	0.01
106	0	0.00	10	7	BG to OF	0.00
107	0	0.00	10	8	BG to ST	0.00
108	0	0.00	10	9	BG to DE	0.00
109	1100	0.47	10	10	BG to BG	0.67
110	9	0.00	10	11	BG to SH	0.01
111	1217	0.51	11	1	SH to DG	0.74
112	3137	1.33	11	2	SH to WG	1.90
113	60	0.03	11	3	SH to FW	0.04
114	349	0.15	11	4	SH to NW	0.21
115	8640	3.65	11	5	SH to YF	5.24
116	848	0.36	11	6	SH to MF	0.51
117	0	0.00	11	7	SH to OF	0.00
118	0	0.00	11	8	SH to ST	0.00
119	247	0.10	11	9	SH to DE	0.15
120	233	0.10	11	10	SH to BG	0.14
121	5516	2.33	11	11	SH to SH	3.34

Appendix E - continued

E.12 Iteration 12 – 1988 to 2003 – Grouped Land Cover Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1988 Class	2003 Class	1988 to 2003 Change	Area in Acres
1	67646	28.61	A	A	No change	41.01
2	1619	0.68	A	B	Grassland to Wetland	0.98
3	5238	2.22	A	C	Grassland to Forest	3.18
4	0	0.00	A	D	Grassland to Stream	0.00
5	1841	0.78	A	E	Grassland to Developed / Bare Ground	1.12
6	882	0.37	A	F	Grassland to Shrub	0.53
7	2173	0.92	B	A	Wetland to Grassland	1.32
8	24889	10.53	B	B	No change	15.09
9	845	0.36	B	C	Wetland to Forest	0.51
10	0	0.00	B	D	Wetland to Stream	0.00
11	102	0.04	B	E	Wetland to Developed / Bare Ground	0.06
12	2	0.00	B	F	Wetland to Shrub	0.00
13	506	0.21	C	A	Forest to Grassland	0.31
14	5827	2.46	C	B	Forest to Wetland	3.53
15	94343	39.90	C	C	No change	57.20
16	0	0.00	C	D	Forest to Stream	0.00
17	535	0.23	C	E	Forest to Developed / Bare Ground	0.32
18	1593	0.67	C	F	Forest to Shrub	0.97
19	0	0.00	D	A	Stream to Grassland	0.00
20	223	0.09	D	B	Stream to Wetland	0.14
21	0	0.00	D	C	Stream to Forest	0.00
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	2680	1.13	E	A	Developed / Bare Ground to Grassland	1.62
26	266	0.11	E	B	Developed / Bare Ground to Wetland	0.16
27	865	0.37	E	C	Developed / Bare Ground to Forest	0.52
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	3984	1.68	E	E	No change	2.42
30	163	0.07	E	F	Developed / Bare Ground to Shrub	0.10
31	4354	1.84	F	A	Shrub to Grassland	2.64
32	409	0.17	F	B	Shrub to Wetland	0.25
33	9488	4.01	F	C	Shrub to Forest	5.75
34	0	0.00	F	D	Shrub to Stream	0.00
35	480	0.20	F	E	Shrub to Developed / Bare Ground	0.29
36	5516	2.33	F	F	No change	3.34

Appendix E - continued

E.13 Iteration 13 – 1947 to 2003 – Eleven Land Cover Class Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	47 to 03 Change	Area in Acres
1	2282	0.21	1	1	No change	1.38
2	2316	0.22	1	2	WG to DG	1.40
3	4336	0.41	1	3	WG to FW	2.63
4	9544	0.89	1	4	WG to NW	5.79
5	13931	1.30	1	5	WG to YF	8.45
6	9526	0.89	1	6	WG to MF	5.78
7	246	0.02	1	7	WG to OF	0.15
8	0	0.00	1	8	WG to ST	0.00
9	447	0.04	1	9	WG to DE	0.27
10	49	0.00	1	10	WG to BG	0.03
11	288	0.03	1	11	WG to SH	0.17
12	9335	0.87	2	1	DG to DG	5.66
13	70806	6.62	2	2	No change	42.94
14	1020	0.10	2	3	DG to FW	0.62
15	2073	0.19	2	4	DG to NW	1.26
16	205588	19.22	2	5	DG to YF	124.67
17	18898	1.77	2	6	DG to MF	11.46
18	4269	0.40	2	7	DG to OF	2.59
19	0	0.00	2	8	DG to ST	0.00
20	4770	0.45	2	9	DG to DE	2.89
21	2955	0.28	2	10	DG to BG	1.79
22	13128	1.23	2	11	DG to SH	7.96
23	0	0.00	3	1	FW to DG	0.00
24	24	0.00	3	2	FW to WG	0.01
25	978	0.09	3	3	No change	0.59
26	0	0.00	3	4	FW to NW	0.00
27	14160	1.32	3	5	FW to YF	8.59
28	812	0.08	3	6	FW to MF	0.49
29	0	0.00	3	7	FW to OF	0.00
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	0	0.00	3	10	FW to BG	0.00
33	1	0.00	3	11	FW to SH	0.00
34	1271	0.12	4	1	NW to DG	0.77
35	145	0.01	4	2	NW to WG	0.09
36	15595	1.46	4	3	NW to FW	9.46
37	12625	1.18	4	4	No change	7.66
38	910	0.09	4	5	NW to YF	0.55
39	2884	0.27	4	6	NW to MF	1.75

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	47 to 03 Change	Area in Acres
40	224	0.02	4	7	NW to OF	0.14
41	0	0.00	4	8	NW to ST	0.00
42	0	0.00	4	9	NW to DE	0.00
43	0	0.00	4	10	NW to BG	0.00
44	2	0.00	4	11	NW to SH	0.00
45	36	0.00	5	1	YF to DG	0.02
46	225	0.02	5	2	YF to WG	0.14
47	2658	0.25	5	3	YF to FW	1.61
48	3620	0.34	5	4	YF to NW	2.20
49	69587	6.51	5	5	No change	42.20
50	165518	15.47	5	6	YF to MF	100.37
51	22386	2.09	5	7	YF to OF	13.58
52	0	0.00	5	8	YF to ST	0.00
53	721	0.07	5	9	YF to DE	0.44
54	0	0.00	5	10	YF to BG	0.00
55	375	0.04	5	11	YF to SH	0.23
56	274	0.03	6	1	MF to DG	0.17
57	237	0.02	6	2	MF to WG	0.14
58	1652	0.15	6	3	MF to FW	1.00
59	488	0.05	6	4	MF to NW	0.30
60	4068	0.38	6	5	MF to YF	2.47
61	5584	0.52	6	6	No change	3.39
62	162904	15.23	6	7	MF to OF	98.79
63	0	0.00	6	8	MF to ST	0.00
64	117	0.01	6	9	MF to DE	0.07
65	7	0.00	6	10	MF to BG	0.00
66	7	0.00	6	11	MF to SH	0.00
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	111	0.01	8	4	ST to NW	0.07
82	708	0.07	8	5	ST to YF	0.43

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	47 to 03 Change	Area in Acres
83	227	0.02	8	6	ST to MF	0.14
84	84	0.01	8	7	ST to OF	0.05
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	163	0.02	9	1	DE to DG	0.10
90	214	0.02	9	2	DE to WG	0.13
91	0	0.00	9	3	DE to FW	0.00
92	192	0.02	9	4	DE to NW	0.12
93	2612	0.24	9	5	DE to YF	1.58
94	338	0.03	9	6	DE to MF	0.20
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	185	0.02	9	9	DE to DE	0.11
98	0	0.00	9	10	DE to BG	0.00
99	0	0.00	9	11	DE to SH	0.00
100	248	0.02	10	1	BG to DG	0.15
101	52	0.00	10	2	BG to WG	0.03
102	0	0.00	10	3	BG to FW	0.00
103	71	0.01	10	4	BG to NW	0.04
104	16241	1.52	10	5	BG to YF	9.85
105	841	0.08	10	6	BG to MF	0.51
106	134	0.01	10	7	BG to OF	0.08
107	0	0.00	10	8	BG to ST	0.00
108	82	0.01	10	9	BG to DE	0.05
109	7	0.00	10	10	BG to BG	0.00
110	178	0.02	10	11	BG to SH	0.11
111	5	0.00	11	1	SH to DG	0.00
112	191	0.02	11	2	SH to WG	0.12
113	626	0.06	11	3	SH to FW	0.38
114	2	0.00	11	4	SH to NW	0.00
115	139179	13.01	11	5	SH to YF	84.40
116	35839	3.35	11	6	SH to MF	21.73
117	4892	0.46	11	7	SH to OF	2.97
118	0	0.00	11	8	SH to ST	0.00
119	364	0.03	11	9	SH to DE	0.22
120	0	0.00	11	10	SH to BG	0.00
121	1	0.00	11	11	SH to SH	0.00

Appendix E - continued

E.14 Iteration 14 – 1947 to 2003 – Grouped Land Cover Matrix – Section 13

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	1947 to 2003 Change	Area in Acres
1	84739	7.92	A	A	No change	51.38
2	16973	1.59	A	B	Grassland to Wetland	10.29
3	252458	23.60	A	C	Grassland to Forest	153.08
4	0	0.00	A	D	Grassland to Stream	0.00
5	8221	0.77	A	E	Grassland to Developed / Bare Ground	4.98
6	13416	1.25	A	F	Grassland to Shrub	8.13
7	1440	0.13	B	A	Wetland to Grassland	0.87
8	29198	2.73	B	B	No change	17.70
9	18990	1.78	B	C	Wetland to Forest	11.51
10	0	0.00	B	D	Wetland to Stream	0.00
11	0	0.00	B	E	Wetland to Developed / Bare Ground	0.00
12	3	0.00	B	F	Wetland to Shrub	0.00
13	772	0.07	C	A	Forest to Grassland	0.47
14	8418	0.79	C	B	Forest to Wetland	5.10
15	430047	40.20	C	C	No change	260.76
16	0	0.00	C	D	Forest to Stream	0.00
17	845	0.08	C	E	Forest to Developed / Bare Ground	0.51
18	382	0.04	C	F	Forest to Shrub	0.23
19	0	0.00	D	A	Stream to Grassland	0.00
20	111	0.01	D	B	Stream to Wetland	0.07
21	1019	0.10	D	C	Stream to Forest	0.62
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	677	0.06	E	A	Developed / Bare Ground to Grassland	0.41
26	263	0.02	E	B	Developed / Bare Ground to Wetland	0.16
27	20166	1.89	E	C	Developed / Bare Ground to Forest	12.23
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	274	0.03	E	E	No change	0.17
30	178	0.02	E	F	Developed / Bare Ground to Shrub	0.11
31	196	0.02	F	A	Shrub to Grassland	0.12
32	628	0.06	F	B	Shrub to Wetland	0.38
33	179910	16.82	F	C	Shrub to Forest	109.09
34	0	0.00	F	D	Shrub to Stream	0.00
35	364	0.03	F	E	Shrub to Developed / Bare Ground	0.22
36	1	0.00	F	F	No change	0.00

Appendix E - continued

E.15 Iteration 15 – 1947 to 2003 – Eleven Land Cover Class Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	47 to 03 Change	Area in Acres
1	2131	0.90	1	1	No change	1.29
2	2249	0.95	1	2	WG to DG	1.36
3	1960	0.83	1	3	WG to FW	1.19
4	5142	2.17	1	4	WG to NW	3.12
5	5350	2.26	1	5	WG to YF	3.24
6	1615	0.68	1	6	WG to MF	0.98
7	27	0.01	1	7	WG to OF	0.02
8	0	0.00	1	8	WG to ST	0.00
9	290	0.12	1	9	WG to DE	0.18
10	49	0.02	1	10	WG to BG	0.03
11	0	0.00	1	11	WG to SH	0.00
12	9268	3.92	2	1	DG to WG	5.62
13	61194	25.88	2	2	No change	37.10
14	1009	0.43	2	3	DG to FW	0.61
15	1925	0.81	2	4	DG to NW	1.17
16	35880	15.17	2	5	DG to YF	21.75
17	4710	1.99	2	6	DG to MF	2.86
18	19	0.01	2	7	DG to OF	0.01
19	0	0.00	2	8	DG to ST	0.00
20	3755	1.59	2	9	DG to DE	2.28
21	2569	1.09	2	10	DG to BG	1.56
22	7584	3.21	2	11	DG to SH	4.60
23	0	0.00	3	1	FW to DG	0.00
24	21	0.01	3	2	FW to WG	0.01
25	975	0.41	3	3	No change	0.59
26	0	0.00	3	4	FW to NW	0.00
27	219	0.09	3	5	FW to YF	0.13
28	406	0.17	3	6	FW to MF	0.25
29	0	0.00	3	7	FW to OF	0.00
30	0	0.00	3	8	FW to ST	0.00
31	0	0.00	3	9	FW to DE	0.00
32	0	0.00	3	10	FW to BG	0.00
33	1	0.00	3	11	FW to SH	0.00
34	1251	0.53	4	1	NW to DG	0.76
35	143	0.06	4	2	NW to WG	0.09
36	7404	3.13	4	3	NW to FW	4.49
37	12077	5.11	4	4	No change	7.32
38	374	0.16	4	5	NW to YF	0.23

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	47 to 03 Change	Area in Acres
39	97	0.04	4	6	NW to MF	0.06
40	19	0.01	4	7	NW to OF	0.01
41	0	0.00	4	8	NW to ST	0.00
42	0	0.00	4	9	NW to DE	0.00
43	0	0.00	4	10	NW to BG	0.00
44	0	0.00	4	11	NW to SH	0.00
45	36	0.02	5	1	YF to DG	0.02
46	27	0.01	5	2	YF to WG	0.02
47	1648	0.70	5	3	YF to FW	1.00
48	411	0.17	5	4	YF to NW	0.25
49	6080	2.57	5	5	No change	3.69
50	27334	11.56	5	6	YF to MF	16.57
51	197	0.08	5	7	YF to OF	0.12
52	0	0.00	5	8	YF to ST	0.00
53	7	0.00	5	9	YF to DE	0.00
54	0	0.00	5	10	YF to BG	0.00
55	382	0.16	5	11	YF to SH	0.23
56	273	0.12	6	1	MF to DG	0.17
57	169	0.07	6	2	MF to WG	0.10
58	3	0.00	6	3	MF to FW	0.00
59	0	0.00	6	4	MF to NW	0.00
60	347	0.15	6	5	MF to YF	0.21
61	1610	0.68	6	6	No change	0.98
62	7170	3.03	6	7	MF to OF	4.35
63	0	0.00	6	8	MF to ST	0.00
64	113	0.05	6	9	MF to DE	0.07
65	7	0.00	6	10	MF to BG	0.00
66	8	0.00	6	11	MF to SH	0.00
67	0	0.00	7	1	OF to DG	0.00
68	0	0.00	7	2	OF to WG	0.00
69	0	0.00	7	3	OF to FW	0.00
70	0	0.00	7	4	OF to NW	0.00
71	0	0.00	7	5	OF to YF	0.00
72	0	0.00	7	6	OF to MF	0.00
73	0	0.00	7	7	No change	0.00
74	0	0.00	7	8	OF to ST	0.00
75	0	0.00	7	9	OF to DE	0.00
76	0	0.00	7	10	OF to BG	0.00
77	0	0.00	7	11	OF to SH	0.00
78	0	0.00	8	1	ST to DG	0.00
79	0	0.00	8	2	ST to WG	0.00
80	0	0.00	8	3	ST to FW	0.00
81	0	0.00	8	4	ST to NW	0.00

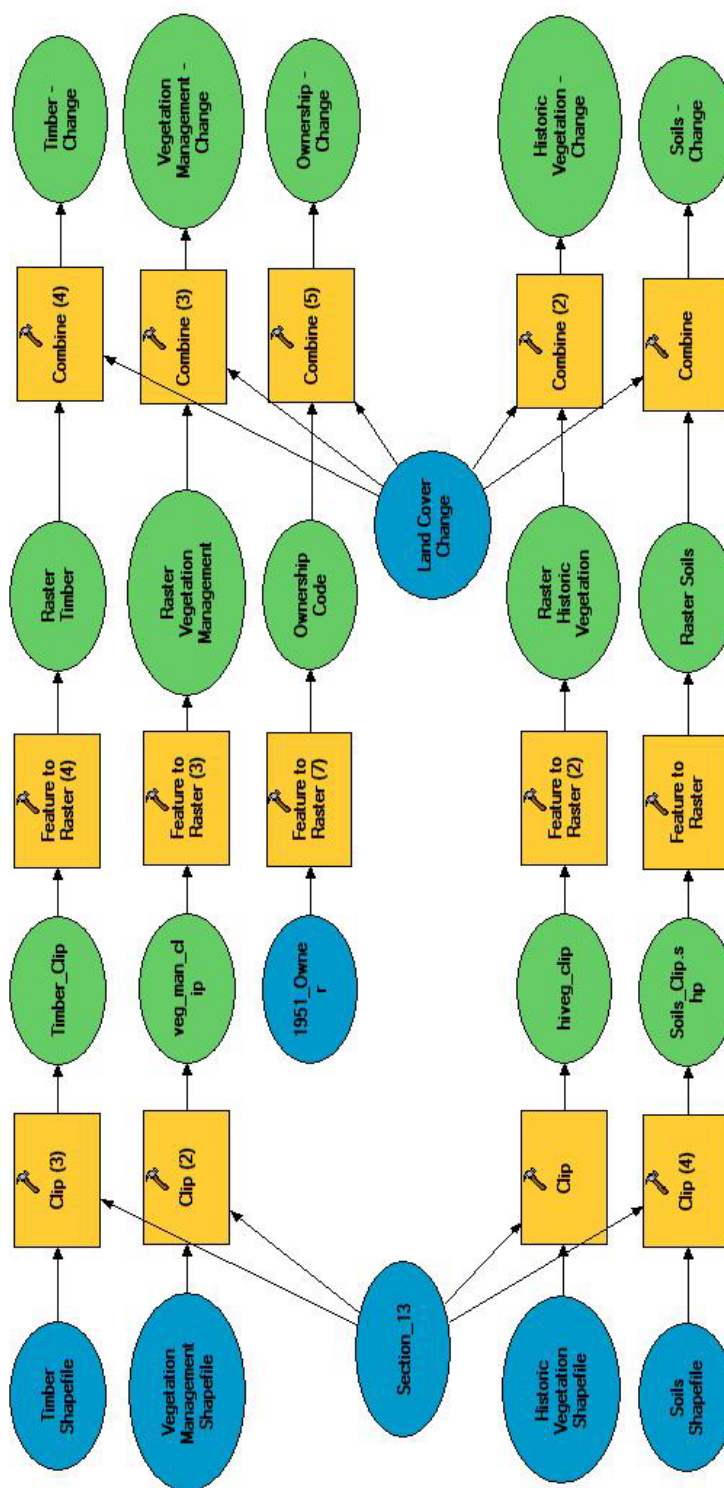
Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	47 to 03 Change	Area in Acres
82	0	0.00	8	5	ST to YF	0.00
83	0	0.00	8	6	ST to MF	0.00
84	0	0.00	8	7	ST to OF	0.00
85	0	0.00	8	8	ST to ST	0.00
86	0	0.00	8	9	ST to DE	0.00
87	0	0.00	8	10	ST to BG	0.00
88	0	0.00	8	11	ST to SH	0.00
89	166	0.07	9	1	DE to DG	0.10
90	130	0.05	9	2	DE to WG	0.08
91	0	0.00	9	3	DE to FW	0.00
92	191	0.08	9	4	DE to NW	0.12
93	279	0.12	9	5	DE to YF	0.17
94	20	0.01	9	6	DE to MF	0.01
95	0	0.00	9	7	DE to OF	0.00
96	0	0.00	9	8	DE to ST	0.00
97	115	0.05	9	9	DE to DE	0.07
98	0	0.00	9	10	DE to BG	0.00
99	0	0.00	9	11	DE to SH	0.00
100	244	0.10	10	1	BG to DG	0.15
101	53	0.02	10	2	BG to WG	0.03
102	0	0.00	10	3	BG to FW	0.00
103	66	0.03	10	4	BG to NW	0.04
104	0	0.00	10	5	BG to YF	0.00
105	491	0.21	10	6	BG to MF	0.30
106	13	0.01	10	7	BG to OF	0.01
107	0	0.00	10	8	BG to ST	0.00
108	6	0.00	10	9	BG to DE	0.00
109	7	0.00	10	10	BG to BG	0.00
110	180	0.08	10	11	BG to SH	0.11
111	4	0.00	11	1	SH to DG	0.00
112	0	0.00	11	2	SH to WG	0.00
113	420	0.18	11	3	SH to FW	0.25
114	2	0.00	11	4	SH to NW	0.00
115	10579	4.47	11	5	SH to YF	6.41
116	6747	2.85	11	6	SH to MF	4.09
117	1196	0.51	11	7	SH to OF	0.73
118	0	0.00	11	8	SH to ST	0.00
119	24	0.01	11	9	SH to DE	0.01
120	0	0.00	11	10	SH to BG	0.00
121	1	0.00	11	11	SH to SH	0.00

Appendix E - continued

E.16 Iteration 16 – 1947 to 2003 – Grouped Land Cover Matrix – Historic Meadow

Matrix Number	Histogram Numbers	Percent	1947 Class	2003 Class	1947 to 2003 Change	Area in Acres
1	74842	31.65	A	A	No change	45.37
2	10036	4.24	A	B	Grassland to Wetland	6.08
3	47601	20.13	A	C	Grassland to Forest	28.86
4	0	0.00	A	D	Grassland to Stream	0.00
5	6663	2.82	A	E	Grassland to Developed / Bare Ground	4.04
6	7584	3.21	A	F	Grassland to Shrub	4.60
7	1415	0.60	B	A	Wetland to Grassland	0.86
8	20456	8.65	B	B	No change	12.40
9	1115	0.47	B	C	Wetland to Forest	0.68
10	0	0.00	B	D	Wetland to Stream	0.00
11	0	0.00	B	E	Wetland to Developed / Bare Ground	0.00
12	1	0.00	B	F	Wetland to Shrub	0.00
13	505	0.21	C	A	Forest to Grassland	0.31
14	2062	0.87	C	B	Forest to Wetland	1.25
15	42738	18.07	C	C	No change	25.91
16	0	0.00	C	D	Forest to Stream	0.00
17	127	0.05	C	E	Forest to Developed / Bare Ground	0.08
18	390	0.16	C	F	Forest to Shrub	0.24
19	0	0.00	D	A	Stream to Grassland	0.00
20	0	0.00	D	B	Stream to Wetland	0.00
21	0	0.00	D	C	Stream to Forest	0.00
22	0	0.00	D	D	No change	0.00
23	0	0.00	D	E	Stream to Developed / Bare Ground	0.00
24	0	0.00	D	F	Stream to Shrub	0.00
25	593	0.25	E	A	Developed / Bare Ground to Grassland	0.36
26	257	0.11	E	B	Developed / Bare Ground to Wetland	0.16
27	803	0.34	E	C	Developed / Bare Ground to Forest	0.49
28	0	0.00	E	D	Developed / Bare Ground to Stream	0.00
29	128	0.05	E	E	No change	0.08
30	180	0.08	E	F	Developed / Bare Ground to Shrub	0.11
31	4	0.00	F	A	Shrub to Grassland	0.00
32	422	0.18	F	B	Shrub to Wetland	0.26
33	18522	7.83	F	C	Shrub to Forest	11.23
34	0	0.00	F	D	Shrub to Stream	0.00
35	24	0.01	F	E	Shrub to Developed / Bare Ground	0.01
36	1	0.00	F	F	No change	0.00

Appendix F – GIS Analysis – ArcGIS 9.1 Modelbuilder diagram of Soils, Historic Vegetation, Management, Timber and Ownership layer analyses



Appendix G - GIS Analysis – Slope and Aspect Data

Land Cover Change Class	Count	Slope Percent	Aspect
Developed / Bare Ground to Developed / Bare Ground	122	0 to 10	North
Developed / Bare Ground to Developed / Bare Ground	110	0 to 10	South
Developed / Bare Ground to Developed / Bare Ground	28	10 to 30	North
Developed / Bare Ground to Developed / Bare Ground	12	10 to 30	South
Developed / Bare Ground to Developed / Bare Ground	1	>30	North
Developed / Bare Ground to Developed / Bare Ground	1	0 to 10	Flat
Developed / Bare Ground to Forest	7687	10 to 30	North
Developed / Bare Ground to Forest	3902	>30	North
Developed / Bare Ground to Forest	3181	0 to 10	North
Developed / Bare Ground to Forest	2538	10 to 30	South
Developed / Bare Ground to Forest	2286	0 to 10	South
Developed / Bare Ground to Forest	562	>30	South
Developed / Bare Ground to Forest	6	0 to 10	Flat
Developed / Bare Ground to Forest	3	10 to 30	Flat
Developed / Bare Ground to Forest	1	>30	Flat
Developed / Bare Ground to Grassland	339	0 to 10	South
Developed / Bare Ground to Grassland	293	0 to 10	North
Developed / Bare Ground to Grassland	23	10 to 30	South
Developed / Bare Ground to Grassland	22	10 to 30	North
Developed / Bare Ground to Shrub	113	0 to 10	South
Developed / Bare Ground to Shrub	54	0 to 10	North
Developed / Bare Ground to Shrub	10	10 to 30	South
Developed / Bare Ground to Shrub	1	10 to 30	North
Developed / Bare Ground to Wetland	121	0 to 10	South
Developed / Bare Ground to Wetland	113	0 to 10	North
Developed / Bare Ground to Wetland	19	10 to 30	North
Developed / Bare Ground to Wetland	10	10 to 30	South
Forest to Developed / Bare Ground	297	0 to 10	South
Forest to Developed / Bare Ground	244	0 to 10	North
Forest to Developed / Bare Ground	133	10 to 30	South
Forest to Developed / Bare Ground	111	10 to 30	North
Forest to Developed / Bare Ground	59	>30	North
Forest to Developed / Bare Ground	1	0 to 10	Flat
Forest to Forest	109465	10 to 30	South
Forest to Forest	96542	10 to 30	North
Forest to Forest	78751	0 to 10	South
Forest to Forest	66520	0 to 10	North
Forest to Forest	43514	>30	North
Forest to Forest	35125	>30	South
Forest to Forest	94	0 to 10	Flat

Land Cover Change Class	Count	Slope Percent	Aspect
Forest to Forest	31	10 to 30	Flat
Forest to Forest	5	>30	Flat
Forest to Grassland	362	0 to 10	South
Forest to Grassland	249	0 to 10	North
Forest to Grassland	112	10 to 30	North
Forest to Grassland	46	10 to 30	South
Forest to Grassland	2	>30	North
Forest to Grassland	1	0 to 10	Flat
Forest to Shrub	194	0 to 10	South
Forest to Shrub	107	0 to 10	North
Forest to Shrub	58	10 to 30	South
Forest to Shrub	23	10 to 30	North
Forest to Wetland	3684	0 to 10	South
Forest to Wetland	3061	0 to 10	North
Forest to Wetland	974	10 to 30	South
Forest to Wetland	668	10 to 30	North
Forest to Wetland	14	>30	South
Forest to Wetland	9	0 to 10	Flat
Forest to Wetland	8	>30	North
Grassland to Developed / Bare Ground	3715	0 to 10	South
Grassland to Developed / Bare Ground	3342	0 to 10	North
Grassland to Developed / Bare Ground	634	10 to 30	South
Grassland to Developed / Bare Ground	479	10 to 30	North
Grassland to Developed / Bare Ground	37	>30	North
Grassland to Developed / Bare Ground	8	>30	South
Grassland to Developed / Bare Ground	6	0 to 10	Flat
Grassland to Forest	96421	10 to 30	South
Grassland to Forest	43475	0 to 10	South
Grassland to Forest	42930	10 to 30	North
Grassland to Forest	38993	0 to 10	North
Grassland to Forest	20830	>30	South
Grassland to Forest	9748	>30	North
Grassland to Forest	50	0 to 10	Flat
Grassland to Forest	10	10 to 30	Flat
Grassland to Forest	1	>30	Flat
Grassland to Grassland	35467	0 to 10	North
Grassland to Grassland	34715	0 to 10	South
Grassland to Grassland	10522	10 to 30	South
Grassland to Grassland	3908	10 to 30	North
Grassland to Grassland	65	0 to 10	Flat
Grassland to Grassland	41	>30	South
Grassland to Grassland	20	>30	North
Grassland to Grassland	1	10 to 30	Flat

Land Cover Change Class	Count	Slope Percent	Aspect
Grassland to Shrub	5104	0 to 10	South
Grassland to Shrub	4855	0 to 10	North
Grassland to Shrub	2044	10 to 30	South
Grassland to Shrub	1337	10 to 30	North
Grassland to Shrub	37	>30	South
Grassland to Shrub	24	>30	North
Grassland to Shrub	12	0 to 10	Flat
Grassland to Shrub	3	10 to 30	Flat
Grassland to Wetland	7023	0 to 10	South
Grassland to Wetland	6435	0 to 10	North
Grassland to Wetland	2130	10 to 30	South
Grassland to Wetland	1310	10 to 30	North
Grassland to Wetland	34	>30	South
Grassland to Wetland	33	>30	North
Grassland to Wetland	8	0 to 10	Flat
Shrub to Developed / Bare Ground	192	0 to 10	North
Shrub to Developed / Bare Ground	113	10 to 30	North
Shrub to Developed / Bare Ground	42	0 to 10	South
Shrub to Developed / Bare Ground	17	10 to 30	South
Shrub to Forest	58890	10 to 30	South
Shrub to Forest	34955	10 to 30	North
Shrub to Forest	22795	>30	North
Shrub to Forest	22345	>30	South
Shrub to Forest	20875	0 to 10	South
Shrub to Forest	20012	0 to 10	North
Shrub to Forest	18	0 to 10	Flat
Shrub to Forest	14	10 to 30	Flat
Shrub to Forest	6	>30	Flat
Shrub to Grassland	115	0 to 10	North
Shrub to Grassland	55	0 to 10	South
Shrub to Grassland	13	10 to 30	North
Shrub to Grassland	13	10 to 30	South
Shrub to Shrub	1	0 to 10	North
Shrub to Wetland	318	0 to 10	North
Shrub to Wetland	186	0 to 10	South
Shrub to Wetland	82	10 to 30	North
Shrub to Wetland	41	10 to 30	South
Shrub to Wetland	1	0 to 10	Flat
Stream to Forest	334	10 to 30	South
Stream to Forest	209	0 to 10	South
Stream to Forest	191	>30	South
Stream to Forest	166	10 to 30	North
Stream to Forest	88	0 to 10	North

Land Cover Change Class	Count	Slope Percent	Aspect
Stream to Forest	31	>30	North
Stream to Wetland	47	10 to 30	North
Stream to Wetland	28	0 to 10	North
Stream to Wetland	21	0 to 10	South
Stream to Wetland	15	10 to 30	South
Wetland to Forest	10949	10 to 30	South
Wetland to Forest	2817	0 to 10	South
Wetland to Forest	1678	>30	South
Wetland to Forest	1531	0 to 10	North
Wetland to Forest	1456	10 to 30	North
Wetland to Forest	556	>30	North
Wetland to Forest	3	0 to 10	Flat
Wetland to Grassland	740	0 to 10	South
Wetland to Grassland	630	0 to 10	North
Wetland to Grassland	45	10 to 30	South
Wetland to Grassland	23	10 to 30	North
Wetland to Grassland	2	0 to 10	Flat
Wetland to Shrub	3	0 to 10	South
Wetland to Wetland	12875	0 to 10	South
Wetland to Wetland	12441	0 to 10	North
Wetland to Wetland	2292	10 to 30	South
Wetland to Wetland	1490	10 to 30	North
Wetland to Wetland	63	>30	South
Wetland to Wetland	22	0 to 10	Flat
Wetland to Wetland	15	>30	North

Appendix H – GIS Analysis – Soil Data

Land Cover Change Class	Count	Soil Type
Developed / Bare Ground to Developed / Bare Ground	139	Kinney
Developed / Bare Ground to Developed / Bare Ground	78	McCully
Developed / Bare Ground to Developed / Bare Ground	13	Horeb
Developed / Bare Ground to Developed / Bare Ground	12	Minniece
Developed / Bare Ground to Forest	1273	Kinney
Developed / Bare Ground to Forest	285	McCully
Developed / Bare Ground to Forest	31	Horeb
Developed / Bare Ground to Forest	9	Minniece
Developed / Bare Ground to Grassland	18	Kinney
Developed / Bare Ground to Grassland	11	Horeb
Developed / Bare Ground to Grassland	1	Minniece
Developed / Bare Ground to Shrub	4	Horeb
Developed / Bare Ground to Shrub	1	Kinney
Developed / Bare Ground to Wetland	21	Kinney
Developed / Bare Ground to Wetland	5	Horeb
Forest to Developed / Bare Ground	165	Kinney
Forest to Developed / Bare Ground	16	McCully
Forest to Developed / Bare Ground	14	Minniece
Forest to Developed / Bare Ground	13	Horeb
Forest to Forest	15347	Kinney
Forest to Forest	7423	McCully
Forest to Forest	705	Horeb
Forest to Forest	7	Minniece
Forest to Grassland	16	Horeb
Forest to Grassland	5	Kinney
Forest to Shrub	7	Horeb
Forest to Shrub	6	Kinney
Forest to Wetland	382	Kinney
Forest to Wetland	151	McCully
Forest to Wetland	47	Horeb
Forest to Wetland	13	Minniece
Grassland to Developed / Bare Ground	869	Kinney
Grassland to Developed / Bare Ground	307	McCully
Grassland to Developed / Bare Ground	21	Minniece
Grassland to Developed / Bare Ground	17	Horeb
Grassland to Forest	10269	Kinney
Grassland to Forest	2346	McCully
Grassland to Grassland	4072	Kinney
Grassland to Grassland	296	Minniece
Grassland to Grassland	108	McCully
Grassland to Grassland	3	Horeb

Land Cover Change Class	Count	Soil Type
Grassland to Shrub	575	Kinney
Grassland to Shrub	9	Minniece
Grassland to Shrub	3	Horeb
Grassland to Wetland	516	Kinney
Grassland to Wetland	243	Minniece
Grassland to Wetland	68	McCully
Grassland to Wetland	12	Horeb
Shrub to Developed / Bare Ground	159	Kinney
Shrub to Developed / Bare Ground	15	Minniece
Shrub to Developed / Bare Ground	10	McCully
Shrub to Developed / Bare Ground	2	Horeb
Shrub to Forest	7973	Kinney
Shrub to Forest	2137	McCully
Shrub to Forest	14	Minniece
Shrub to Forest	14	Horeb
Shrub to Grassland	136	Kinney
Shrub to Grassland	60	Minniece
Shrub to Grassland	11	McCully
Shrub to Grassland	3	Horeb
Shrub to Shrub	9	Kinney
Shrub to Shrub	5	Horeb
Shrub to Wetland	187	Kinney
Shrub to Wetland	18	McCully
Shrub to Wetland	16	Minniece
Shrub to Wetland	3	Horeb
Stream to Forest	17	Kinney
Stream to Forest	3	Horeb
Wetland to Forest	1663	Kinney
Wetland to Forest	357	McCully
Wetland to Forest	23	Horeb
Wetland to Grassland	57	Kinney
Wetland to Grassland	9	Minniece
Wetland to Grassland	2	Horeb
Wetland to Shrub	11	Kinney
Wetland to Shrub	4	Horeb
Wetland to Wetland	1326	Kinney
Wetland to Wetland	737	McCully
Wetland to Wetland	249	Minniece
Wetland to Wetland	97	Horeb

Appendix I – GIS Analysis – Historic Vegetation Data

Land Cover Change Class	Count	Historic Vegetation
Developed / Bare Ground to Developed / Bare Ground	261	Douglas fir
Developed / Bare Ground to Developed / Bare Ground	13	Roemer's fescue
Developed / Bare Ground to Forest	19637	Douglas fir
Developed / Bare Ground to Forest	529	Roemer's fescue
Developed / Bare Ground to Grassland	362	Douglas fir
Developed / Bare Ground to Grassland	315	Roemer's fescue
Developed / Bare Ground to Shrub	178	Roemer's fescue
Developed / Bare Ground to Wetland	158	Douglas fir
Developed / Bare Ground to Wetland	105	Roemer's fescue
Forest to Developed / Bare Ground	727	Douglas fir
Forest to Developed / Bare Ground	118	Roemer's fescue
Forest to Forest	425970	Douglas fir
Forest to Forest	4077	Roemer's fescue
Forest to Grassland	565	Roemer's fescue
Forest to Grassland	207	Douglas fir
Forest to Shrub	382	Roemer's fescue
Forest to Wetland	8273	Douglas fir
Forest to Wetland	145	Roemer's fescue
Grassland to Developed / Bare Ground	6708	Douglas fir
Grassland to Developed / Bare Ground	1513	Roemer's fescue
Grassland to Forest	249387	Douglas fir
Grassland to Forest	3071	Roemer's fescue
Grassland to Grassland	73900	Douglas fir
Grassland to Grassland	10839	Roemer's fescue
Grassland to Shrub	11744	Douglas fir
Grassland to Shrub	1672	Roemer's fescue
Grassland to Wetland	15725	Douglas fir
Grassland to Wetland	1248	Roemer's fescue
Shrub to Developed / Bare Ground	364	Douglas fir
Shrub to Forest	179910	Douglas fir
Shrub to Grassland	196	Douglas fir
Shrub to Shrub	1	Douglas fir
Shrub to Wetland	628	Douglas fir
Stream to Forest	1019	Douglas fir
Stream to Wetland	111	Douglas fir
Wetland to Forest	18961	Douglas fir
Wetland to Forest	29	Roemer's fescue
Wetland to Grassland	1440	Douglas fir
Wetland to Shrub	3	Douglas fir
Wetland to Wetland	26692	Douglas fir
Wetland to Wetland	2506	Roemer's fescue

Appendix J – GIS Analysis – Ownership Data

Land Cover Change Class	Count	Ownership Progression
Developed / Bare Ground to Developed / Bare Ground	125	Private - Private - Private
Developed / Bare Ground to Developed / Bare Ground	76	Public - Private - Private
Developed / Bare Ground to Developed / Bare Ground	73	Private - Public - Public
Developed / Bare Ground to Forest	16697	Public - Private - Private
Developed / Bare Ground to Forest	1710	Private - Private - Private
Developed / Bare Ground to Forest	1048	Private - Private - Public
Developed / Bare Ground to Forest	711	Private - Public - Public
Developed / Bare Ground to Grassland	677	Private - Private - Private
Developed / Bare Ground to Shrub	178	Private - Private - Private
Developed / Bare Ground to Wetland	263	Private - Private - Private
Forest to Developed / Bare Ground	639	Public - Private - Private
Forest to Developed / Bare Ground	199	Private - Private - Private
Forest to Developed / Bare Ground	7	Private - Public - Public
Forest to Forest	130453	Public - Private - Private
Forest to Forest	87087	Public - Public - Public
Forest to Forest	86394	Private - Public - Public
Forest to Forest	67366	Private - Private - Private
Forest to Forest	58747	Private - Private - Public
Forest to Grassland	772	Private - Private - Private
Forest to Shrub	382	Private - Private - Private
Forest to Wetland	4489	Private - Private - Private
Forest to Wetland	2196	Private - Private - Public
Forest to Wetland	1733	Private - Public - Public
Grassland to Developed / Bare Ground	7182	Private - Private - Private
Grassland to Developed / Bare Ground	460	Private - Private - Public
Grassland to Developed / Bare Ground	411	Private - Public - Public
Grassland to Developed / Bare Ground	168	Public - Private - Private
Grassland to Forest	83746	Private - Private - Private
Grassland to Forest	67255	Public - Public - Public
Grassland to Forest	50091	Public - Private - Private
Grassland to Forest	31642	Private - Private - Public
Grassland to Forest	19724	Private - Public - Public
Grassland to Grassland	80614	Private - Private - Private
Grassland to Grassland	2698	Private - Private - Public
Grassland to Grassland	999	Private - Public - Public
Grassland to Grassland	428	Public - Private - Private
Grassland to Shrub	11832	Private - Private - Private
Grassland to Shrub	1202	Private - Private - Public
Grassland to Shrub	382	Public - Private - Private
Grassland to Wetland	15020	Private - Private - Private
Grassland to Wetland	1953	Private - Private - Public

Land Cover Change Class	Count	Ownership Progression
Shrub to Developed / Bare Ground	362	Public - Private - Private
Shrub to Developed / Bare Ground	2	Private - Private - Public
Shrub to Forest	86148	Public - Private - Private
Shrub to Forest	46027	Public - Public - Public
Shrub to Forest	22365	Private - Private - Public
Shrub to Forest	16358	Private - Public - Public
Shrub to Forest	9012	Private - Private - Private
Shrub to Grassland	196	Private - Private - Public
Shrub to Shrub	1	Private - Private - Private
Shrub to Wetland	464	Private - Private - Public
Shrub to Wetland	85	Private - Private - Private
Shrub to Wetland	79	Private - Public - Public
Stream to Forest	905	Public - Private - Private
Stream to Forest	114	Private - Private - Private
Stream to Wetland	111	Private - Private - Private
Wetland to Forest	14342	Public - Private - Private
Wetland to Forest	2209	Private - Public - Public
Wetland to Forest	1907	Private - Private - Private
Wetland to Forest	532	Private - Private - Public
Wetland to Grassland	1314	Private - Private - Private
Wetland to Grassland	126	Private - Private - Public
Wetland to Shrub	3	Private - Private - Private
Wetland to Wetland	14163	Private - Private - Private
Wetland to Wetland	10141	Private - Private - Public
Wetland to Wetland	4894	Private - Public - Public

