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Mapping a Historic Bitterroot Valley, Montana Landscape Using General Land Office Surveyors' Field Notes

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MAPPING A HISTORIC BITTERROOT VALLEY, MONTANA LANDSCAPE USING GENERAL LAND OFFICE SURVEYORS' FIELD NOTES

By

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Thesis

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Abstract

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MAPPING A HISTORIC BITTERROOT VALLEY, MONTANA LANDSCAPE
USING GENERAL LAND OFFICE SURVEYORS' FIELD NOTES

Chairperson: Dr. Paul Wilson

The late 1800s Bitterroot Valley, Montana, landscape and settlement patterns were summarized and mapped using the General Land Office (GLO) surveyors' field notes. Surveyors' observations of six townships from Hamilton to the Stevensville vicinity were examined in several ways. A total of 3321 points of ecological and geographic information and 422 miles of vegetation were mapped from the field notes. Surveyor information, vegetation composition, tree abundance, vegetation spatial structure and distribution of vegetation types were characterized in a multi-part historic vegetation data assemblage of point, line and polygon feature classes. Aquatic, topographic and cultural aspects of the area contributed to the historic landscape configuration. A GLO land cover classification was derived using surveyors' terminology and crosswalked with current land cover classes. The culmination of this research produced historic vegetation maps and evaluations, summaries of historic cultural, topographic and aquatic features and an unpretentious comparison of GLO vegetation to current land cover. GLO vegetation along all section lines compared to current land cover revealed differences between historic and current vegetation conditions. Highest differences were decreases in Upland Timber and Prairie-No Timber, and increases in GLO Field and Bottomland Timber near-equivalents. The current conditions of land that surveyors described as GLO Upland Timber and Prairie-No Timber were reported. The methodology applied to the Bitterroot Valley could be used to map extensive areas of Montana, providing quantitative and descriptive observations of a pre-satellite landscape.

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Most of all, thank you to my husband and botanist friend, Steve Shelly, for his unending patience and steadfast support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

UNIT CONVERSIONS

1 chain = 20.1168 meters
1 chain = 66 feet
1 chain = 100 links
1 link = 0.2012 meters
1 link = 7.92 inches
1 link = 20.1168 centimeters
10 square chains = 1 acre
640 acres = 1 section
36 sections = 1 township
1 meter = 3.2808 feet

INTRODUCTION

Across the continental United States west of the Appalachian Mountains, land surveyors mapped the original grid of township and range lines and section boundaries, called the Public Land Survey (PLS). This system of land subdivision has heavily influenced the character and use of the American landscape. The field notes and plat maps of the rectangular Public Land Survey of the U.S. General Land Office (GLO) are the most comprehensive record known of the nature of the land surface before most European settlement began in the nineteenth century. Covering nearly every square mile of the public domain from Ohio to California, GLO surveyors' field notes form a systematic collection of historic land cover data available from no other source. Although the survey was conducted to facilitate distribution of public lands into private ownership, the notes and plat maps may be applied to determine historic landscapes, vegetation patterns, soil conditions and cultural impacts. This information has been used in numerous studies to map historic plant community composition and document changes in land and vegetation features over time (Wang, 2005). Researchers in several states, including Michigan (Bourdo, 1956), Wisconsin (Radeloff *et al*., 1998, 1999), Alabama (Rankin and Davis, 1971), Wyoming (Andersen and Baker, 2005), Missouri (Schroeder, 1981; Batek *et al*., 1999), Iowa (Anderson, 1996), Illinois (Nelson, 1997), Colorado (Langley, 2004; Williams and Baker, 2012), Oregon (Christy and Alverson, 2011a), Montana (White, 1976; Habeck, 1994) and numerous others, have used the GLO survey notes to describe vegetation and associated land features in a pre- and early Euro-American settlement era condition. General Land Office records are useful because comprehensive and systematic measurements of historic tree composition, size and timberland structure, as well as descriptions and maps showing the location and extent of former prairies, barrens, shrublands, swamps and marshes, ponds, rivers, and streams can be derived from them (Nelson, 1997). Recently, GLO studies have been applied to question management practices applied to both private and federal lands. U. S. Geological Survey and U. S. Department of Agriculture researchers have assessed the state of Iowa's GLO condition, providing an analysis of land cover changes, for use as context for the evaluation of the benefits of the U.S.D.A. Conservation Reserve Program (CRP) and Wetland Reserve Program (WRP) (Gallant *et al*., 2011). GLO-derived historic forest structure and related fire severity estimations over several western states suggest that former dry-forest landscapes were much more variable than some researchers have described in the past (Williams and Baker, 2012).

Unlike most early explorers' historical descriptions that may be accurate but only describe a portion of the landscape, the GLO records provide extensive, systematic, and quantifiable, albeit generalized, data that can be used to map a baseline historic condition for any of the lands surveyed. Although GLO records have been studied extensively to provide ecological land descriptions, inclusion of aquatic and cultural information, in addition to the vegetation, to give a more complete portrayal of the land has not been as widely documented.

The purpose of this thesis was to create a methodology using General Land Office records, to produce historic vegetation maps and geographic data summaries, and to explore historic to current land cover differences, in the Bitterroot Valley, Ravalli County, Montana. The approach to documenting vegetation type, structure and extent; tree types, size and distance from section corners; and aquatic, cultural, and landform information, in surveyors’ language, for mapping, summarization and comparison, included these objectives:

1. determine an overall ArcGIS geodatabase structure to house all GLO data and other data layers including elevation, topographic maps, soils, NAIP imagery, hydrology, roads and political boundaries to aid in digitizing vegetation points, lines and polygons;
2. establish a database design that encodes the historic vegetation, aquatic, cultural and landform points from the GLO survey notes;
3. collect the Bitterroot Valley GLO survey data in point feature classes;
4. document surveyor information including surveyor name, date, townships surveyed, and surveyors’ general descriptions of the study area;
5. using the GLO survey point data collected in Objective 3, define vegetation along section lines;
6. develop vegetation polygon boundaries for a subset of the study area, in surveyor’s terminology, representing broad historic vegetation types including prairie or grassland, shrubland, upland and riparian forests, open woodlands, and wetlands, using soils and elevation data;
7. create summaries and maps of tree and non-vegetation point information—aquatic, cultural and topographic data—documented by surveyors;
8. illustrate differences in GLO vegetation and current land cover along section lines with the intention to describe only the largest land cover categories and those where the greatest differences occurred; and

9. discuss the challenges of relating GLO vegetation maps and summaries to current conditions.

A successful methodology for generating historic vegetation representations and summarizing historic geographic patterns of the Bitterroot Valley could be applied to other intermountain valleys in the Rocky Mountain region that contain comparable landscape and vegetation features. This is important because the valleys of mountain regions have generally experienced more settlement and changes in land use than the surrounding steep and uncultivable foothill and mountainous topography. Certain types of intact vegetation communities in mountain valleys, such as native grasslands and shrublands, wetlands and riparian forests, are likely quite rare and may be considered a high priority for protection and management by conservationists. A description of historic land conditions, as defined by the surveyors, may provide a point of reference to compare to current and future changing conditions, and may increase the understanding of an area's contemporary vegetation structure, associated ecological processes and interrelated physical geography. This benchmark may help support conservation decisions concerning the management of forest, grassland and water resources or the restoration of native vegetation types under the care of public land managers, land trusts or private individuals involved in conservation or restoration.

Government land management agencies and conservation organizations are looking toward restoration of historically open forests and woodlands as a method to recover more natural forest structure, functions and processes on the landscape (Montana Forest Restoration Committee, 2011). Historically, certain ponderosa pine ecosystems in the inland Northwest may have been maintained in an open condition with frequent low-intensity ground fires (Arno, 1997). Fire exclusion during the past century has allowed some of these forests to fill in with less fire resistant species and become more prone to very large, damaging crown fires. Research of historic landscapes has demonstrated that vegetation is highly dynamic and variable over time (Veblen, Romme and Regan, 2012). Lower elevation ponderosa pine may have experienced a low-severity fire regime, while mixed- or variable-severity fire regimes were more common in ponderosa pine zones at higher elevations. GLO records may provide an extensive view of locations for fire-maintained forest landscape restoration, which in some areas potentially offers an opportunity to reduce occurrences of extremely destructive fires. Planning efforts aiming to restore landscape patterns and processes to create sustainable, resilient future conditions may be enhanced by historic ecological information derived from the GLO records. The Hiawatha National Forest (2006) in Michigan and other national forests have used survey data to describe historic landscape diversity and forest reference conditions for potential management purposes.

Where ecological, social and political circumstances permit landscape restoration attempts, GLO survey data may offer a broad view of where restoration of different vegetation types (forest, woodland or grassland) may be possible. Used in conjunction with or as input to historic range of variation (HRV) analyses, the GLO historic context may be applied in the prioritization of areas and types of restoration projects. The HRV of ecological conditions is defined as:

> “the variation of ecological characteristics and processes over scales of time and space that are appropriate for a given ecosystem management application” (Romme, Wiens and Safford, 2012).

The HRV for a geographic extent defines historical, ecological knowledge of a time period useful for natural resource conservation. HRV provides an estimation of the fluctuation of ecological variables and processes including disturbance regimes, forest stand structure, degree of patchiness in a landscape, and species and structural diversity that occurred over a specified past period (Romme, Weins and Safford, 2012). Like HRV, GLO conditions may not be considered as specific management targets, but as a means for understanding ecosystem processes and changes between historic, current and potential future conditions, providing perspective for land management choices.

Beyond use for ecological management and planning, a region or state-wide GLO survey data repository may be relevant for anthropological research pursuits requiring the understanding of the early settlement landscape and cultural features such as cabin, house and mill locations, early settlers’ names, timber harvests, plowed areas, and road, trail, river, creek, ditch and fence locations. Because of the general nature of the GLO information, it may or may not be useful for a site-specific project. GLO-derived maps provide an additional level of reference information that may possibly offer a foundation for future land management decisions and research endeavors.

BACKGROUND

Reading and describing the earth's physical and cultural landscapes are fundamental traditions in the discipline of geography. In Baker's *Geography and History-Bridging the Divide*, (2003) American geographer Pierce F. Lewis (1979) is cited for his tenets of reading the human landscape. His views of the cultural landscape are applicable to the study of General Land Office notes. "The man-made landscape provides strong evidence of the kind of people we are and were, and are in the process of becoming," Lewis says. The rectangular survey pattern of early American land settlement gave us the enduring framework for our conversion of forests, wetlands and prairie plains to productive farms and ranches. The resulting checker-boarding of the continent with township and section boundaries provided the reference system for locating property boundaries and in many areas helped define the configuration of transportation systems that transformed the natural face of the country. Paradoxically, this legal survey information that was recorded as part of the country's goal of disseminating public land to individuals to plow and pasture, is now used to examine aspects of nature and history that were altered by the system's implementation.

GLO Studies

Langley (2004) compiled a detailed history of General Land Office surveys from the period following the Revolutionary War, including a review of the Land Ordinance of 1785, which established the initial plan for land division and disposal in the Western Territory. The Seven Ranges Survey in Ohio was the testing ground for the United States Public Land Survey established by the Land Ordinance. The administration of the survey by the General Land Office was established in 1812, reorganized in 1836, transferred from the Department of the Treasury to the new Department of the Interior in 1849, and merged into the Bureau of Land Management (BLM) in 1946. The GLO survey was conducted in most states west and south of Ohio. The thirteen colony states and several others in the southeast United States used the less systematic metes and bounds survey method.

Batek (1994) listed over seventy ecological studies using GLO survey records at various scales—from townships to counties to states to regions—to map presettlement vegetation and relate it to environmental and cultural patterns, to determine prairie-forest border locations, and to compare past to present vegetation. He summarized methods of vegetation reconstruction and analysis used in these studies, providing a substantial information base for researchers to peruse. Wang (2005) also provided a substantial reference assessment, extensively reviewing GLO studies based on the geographic characteristics of space, theme and time, and investigated how data quality components influence analysis based on study purpose and spatial extent.

Studies using GLO survey notes in the western United States, while perhaps not as extensive to date as in the Midwestern states, provide insight into past land conditions. Galatowitsch (1990) summarized reconstructed presettlement landscapes in the west, concentrating on riparian habitats in western Oregon (Sedell and Froggatt, 1984) and northeastern Colorado (Savonen, 1985), and grasslands in New Mexico (Buffington and Herbel, 1965). Anderson and Baker (2005) documented historical openings in the Medicine Bow Mountains of Wyoming with GLO survey notes, compared the historical representation to present-day situations and used logistic regression models to predict tree invasion of openings. Prairie was the most extensive vegetation type Christy and

Alverson (2011a) reported from 202 townships of mapped historic vegetation in the Willamette Valley, Oregon. Their study included ten historic vegetation classes and 66 subclasses based on GLO survey data. Dilts *et al*. (2012) compared settlement-era GLO land cover to current vegetation in the Walker River Basin in Nevada and California. Major land cover changes detected were the conversion of native vegetation to agriculture, a decline in riparian gallery forest patches and a shift from mesic vegetation types to more xeric types. Historic structure and fire-severity of large dry forest landscapes on the Colorado Front Range, the Mongollon Plateau and Black Mesa in Arizona, and the Oregon Blue Mountains were reconstructed with GLO survey section line and bearing tree data by Williams and Baker (2012). Their results indicated that historic dry forests were quite variable in structure and fire severity, and ranged from the perceived dominant condition of open park-like stands of large trees to include areas of dense forests and forests with a well-developed understory and shrub layer. Conclusions from this work indicated that in addition to frequently occurring low-severity ground fires, higher-severity fires were a normal part of the historic landscape.

General Land Office survey records in western Montana date back to 1867 when the initial survey point was established near Willow Creek, about twelve miles south of Three Forks (Safford, 2005). Within the state, these records have been used to reconstruct presettlement forest structure at the University of Montana Lubrecht Experimental Forest (White, 1976) and to assess forest succession in ponderosa pine/Douglas fir forests in the historic Fort Missoula Timber Reserve in Pattee Canyon, Missoula, Montana (Habeck, 1994). Rich (2011) documented increased tree density, mean tree diameter decrease and a shift from nearly pure ponderosa pine forest to a pine/Douglas fir condition using GLO notes to compare historic to current conditions at the Montana Fish, Wildlife and Park's Three Mile Game Range in the Bitterroot Valley.

Public Land Survey Procedures

Surveyors recorded "a full and complete topographical description of the country surveyed, as to every matter of useful information, or likely to gratify public curiosity" (Stewart, 1935). They recorded the notes in precisely the order in which the work was done on the ground. Outer township lines were surveyed first, then the interior section lines, often by different surveying crews at different times (Hutchison, 1988). Distances were measured with a surveyor's chain, 100 links (66 feet, or 20.1168 meters) in length. One link equaled 7.92 inches (20.1168 centimeters). Corner posts were set at mile (80 chains) and one-half mile (40 chains) locations along the section line. A section corner position was described using four bearing trees (where present), one in each of four quadrants surrounding the corner (Stewart, 1935). Quarter corner posts, set a half mile between corners, required only two bearing trees. Bearing trees were to be healthy and long-lasting species, of appropriate size to be blazed and labeled with an axe, and were to be within 300 links of the corner (White, 1991). Section corners in very open woodlands or grasslands (and other vegetation types with fewer trees than closed forests) did not have four trees close enough to the section corner to serve as bearing trees. If trees were available within the recommended distance for blazing in these open landscapes, they were marked, measured and recorded. If no trees existed, wood stakes, soil and rock mounds or constructed trenches were designated as section corners and quarter corners (Stewart, 1935). Surveyors' field notes for the open land section corners explicitly state that no trees were located and described the subsequent method of corner location (Habeck, 1994).

Hutchison (1988) compiled the categories of information surveyors recorded at corners and along section lines in Illinois:

1. Bearing trees—two to four trees, with common names, tree diameter in inches, compass bearing from corner points, and distances from corners in links.
2. Line trees—one or more trees with common names, diameter and distance along section lines between corners.
3. Topographic features—cliffs, precipices, bluffs, hills, ravines, gulches, mountains, caves.
4. Water features—streams with width in chains and links and direction and character of flow (also termed brooks, runs, branches, drains, courses, creeks, and rivers); ponds, swamps, marshes, lakes and springs with points of entering and leaving along section line.
5. Upland natural communities—timber, prairie and barrens with points of entering and leaving along section lines.
6. Unusual features—salt licks, mineral deposits, graves.
7. Artificial features—Indian features (villages, fortifications, mounds and clearings), settlement features (clearings, fields, mills, mines, quarries, and structures).
8. Trails and roads—locations crossed by section lines and directions of travel.

Individual surveyors used different terms for land description. General land character comments describing each mile included topography descriptors such as flat, level, low, broken, even, uneven, rolling, hilly, steep, ascending, descending, bottom, and ridges. Soils were described with phrases such as: good for cultivation, poor for cultivation, rich, dry, thin, cold, wet, swampy, clayey, stony, rocky, flint, light, plow land, good for wheat, sandy, first rate, second rate and third rate (Hutchinson, 1988). Vegetation for a section line was summarized as different types of timber, barrens or prairie (Schroeder, 1983). Common names were given for trees in order of dominance, with occasional notes of sizes, quality and density (poor, shrubby, dead, fallen, windthrow, burnt, thinly timbered, scattering timber, heavy timber, few trees). Understory descriptors included dominant shrubs, saplings and vines, density notes (brush, thickets, no undergrowth, little undergrowth, and groundcover), and high or low grasses.

The volume of data the surveyors were responsible for transcribing into their field books was very substantial, but at the same time it was never detailed enough to provide a near-complete picture of the land. All vegetation data collection may have been perceived as secondary in importance to the location and marking of section corners. It is unlikely the data were collected in a completely consistent or objective manner, due to the survey instructions of the time, number of survey contracts within an area (some areas were surveyed more than once) and harsh weather conditions. According to the Minnesota Bearing Tree Database administrators (Minnesota Department of Natural Resources, Natural Heritage Information System; Almendinger, 1997), when dealing with tree data, it may be reasonably safe to assume a certain species was present if the surveyor documented it, but it is not safe to assume that an undocumented tree was absent from a section corner, due to the small sample size of up to four trees per corner and potential surveyor bias.

Instruction to surveyors from their surveyor general supervisors varied, and changed over time and jurisdiction. Seeing this as problematic, the General Land Office issued an expanded set of instructions in 1855 entitled *Instructions to the Surveyors General of the Public Lands of the United States for those Surveying Districts Established in and since the Year 1850* (White, 1991), containing a *Manual of Instructions to Regulate the Field Operations of Deputy Surveyors* (McIntyre, 1978). Updated manuals addressed changes in technology, but generally, later surveys were conducted using the standard directives of 1855.

Bias, Error and Fraud Considerations

Despite the seemingly detailed instructions and procedures, error and biases and even fraud were known to occur (Cazier, 1976). Bias may be hard to assess, and if undetermined, can unknowingly limit a study's usefulness. A representative sample of forest character (including dominant tree species, total number and types of tree species and sizes) may not have been objectively described by a surveyor's choice of witness trees. The intention of the survey was not to provide ecological data but to give legal description to the land. Surveyors likely avoided small trees which may have high mortality after blazing and large trees that were likely to be cut for lumber. Trees like junipers or other species that were hard to blaze due to thick branching patterns were also probably avoided. Bourdo (1956) and Maines *et al*. (2001) found surveyor bias in tree species selection and size. White (1976) identified selectivity against small and very large diameter trees while evaluating historic forest structure of the University of Montana

Lubrecht Experimental Forest. Ecological bias in tree selection was actually initiated by the instructions to the surveyors. They were directed to select “only the soundest and thriftiest of the trees, and of the size and kind which experience teaches will be the most permanent and lasting” (Stewart, 1935). Almendinger (1997) points out that bias in GLO data undoubtedly exists in tree selection, diameter and distance from corners. Suggestions for determining bias will be discussed in the Methods section.

Surveyor errors could be made through misidentification of tree species, poor measurements taken from section corner to witness tree, quadrant location determination and bearing measurement within the quadrant. Occasionally the data for locations is simply missing. Generalizing bearing tree names to the genus level—‘pine’, ‘oak’, or ‘ash’, instead of a specific species was commonly documented in Minnesota (Almendinger, 1997). Ambiguity in identification when describing dominant trees along sections lines was also a common occurrence.

Documented accounts of survey fraud are retained at the Regional Bureau of Land Management Office in Boulder, Colorado. One notable example, involving approximately 300 contracts, is the Benson syndicate frauds of 1873-1885 which included California deputy surveyors, the survey general office clerks, fictitious settlers and San Francisco banks (Cazier, 1976). One present-day Ravalli County surveyor, questioned at a July 2010 U.S. Forest Service presentation on the survey of the Bitterroot National Forest, has found no evidence of fraudulent GLO survey practices in Ravalli County (Luebke, pers. comm.). Comparing GLO survey topographic locations such as stream positions, hills and creek bottoms with current imagery and contour lines as the data were collected, confirmed the general credibility of the survey records in the Bitterroot Valley study area.

STUDY AREA

The north-draining Bitterroot Valley is over seventy miles long and ten miles wide, and bounded by the Bitterroot Mountains on the west and the Sapphire Mountains on the east. The study area includes six townships in the central portion of the valley, from Hamilton to the vicinity north of Victor, just south of Stevensville (Figure 1). The GLO survey occurred here from 1870 to 1924. The landscape diversity of this area provided opportunities to assess the survey's interpretation of a wide variety of vegetation types and landforms in limited space, instead of mapping a more homogeneous landscape. The six townships, T06N R20W-T08N R21W, include many vegetation communities from level to hilly grasslands, sagebrush shrublands on high,

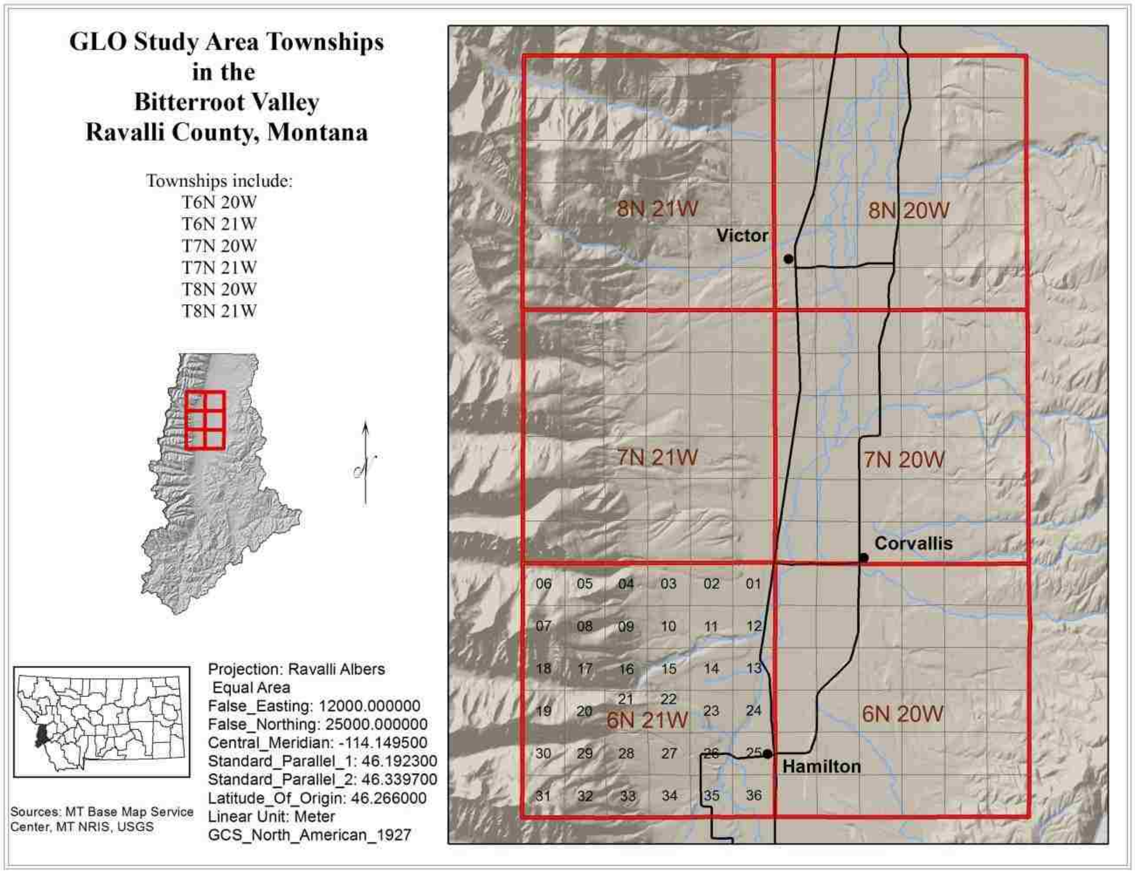


Figure 1. Study Area Townships.

rolling benches, wetlands and deciduous riparian forests in the Bitterroot River floodplain, ponderosa pine woodlands in the bottoms and throughout the foothills and Douglas fir, pine, larch, and subalpine fir-spruce forests in rugged mountains.

The ebbs and flows of the Ice Age Glacial Lake Missoula greatly contributed to the valley's geologic and topographic constitution (Partee, 1910). Leiberg also reported evidence of a past lake, in the Bitterroot Forest Reserve vicinity in the 1899 U.S. Geological Survey Annual Report to the Secretary of the Interior. He indirectly presents a subtle reminder that the GLO surveyors' land description is but one point in history with his description of the "Bitterroot Lake":

> "Like many of the valleys constituting the Columbia River watershed, it appears to have been at one time a depression holding a lake, or, rather, an arm of a much larger lake lying to the northward which covered to a large extent the present head of Clarks Fork of the Columbia River Basin…….The existence of the lake was probably due to a blocking of the valley trough of Clarks Fork by ice masses sliding into it from the adjacent mountains."

Leiberg reasoned that following the lake's drainage, the river and its numerous channels cut around and through gravel and boulder glacial deposits, flowing across the valley creating benches, terraces and bayous. He described meadows formed from old channels filled "with loam and mold, and springs and stagnant water." Other channels were:

> "….filled with masses of liquid ooze covered with close and tough turf to which the mere pressure of a human footstep imparts an undulatory movement, but which nevertheless possess sufficient tenacity to sustain the weight of grazing animals."

"Innumerable springs," flat marshy expanses and small lakes occupied the heads of the Bitterroot canyons. Sphagnum "bogs" (fens) were common around small lakes in subalpine meadows. Marshy expanses adjacent to barren rock slides provided stark moisture contrasts through portions of the canyons. Dams were constructed at Mill and Big Creeks for irrigation water storage.

According to Leiberg, two forest zones, “the yellow (ponderosa) pine zone” (up to 5800 feet [1770 meters]) and “the subalpine fir zone,” represent the mountainous forested area. The lower limits of the subalpine zone depend on moisture and aspect. In the canyons, the subalpine zone may extend down to 4200 feet (1280 meters) on north-facing slopes, 1600 feet (490 meters) below the upper boundary of the yellow pine zone on south-facing slopes. Species occurring for each zone were listed in order of abundance. The yellow pine zone was comprised of red fir (Douglas fir), ponderosa pine, lodgepole pine, white fir, balsam (cottonwood), and aspen. The subalpine zone contained lodgepole pine, subalpine fir, whitebark pine, tamarack (western larch), Lyall’s larch, white fir, Engelmann spruce, yews and willows.

The south and west slopes below 5200 feet (1590 meters) held an open growth of timber, with grasses and sedges as groundcover. The ground was usually free of undergrowth and the grasses rarely formed a continuous sod (Leiberg, 1899). Fire had removed relatively small areas of yellow pine or mixed pine-“red fir” due to the open nature of the forest and the resistance of the pine. Far more timber had been reduced by harvest in the valley.

Losensky (1994) summarized the historic forest vegetation types of the Columbia River Basin using 1930-40s U.S. Forest Service surveys. A Montana ponderosa pine forest type that historically occurred in the Bitterroot Valley was described as having a grassy ground flora and was normally restricted to broad valley bottoms or lower to mid-slopes on high energy aspects. Stands commonly were very open with little shrub growth.

The ponderosa pine savanna cover type likely existed in the Bitterroot Valley as a fringe community intermingled with valley grasslands containing groups of trees too small to map separately.

Before European-descendant explorers arrived, the Bitterroot Valley was inhabited by the Flathead Tribe of the Salish Indian Nation (U. S. Department of Agriculture, 1959). The Salish had permanently occupied the valley since the early 1700s, most likely maintaining large areas of open grasslands for their horses with fire (Richey, 1999). Prior to this time, tribe members spent seasons hunting deer, elk and sheep and gathering bitterroots and camas, while passing through to traditional fishing areas to the west and bison hunting grounds in the Plains. In 1805, the valley's early white explorers, Meriwether Lewis and William Clark, met and traded with Salish on their journey down the valley. The easterners described a variety of landscape elements—a range of poor and stony to rich, black soils, timber of "pitch" pine, cottonwood, and willow bushes, elderberry, serviceberry, choke cherries on the river branches, and plains of grass and "wild hyssop" (probably sagebrush) (Moulton, 1997). Following Lewis and Clark were trappers from the north. In 1841, Jesuit priest Father DeSmet founded the St. Mary's Mission near present day Stevensville. Father Ravalli, the county's namesake, took over mission responsibilities in 1845, and then sold it to John Owen who converted it into a trading post in 1850. Part of the Oregon Territory created in 1848, the valley was reassigned to the Washington Territory, then the Idaho Territory, before organization of the Montana Territory in 1864. In 1889, the time of Montana's statehood, the valley was within Missoula County, which included all Montana land west of the Continental Divide. The Bitterroot Valley became part of Ravalli County in 1893 (U. S. Department of Agriculture, 1959). Early settlers grew wheat, oats, barley, and potatoes, and raised cattle, horses and sheep on the valley's abundant grass. The booming mining economies of Anaconda and Butte were supported by Bitterroot agriculture and timber. The completion of the railroad in 1883 transformed logging operations from small, local endeavors to industrial lumber enterprises (Richey, 1999). Apple orchards were planted after timber was cleared, with hopes that proposed irrigation canals would bring new life to former forest land. In the mid-1890s, development schemes promoted subdivided ten-acre parcels that included orchard acreage within clustered communities. Blight and several drought years brought the end to the orchard communities within thirty years. Many Salish had remained on small acreages in the valley until 1891, when they left due to government pressure and moved north to the reservation near Flathead Lake (U. S. Department of Agriculture, 1959). By the 1890s, the Bitterroot Valley resembled eastern settled valleys. Since the valley was partly settled during the GLO survey period, the documentation of roads, houses, ditches, saw mills and other cultural features provide an added perspective to the interpretation of the GLO landscape which usually included mostly vegetation, landform and soils descriptions.

The current-day intermountain grassland ecosystems of the Bitterroot and other western Montana valleys are considered one of the state's ecological areas in great need of conservation as described in the Montana Comprehensive Fish and Wildlife Conservation Strategy (2005). Most of Montana's river valley native grasslands, including the Bitterroot Valley, were once dominated by bunch grasses, most likely Idaho fescue (*Festuca idahoensis*), rough fescue (*Festuca campestris*), and bluebunch wheatgrass (*Agropyron spicatum*), and have been replaced by irrigated agricultural fields and non-native forage species. Bunchgrass prairie with sagebrush still occurs in undeveloped areas on the foothills and bench lands (McNab and Avers, 1994). Kudray and Schemm (2010) found that wetlands currently comprise approximately 25 square miles of the Bitterroot Valley, mostly in the form of riverine wetlands. Emergent wetlands, peatlands and slope wetlands are present in small percentages and are degraded due to non-native vegetation and poor land use practices. Valley forest conditions presently include riparian areas of cottonwood (*Populus trichocarpa*), ponderosa pine (*Pinus ponderosa*) and willows (*Salix* spp.), and uplands are dominated by Douglas fir (*Pseudotsuga menziesii*) and ponderosa pine, with western larch (*Larix occidentalis*) and subalpine fir (*Abies lasiocarpa*) commonly present (McNab and Avers, 1994). A 1995 U. S. Forest Service (USFS) study of the Bitterroot Front comparing historic to modern forests showed that Douglas fir has substantially increased in lower elevation (4500 to 5800 feet [1370 to 1770 meters]) forest and woodland areas formerly dominated by ponderosa pine (Hartwell *et al*., 2000). The USFS research, conducted within and just north of the GLO study area, found that fire-tolerant ponderosa pine has been reduced from 52 percent to 26 percent of total basal area, while Douglas fir increased in relative percent of total basal area from 19 to 55 percent since 1900. Additionally, western larch declined from 26 percent to 11 percent in lower elevations and from 24 percent to 6 percent in middle elevations (5800 to 6900 feet [1770 to 2100 meters]). In upper elevations (6900 to 7500 feet [2100 to 2290 meters]), lodgepole pine relative abundance increased 13 percent and whitebark pine decreased from 39 to 11 percent of total basal area (Hartwell *et al*., 2000). Species abundances have shifted due to logging, increased fire suppression and settlement throughout the forested portion of the valley over time, but the types of tree species have not changed since Leiberg’s account.

METHODS

While it has been documented that the GLO notes provide some of the most comprehensive systematic information available for historic mapping nationwide, determining the adequacy of the information, specifically for the Bitterroot Valley, required the collection and assessment of this study area's data. The procedures for this evaluation involved designing the project geodatabase; assembling and preparing the supporting base data for use in gathering and mapping GLO information; collecting the GLO data; classifying vegetation types; summarizing characteristics of the vegetation, aquatic, topographic and cultural information; mapping the historic vegetation; and reporting differences between historic vegetation and current land cover. The complete methodology follows.

Geodatabase Design

An ArcGIS 10 (ESRI) file geodatabase incorporating appropriate thematic layers of geographic information was designed as the foundation for collection of GLO points and lines representing the historical ecological and cultural features. A geodatabase stores spatial data and associated non-spatial attribute data in an ordered assemblage. Geographic elements having the same spatial representation (points, lines or polygons) and sharing a common set of descriptive attributes form separate feature classes such as townships, streams or parcels. Feature classes are the counterpart to the older ESRI shapefile format. Sets of related feature classes are organized into feature datasets to manage spatial reference systems. The file geodatabase structure included six feature datasets and several feature classes, raster datasets and Access data tables (Table 1). Data were organized hierarchically by geographic extent, from state and county-level data in the Montana State Plane projection, to the study area with a local Albers Equal Area projection (Appendix I).

Table 1. Geodatabase Structure.

BitterrootGLO.gdb	
Montana State Map	Feature Dataset
State Boundary	Feature Class
County Boundary	“
Ravalli County	Feature Dataset
Cities	Feature Class
Roads	“
Hydrology	“
Ravalli County Boundary	“
GCDB PLSS Points	“
GCDB Township Polygons	“
Soils	Feature Dataset
Bitterroot Valley Survey	Feature Class
Bitterroot National Forest Survey	“
Bitterroot Valley Soils Data	Access Table
Bitterroot National Forest Soils Data	“
Combined Valley and Forest Soils	Feature Class
Study Area	Feature Dataset
Cities	Feature Class
Roads	“
Hydrology	“
Contours	“
GCDB PLSS Points	“
GCDB PLSS Township Polygons	“
Study Area Soils	“
Bitterroot National Forest Stand Data	“
GLO Data	Feature Dataset
GCDB PLSS Points	Feature Class
Section Points (digitized from GLO notes)	“
Tree Points (from Section Points)	“
Line Description Points (from Section Points)	“
Section Lines Vegetation (from Line Description)	“
Cultural Features (from Section Points)	“
Aquatic Features (from Section Points)	“
Topographic Features (from Section Points)	“
Vegetation Polygons (from Section Lines, Soils, etc.)	“
Surveyors	“
GLO Products	Feature Dataset
Landcover Points	Feature Class

BitterrootGLO.gdb	
Buffered Section Lines	Feature Class
Landcover Points - Section Lines Intersection	”
Township GLO General Descriptions	Table
USGS 1:24000 Topographic Maps (DRGs)	Raster
Digital Elevation Model (NED)	Raster
GLO Plat Maps	“
NAIP Imagery (2005, 2009)	“
1902 Land Classification and Timber Density Map	“
2010 Montana Land Cover	“

Assembling and Preparing Base Data

Before the GLO survey data could be collected, supporting data were gathered and processed in various ways to prepare it for use. Montana state and county level data, including county and state boundaries, cities, hydrology, roads, land cover, USGS 7.5 minute topographic data, imagery, soils (Soil Survey Geographic Database—SSURGO), and Geographic Coordinate Database Public Land Survey System (GCDB PLSS) points, sections and townships were obtained through the Montana State Library’s Montana Spatial Data Infrastructure (MSDI) website (*http://giscoordination.mt.gov/default.asp*). The spatial reference system for MSDI data was the NAD83 Montana State Plane FIPS2500 using the Lambert Conformal Conic projection. All datasets were clipped to the study area boundaries and reprojected into a local Albers Equal Area NAD27 projection. An Albers Equal Area projection is appropriate for dealing with areal extents—townships, sections and vegetation polygons. The NAD27 datum was necessary because the GCDB latitude and longitude coordinates were taken from survey data that used NAD27.

The Geographic Coordinate Database (GCDB), maintained by the Bureau of Land Management (BLM), is a continually updated digital representation of the Public Land

Survey System (PLSS) assembled from surveys, field notes and plats. GCDB point data documents PLSS corners down to the quarter-quarter section (the corners of every 40-acre parcel) using numeric codes that identify the location of each point within a section. The GCDB is the most accurate PLSS data in existence. The accuracy of the coordinates is relative to the time of the most recent survey of the location. Coordinates documented from 1800s surveys have less accuracy reliability than locations generated from current GPS technology. Although GCDB enhancements are ongoing, substantial error exists at many locations. Within the study area coordinate errors range from 0 to 135 feet (0 to 41 meters). It was recognized at the project's onset that GLO data accuracy would be inherently related to GCDB coordinate accuracy.

The section corner and quarter corner locations were selected out of the full GCDB point data set and used to record GLO field note data. A single GCDB section corner or quarter corner point record was copied, and attributes were added to this copied point, for each feature encountered at section corners and along section lines in the survey field notes. Attributes, including specific vegetation, aquatic or cultural feature codes, and the method for locating these points in their correct locations along section lines, are discussed in the following section.

In Christy and Alverson's (2011a) Oregon historic vegetation mapping efforts, soils information was referenced for estimating vegetation boundaries within section interiors. Two separate Natural Resources Conservation Service (NRCS) SSURGO soil surveys (1:24,000) cover the Bitterroot study area: the Bitterroot Valley (MT645) and the Bitterroot Forest (MT647) soil surveys. Spatial data from the two surveys were clipped to the study area boundaries and appended into one feature class. Soil map unit polygons in the spatial data are linked to attributes in an associated Access database by the unique identifier 'MUKEY'. The SSURGO map unit field is the smallest mapable unit but it may have up to three different unmapped soil components in one mapped polygon. For each soil component, there are 60 different properties and interpretations in 84 different component tables. Additionally, for each component, up to six soil layers are possible, and for each layer 28 soil properties are possible (USDA, 1995). In order to deal with these complex one to many relationships, the data were queried to obtain a dominant soil suborder condition for each map unit. The suborder level of hierarchy was chosen because suborder soil characteristics could be helpful, while not overwhelmingly detailed, for determining vegetation type at a general classification level. Soil suborders are second in order of the six classes of soil taxonomy—order, suborder, great group, subgroup, family and series. Of the twelve soil orders occurring worldwide, five exist in the study area. Mollisols were formed mostly under prairie vegetation. Alfisols formed primarily under forest vegetation. Entisols are young soils, typically alluvial with little sign of horizon development. Inceptisols are more developed than Entisols. Histosols are organic soils (USDA Soil Survey Staff, 1999). Within those orders, eight suborders are located within the study area: Ustolls, Cryolls, Aquolls (all Mollisols), Ustalfs (Alfisol), Fluvents (Entisol), Ustepts, Cryepts (Inceptisols) and Hemists (Histosol). Factors that differentiate suborders vary from order to order and include the presence or absence of properties associated with soil moisture, vegetation type, subhorizon characteristics, climate and major parent material. For example, soil moisture and temperature are important influences in differentiation of the suborders of the order Alfisol. Suborders within the Entisol order are distinguished for an absence of horizon differentiation by various causes: including soil moisture conditions or young soil conditions due to continuing deposition or recent erosion. Detailed descriptions of soil suborders and all other classification levels are described in the 1999 *USDA NRCS Soil Taxonomy–A Basic System for Soil Classification for making and Interpreting Soil Surveys*. Suborders within the study area are listed with the probable vegetation they were formed under in Appendix II.

Two Microsoft Access queries were written to determine the dominant soil suborder for each map unit. The first soil suborder query aggregated and summed the soil component percentages for each map unit by soil suborder (Appendix II). A second query then displayed the component suborder with the highest total percent composition to limit the data to a one-to-one dominant condition suborder for each map unit. These two queries were repeated for the dominant ecological description field to provide predicted vegetation information, in addition to soil suborder. The resultant tables were joined to the soil polygon layer and used in mapping major vegetation polygons. Queries were written with the assistance of Jay Skovlin, Missoula County NRCS Soil Scientist.

Aerial imagery for the study area (2009 U.S. Farm Services Agency National Agricultural Imagery Program [NAIP]) was obtained from MSDI and used with soils data to compare current situations to historic data to better map vegetation polygons.

Elevation contours were derived from a U. S. Geological Survey 30-meter Digital Elevation Model (*http://seamless.usgs.gov*) and used along with roads, hydrography and 1:24,000 topographic digital raster graphics (DRGs) to check for surveyor error by comparing the surveyors' location of streams, ravines, and roads to the current data sources and for mapping vegetation polygons.

Forest stand data were obtained from the Bitterroot National Forest, Hamilton and Stevensville offices. Stand boundaries were used as a limited, secondary source in mapping vegetation polygons in addition to soils, NAIP imagery and elevation.

The 2010 Montana Land Cover classification was used to indicate differences between GLO and current conditions. The layer was produced by the Montana Natural Heritage Program, the University of Idaho Northwest Gap Analysis Program (NWGAP) and Sanborn Inc. as part of the Pacific Northwest ReGAP Analysis effort. The modeling effort applied Classification and Regression Tree Models to 30-meter resolution 2002-2005 Landsat ETM+ imagery. The dataset integrates the National Land Cover Dataset (NLCD), the National Wetlands Inventory, 2005 NAIP imagery and the National Hydrography Dataset with a reclassification based on plot-level field data. The theme is recommended for use at the regional and landscape levels, and is not recommended for analyses at less than 1:100,000 scale. An accuracy assessment was not made available with the layer, but accuracy is presumed to be considerably higher than the NLCD alone. Natural and human land cover classes are subdivided into three hierarchical levels of increasing vegetation and land use specificity (Appendix III). The Level 1 land cover class is generally based on vegetation physiognomy, aquatic and alpine classes, and human land uses. Vegetation class definitions generally follow NatureServe’s International Classification of Ecological Communities Terrestrial Vegetation of the United States (Grossman *et al*., 1998; Anderson *et al*., 1998). Level 2 incorporates information on elevation and climate. Level 3, the most detailed level of classification, contains Montana-specific ecological systems and land use classes. Ecological systems are determined by the Montana Natural Heritage Program (*http://fieldguide.mt.gov/*).

The GLO surveyors' field notes for the study area, scanned and preserved on microfiche, are located at the Bureau of Land Management (BLM) Missoula office (Appendix IV). Township plat maps (MrSID images) were downloaded from the BLM GLO website (*http://www.glorecords.blm.gov/beta/search/default.aspx*). Plat maps were drawn, at various levels of detail, after field surveys were completed. In some areas of the country, plat maps contain quite detailed vegetation boundaries, including prairie, forest, barren and wetland extents, but that level of information was not provided on plats of the Bitterroot Valley study area. Only agricultural and mountainous areas were delineated, without vegetation distinctions. The plats were useful, however, for mapping different survey contracts, and summarizing dates and surveyors for a township (Appendix V).

Collecting the GLO Data

Data were collected from microfiche copies of the field notes at the Missoula BLM Office. Data were entered into two initial files: the Township_Description Excel table and the Section_Points ArcGIS feature class. This method of point collection is similar to the process used by the Oregon Natural Heritage historic vegetation studies (Hickman, pers. comm.; Christy and Alverson, 2011b). Point data collection took place from October 2011 through February 2012. After point data were entered and coded by vegetation, aquatic, topographic or cultural categories, a vegetation lines feature class was created using the point information. Vegetation lines were mapped for the six townships and classified at two levels, by Major Vegetation Type based on timber structure (Open Timber, Dense Timber, Prairie-No Timber, etc.), and by Tree Association/Land Classes (Pine-fir-larch, Cottonwood-pine, Pine, Aspen, Prairie, Field, etc.). Polygons of major vegetation types were created for one of the six townships using the classified vegetation lines, along with soils, aerial imagery and contours. Procedures for creation of each data type are discussed in more detail in the following sections.

The Township_Description Excel table holds fields describing the location of the township lines, the names of surveyors, completion dates and volumes of the surveys, and the surveyors' general descriptive summary of the land within the township (Table 2). The general township description provided at the end of each survey, whether the survey contract encompassed a single township line or the subdivision of sections within the township, sometimes provided additional ecological and cultural information that was not documented elsewhere in the line notes (Appendix VI).

The Section_Points feature class recorded survey data points including section corner markers, bearing trees, vegetation entry and exit points, water, roads, fences, houses, etc., as surveyors documented them along the survey lines, using GCDB section and quarter section points. Section_Points contains the initial base of information from which all other feature classes (points, lines and polygons) were formed. Attribute fields similar to those described in the Oregon GLO Database Structure and Data Entry Guide (Christy *et al*., 2011) hold information on the section location within the township, the

Table 2. Township Description Fields.

Field name	Description
TOWNSHIP	Identifies the particular township (e.g. 08N21W)
BOUNDARY /SUBDIVISION	Identifies the part of township to which the descriptive data referred. (North, East, South or West township lines or Subdivision of township into sections)
SURVEYOR	The surveyor(s) contracted with the GLO to conduct the survey
APPROVED_DATE	The approved date of the completed field survey. There are other dates that were applied to each township by surveyors—the date the survey was issued, dates surveyors were on the ground. Surveys of exterior boundary lines and the subdivision of the 36 sections occurred at different times, sometimes years apart. Dates surveyors were on the ground were sometimes but not always listed in the notes
GEN_DES	Entire description given at the end of the township line, or the end of the subdivision of the township
VOLUME	Volume and page number of survey archive

direction and distance of the survey lines, topography, streams, soils, trees, cultural features and vegetation (Table 3). To create a new point along a section line a GCDB corner point was copied, and the GLO feature data were entered as attributes of the copied point. When data entry for all six townships was completed, these copied points with GLO information were still at the same location as the GCDB points. Formulas for calculating new point locations along section lines and around section corners used coordinate geometry trigonometric functions, applying the distance of the feature along the section line and direction measurements (bearings) from the GCDB section corners and quarter corners, in ArcGIS Field Calculator (Appendix VII). The GLO data with new x- and y- values situated along the section lines or around the section corners and quarter corners were then added as XY events, and exported as a new feature class.

Subsets of the initial point data, including tree type, vegetation structure type, tree associations, undergrowth, burned areas, section line descriptions, aquatic, topographic and cultural features were sorted by code, exported into separate feature classes to create additional topic-specific datasets, and then mapped and summarized for all six townships.

Table 3. Section_Points Attribute Field Descriptions.

Field name	Description
TOWNSHIP	Identifies every record for a particular township, six-character address (e.g. 08N21W)
LINE	Section line within township, five character address, section numbers entered in ascending order (e.g. 09_10, 26_35)
DIR	Direction surveyor is headed along section line (e.g. N, E)
DIST_CL	Distance along line from the starting point at the section corner in links (links =chains *100) (Numerical field) (e.g. 1-8000)
DIST_M	Distance in meters (links *.2012 = meters) (Numerical field) (e.g. 0.2012 -1609.34)
CODE	Code to facilitate sorting of data types in the intercept field (e.g. C=corner, M= manmade, V=vegetation, W=water) (Appendix VIII).
INTERCEPT	Description of feature encountered or action taken, has a specific chained distance along line, records topography, roads, fields, fences, houses, vegetation changes (e.g. enter prairie, leave timber)
SPECIES	Names of trees mentioned in notes. Are either species intercepted along survey line, or bearing trees or witness trees for quarter or section corners

Field name	Description
TREE_DIAM	Diameter in inches of witness and line trees. Numeric field.(e.g. 6, 10, 24)
QUADRANT	For determining which formula to use Field Calculator to create new X and Y coordinates for feature. (e.g. NE, SE, SW, NW) (Appendix VII)
BEAR_DEG	Bearing from a corner or quarter to a bearing tree, up to four trees per corner, two trees per quarter corner. Also used for features other than trees.
VEG_CODE	Vegetation code derived from line description. May include one or more codes. (Appendix VIII)
YEAR	Year the survey was completed for the section line. This is not always the same as the year the township boundaries were surveyed.
SURVEYOR	Surveyor name
LINE_DESC	The surveyor's description of the section line just completed. The description, recorded in the field notes at the end of a line survey, includes general topography, soils and lists major trees and undergrowth. Information was used to create the vegetation line feature class.(e.g. "Land hilly, soil rocky 3rd rate, timber scattering pine, West half prairie", or "Land nearly level, soil 2nd rate. Pine on hills, thick brush in creek bottom")
TREE1_DIS	Tree 1 distance to corner
TREE2_DIS	Tree 2 distance to corner
TREE3_DIS	Tree 3 distance to corner
TREE4_DIS	Tree 4 distance to corner
TREESPERCNR	Number of trees per corner
AVGDIST	Average distance of trees per corner
POINT_X_M	Original x coordinate of GCDB point in meters (Numeric fields for all coordinates)
POINT_Y_M	Original y coordinate of GCDB point in meters
X_NE	New x coordinate for all data in the NE Quadrant using original (POINT_X_M) coordinate, bearing, and distance from original coordinate
Y_NE	New y coordinate for all data in the NE Quadrant using original (POINT_Y_M) coordinate, bearing, and distance from original coordinate
X_SE	New x coordinate for all data in the SE Quadrant using original (POINT_X_M) coordinate, bearing, and distance from original coordinate
Y_SE	New y coordinate for all data in the SE Quadrant using original (POINT_Y_M) coordinate, bearing, and distance from original coordinate
X_SW	New x coordinate for all data in the SW Quadrant using original (POINT_X_M) coordinate, bearing, and distance from original coordinate
Y_SW	New y coordinate for all data in the SW Quadrant using original (POINT_Y_M) coordinate, bearing, and distance from original coordinate
X_NW	New x coordinate for all data in the NW Quadrant using original (POINT_X_M) coordinate, bearing, and distance from original coordinate
Y_NW	New y coordinate for all data in the NW Quadrant using original (POINT_Y_M) coordinate, bearing, and distance from original coordinate
NEW_X	x coordinate copied and pasted
NEW_Y	y coordinate copied and pasted
NOTES	Volume of field notes and page of microfiche and miscellaneous information

Mapping Vegetation Lines

Surveyors recorded chain and link distances where they entered and exited prairies, brushy areas, swampy areas, forests, etc. along a section line between section corners. Section_Point entrance and exit locations were used to create line data—a Section_Lines feature class (Table 4)—that illustrates the positions of contiguous vegetation types along section lines of the six-township study area. Vegetation lines were digitized and attributed by vegetation type. The Major Vegetation Types and Tree Associations/Land Classes of the lines were classified and mapped. Mileage for each line segment was calculated and summarized.

Table 4. Section_Lines Attribute Field Descriptions.

Field name	Description
TOWNSHIP	Identifies every record for a particular township, six-character address (e.g. 08N21W)
LINE	Section line within township, five characters, section numbers entered in ascending order. (e.g. 01_06, 01_02)
DIR	Direction surveyor is headed along section line
VEG_TYPE	Tree type or vegetation within line segment. Derived from LINE_DESC and VEG_CODE point fields. Raw data from field notes
LINE_TIMBER_TYPE	Timber type listed at the end of a section line, general description of the entire line, sometimes different than the VEG_TYPE
MAJOR_TYPE	Classification of vegetation structure from the line description in the SECTION_POINTS feature class.(LINE_DESC) (e.g. timber, open timber, dense timber, heavy timber, no timber, prairie, swamp).
TREE_TYPE_ ASSOCIATIONS	Tree association described by survey for that portion of line. This field was used to group into TREE_ASSOCIATION/ LAND_CLASSES.
TREE_ASSOCIATION /LAND_CLASS	Associations aggregated by most numerous TREE_TYPE_ ASSOCIATIONS (e.g. Pine, Pine-fir-larch; Cottonwood-willow) and other non-treed groups (e.g. Field, Meadow, Prairie). Determined after all vegetation lines were digitized.
MILES	Mileage of a vegetation line segment.

GLO Vegetation Classification

Vegetation classification systems generally use species composition, percent canopy cover, tree density and diameter from numerous research plots, along with climate, landform, geology, soils data and expert opinion to determine vegetation categories. The GLO notes describing the Bitterroot Valley study area provided quantitative point data (tree type and diameter), only near section corners and quarter corners and along section lines. Areas in between must be extrapolated. It is suggested by past studies (Bourdo, 1956; Almendinger, 1997) that due to surveyors' bias against small and very large bearing trees, and certain species of trees, and due to the small sample size (only a maximum of four trees per section corner, and two per quarter corner), the use of bearing tree density and diameters from point data may not be suitable measurements to calculate overall vegetation structure and composition. Following this standard, tree point data were not used for vegetation classification in this study except as a periodic check for accuracy of vegetation line descriptions, which were used as the primary source for classification.

Two classification levels were developed to describe vegetation along section lines. Both levels were categorized only with surveyors' terms of vegetation structure and composition, as opposed to applying a contemporary ecological classification system based on current or potential vegetation, or existing classifications relying on habitat types, canopy cover percentages or tree age, densities or size. The first level, Major Vegetation Types, used surveyor-described vegetation structure descriptions. Structure is defined by timber density remarks (e.g. dense or open timber) and open land descriptions (e.g. prairie, meadow or no timber) recorded at the end of each section line. The second, more specific level describes Tree Associations/Land Classes based on tree type and non-treed land cover also from line descriptions. These raw classification categories allow users of the data to know almost exactly what the surveyors recorded, instead of applying current-day non-surveyor terms for vegetation structure such as forest, woodland and savanna. These ecological terms may not be consistently defined across different geographic locations. Christy and Alverson (2011a) based Oregon forest, woodland and savanna distinctions on GLO line descriptions, but also partially upon bearing tree distances to corners. Treed areas were classified as “Forests” if bearing trees averaged less than 100 links (20 meters) from their section corner and all bearing trees were present. “Woodlands” had bearing trees averaging 100 to 200 links (20 to 40 meters) from their corners with most bearing trees present. “Savanna” bearing tree average distances ranged between 200 and 400 links (40 to 80 meters), also with most bearing trees present. These distances may be different than distances used to describe the same woodland and savanna terms in other geographic settings. Restricting the portrayal of the historic vegetation to only surveyors’ terms may provide a more standardized approach to researchers using dissimilar state or regional vegetation classification systems. It should be noted however, that surveyors’ descriptors are also not strictly defined, so may vary by region and by surveyor. For example, the infrequently described “Meadow” category in Iowa (Gallant *et al.*, 2011) appeared to indicate high-moisture areas along drainages and swales. In the Bitterroot Valley study area, meadows were described occasionally along streams, were sometimes associated with cottonwoods, and were often associated with fences. Moisture was not directly associated with meadow descriptions. Presence of moisture could only be inferred by the description of meadow in proximity to cottonwoods or streams.

Major Vegetation Types were classified by grouping timber structure categories described as open, scattering (or few), heavy and dense. Other non-timbered types were derived from the Section_Points, Line_Desc and Veg_Code fields. Major Vegetation Types included sixteen classes: Brush, Timber, Heavy Timber, Scattering Timber, Open Timber, Dense Timber, Burned Timber, Cut Timber, Timber Bottom, Gravel Bar, Meadow, Water, Field, Cliff, Swampy areas and Prairie-No Timber. Lines having no timber were combined with lines described as prairie into the Prairie-No Timber type at the broader Major Vegetation Type classification level, and separated into two distinct classes in the second more narrowly defined classification level, Tree Associations/Land Classes.

The assumption that many No Timber areas were mostly prairie or had been prairie before plowing seems applicable, given the general descriptions of the initial township boundary survey (Appendix VI). Portions of T07N R20W that included No Timber line descriptions were described as:

> “bottom land, gradually rising into bench and table land and high rolling prairie. The soil is a deep sandy loam of inexhaustible fertility admirably adapted to the raising of grain and to grazing purposes” (George Irvine, 1872).

T08N R21W was known as:

> “the garden spot of the valley, and the splendid crops of grain and vegetables raised thereon testify to the appropriateness of the term, whilst the adjacent foot hills are covered with a luxuriant growth of rich bunch grasses leaving this township unsurpassed by any in the valley for grazing purposes” (Henry Rohleder, 1872).

George Irvine described a variety of land types, but did not use “prairie” in this general description of T06N R21W even though prairie is the descriptor for several miles of line in the GLO subdivision line notes:

> “The greater portion of this township lies west of the Bitter Root River and extends to the foothills of the Bitter Root Range of mountains. The surface of the country is bottom and high bench land, all of which can be well watered by the various streams that run through them. The soil is of an excellent quality well adapted to the raising of grain and for meadow and grazing purposes. Timber is abundant and of good quality for building and farming purposes. The bottomland is principally settled.” 08/06/1872.

In the adjacent T06N R20W, Paul Bickel (1894) specifically describes an area supporting a prairie grass—“blue joint” (possibly *Calamagrostis* sp.):

> “Along Skalkaho Creek there is excellent range for stock and in many places blue joint hay grows wild.”

Areas of sagebrush occurred within areas of the Prairie-No Timber designation. Sagebrush was not listed in specific locations in the subdivision line descriptions of any townships, but surveyors George Irvine and Henry Rohleder (1872) recorded its occurrence, as well as meadow land, river bottom timber and agricultural land, in the general description of the T08N R20W outer township boundary survey:

> “This township is known in the Bitter Root Valley as the sagebrush country. It lies chiefly east of the Bitter Root River. One tier of Sections however lie upon an Island in the river, and in the finest body of meadow land in the Bitter Root Valley. The remaining portion of the township away from the river bottom is a level plateau, the soil of which is a rich alluvium. Timber is abundant along the Bitter Root River and Sweathouse and Lower Big Creek by which streams the township is well watered. This township is thickly settled, fine, large, well cultivated and highly improved farms are on every land, and splendid crops of grain and vegetables are raised. The lands are agricultural.”

Consideration of tree size or distance from a section corner was not overtly part of the Major Vegetation Type classification process due to the surveyors’ undefined use of recurring descriptors—Dense, Heavy, Open and Scattering—timber types. The descriptors could have dual meanings. “Dense” possibly described young, small diameter forest regrowth after a cut or burn, or may have refered to a thick, larger diameter, old lodgepole pine stand. “Heavy” could have defined very large old trees that were considered heavy to transport to the saw mill. But “Heavy” perhaps meant thickly timbered.

Difference between the use of the terms “Open” and “Scattering” was not well defined by comparing locations of those descriptions. Scattering Timber was described in the eastern hills and the western mountains, and in between in the river bottom. Open Timber was used to a lesser degree overall, and also in hill, valley and mountain locations. The average tree number of Scattering and Open Timber lines was compared, in spite of possible selection bias, by spatially joining vegetation lines to the tree corner points in ArcGIS. The average number of trees located at a section corner, for lines that contained trees, was very similar for both Scattering and Open categories. Scattering had an average of 3.5 trees per corner and Open had 3.4 trees per corner, where trees occurred. The spatial join also allowed the number of trees at a section corner (which was collected as an attribute of the Section_Points feature class) to be viewed simultaneously with lines described as Open and Scattering Timber (Figures 2 and 3). Scattering Timber lines that had trees at one or both corners numbered 28 out of the total number of 52 Scattering Timber Vegetation lines. Almost half (24) of the Scattering Timber lines had no bearing trees at their corners (a few short lines did not extend to corners). Figure 2 illustrates Scattering Timber lines by number of trees present on at least one section corner. Treed section corners with circles of increasing size represent increasing distances (from <20 meters to > 40 meters) from tree to corner.

Open Timber lines that had trees at one or both corners numbered 18 out of the total number of 21 Open Timber vegetation lines (Figure 3). Only three of the Open Timber lines had no trees at their corners. The overall average distance from bearing trees to their section corners for Scattering Timber was 22 meters (107 links), and 16 meters (80 links) for Open Timber. These distances correspond to Christy and Alverson's (2011a) "Woodland" category (20 to 40 meters) for Scattering Timber, and "Forest"

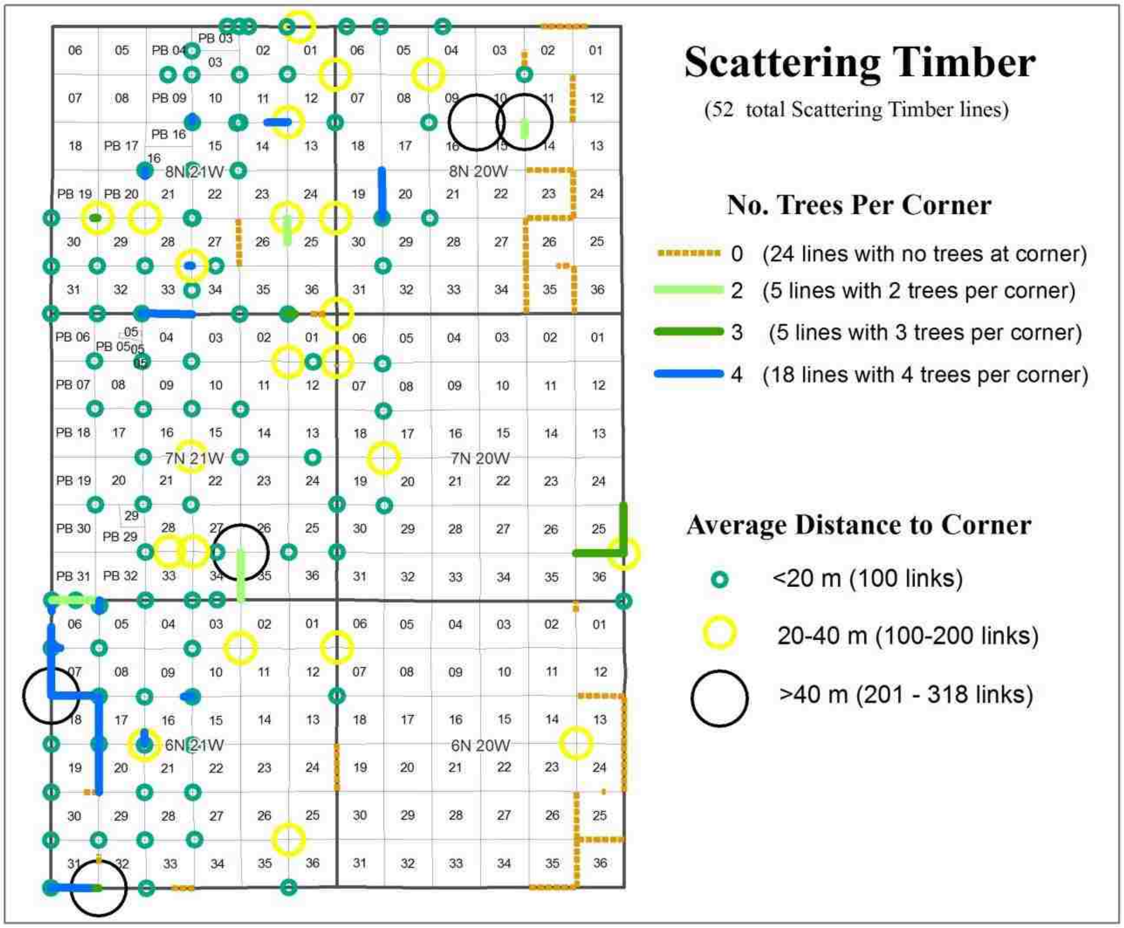


Figure 2. Scattering Timber-Number of trees per corner for Scattering Timber, and average distance to corner for corners with bearing trees.

category (< 20 meters or 100 links) for Open Timber. These differences between Scattering and Open may indicate a tendency for surveyors to have described minor wooded areas with widely spaced trees set in matrices of prairies or extremely rocky, open mountainous areas, with the term “Scattering;” and conversely, suggest an inclination to have labeled predominantly timbered areas with widely spaced trees as “Open.” In order to further assess this speculation, a larger area exhibiting these conditions deserves exploration.

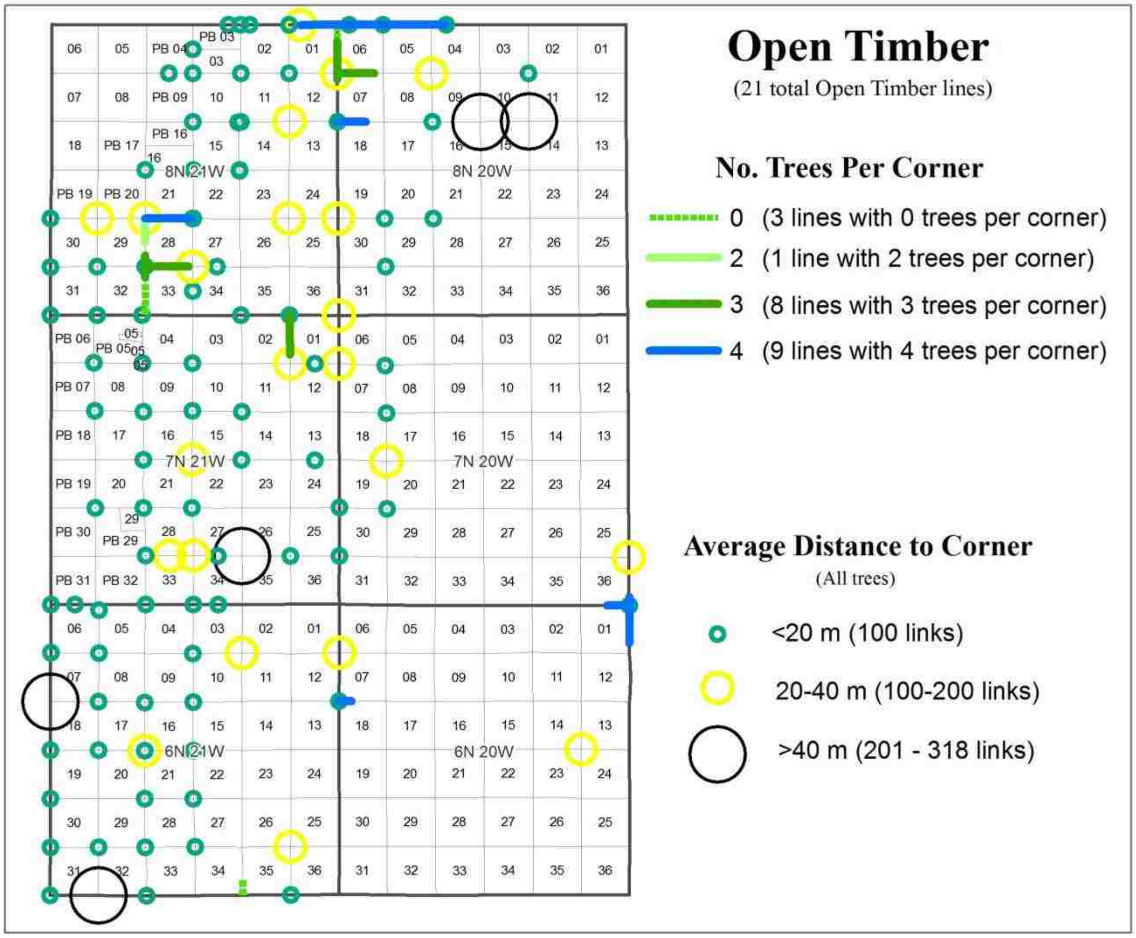


Figure 3. Open Timber-Number of trees per corner for Open Timber, and average distance to corner for corners with bearing trees.

The second, more detailed GLO line classification level, termed Tree Association/ Land Classes, was categorized from vegetation information gathered in the Veg_Type and Tree_Type_Association fields. Surveyor-described vegetation groupings were sorted into a workable number of similar assemblages of tree types, and other non-treed land description groups nearly identical to Major Vegetation Types such as Prairie, Gravel Bar or Brush. For example, surveyors might have described 25 “Pine-fir-larch” lines, three “Fir-pine-larch” lines, and one “Pine-larch-fir” line in the mountainous portion of the area. These 29 lines would be lumped into the “Pine-fir-larch” tree association class. The classes were designed for this specific six-township location, and may not be appropriate for a larger study area. If tree assemblages of a larger area included 25 “Pine-fir-larch” lines and 1000 “Fir-pine-larch” lines, both types may be grouped into the “Fir-pine-larch” class or may need to be separated into two classes, depending upon the entirety of the line descriptions. Christy and Alverson (2011b) acknowledged that:

> “a progressively expanding vegetation classification develops as different vegetation types are encountered in the survey notes.”

It is important to recognize that if Tree Association/Land Classes had been determined for a very large area, for example, all of the valleys in western Montana instead of only six townships, the classification would be modified and expanded, since more and different vegetation types are likely to have been described with the increased area.

Prior to data collection, a specific species association map was considered a potential product; but this proved an unobtainable goal using only GLO field notes. Species associations could not be readily determined since only the general common names—“pine” or “fir,” were recorded. With information from additional historic accounts, current vegetation classification systems, elevation and aspect data and field visits, specific species and species associations could be identified; but then this project would not have upheld the intention of documenting the surveyors’ actual descriptions.

Mapping Vegetation Polygons

GLO vegetation has been mapped over areas ranging from specific sites to entire states using various methods (Wang, 2005; Marshner, 1930 and 1974; Finley, 1959; Stearns and Guntenspurgen, 1988; and others). For this Bitterroot Valley study, Major Vegetation Types were digitized in the Vegetation_Polygons feature class for one township, T06N R21W. Mapping vegetation polygons was a time-consuming and subjective procedure using the best available supporting data. The highly dissected mountainous landscape increased the difficulty of accurately determining vegetation boundaries within section interiors compared to regions with relatively homogenous topography. These conditions prompted the decision to map only one township as a demonstration of the polygon mapping method.

Polygons were mapped at a scale of 1:24,000, one section at a time, starting at the section line and working inward toward the center of the section. Polygon boundaries located within the interiors of sections were determined using the vegetation lines feature class with soils boundaries, contours, NAIP imagery and occasionally, in forested areas, the U.S. Forest Service Bitterroot Forest stand data, as guides. General guidelines for mapping the vegetation polygons were followed, in the order presented:

1. First, the integrity of the surveyors' descriptions of the section lines was preserved while vegetation polygons were created. Since the surveyors described the actual line, the accuracy of the polygon edges coinciding with the section line should be quite high, and therefore was mapped as described despite potentially conflicting soils or aerial imagery information that may indicate a dissimilar vegetation type.
2. When mapping section interiors, soil suborder boundaries were used to delineate forest types and prairie or non-forest areas.
3. If soil boundaries did not show a contiguous relationship with vegetation lines, in areas of high relief contour lines were followed to connect polygon boundaries to adjacent section lines that contained similar vegetation.

4. If contours did not present clear boundary solutions, aerial imagery was consulted and followed especially where obvious geologic or landform dissimilarities occurred.
5. Occasionally, within the Bitterroot National Forest, timber stand data were checked against the GLO vegetation to define the major type boundary.
6. Prairie areas were sometimes compared to GLO plat map areas labeled “Agricultural” for boundary clarification.
7. It was recognized that under-representation of small vegetation types such as bottomland and lower valley wetlands, subalpine meadows and fields likely exists, for two reasons—because surveyors did not describe the land at a high level of detail, and these small types could have occurred entirely within section boundaries and been completely missed by surveyors.

The intention throughout the polygon mapping process was to estimate the most likely surveyor-defined major vegetation patterns in areas the surveyors did not actually describe, with readily available data layers and without further analysis. Realizing limitations of unknown mapping accuracy within section interiors and the difficulty in objectively repeating the mapping process, this approximation was not used for land cover comparisons. The procedure, however, was a good data examination technique that stimulated familiarization with the physical geography of the area and perhaps could be used to check an objective historic landscape modeling outcome.

Pretest

Before data collection for the entire area was attempted, a trial run of data entry, point and line creation and vegetation polygon digitization was performed. This test ensured that the approach could produce correctly placed features, and that attributes could be sorted and summarized to produce suitable map products and summaries. Data were entered for ten sections and used to improve data entry methodology and coding. Refinement of attribute fields and codes that resulted in the previously shown tables (Tables 2-4) was a continuing process until the appropriate fields, field order, and feature and vegetation codes, were determined. As described previously, GCDB points were used to hold GLO information. Once the test GCDB point data were assigned new coordinates with distance and direction formulas, the locations of points in the test feature class were reviewed to ensure their correct placement along section lines and around section corners. Classification of line and polygon vegetation was not pre-tested. It was not possible to comprehensively classify vegetation types until the information from the entire study area was amassed and the range of types was known.

Checking for Fraudulent Survey Work, Errors and Bias

Most surveys were well executed according to published instructions. Surveyor instructions from 1855 provided for field evaluations to assess the quality of the survey (White, 1991). Field examinations became most effective after 1881 (Stewart, 1935). To check for fraudulent survey work and surveyor errors during this study, while entering data GLO stream and topographic positions were visually compared to 2009 aerial imagery and USGS 7.5 minute topographic quadrangles to verify that GLO locations were in close proximity to corresponding locations on these reliable map sources. Comparison with these sources also allowed a general GLO accuracy verification, realizing that early settlement road and irrigation ditch construction may have substantially changed some contour and drainage patterns (Galatowitsch, 1990).

Very few inconsistencies between GLO streams, hills and other topographic features and current-day mapped features were documented. Nearly all GLO stream crossings, ravines, ridges and hill locations were less than a half chain (10 meters) from their current-day positions. Additional visual comparison of GLO vegetation was made to a 1902 USGS Land Classification and Density of Standing Timber Map from the Twenty-First Annual Report to Congress (Washington Printing Office) (Figure 4). The 1902 map delineated grazing, barren and cultivable lands; woodlands; and cut, burned and merchantable timber at a 1:125,000 scale.

Bias in bearing tree species selection and diameter was considered and acknowledged as a probable circumstance of the dataset. Bias consideration is important if the data were to undergo any kind of ecological analysis comparing spatial arrangement and tree size class distribution (tree density and basal area), as it is uncertain that these trees represented random samples (Bourdo, 1956). Certain tree types may have been preferable for blazing, or were most likely selected for their longevity and sturdiness. Particular trees also may have been avoided for a variety of reasons. Williams and Baker (2010) relocated trees in the western U.S. (Arizona, Colorado and Oregon) to compare bearing tree survey measurements to re-measurements at survey corners. They examined ponderosa pine-dominated forests to determine existence of preferential selection of bearing trees resulting in selected trees not being the closest to the corner, and thus not representing an unbiased sample of the forest. They found minimal selection bias with surveyors selecting the closest tree at least 95 percent of the time.

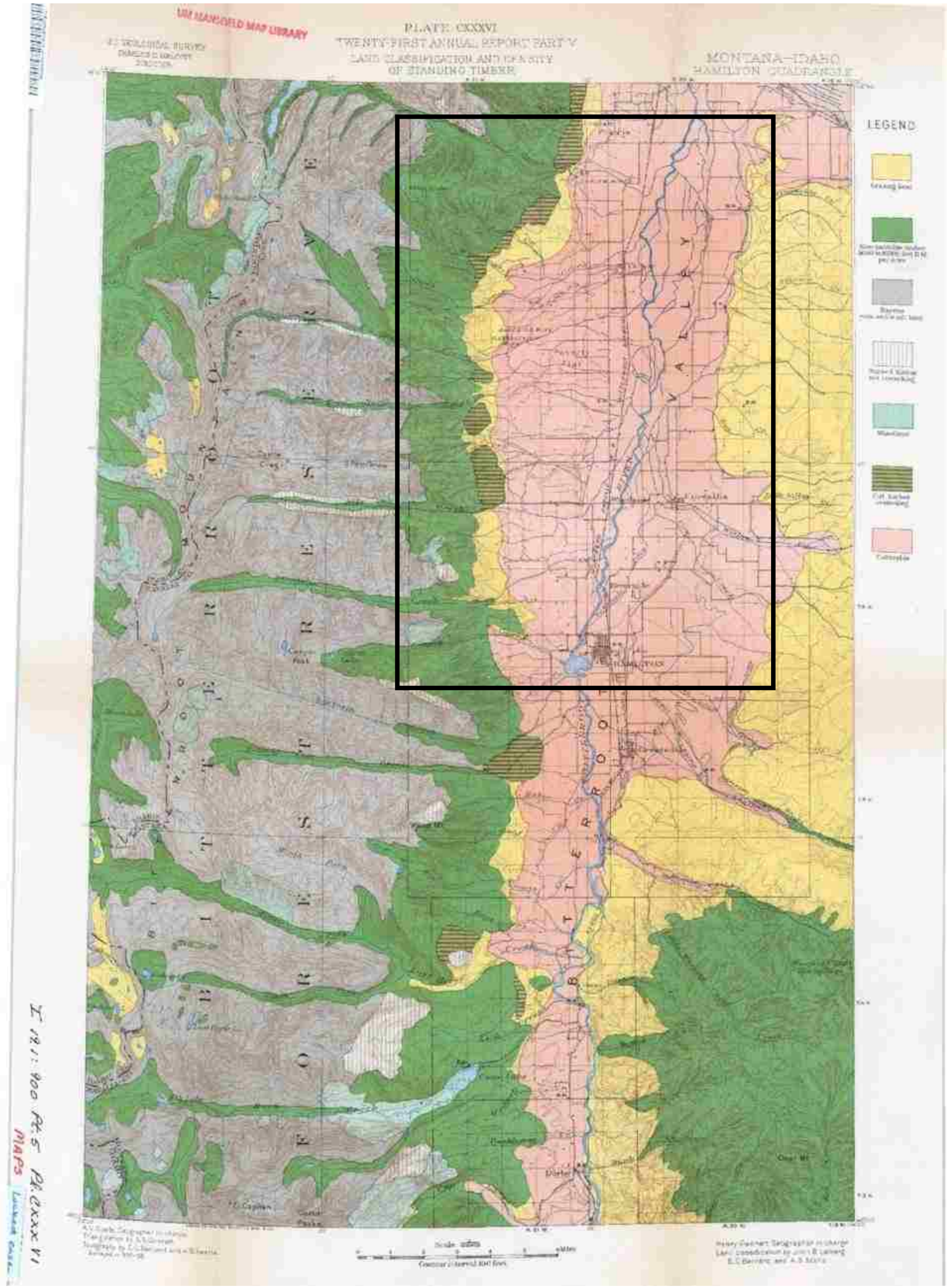


Figure 4. 1902 USGS Land Classification and Density of Standing Timber (Washington Printing Office) The study area is outlined in black. Yellow = grazing land, Green = merchantable timber, Gray = barren, White = burned, Blue = woodland, Green with dark stripes = cut timber, Pink = cultivable land.

To check for bias in bearing tree selection in the Bitterroot Valley, the relative frequencies of bearing trees (points selected by surveyors) were compared to relative frequencies of trees listed in the section line descriptions. In Minnesota, if a tree type was documented more than twice as often as a bearing tree or line description tree, clear bias was assumed (Almendinger, 1997). While selection of bearing trees is presumed to potential subjectivity, line description trees may have been recorded more objectively and in order of dominance. Also, surveyors were not limited to a certain number of line tree types that could be listed. So the line information is not as likely to exhibit the preference associated with selecting for or against certain bearing tree types. Additionally, the line descriptions are free from a small sample size limitation.

Almendinger (1997) gives many considerations for applying bearing tree data to ecological studies. A suggestion for analytical studies using bearing tree type frequency is that the study area should be large enough to include at least 25 trees of the least abundant type. This study only documents what the surveyors recorded. The study area is not large enough to meet a 25 tree minimum (only 4 of the 9 grouped tree types have 25 or more occurrences), so accordingly, the study attempts no statistical analysis using bearing tree type data. The prospect of future research using tree point data from a larger area prompted the desire to check for the extent of bias with the data available. Tree frequency documented by surveyors at corners, quarter corners and along the section lines between corners totaled 880 (Table 5). Bearing trees, at the corner and quarter corners of sections, numbered 778. The total number of line trees—trees found along section lines in-between corners—equaled 102, and the number of trees listed in section line descriptions was 644. Frequency is defined as the number of occurrences of a

Table 5. Tree Frequencies of Occurrence by Location.

Surveyors' Tree Name	Frequency of all tree points at corners, quarter corners and line trees	Frequency of tree points at corners and quarter corners (Bearing trees)	Frequency of tree points along section lines, not at corners or quarter corners	Frequency of lines with tree in section line description
pine	645	554	91	323
fir	119	115	4	136
cottonwood	46	41	5	56
aspen	35	33	2	42
larch	19	19	0	51
spruce	7	7	0	15
birch	6	5	0	6
alder	2	2	0	15
hemlock	1	1	0	0
Total	**880**	**778**	**102**	**644**

specific tree type. Relative frequency is the number of observations of a tree type divided by the total number of tree occurrences expressed as a percentage.

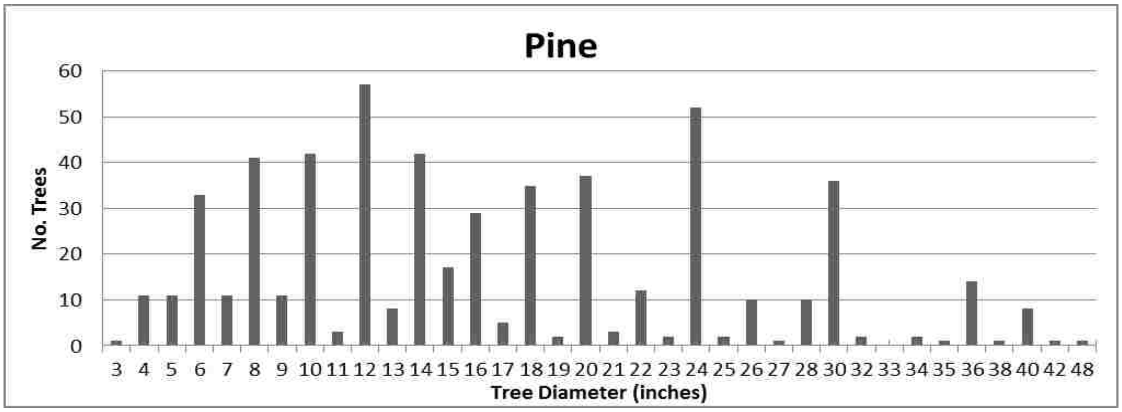
Pine was most selected as a bearing tree (554), and also most frequent as a line tree (91) and as a section line description tree (323). Line trees between corners were not used in comparison for bias. Fir (115 bearing trees, 136 section line description trees), cottonwood (41, 56) and aspen (33, 42) followed in order of bearing trees and line description trees. The compared corner (554/778 = 71.2 %) and line description (323/644 = 50.2 %) relative frequencies for pine suggest that it may have been preferred as a bearing tree, and that bias towards its selection did possibly exist (Table 6). If there was no preference for pine as a bearing tree, the relative frequencies for pine bearing trees and line description trees should be similar. Relative frequencies for all other tree types were lower for corners than for line descriptions, suggesting that these types may have been somewhat avoided as bearing trees. Larch, spruce, birch and alder were

Table 6. Relative Frequency of Bearing Tree Types (778 total trees) Compared to Relative Frequency of Line Description Trees (644 total trees) and Differences.

Surveyors' Tree Name	RF of Trees at corners and quarter corners (%)	RF of Trees in vegetation line descriptions (%)	Difference (Corner RF-Line RF)
pine	71.2	50.2	21.0
fir	14.8	21.1	-6.3
cottonwood	5.3	8.7	-3.4
aspen	4.2	6.5	-2.3
larch	2.4	7.9	-5.5
spruce	0.9	2.3	-1.4
birch	0.1	1.0	-0.9
alder	0.0	2.3	-2.3
hemlock	0.0	0.0	0.0

observed more than twice as often as line description trees compared to their selection as bearing trees, so avoidance of those types as bearing trees seems possible. However, because of such limited selections and descriptions of spruce (7 bearing trees, 15 line descriptions), birch (5, 6) and alder (2, 15), inadequate evidence is provided for certain bias against their selection. Variability in tree selection may be related to the absence or presence of certain species because of topographic, soil, climate and disturbance requirements.

The frequency of diameters for the two most numerous bearing tree types, pine and fir, were plotted and examined qualitatively for bias in tree size selection (Figure 5). Almendinger (1997) cautions that there is clear bias in recording tree diameters. Corner trees were not selected randomly by size; it is presumed that surveyors were looking for well-established trees that were young enough to survive a long period, serving as a marker of the section corner. Surveyors in Minnesota were partial to trees with diameters ranging from 4-12 inches if available (Almendinger 1997). In this Bitterroot Valley



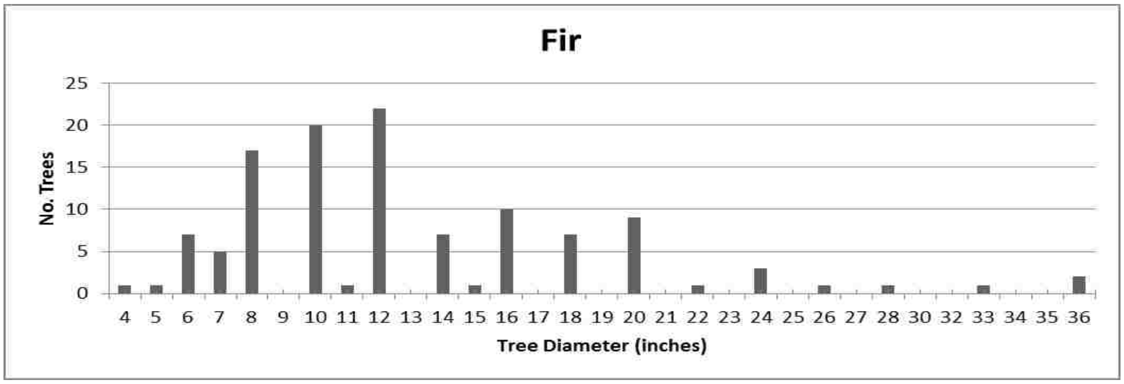


Figure 5. Size Distribution of Pine and Fir Bearing Trees. (Records totaled 554 corner and quarter corner records for "pine", "black pine", and "white pine" combined; 115 corner and quarter corner records for "fir" and "red fir").

study, as in Michigan and Missouri, surveyors tended to estimate diameters in even numbers (Bourdo, 1956; Batek, 1994). It is also possible that surveyors aggregated large diameter trees into 24-, 30-, 36- and 40-inch classes. Pine tree diameters most often chosen, in order of their selection, were 12-, 24-, 10-, 14-, and 8-inch trees. Bias in size selection for pine does not seem as likely as size preference in fir trees. The highest numbers of fir trees were recorded in 12-, 10-, and 8-inch classes. Fir over 20 inches in diameter were infrequently selected. There is no sure method to determine whether larger size classes were generally not available for selection at each corner, or if large fir were selected against, without examination of historic timber records.

For all combined tree types, 12-, 10-, 8-, and 24-inch trees were the most abundant selections (Figure 6). Tree diameters depend upon specific site qualities and past forest and climate processes. Size selection, like tree type selection, may or may not reflect the overall nature of the forest. The average diameter of corner and quarter corner bearing trees in this study is 15.3 inches while the average diameter of line trees is 22.1 inches. This difference may indicate the preference for smaller trees as bearing trees.

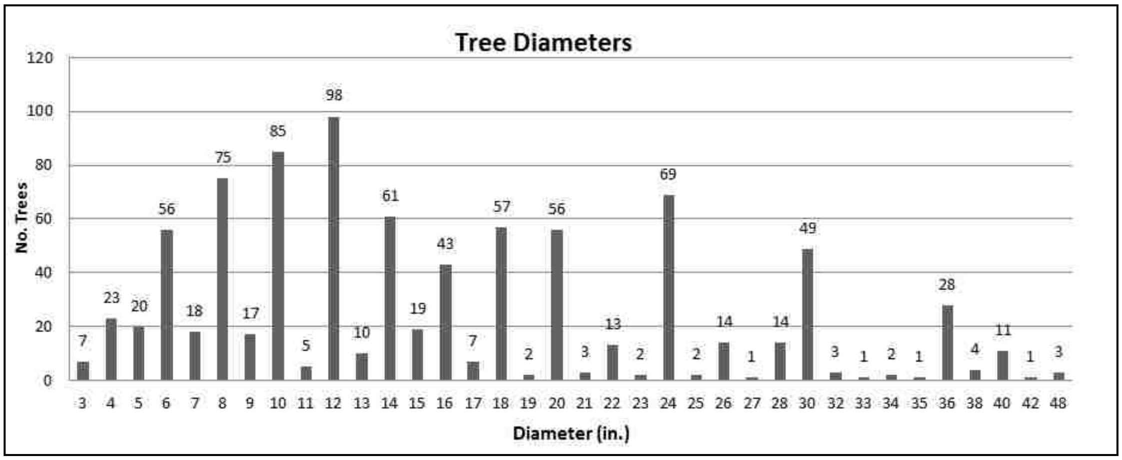


Figure 6. Size Distribution of all Bearing and Line Trees.

Recognizing that bias in tree size and type may exist at some level is the reality of working with GLO data. Knowledge of its existence cannot completely disallow use of the information, for it is the only data of its kind. Gaining awareness of the possible extent of selection preferences that occurred in a specific study area may improve understanding of the limitations of the information for that site.

Differences between GLO and Current Vegetation along Section Lines

The main purpose of this study was to determine an effective methodology for collecting, displaying and summarizing GLO data, so that the method and the data could be applied in future projects. With the methodology completed and data successfully assembled, two examples of the ways in which the GLO vegetation information could be compared to current land cover were undertaken. First, section line GLO vegetation was compared to current land cover along corresponding section lines to estimate the overall differences in percent cover of near-equivalent GLO/current vegetation classes for the six-township area. Gallant *et al*. (2011) used a similar difference comparison to determine wetland changes across the state of Iowa. Differences between GLO and current land cover reveal shifts in relative importance of near-equivalent cover classes in the landscape over time. Additionally, an ArcGIS intersection and selection process was conducted to determine the current land cover classes into which a specific GLO vegetation type transformed, and how much of that GLO type remains in a near-equivalent current condition. Procedures for the two comparisons follow.

To determine overall differences between GLO vegetation and current land cover, a one-pixel width line of land cover, coincident with the surveyed section lines, was extracted from the 2010 Montana Land Cover using the ArcGIS Extract by Mask tool (Figure 7). The non-linear, segmented nature of the land cover (raster) lines accounted for

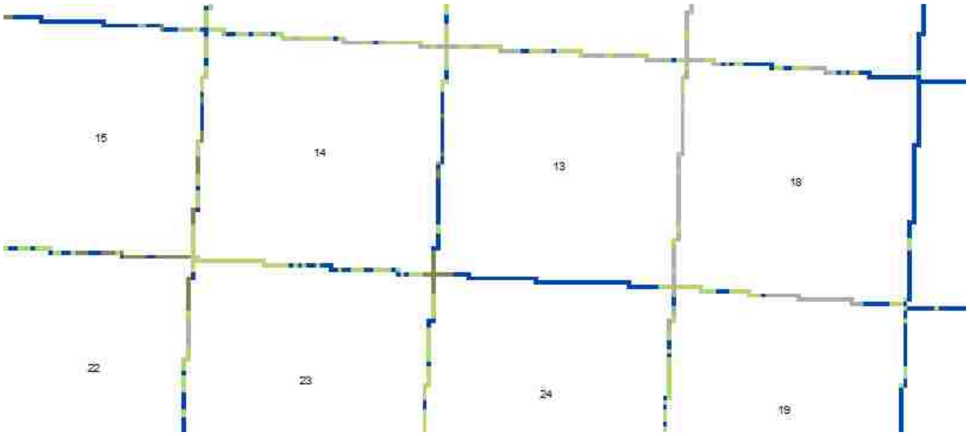


Figure 7. 2010 Montana Land Cover along Section Lines.

a higher total distance in miles of the land cover lines (441.6 miles) compared to the linear GLO section lines (422.3 miles). This inconsistency was negated since differences were summarized in percentages instead of miles.

Before differences could be calculated, GLO Major Vegetation Types and 2010 Montana Land Cover were crosswalked or recategorized into near-equivalent groups (Table 7). The challenge for crosswalks is that no two classifications are 100 percent equivalent. One categorization may have a vegetation/land cover type that does not exist in another system, or it may have a type that is split into two or more different types in another classification. GLO Major Vegetation Types were sometimes aggregated to match similar contemporary land cover types as nearly as possible. The matching effort required using differing levels of land cover (Levels 1 to 3) depending on the coexistence of similar GLO classes. Land cover levels, introduced on page 29, are three hierarchical ranks of increasing vegetation and land use specificity. The Level 1 land cover class

Table 7. GLO Major Vegetation Types and 2010 Montana Land Cover Crosswalk.

GLO Major Vegetation Types	2010 Land Cover (Mixed Levels 1 to 3)
Upland Timber: includes Timber, Timber-Dense, Timber-Heavy, Timber-Open, Timber-Scattering	Forest and Woodland Systems-L1
Prairie_No Timber	Montane Grassland-L2 (Includes Lower Montane, Foothill and Valley Grassland-L3 and Subalpine-Upper Montane Grassland-L3)
Timber-Bottom, Gravel Bar	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland-L3
Brush	Deciduous Shrubland-L2
Meadow	Pasture/Hay-L3
Water	Open Water-L3
Field	Cultivated Crops-L3
Swampy	Emergent Marsh-L3
Timber-Burned	Recently Burned-L2
Timber-Cut	Harvested Forest-L2
Cliff	Rocky Mountain Cliff, Canyon and Massive Bedrock-L3
Not recorded	Developed-L2
Not recorded	Alpine Bedrock and Scree-L3
Not recorded	Alpine-Montane Wet Meadow-L3

is generally based on vegetation physiognomy, aquatic and alpine classes, and human land uses. Level 2 incorporates information on elevation and climate. Level 3, the most detailed, contains Montana-specific ecological systems and land use classes. All Level 3 classes are nested within Level 2 classes, and Level 2 classes are nested within a Level 1 class.

The GLO Upland Timber class combines the Timber, Heavy, Scattering, Open and Dense Timber categories. These grouped categories could only be compared to the most general 2010 Montana Land Cover Level 1 Forest and Woodland Systems. GLO Timber-Bottom and Gravel Bar were combined and matched with Level 3 Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland. The GLO Prairie-No Timber combination was crosswalked with Level 2 Montane Grassland. Other less abundant GLO types had near-equivalent land cover counterparts corresponding to Level 2 or 3. Current developed areas and upper montane, subalpine and alpine distinctions had no GLO near-equivalent Major Vegetation Types as they were not described by surveyors.

The percentages of comparable GLO and current land cover classes were calculated, and percent differences between GLO and contemporary classes were determined. Use of GLO notes to answer questions about the changing landscape requires confidence in the reliability of surveyors and in the accuracy of the contemporary land cover data at a particular study site. It is not within the scope of this study to determine specific reasons for each difference but to describe only where the greatest differences may have occurred.

A second land cover change inquiry was made to determine the types and percentage of contemporary land cover into which a specific GLO class had transformed. This ArcGIS overlay/intersection procedure could potentially be used to determine change in any or all GLO vegetation classes but for this example, only the two most abundant GLO classes, Upland Timber and Prairie-No Timber, were queried. To prepare for the evaluation, the section line land cover raster data were converted to the vector data type. Land cover points were generated from the raster section lines (one vector point for each 30 x 30 meter cell) with the ArcGIS Raster to Point conversion tool. GLO vegetation lines were then buffered by 20 meters, creating narrow polygons of section line vegetation data, to ensure the inclusion of all non-linear land cover points within the polygons' boundaries when the two files were intersected (Figure 8). The intersection of current land cover points with GLO buffered lines allowed attributes of both files to be written to the intersection layer's attribute table. The Upland Timber and Prairie-No Timber vegetation types were selected, separately, from the resulting GLO-land cover intersection point layer to create individual Prairie-No Timber and Upland Timber GLO-land cover feature classes. The types and percentages of current land cover classes that coincided with each of the two GLO types were summarized and mapped. The GLO-land cover intersection point layer could be queried by selecting any additional GLO type or current land cover class to display the near-equivalent current or historic classes that occurred at selected locations, but further examples were not completed for this study.

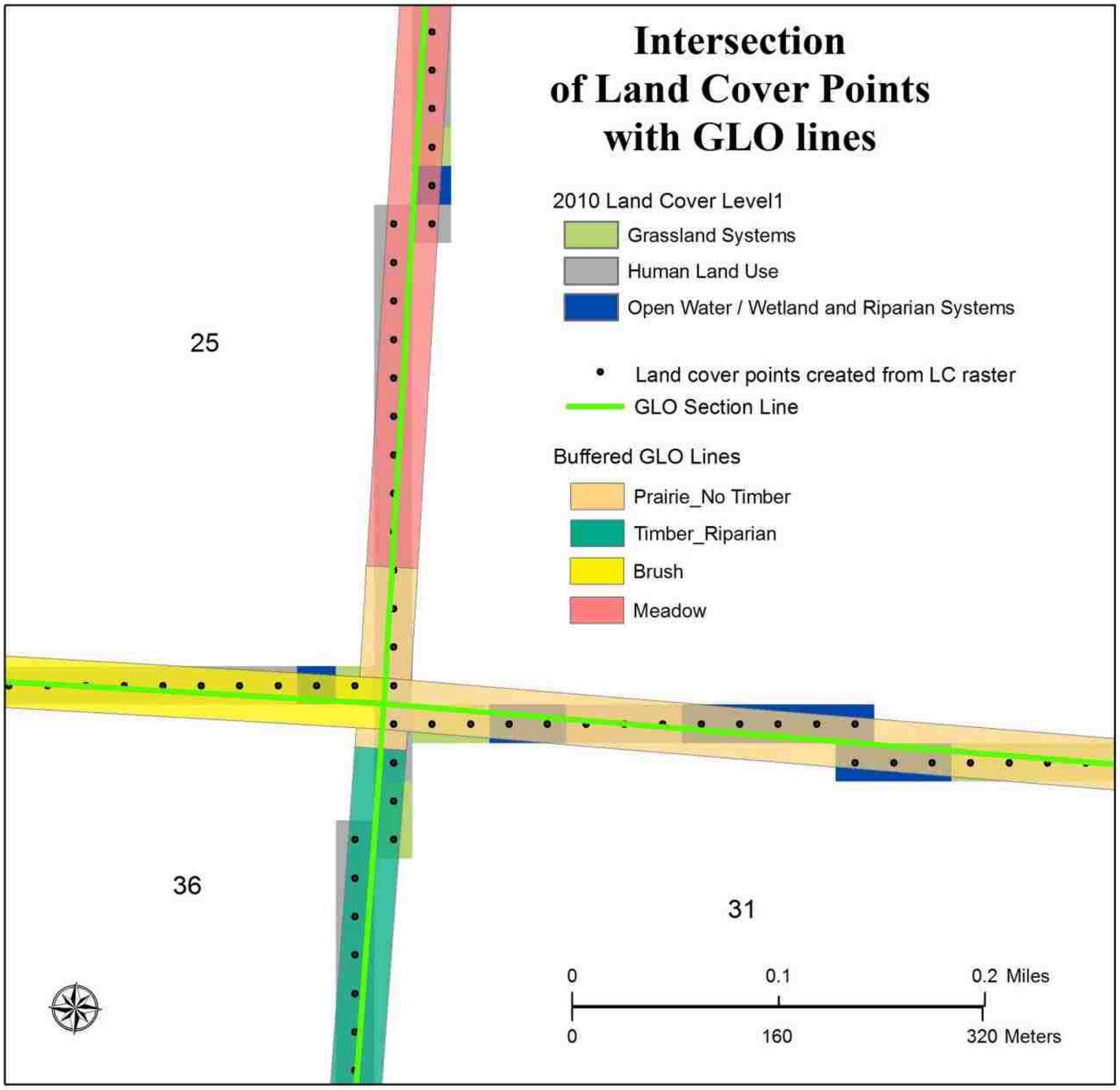


Figure 8. Intersection of Land Cover Points with GLO Lines.

RESULTS

The landscape of the late 1800s and patterns of human effects, according to surveyors' observations, were examined in several ways. The culmination of this research produced historic vegetation maps and evaluations, other geographic information summaries and a comparison of GLO vegetation to current land cover. A total of 3321 points of ecological and geographic information and 422 miles of vegetation were mapped. Results conveying surveyor information, vegetation composition, tree abundance, vegetation spatial structure and distribution of vegetation types are discussed separately. Aquatic, topographic and cultural aspects of the area are also summarized. GLO vegetation along all section lines compared to current land cover revealed differences between historic and current vegetation conditions. Additionally, the current conditions of land described as Upland Timber and Prairie-No Timber by surveyors were determined.

Surveyor Information

Original survey contracts were completed for the study area between 1870 and 1924 by ten surveyors (Figure 9). Information was collected mainly from the original surveys; not from separate mineral surveys and not usually from re-surveys done at later dates to reestablish missing or poorly located corners and lines. Most of the valley and foothills subdivision was completed in 1872 by two deputy surveyors, George Irvine and Henry Rohleder, as a single contract. This contract included all of T06N R20W, T07N R20W, T08N R20W and the eastern portions of T06N R21W, T07N R21W and T08N R21W. The western portion of the latter three townships, which included the more mountainous portion of the area, was surveyed by the remaining six survey contracts in the 1890s and early1900s. Several sections in T08N R21W and T07N R21W were not surveyed by the General Land Office due to the rugged terrain and possibly because these areas were potential federal forest reserves. It is important to recognize that the data collected from the survey is not from one point in time but information collected over a 54-year period that was combined as one dataset. In a few survey contract border areas, surveys of the section lines were repeated, sometimes with different line descriptions. A second survey may have noted situations such as—a section corner was reestablished, the original bearing trees were not relocated, new bearing trees were marked, or the area was recently cut. Only the original surveys for all lines were mapped in this project to reduce complexity.

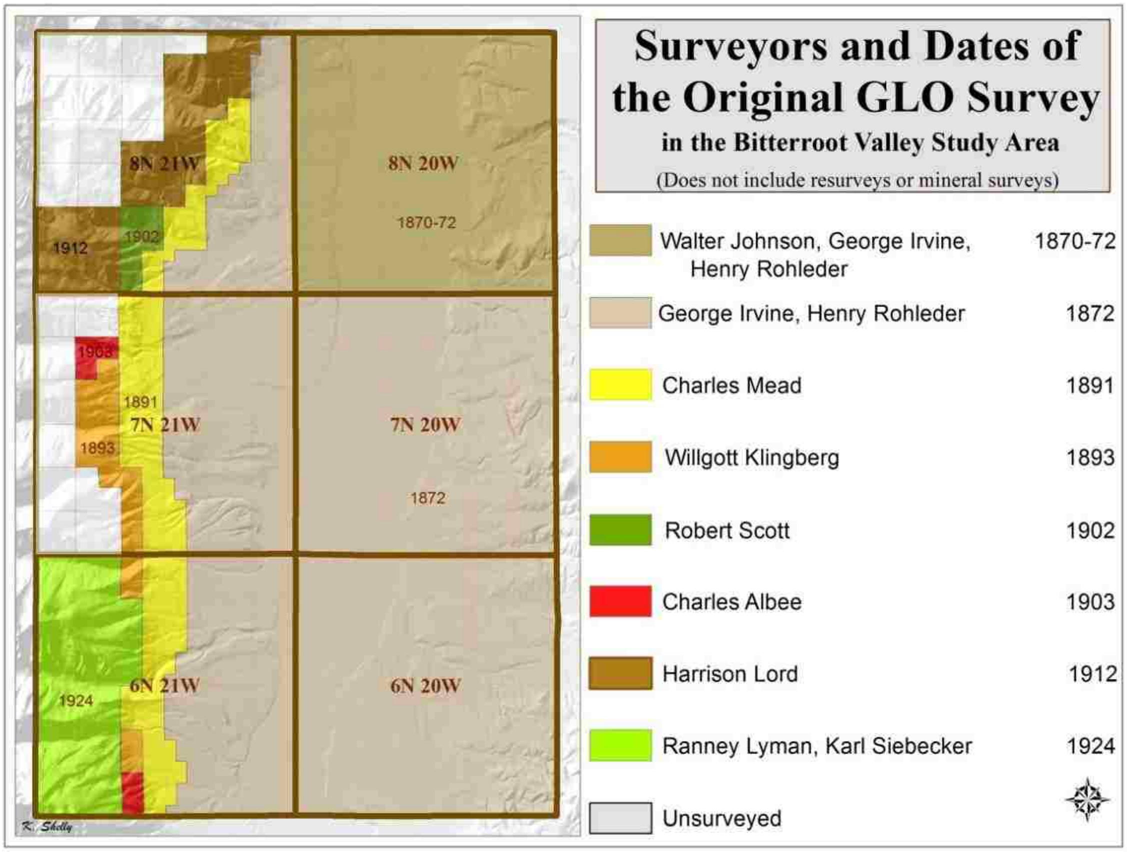


Figure 9. Surveyor Contract Locations and Survey Dates.

Tree Types Recorded by Surveyors

Surveyors' tree names, current common and scientific names along with the frequency of occurrence, diameter range and mean diameter are listed in Table 8. A crosswalk of historic names to current scientific names and common names was compiled (Lackschewitz, 1991). Between fifteen to twenty-three tree species were documented by surveyors. Since surveyors used general common names it was not possible to ascertain absolute identity of some species. According to Bitterroot National Forest timber stand data, at least four types of pines are known to occur in some portion of the study area: ponderosa pine (*Pinus ponderosa*) at lower elevations, and lodgepole pine (*P. contorta* ssp. *latifolia*), western white pine (*P. monticola*), and whitebark pine (*P. albicaulis*) in higher zones. Surveyors generally just recorded the generic "pine," although a few "black pine" (lodgepole pine) and "white pine" were documented. "Larch" and "tamarack" were two different common names used by surveyors for the same species, *Larix occidentalis.* However, if occurring at high elevations, larch or tamarack could be *Larix lyallii* (alpine larch). Surveyors recorded "aspen" and "quaking aspen," which are both *Populus tremuloides*. "Fir" and "red fir," an old name for Douglas fir, were noted, but grand fir (*Abies grandis*) and subalpine fir (*A. lasiocarpa*) also occurred in the area and were not differentiated by surveyors. The surveyors' "white birch" and "birch" could possibly have been the current-day paper birch (*Betula papyrifera*), which may occur as a single-stemmed tree (Lackschewitz, 1991). However, water or river birch (*B. occidentalis*), a multi-stemmed shrub, is known in western Montana riparian zones. The surveyors' "birch" may also have been an alder species (*Alnus* sp.). In subsequent discussion and tables, larch and tamarack are combined into the larch tree type. Aspen and quaking aspen are combined as aspen; fir and red fir are combined into fir; white birch and birch are combined into birch; and white pine, black pine and pine are combined into the pine type. Because of the ambiguous naming relationships, mapping true species using only GLO information was not possible.

Table 8. Bearing and Line Trees Recorded by Surveyors.

Surveyors' Species Name	**Contemporary Common Name Equivalents**	**Probable Scientific Name(s)**	**Fre-quency**	**Diam. Range (in.)**	**Mean Diam. (in.)**
alder	alder	*Alnus incana*	2	3-5	4
aspen	quaking aspen	*Populus tremuloides*	30	3-12	7
birch	river or water birch, paper birch, alder	*Betula occidentalis, B. papyrifera, Alder* sp.	5	3- 9	5
black pine	lodgepole pine	*Pinus contorta var. latifolia*	3	6-12	10
cottonwood	black cottonwood	*Populus trichocarpa*	46	3- 32	13
fir	Douglas fir, subalpine fir, grand fir	*Pseudotsuga menziesii, Abies lasiocarpa, A. grandis*	113	4-36	13
hemlock	mountain hemlock	*Tsuga mertensiana*	1	12	12
larch	western larch, tamarack, alpine larch	*Larix occidentalis, L. lyallii*	5	10-36	17
pine	ponderosa pine, lodgepole pine, western white pine, whitebark pine	*Pinus ponderosa, P. contorta* ssp. *latifolia, P. monticola, P. albicaulis*	640	3-48	18
quaking aspen	quaking aspen	*Populus tremuloides*	5	6-10	8
red fir	Douglas fir	*Pseudotsuga menziesii*	6	6-22	14
spruce	engelmann spruce	*Picea engelmannii*	7	4-14	10
tamarack	western larch, tamarack, alpine larch	*Larix occidentalis, L. lyallii*	14	4-24	14
white birch	paper birch	*Betula papyrifera*	1	5	5
white pine	western white pine	*Pinus monticola*	2	8-13	11
		Total	**880**		

Tree Distribution

Distribution of bearing trees and trees documented along the section lines between corners is shown in Figure 10. The ArcGIS 10 Disperse Markers tool was used to enable all tree points to be illustrated. Thus mapped points are cartographic

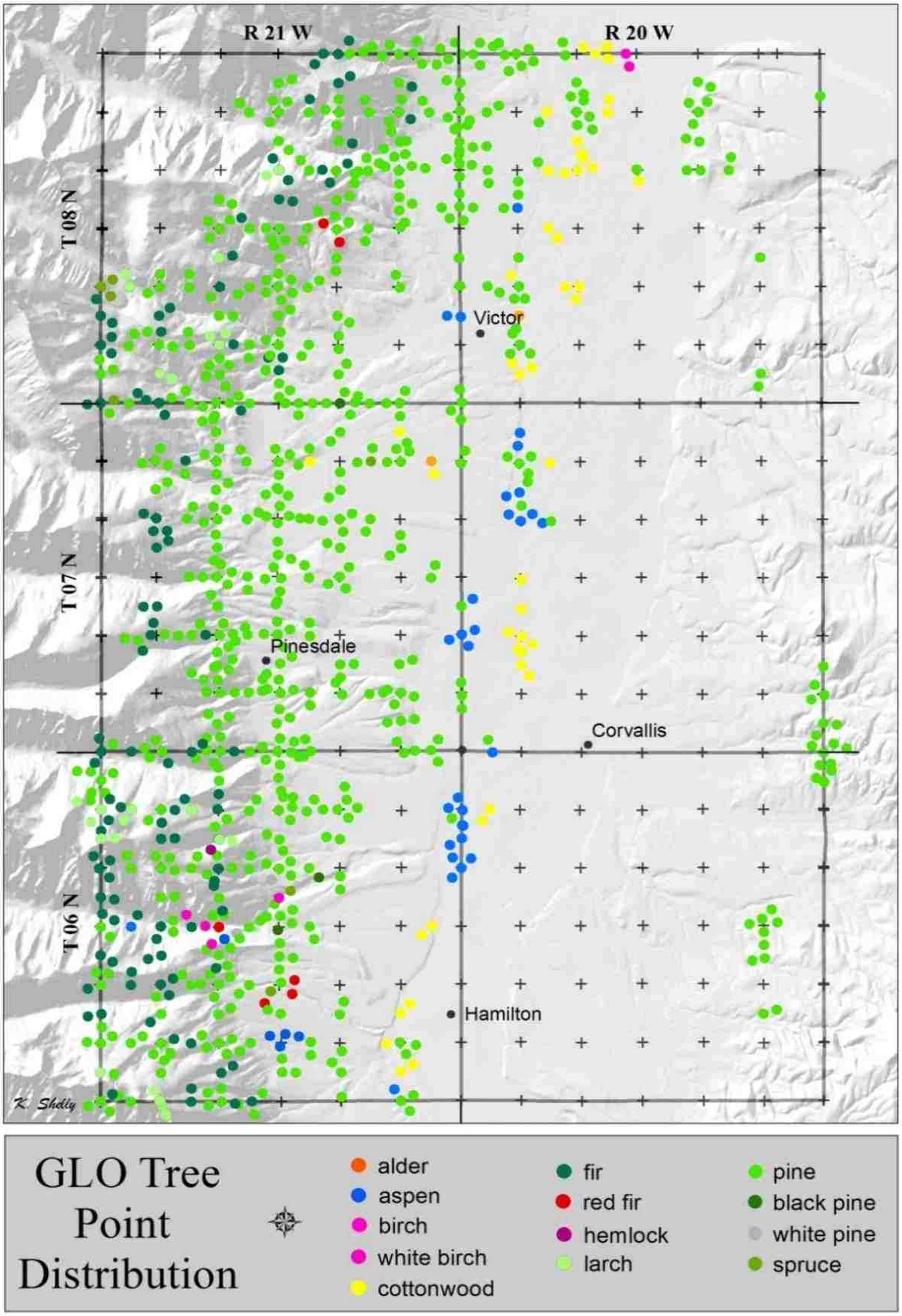
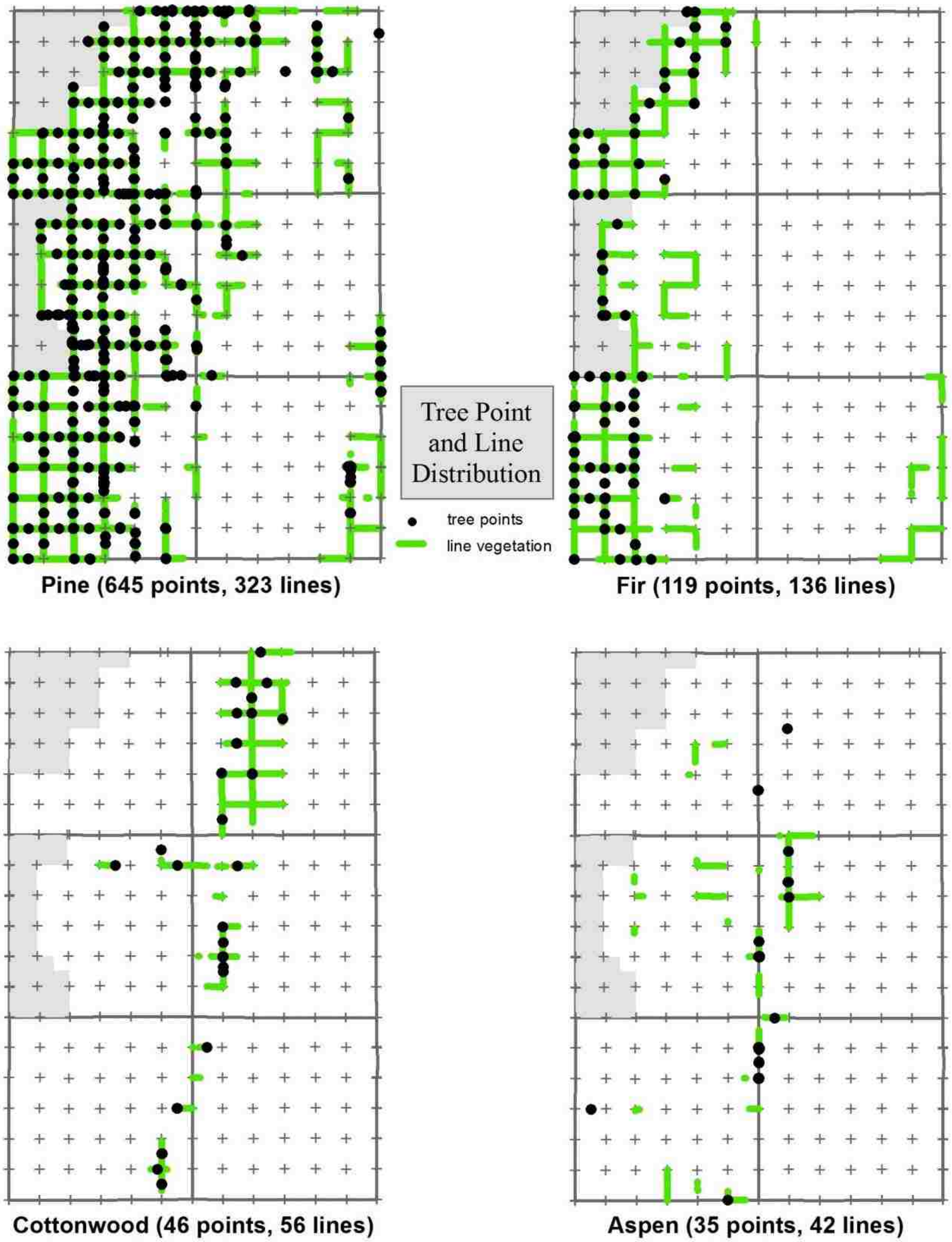


Figure 10. Point Distribution of Bearing and Line Trees.

representations, not actual locations. Eight hundred and eighty trees were recorded in the western mountainous region, along the Bitterroot River riparian area, and scattered on the eastern hills. The ubiquitous pine occurred from the highest western slopes down the high mountain drainages. It frequented the western foothills, grew along ravines and extended down into the valley and dispersed across the floodplain with deciduous trees, following winding river channels. The locations of fir were more limited, mainly in the mountains but occasionally mapped in the lower western foothills. Larch and spruce were recorded in lesser numbers mainly in the upper mountainous reaches. Cottonwood and aspen were occasionally mixed with pine along the river and some lower foothill drainages. Birch, alder and hemlock were rarely designated bearing trees and were uncommonly found along section lines.

Bearing and line tree point locations were mapped with vegetation line description tree locations to determine landscape position consistencies and differences as described by surveyors. Illustration of the line locations in addition to tree points gives a more complete representation of tree distribution (Figures 11 and 12). The GLO distribution of pine broadened when pine points were viewed with the pine lines. Several lines show pine where no bearing tree was mapped, especially in the eastern hills and in several riparian locations. Fir distribution expanded to include the east and west sides of the Bitterroot River when lines were viewed with point locations. Point and line locations for cottonwood were nearly concurrent. Aspen distribution was expanded into the western valley and foothills when lines were added to tree points. Larch point and line distribution was very similar, although more lines than points were recorded. Line and point distribution in spruce, birch and alder were not concurrent; viewing both datasets thus provided a larger range of occurrence than the tree point data alone.



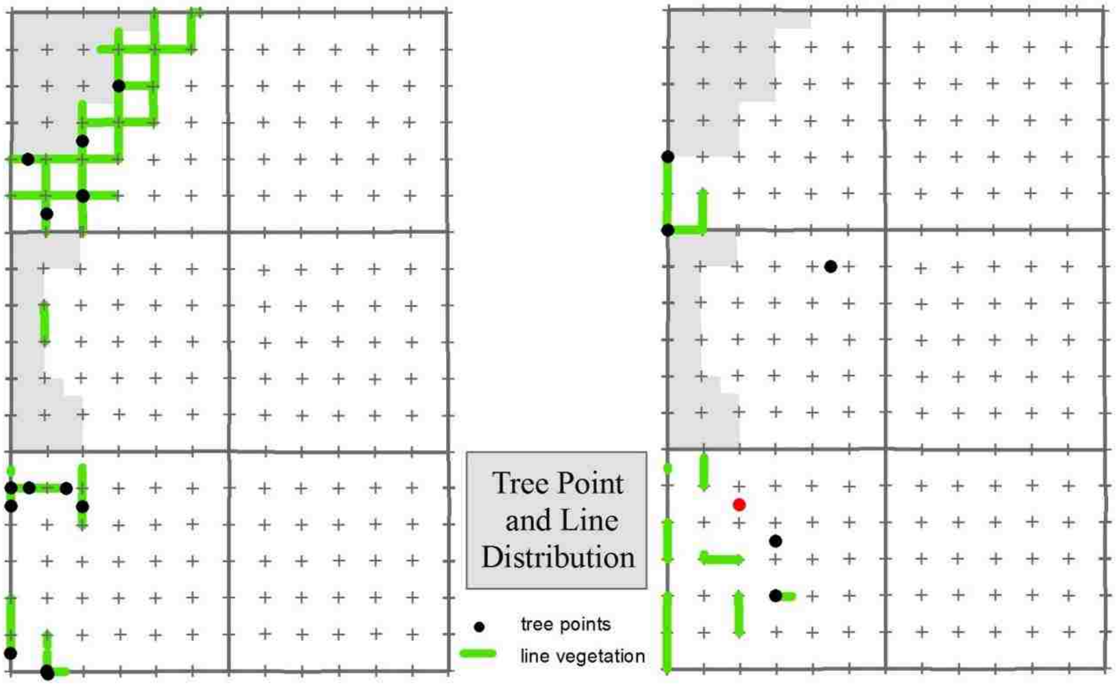
Pine (645 points, 323 lines)

Fir (119 points, 136 lines)

Cottonwood (46 points, 56 lines)

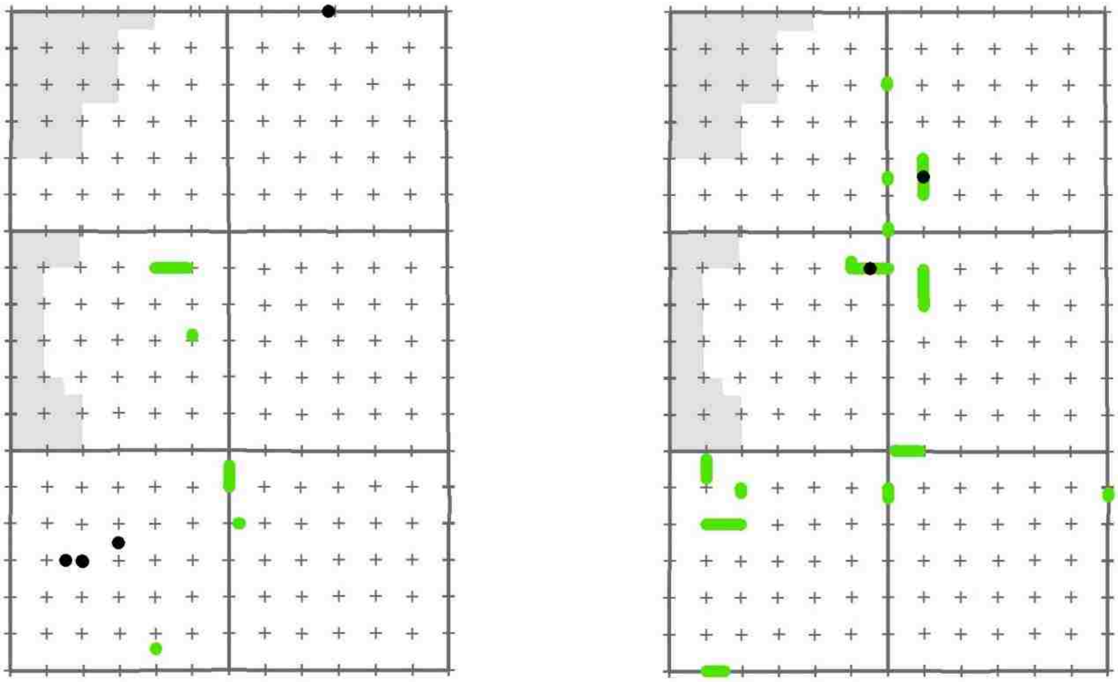
Aspen (35 points, 42 lines)

Figure 11. Pine, Fir, Cottonwood, and Aspen Bearing Tree Point and Line Tree Distributions.



Larch (19 points, 51 lines)

Spruce (7 points, 15 lines)
Hemlock (1 point [red], 0 lines)



Birch (6 points, 6 lines)

Alder (2 points, 15 lines)

Figure 12. Larch, Spruce, Hemlock, Birch, and Alder Bearing Tree Point and Line Tree Distributions.

Cultural, Aquatic and Topographic Information

Euro-American settlement of the Bitterroot Valley started in the 1840s and Indian presence was well established long before the survey began. A U.S. Department of Interior 1889 Indian and settlers' lands map shows several 40-acre Indian tracts in T08N R21W, T07N R21W, T07N R20W and T06N R20W of the study area (Carrington, 1889). Numerous aspects of settlement were documented by the survey, however no mention was made of Indian inhabitants or their constructs. Surveyors described the village of Corvallis, roads to Stevensville and Fort Owen, rural cabins, houses, graves, mines and mills that occupied the landscape. Township descriptions reported at least 300 settlers in the valley in 1872 (Appendix VI). Settlers' surnames, taken from house, mill and mine descriptions in the field notes, included Barthol, Bradford, Catlin, Cleary, Daly, Downey, Elliot, Fulkeson, Griggs, Hiesley, Humble, Johnson, Kern, Mittoner, McVeugh, Neder, Nicols, Richardson, Rickman, Silverthorn and Smith. Human influence cannot be readily determined within the interiors of sections, but the extent of cultural evidence along section lines was frequent enough to indicate a perceptible impact on the natural landscape at the earliest survey date of 1870. Fences, ditches, roads and structures are the majority of 389 objects of settlement summarized in Table 9 and mapped in Figure 13. Fences (145 total, 37.3 %) and irrigation ditches (112, 28.8 %) together accounted for 66.1 percent of all the cultural features and individually were more numerous than road crossings (92, 23.7 %) in this landscape sample. This evidence of agriculture suggests a very tangible human impact on the structure and composition of the valley vegetation and the quality of aquatic resources at this time in settlement history. A study focused only on the vegetation of the GLO may not have provided that awareness.

Table 9. Cultural Features Frequency of Occurrence.

Cultural Features	Frequency	Percent
fence	145	37.3
ditch	112	28.8
road, trail	92	23.7
house, cabin, barn, or stable	24	6.2
sawmill	4	1.0
flume	3	0.8
telephone line	3	0.8
mill	2	0.5
corral	1	0.3
mine shaft	1	0.3
ranger station	1	0.3
town of Corvallis	1	0.3
TOTAL	389	100

Dry creek beds, creeks, rivers and sloughs accounted for most of the 521 aquatic features (Figure 13 and Table 10). Dry creek beds were the most abundant feature encountered, possibly because the majority of the surveys were completed in late July and August and water originating from snowmelt no longer occupied those drainages. The Bitterroot River and its channels were walked across in nearly all instances of the survey. Surveyors recorded “Water low, chained across” frequently when crossing the main branch and channels. Phrases such as “to avoid big bend in river, offset east 5 chains, north 19.7 chains, west 5 chains” were recorded in only a few instances. Distances across sloughs, streams and river channels were recorded when documented by surveyors. River widths ranged from 50 to 350 links (10 to 70 meters). Sloughs in various stages of succession probably held various types of wetland vegetation, but for this study

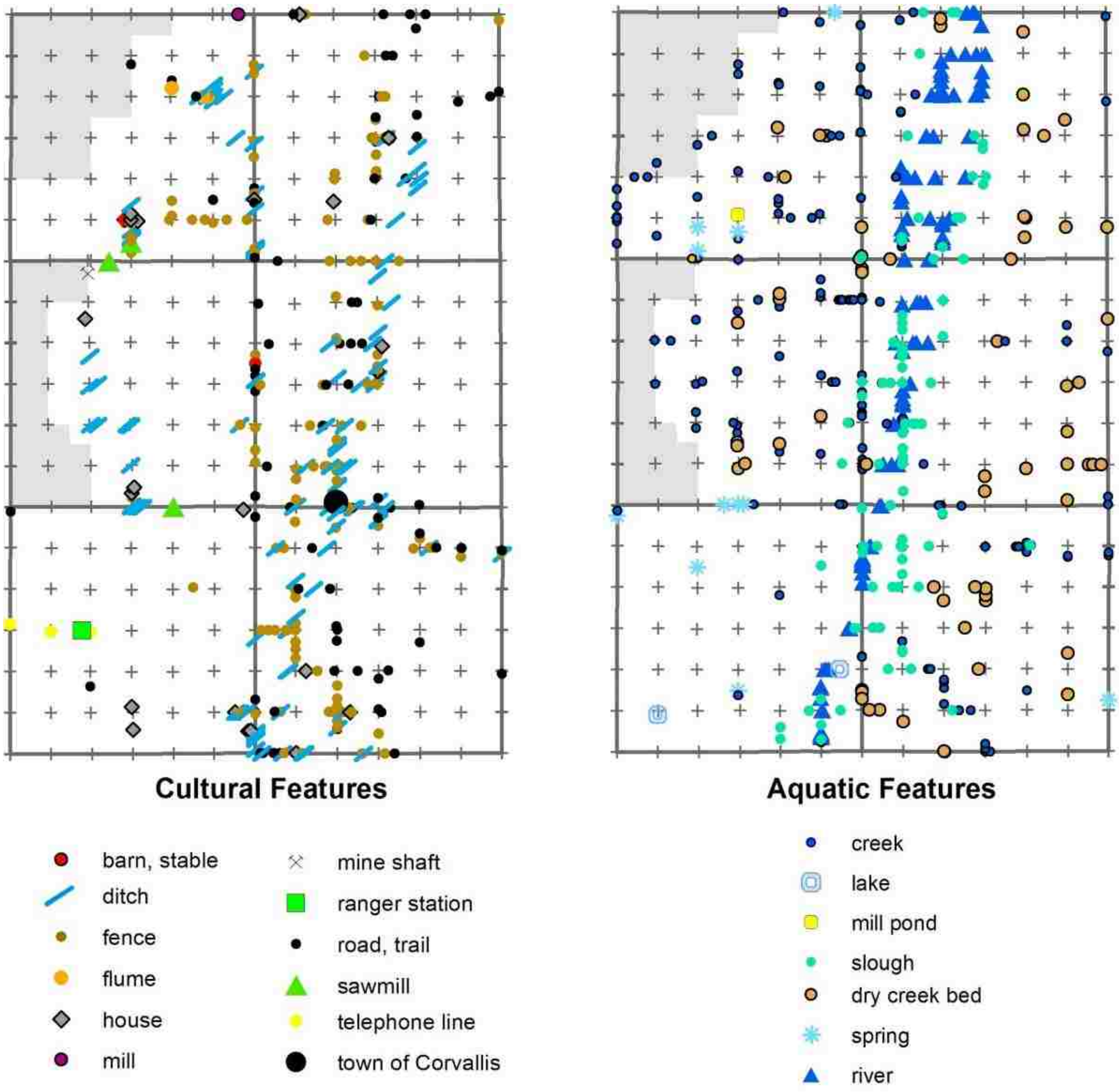


Figure 13. GLO Cultural and Aquatic Points.

were categorized simply as “sloughs,” as the surveyors described them. Sloughs ranged from 5 to 750 links (1 to 151 meters) wide.

Topographic data were collected for five of the six townships (Table 11). T06N R21W, in the southwest corner of the study area, was mostly excluded due to lack of time. Surveyors described 24 different topographic elements as points along section lines. Ravines by far were the most commonly encountered topographic description

Table 10. Aquatic Features Frequency of Occurrence.

Aquatic Features	Frequency	Percent
dry creek bed	164	31.5
creek	153	29.4
river	99	19.0
slough	91	17.5
spring	11	2.1
lake	2	0.4
mill pond	1	0.2
TOTAL	521	100

Table 11. Topographic Features Frequency of Occurrence.

Topographic Features	Frequency	Percent
ravine	119	46.5
creek bottom	32	12.5
hill	15	5.9
bottom	12	4.7
gulch	12	4.7
bluff	10	3.9
ridge	8	3.1
river bottom	8	3.1
cliff	7	2.7
rolling ground	7	2.7
bench	4	1.6
granite boulders	3	1.2
mountain	3	1.2
valley	3	1.2
butte	2	0.8
level ground	2	0.8
table land	2	0.8
other (one record each of bank, canyon, draw, granite ledge, rise, rocky, rocky spur)	7	2.7
TOTAL	256	100

(119 occurrences, 46.5 % of total) followed by creek bottom (32 occurrences, 12.5 %). Creek bottom (32 occurrences), river bottom (8) and bottom (12) were separate bottomland descriptors accounting for 20.3 percent of all topographic features.

Vegetation Lines

The line mapping effort was an important accomplishment of the study as it provided two levels of surveyor-defined vegetation information: 1.) broad vegetation structure classes called Major Vegetation Types; and 2.) the more specific vegetation (tree, brush, open lands) composition class called Tree Associations/Land Classes. Ten overall categories, which include eighteen Major Vegetation Types were identified along 422.3 miles of section line in the Bitterroot Valley study area (Figure 14). From areas of greatest to least extent, the categories include: 1.) Prairie-No Timber; 2.) Upland Timber (includes nine timber types); 3.) Bottomland Timber; 4.) Brush; 5.) Cliff/Bluff; 6.) Field; 7.) Gravel Bar; 8.) Meadow; 9.) Swampy; and 10.) Water. Nine upland timber major types described were: Timber, Heavy, Scattering, Open, Open- Heavy, Dense, Dead, Cut, and Burned. The abundance of major types was summarized by mileage and percentage of total line distance (Table 12). Ninety percent of the surveyed lines were defined by five of the eighteen Major Vegetation Types. The most abundant occurrences included Prairie-No Timber with 192.9 miles, Timber with 72.3 miles, Heavy Timber with 52.7 miles, Scattering Timber with 33 miles and Timber-Bottom with 30.5 miles. The Prairie-No Timber type encompassed level and undulating valley bottoms, benches and rolling hills in the eastern portion of the area and occurred less frequently in the western foothills. Timber was found throughout the western foothills, reaching up into the mountains, and descending and intermixing with Brush and Prairie en route to the

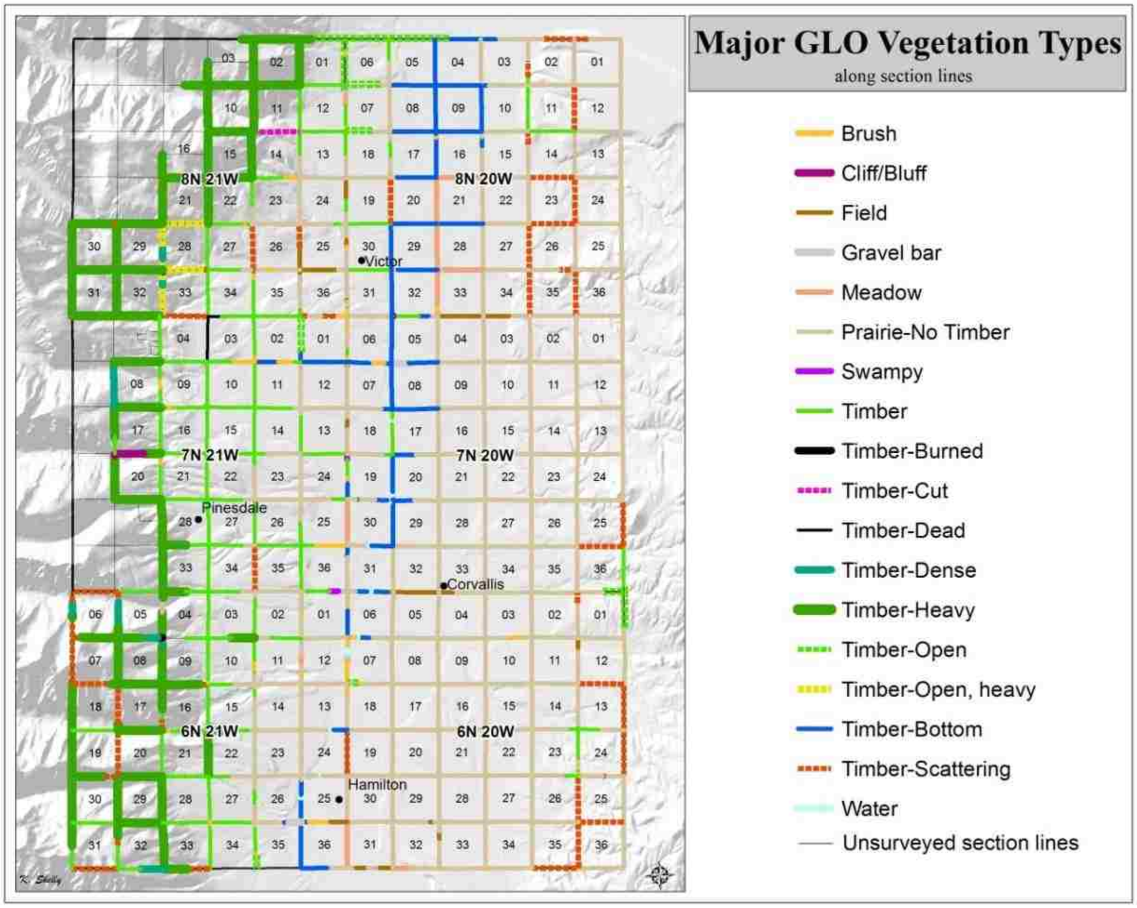


Figure 14. Major Vegetation Types along Section Lines (1870-1924).

Bitterroot River. Descriptions of Timber were mixed with Timber-Bottom along the river and rarely reached the eastern hills. Heavy Timber was described in the mountainous western reaches of the survey extent, infrequently following drainages eastward to lower elevations. Scattering Timber was distributed irregularly in the eastern hills in the most dissected areas. It also occurred on rocky, steep mountainous slopes in the southwest region and infrequently reached from the western foothills toward valley openings. The lower valley was quite varied, holding mostly Timber-Bottom and Prairie-No Timber types with interspersed Brush and Meadow. A very small number of wetlands termed Swampy areas (Sloughs were recorded only as points so were not used in the line mapping process) contributed to the valley floor vegetation diversity. Very low

Table 12. Surveyors' Major Vegetation Types from Section Line Descriptions.

Major Vegetation Type		No. Lines	Miles	% Upland Timber Miles	% Total Miles
Prairie_No Timber		282	192.9		45.7
Timber Upland Combined		353	175.4		41.4
	Timber	135	72.3	17.1	
	Timber_Heavy	72	52.7	12.5	
	Timber_Scattering	52	33.0	7.8	
	Timber_Open	15	8.2	1.9	
	Timber_Open, Heavy	6	3.4	0.8	
	Timber_Dense	9	3.2	0.8	
	Timber_Dead	3	1.3	0.3	
	Timber_Cut	1	1.1	0.2	
	Timber_Burned	3	0.2	0.0	
Timber_Bottom		58	30.5		7.2
Brush		50	7.5		1.8
Field		20	6.6		1.6
Meadow		17	7.2		1.7
Water		13	0.4		0.1
Gravel bar		11	0.8		0.2
Cliff/Bluff		3	0.7		0.2
Swampy		2	0.3		0.1
Total Miles			**422.3**		**100.0**

occurrences of disturbed land were recorded in the Field, Cut Timber, Burned Timber and Dead Timber categories.

Approximately 37 miles were not surveyed due to extreme mountainous terrain—including 22 miles of section line in northwestern Township 08N R21W and 15 miles in western T07N R21W. Additionally, data for two miles on the southern border of T06N R21W were not located.

Vegetation composition along section lines was recorded as Tree Associations/ Land Classes (Figure 15). Thirteen Tree Associations, and ten non-forested Land Classes that correspond to the Major Vegetation Types, were mapped. Land Classes could not be defined with further specificity since non-woody vegetation was not described more fully

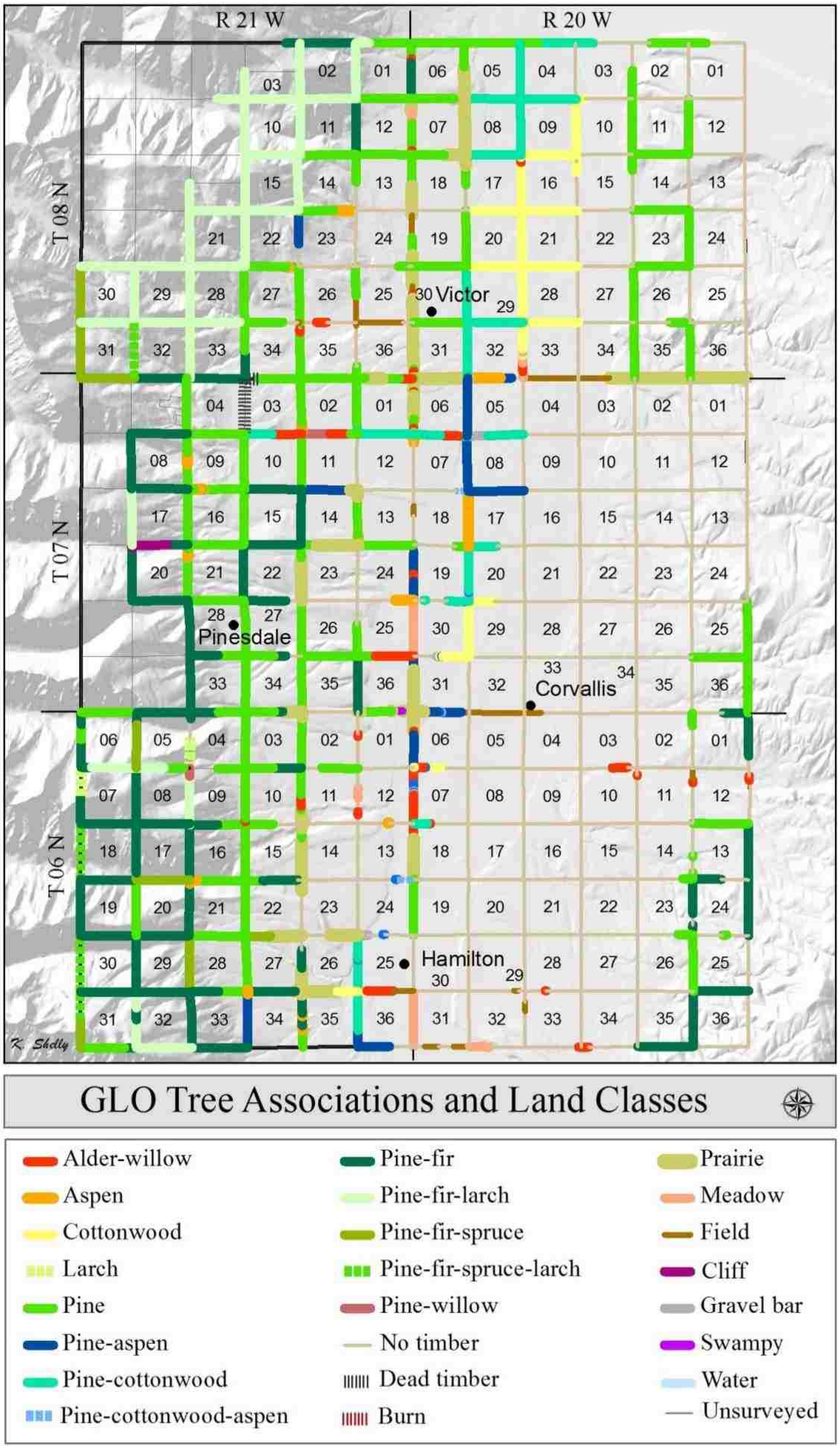


Figure 15. GLO Tree Associations/Land Classes.

by surveyors. Tree Association/Land Class mileage and percent of total miles are listed by frequency of line occurrence in Table 13. Organization by frequency of lines instead of by mileage recognizes inherently smaller patch-like associations that were occasionally more abundant in the study area than larger homogeneous associations with higher mileage. In the study area, class abundance by mileage mostly mimicked class frequency of occurrence, with the exceptions of Alder-willow and Aspen which occurred at generally higher frequencies and lesser mileage when compared to other forest types.

Table 13. Tree Associations/Land Classes from Section Line Descriptions.

Tree Associations/Land Classes		**No. Lines**	**Total Miles**	**% Total Miles**
No Timber		237	175.8	41.6
Timber – Upland and Bottomland				
	Pine	138	79.4	18.8
	Pine-fir	75	49.0	11.6
	Pine-fir-larch	46	28.4	6.7
	Alder-willow	35	6.0	1.4
	Cottonwood	28	13.4	3.2
	Pine-cottonwood	26	15.5	3.7
	Aspen	21	3.4	0.8
	Pine-aspen	16	8.7	2.1
	Pine-fir-spruce	12	6.8	1.6
	Pine-fir-spruce-larch	5	3.6	0.9
	Dead timber	3	1.3	0.3
	Larch	2	1.1	0.3
	Pine-willow	2	0.6	0.2
	Pine-cottonwood-aspen	2	0.5	0.1
Prairie		46	17.1	4.1
Field		20	6.6	1.6
Water		13	0.4	0.1
Gravel bar		10	0.6	0.1
Meadow		9	2.9	0.7
Cliff		2	0.7	0.2
Swampy		2	0.3	0.1
Burn		1	0.1	0.0
		Total Line Miles/Percent	**422.3**	**100.0**

The No Timber class, with 237 line occurrences (41.6 %), and Prairie with far fewer occurrences (46, 4.1 %), were recognized as separate categories at this finer classification level. One may only speculate that lines described as No Timber by the surveyors were analogous to areas labeled Prairie or areas that were formerly Prairie before agricultural conversion. These areas may have contained sagebrush or other undescribed shrubs, or were grassy openings in a forest or perhaps were burned, barren, steep or rocky areas incapable of supporting vegetation. It is only definitive that timber was not present.

The three most abundant tree associations, Pine (18%), Pine-fir (11.6%), and Pine-fir-larch (6.7%), account for 37.1 percent of the total miles, and along with No Timber (41.6%) and Prairie (4.1%), account for 82.8 percent of the vegetation along section lines. All other Tree Associations/Land Classes individually comprised less than 4 percent of the total mileage of section lines.

Tree Associations/Land Classes were summarized by Major Vegetation Type in Table 14. Pine, the most common class, comprised 79.4 miles of line, and occurred in most of the timbered Major Vegetation Types: Timber (11.6 % of Tree Associations/ Land Classes total), Scattering Timber (5.0 %), Open Timber (1.4 %), Heavy Timber (0.4 %) and Dense Timber (0.2 %). Pine was described in line descriptions widely across the western mountains and foothills. It occurred with cottonwood and aspen in the riparian zones and grew on the eastern benches and the high rolling hills on the east side of the valley.

The Pine-fir class occupied 49 miles of line in Heavy Timber (4.6 %), Timber (3.7 %), Scattering Timber (2.6 %), Open Timber (0.5 %) and Dense Timber (0.3 %).

Pine-fir coexisted with Pine in the southeast hills and occupied higher positions in the landscape on the western slopes, extending to subalpine elevations at the western edge of T06N R21W. The variable locations documented for this type promotes speculation that more than one species of fir and/or pine were most likely present though not indicated by the surveyors' general naming convention.

Pine-fir-larch, the third most abundant Tree Association Class, covered 28.4 miles. Pine-fir-larch was the most abundant class in Heavy Timber (5.3 %), and occurred as very small percentages of the total in other Major Types: Open Timber (0.8 %), Timber (0.3 %), Dense Timber (0.2 %), and Scattering Timber (0.1 %). Pine-fir-larch occurred along the western mountainous reaches, and was described extensively along the western edge of the surveyed area in T08N R21W. All individual timbered Tree Associations/Land Classes were surpassed by the cover of the No Timber class.

Table 14. Tree Associations/Land Classes by Major Vegetation Type.

Major Vegetation Type	Tree Association/Land Classes	TrAs/LC Percent	Major Type Percent
Prairie-No Timber			**45.7**
	No Timber	41.6	
	Prairie	4.1	
Upland Timber			**41.5**
Timber			17.1
	Pine	11.6	
	Pine, fir	3.7	
	Pine, aspen	0.7	
	Aspen	0.5	
	Pine, fir, larch	0.3	
	Pine, fir, spruce	0.2	
	Pine, cottonwood	0.1	
Heavy Timber			12.6
	Pine, fir, larch	5.3	
	Pine, fir	4.6	
	Pine, fir, spruce	1.3	
	Pine, fir, spruce, larch	0.9	

Major Vegetation Type	Tree Association/Land Classes	TrAs/LC Percent	Major Type Percent
	Pine	0.4	
	Larch	0.1	
Scattering Timber			7.8
	Pine	5.0	
	Pine, fir	2.6	
	Larch	0.1	
	Pine, fir, larch	0.1	
Open Timber (includes Open, Heavy)			2.8
	Pine	1.4	
	Pine, fir, larch	0.8	
	Pine, fir	0.5	
	Pine, cottonwood	0.1	
Dense Timber			0.8
	Pine, fir	0.3	
	Pine, fir, larch	0.2	
	Pine	0.2	
	Pine, fir, spruce	0.1	
	Pine, willow	0.0	
Dead Timber			0.3
Cut Timber			0.3
Burned Timber			0.04
Bottomland Timber			**7.2**
	Pine, cottonwood	3.5	
	Cottonwood	2.1	
	Pine, aspen	1.4	
	Pine, cottonwood, aspen	0.1	
	Pine, willow	0.1	
Brush			**1.8**
	Alder, willow	1.4	
	Aspen	0.3	
Meadow			**1.7**
	Cottonwood meadow	1.0	
	Meadow	0.7	
Field	Field		**1.6**
Gravel Bar	Gravel Bar		**0.2**
Cliff/Bluff	Cliff/Bluff		**0.2**
Swampy	Swampy		**0.1**
Water	Water		**0.1**

In summary, the GLO portrayal of section line vegetation documents that the landscape contained extensive open non-timbered and prairie areas in the valley and adjacent eastern foothills. These openings probably fingered westward into scattering and closed pine lands. Surveyors described the forest with similar tree composition to current conditions. Mixed conifer forests replaced pine timber as elevation increased and steep mountains emerged. Timber was rarely described with undergrowth. Occasionally, patchy brush areas followed drainages from the valley up through the western hills. Riparian forests of cottonwood, pine and aspen, again with no undergrowth, followed the river and intermingled with open prairie, meadows and very rare accounts of wetland communities. Line descriptions did not allow differentiation between different prairie types, except for the few references to meadow. Also since there was no distinction between multiple species of pine, fir and larch potentially occurring in the study area, definite species associations could not be described along lines or extended into section interiors.

GLO Line Evaluation using the 1902 Historic Timber Density Map

The 1902 United States Geological Survey (USGS) Bitterroot Valley Land Classification and Density of Standing Timber Map (Gannett and Goode, 1902) provided the opportunity to check the GLO vegetation lines against another historic data source, to confirm general GLO legitimacy. The map, delineating grazing and cultivable land, woodland, barren land and cut, burned and merchantable timber, was visually compared to GLO Major Vegetation Types (Figure 16). Tree associations could not be compared because the 1902 map did not record tree type. As expected, one-to-one relationships did not exist between data layers. Multiple GLO classes occurred across multiple, noncorresponding 1902 land classifications. The type of detail provided in GLO vegetation structure classes did not correspond to the detail in timber harvest and land classes. However, by visually comparing the Major Vegetation Types to the 1902 Land and Timber Map, it was recognized that at least forested and open land locations generally coincided. The Prairie_No Timber class corresponded to the 1902 non-treed, cultivable and grazed categories. GLO bottomland timber was described in appropriate areas along the USGS-mapped Bitterroot River, but the 1902 map lacked the bottomland timber category. In some cases the 1902 grazing land on the western foothills corresponded to

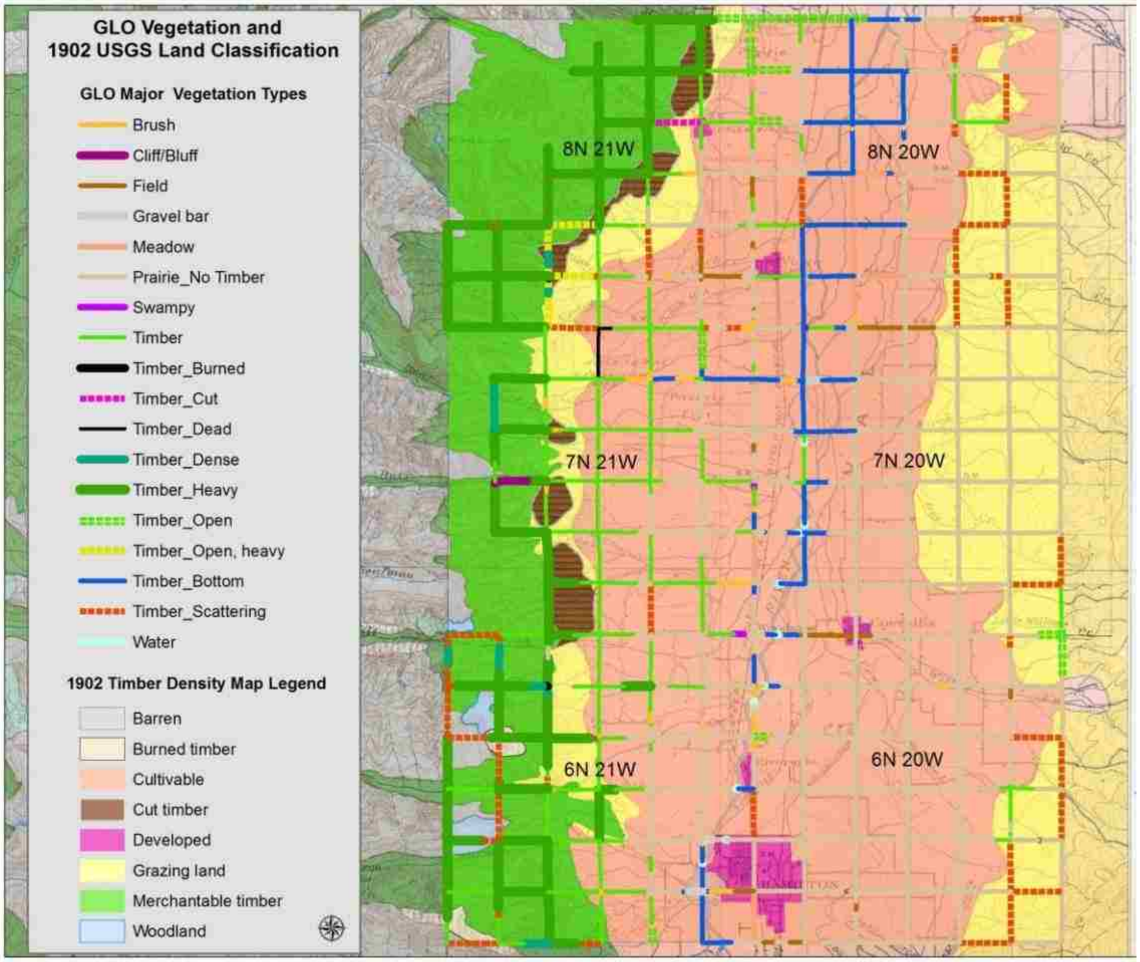


Figure 16. GLO and 1902 USGS Land Classification and Timber Density Comparison (Gannett and Goode, 1902).

various timber classes in the GLO interpretation. However those land descriptions are not mutually exclusive, as timbered land with an open, grassy ground flora would have been suitable for grazing. Some GLO timber classes overlaid 1902 cultivable lands. Again, the two categories could coexist—timbered land could certainly have been cultivated after timber was harvested and converted to cropland, if soils and slope were suitable. Harvested and burned areas were mapped in both instances. Harvested timber appeared to be more abundant on the 1902 map, and in different locations than in the GLO representation. Portions of the 1902 USGS harvested areas were surveyed in 1893 while other 1902 harvested areas were not surveyed until 1912. Like the harvested timber, burned areas appeared in different locales in each mapping, even though evidence of the burned areas from the earlier mapping may have been present for the later mapping efforts. Beyond these inconsistencies, indication of more extensive inaccuracies or surveyor fraud was not discovered by this evaluation, and the GLO data was considered generally acceptable and un-falsified. The 1902 classification was also cursorily compared with T06N R21W Major Vegetation Types for general agreement in overall vegetation boundaries, and finding similar results, further examination was not pursued (Appendix IX).

Major Vegetation Types of T06N R21W

Vegetation boundaries for section interiors were estimated for T06N R21W (Figure 17). Vegetation polygons were subjectively interpolated and classified by Major Vegetation Type line descriptions following the procedures described on pages 43-44. Soils and elevation data and NAIP imagery supported boundary determination. The

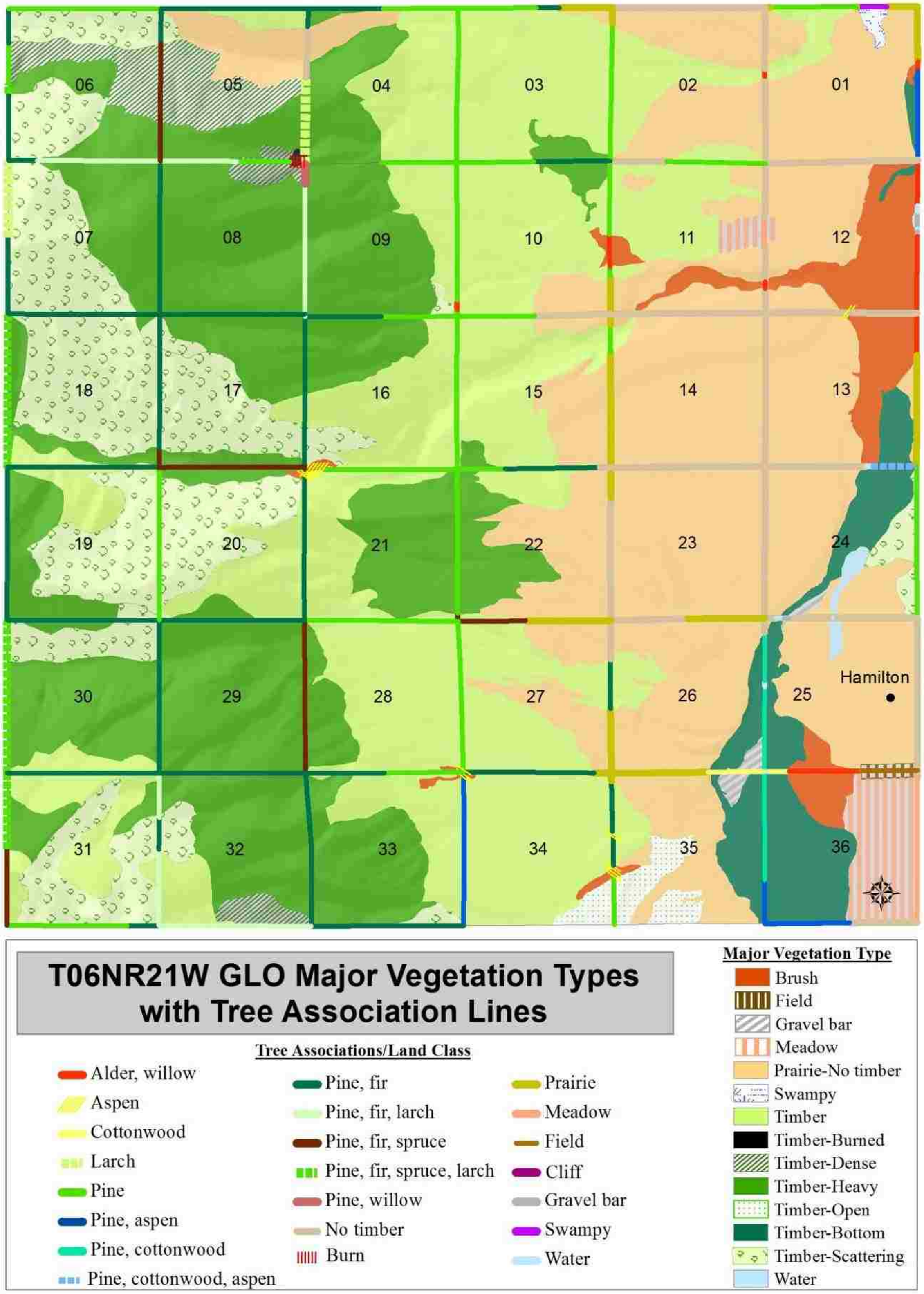


Figure 17. Major Vegetation Types in T06N R21W with Tree Associations/Land Classes Lines.

Major Vegetation Type polygon boundaries estimate the overall vegetation structure of section interiors. By overlaying the Tree Associations/Land Classes along section lines on the Major Vegetation Type polygons, structure can be visualized jointly with tree types and non-treed land class descriptions.

Situated on the western tier of townships with mountainous terrain covering nearly half of its area, according to the GLO polygon estimation the township was two-thirds timbered. Upland Timber covered 23.5 square miles or 65.2 percent of the township (Table 15). Three types—Timber, Heavy Timber and Scattering Timber accounted for 96 percent of the total Upland Timber. Dense, Open and Burned Timber occurred over small areas. Prairie-No Timber extended over 26.2 percent of the township area. It occupied the lower elevation eastern foothills and was also represented on the valley floor mixed with Meadow and a few small Fields. Bottomland Timber, accounting

Table 15. Major Vegetation Types in T06N R21W.

Major Vegetation Types		**Sq. Miles Upland Timber**	**Sq. Miles**	**% Total Area**
Upland Timber			23.5	65.2
	Timber (26.4%)	9.5		
	Timber-Heavy (23.9%)	8.6		
	Timber-Scattering (12.2%)	4.4		
	Timber-Dense (2.0%)	0.7		
	Timber-Open (0.7%)	0.3		
	Timber-Burned (0.0%)	0.0		
Prairie_No Timber			9.4	26.2
Timber_Bottom (3.6%), Gravel Bar (0.2%)			1.4	3.8
Brush			1.1	3.0
Meadow			0.5	1.4
Water			0.1	0.2
Field			0.0	0.1
Swampy			0.0	0.1
Total			**36**	**100**

for 3.8 percent of the township's cover, occurred with open Gravel Bars along the river and intermixed with Brush, Prairie and areas described as "Swampy."

Township General Descriptions

Township general descriptions were written by surveyors at the end of the field notes for each contract, whether the contract was for delineating an exterior township boundary or an interior subdivision. Descriptions varied in length and detail, and sometimes provided information not available elsewhere in the field notes. Summaries of all descriptions illustrate the variety of information provided by all surveyors of each township (Table 16). In the lower valley, a growing population of at least 300 settlers

Table 16. Summary of General Descriptions of all Townships.

TOWNSHIP	SURVEYORS	VEGETATION/LAND SUMMARY	DATES
T08NR20W	Walter W. Johnson, Henry C. Rohleder, George Irvine	Large, well cultivated, highly improved farms. luxuriant crops of grain and vegetables. many improved ranches, several ranches on Fred Burr and Dry Creeks. One of the finest agricultural districts in the Territory of Montana. The village of Stevensville contains about 20 houses. There are some 10 farms already settled. 300 whites. Pine and pine/cottonwood timber on the river. Bitter Root river average width 300 links. Timber is abundant on river, and on Sweathouse and Lower Big Creek. Island in river. Finest body of meadow land in the valley. Numerous streams, tableland, bottom and high rolling prairie, prairie terminating in the foot hills. Probably more than eight hundred at the present time and is rapidly increasing. Sagebrush country. Growth of rich bunch grass, unsurpassed by any in the valley for grazing purposes. The lands are agricultural.	1870, 1872
T08NR21W	Henry C. Roleder, Charles Mead, R. Scott, H. Lord	Splendid farming land a portion of which is already occupied. Bottoms and uplands comprise an agricultural district, the garden spot of the valley. Splendid crops of grain and vegetables. Foot hills are covered with a luxuriant growth of rich bunch grasses unsurpassed by any in the valley for grazing purposes. The lands are agricultural. Timber is abundant. Western tiers: Very rough and mostly worthless. It has been nearly stripped of its valuable timber. Sweathouse Creek runs through the township and affords water for irrigating the valley and bench lands below. Many indications of mineral bearing quartz lodes. Mountainous and covered with a heavy growth of fir and pine timber of	1872, 1891, 1902, 1912

TOWNSHIP	SURVEYORS	VEGETATION/LAND SUMMARY	DATES
T08 NR21W (Cont.)		good quality. Abundant growth of pine, fir and some tamarack. Bench land, mostly covered with timber and undergrowth. Fair growth of pine, fir and spruce very rocky. Very high and rugged mountain. No timber of marketable value. Fair growth of heavy timber, high rugged and practically impassable mountains. Slopes covered with small scrubby timber of inferior quality of no market value.	
T07NR20W	Henry Rohleder, George Irvine	Most excellent land, well settled. The village of Corvallis, in Section 32 of this township consisting of two stores, a blacksmith shop, post office and a number of neat dwellings. Numerous fine ranches in excellent condition in the township. The lands are agricultural. Bottom land gradually rising into bench and table land and high rolling prairie. Timber is found along the Bitter Root River.	1872
T07NR21W	Henry Rohleder, George Irvine, Charles Mead, W.Klingberg, Willgott	Some excellent farming land. Chiefly high rolling prairie terminating in the west foot hills, a portion on the east is river bottom, well watered by the various creeks which run through the township. Timber is abundant, several ranches on Fred Burr and Dry Creek. There are about 5 settlers in this township (1893). Western Tier: Well timbered, much of it has been cut off. Well watered by Fred Burr and Bear Creeks and by small streams. Very rough and mountainous land. Rocky. Timber pine and fir 1st quality valuable for saw timber. West boundary very high and rugged mountains. Rough and broken land. No indications of valuable mineral deposits. Timber of 1st quality, pine, fir, and tamarac, suitable for saw timber. Several springs and small creeks, especially the Fred Burr Creek.	1872, 1891, 1893
T06NR20W	Henry Rohleder, George Irvine, Paul A. Bickel	Considerable amount of excellent farming land. Well settled. Level prairie, with bottom land near the Bitter Root River, on Girds and Willow Creeks. On the east it is shut in by the Rock Creek range of mountains. Along the streams the land for agricultural purposes is unsurpassed. The bank of the Bitter Root is well wooded. Also an abundant supply of wood for fuel on the eastern border of the township. Many well cultivated farms which produce splendid crops of wheat, oats and barley. [east township line survey] The land along this township line is mountainous all the way along the south end. On the south end it is heavily covered with timber. Along Skalkaho Creek there is excellent range for stock and many places blue joint hay grows wild. Marcus Daly has a ranch just East of line in Sec 6 T5NR19W (1894).	1872, 1894
T06NR21W	George Irvine, Charles Mead, Lyman	The greater portion of this township lies west of the Bitter Root River and extends to the foothills of the Bitter Root Range of mountains. The surface of the country is bottom and high bench land, all of which can be well watered by the various streams that run through them. The soil is well adapted to the raising of grain and for meadow and grazing purposes. Timber is abundant and of good quality for building and farming purposes. Thickly covered with pine	1872, 1891, 1924

TOWNSHIP	SURVEYORS	VEGETATION/LAND SUMMARY	DATES
T06NR21W (Cont.)		timber and is well watered by several little streams. Five miles west of Hamilton Montana is rugged mountainous land, draining directly into the valley of the Bitter Root River. Elevation ranges from about 4000 ft. above sea level, where Blodgett and Mill Creeks leave their canyons, to about 8400 ft. on the high divide between Blodgett and Mill Creeks. Very good timber on the lower slopes along the canons, especially in the fifth tier of sections. No agricultural areas are found in the two west tiers. Some high bench land in sections 9 and 16 may be utilized for fruit and grain raising but very stony. The canyons are remarkably scenic on account of the peculiar cliff formations and precipitous walls extending transversely from the main canyon walls, formations are confined largely to the north walls of the canyons.	

is documented in T08N R20W. The numerous accounts of productive farms and ranches portray the area as more developed than the vegetation line descriptions suggest. Timber is described as abundant along the river and several creeks. Quality of the timber is high, and first rate in some areas; but cut, or “stripped” in some mountainous areas in later surveys. Bottom and rolling, table and bench lands, with bunchgrasses and blue joint grass were included in prairie descriptions. Meadow, sagebrush, and excellent range are descriptors of other open lands. High and rugged mountains, quartz lodes, scenic canyons and peculiar cliffs are mentioned. Native American presence was not indicated by surveyors even though historic maps document their presence during this period (Carrington, 1889). Nor was the occurrence of saturated soils and bogs recorded as they were in Leiberg’s accounts (1899). However incomplete, the information supplied by these descriptive summaries, used in combination with the point and line data, provides the most comprehensive landscape picture that can be derived from surveyor information.

GLO and Current Land Cover Section Line Differences

Major Vegetation Types along all section lines of the study area were compared to current land cover along identical lines (Table 17). Differences in percent cover of near-equivalent GLO/current vegetation classes for the six-township area were determined (Methods, pages 53-54). These differences (GLO % - LC %) represent shifts in relative extents of cover classes in the landscape over time. These results are not the same as calculations of percentage change within individual cover classes ([LC % - GLO %] / GLO %), which would show changes over time in specific classes within the overall landscape. Considerable departures from historic to current conditions appear to have occurred in several classes. Decreases in cover along section lines occurred in the two largest GLO classes, Upland Forest and Prairie-No Timber. The largest difference, a 24.2 percent decrease, occurred in the Upland Timber/Forest and Woodland System near-equivalent class. The Prairie-NoTimber/Montane Grasslands class decreased by 11.5 percent. The Field/Cultivated Crops class exhibited the highest increase in cover over time, 16.2 percent, followed by an 8.4 percent increase in the Timber Bottom Gravel Bar/Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland class. Other smaller differences occurred between the remaining classes. Several contemporary land cover classes were not mentioned by GLO surveyors in section line descriptions. These classes with no historic equivalents comprised 12.6 percent of the total current land cover. The Developed class (9.7 percent) accounted for the majority of those land cover classes. Although an equivalent GLO line description was not recorded for settled areas; cabins, houses, mills, and villages could be mapped as buffered points or lines to provide an estimate of GLO "developed" or settled land along section lines.

Table 17. GLO Major Vegetation Types and 2010 Land Cover—Percentages and Differences along Section Lines.

GLO Major Vegetation Type	GLO %	2010 Land Cover (Levels L1 to L3)	LC %	Difference in % (GLO-LC)
Prairie_No Timber	45.7	Montane Grassland-L2	34.2	-11.5
Upland Timber: Timber (17.1%), Timber-Dense (0.8%), Timber-Heavy (12.50%), Timber-Open (1.9%), Timber-Open, Heavy (0.8%) Timber-Scattering (7.8%)	41.2	Forest and Woodland Systems-L1	17.0	-24.2
Timber_Bottom(7.2%), Gravel Bar(0.2%)	7.4	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland-L3	15.8	+8.4
Brush	1.8	Deciduous Shrubland-L2	0.9	-0.9
Meadow	1.7	Pasture/Hay-L3	0.1	-1.6
Field	1.6	Cultivated Crops-L3	17.8	+16.2
Timber-Cut	0.2	Harvested Forest-L2	1.4	+1.2
Cliff	0.2	Rocky Mountain Cliff, Canyon and Massive Bedrock-L3	0.8	+0.6
Water	0.1	Open Water-L3	0.1	0.0
Swampy	0.1	Emergent Marsh-L3	0.0	-0.1
Timber-Burned	0.0	Recently Burned-L2	1.4	+1.4
Not recorded in GLO lines	0.0	Developed-L2	9.7	+9.7
Not recorded in GLO lines	0.0	Alpine-Montane Wet Meadow-L3	0.7	+0.7
Not recorded in GLO lines	0.0	Rocky Mountain Montane-Foothill Deciduous Shrubland-L3	0.5	+0.5
Not recorded in GLO lines	0.0	Rocky Mountain Subalpine Deciduous Shrubland-L3	0.4	+0.4
Not recorded in GLO lines	0.0	Alpine Bedrock and Scree-L3	0.1	+0.1
Not recorded in GLO lines	0.0	Rocky Mountain Subalpine Woodland and Parkland-L3	0.1	+0.1
Not recorded in GLO lines	0.0	Rocky Mountain Subalpine-Montane Mesic Meadow-L3	0.0	0.0

In addition to calculating overall differences in all near-equivalent classes between the two time periods, the percentages of current land cover classes corresponding to the two most abundant GLO classes, Upland Timber and Prairie-No Timber, were determined. By this method, unchanged near-equivalent current land cover as well as converted land was quantified along section lines.

Of lines classified as GLO Prairie-No Timber, 44.9 percent remained in a similar contemporary grassland state. The remaining 55.1 percent converted to eight different current land cover types (Table 18). Major changes included conversion to Cultivated Crops, which accounts for 30.9 percent of the former Prairie-No Timber, followed by Developed land at 15.2 percent and Riparian Woodland and Shrubland at 7.7 percent.

Table 18. Current Land Cover Classes converted from GLO Prairie-No Timber and Upland Timber.

% GLO Prairie-No Timber	% GLO Upland Timber	2010 Land Cover (Mixed Levels 1 to 3) Converted from GLO Types	Near-Equivalent GLO Major Vegetation Types
44.9	26.9	Montane Grassland- L2	Prairie_No Timber
0.8	**39.8**	Forest and Woodland Systems-L1	Upland Timber: includes Timber, Timber-Dense, Timber-Heavy, Timber-Open, Timber-Scattering
30.9	3.7	Cultivated Crops-L3	Field
15.2	4.1	Developed-L2	Not recorded
7.7	13.8	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland-L3	Timber-Bottom, Gravel Bar
-	3.5	Harvested Forest-L2	Timber-Cut
-	3.4	Recently Burned-L2	Timber-Burned
0.2	1.9	Deciduous Shrubland-L2	Brush
0.1	1.6	Rocky Mountain Cliff, Canyon and Massive Bedrock-L3	Cliff
0.4	1.0	Alpine-Montane Wet Meadow-L3	Not recorded
-	0.2	Alpine Bedrock and Scree-L3	Not recorded
0.1	-	Pasture/Hay-L3	Meadow
-	0.1	Emergent Marsh-L3	Swampy
-	-	Open Water-L3	Water

Small proportions of current Forest and Woodland Systems, Deciduous Shrubland, Pasture/Hay and Wet Meadow were formerly classified as Prairie-No Timber. Locations of the GLO Prairie-No Timber conversions are represented in Figure 18.

Upland Timber changes exhibited more extensive incongruences than Prairie_No Timber. Only 39.8 percent of the GLO Upland Timber remained in its near-equivalent Forest and Woodland Systems class (Table 18, Figure 19). Eleven other current land cover classes hold the remaining 60.2 percent. Over one quarter of GLO Upland Timber converted to Grassland (26.9 %). Nearly 14 percent of Upland Timber was mapped as current Riparian Woodland and Shrubland. This discrepancy between upland and

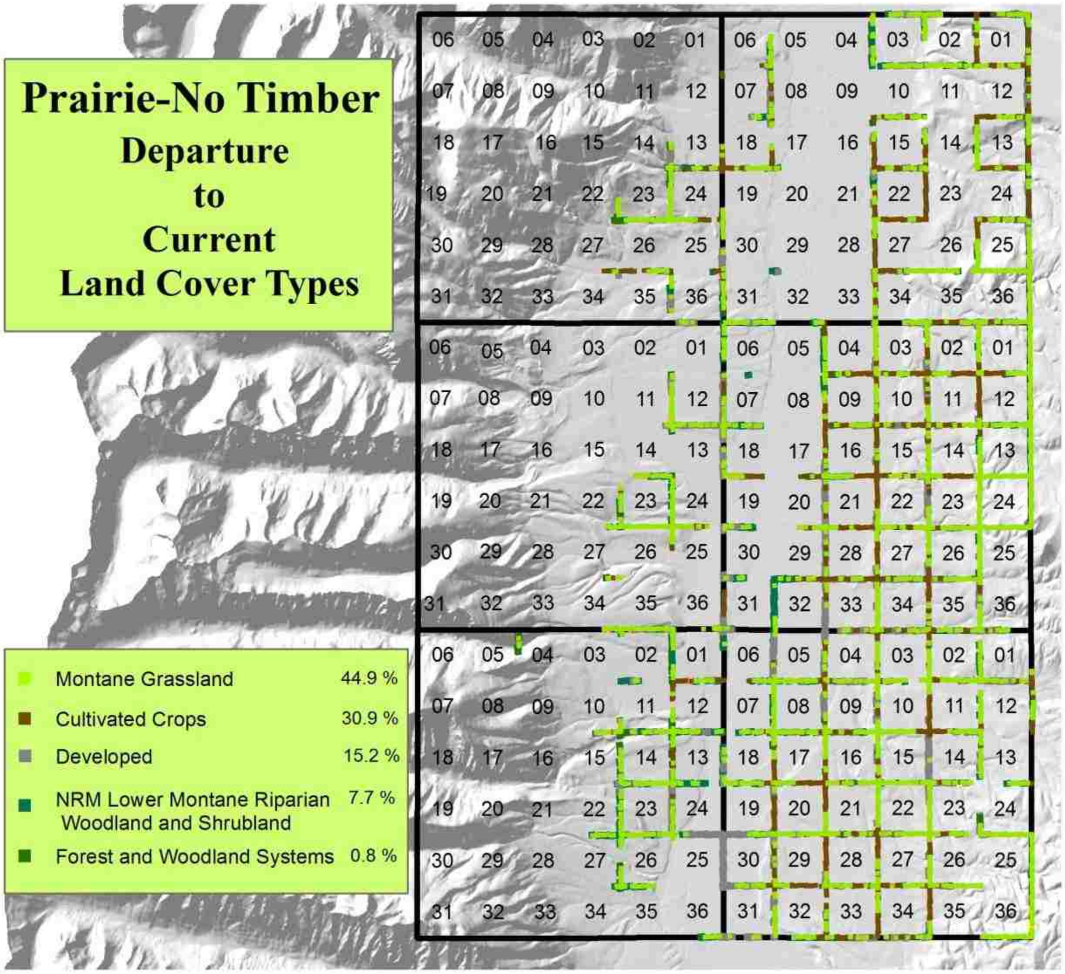


Figure 18. Prairie-No Timber Departure to Current Land Cover Types.

bottomland locations may indicate that surveyors were not always consistent in distinguishing between bottomland timber and other timber types. In several locations within the Bitterroot River valley near the river, section lines adjacent to Timber-Bottom were described as Timber or Scattering Timber, not Timber_Bottom (Figures 14 and 19).

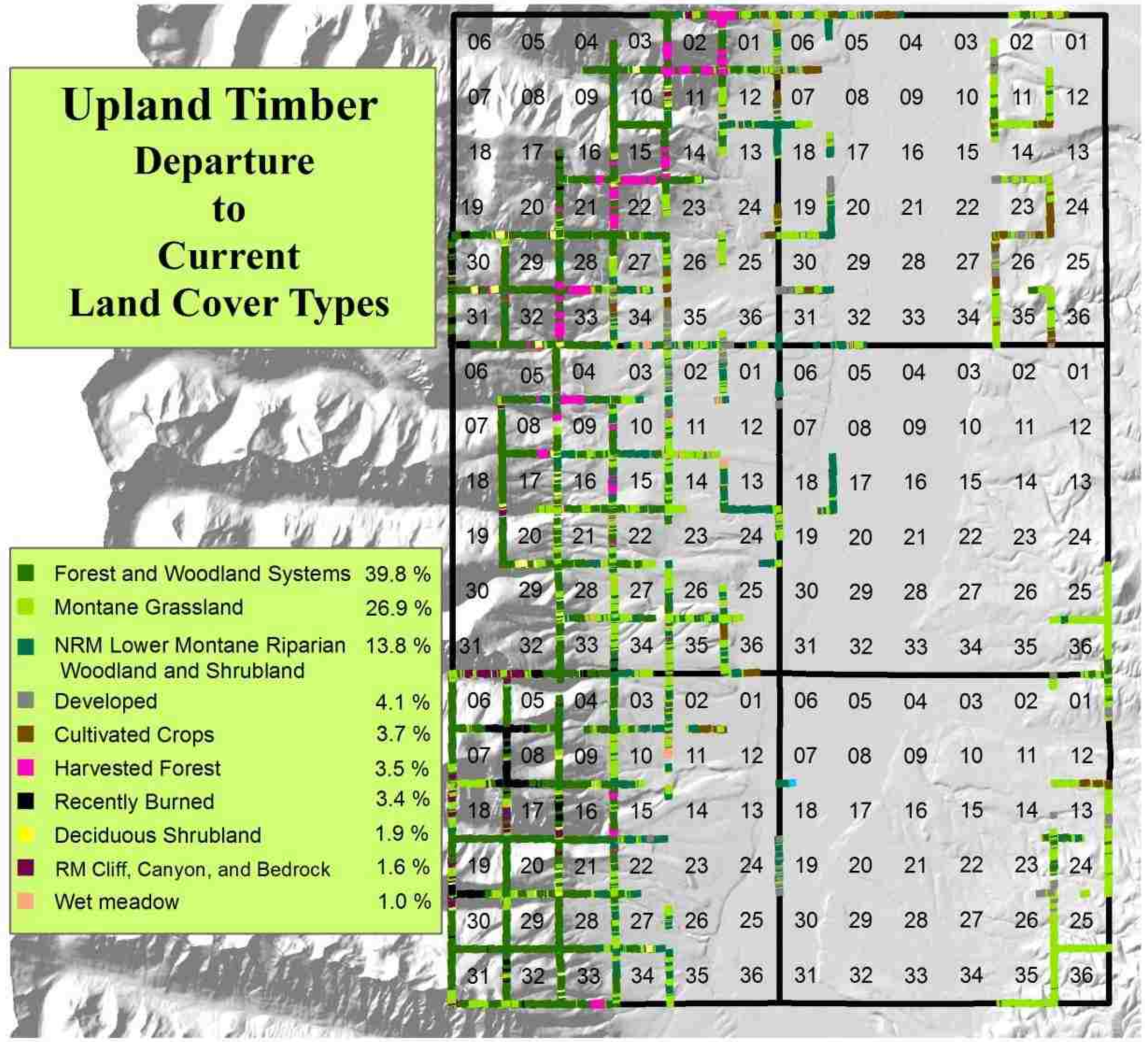


Figure 19. Upland Timber Departure to current Land Cover Types.

Smaller differences occurred in the remainder classes. Developed land, Cultivated Crops, Recently Burned, Harvested Forest, and Upper Montane Grassland each occupy approximately 3 to 4 percent of former Upland Timber area. Less than two percent of each of the Deciduous Shrubland; Cliff, Canyons and Massive Bedrock; Alpine-Montane

Wet Meadow; Alpine Bedrock and Scree and Emergent Marsh classifications now occur in former GLO Upland Timber locations.

Overlaying the GLO/current land cover intersection on aerial imagery illustrates modern landscape locations of Prairie-No Timber and segments where it has converted to other current land cover types (Figure 20). This intersection layer may be used as a tool to learn about a particular point on the landscape. If overlaid on public land or land acquired for conservation purposes, broad management and restoration potential may be evaluated. Appropriate areas for restoration may be targeted and prioritized.

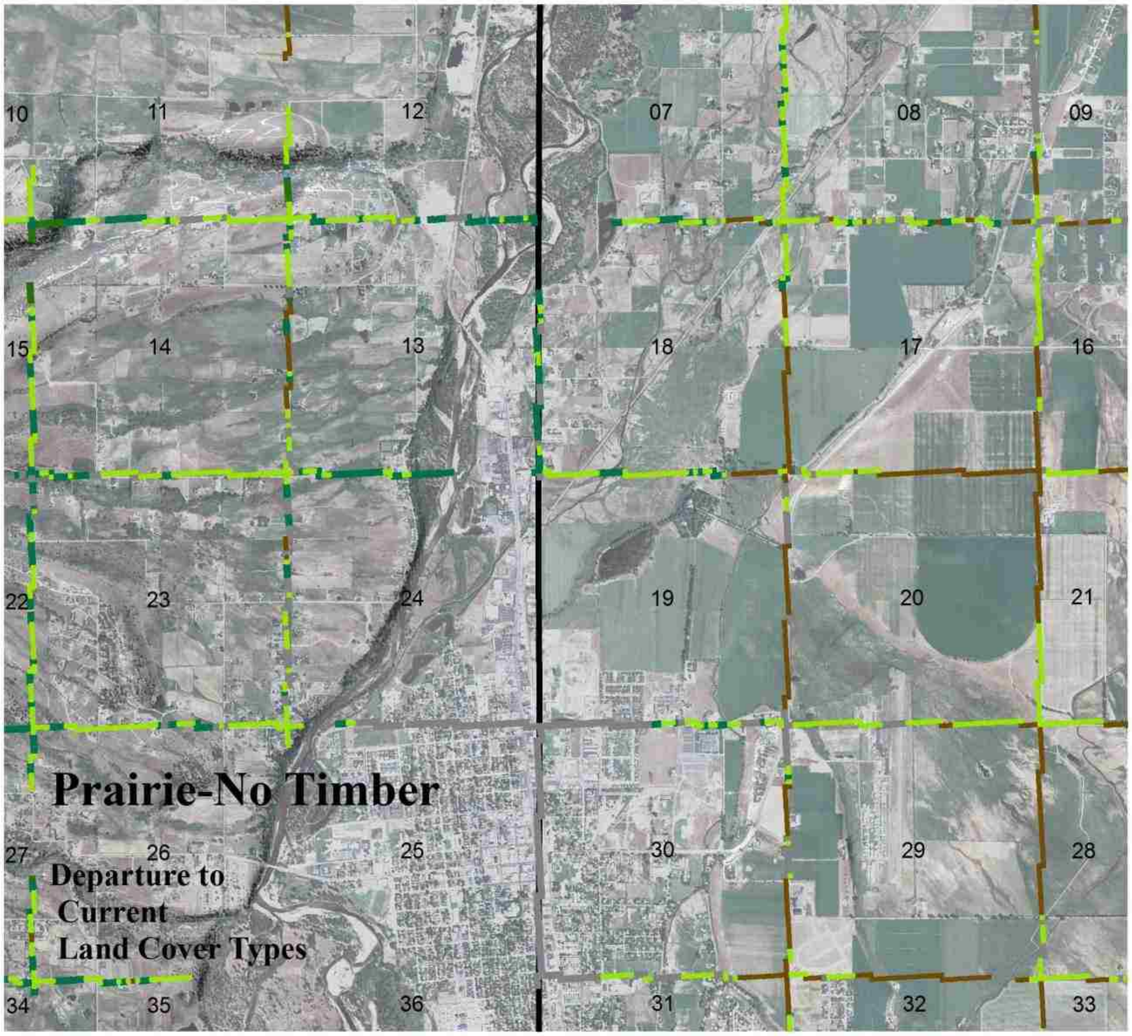


Figure 20. Prairie-No Timber Departure to Current Land Cover near Hamilton, Montana (for legend see Figure 18).

This cursory evaluation of landscape differences is an initial exploration of how GLO information might be used to help understand how the modern landscape came to be. The exercise demonstrates the complexity of comparing the two different vegetation/land cover datasets and is a launching point for further analysis, recognizing that this comparison may not provide sound results in some near-equivalent classes given the accuracies of the datasets and the crosswalk. The comparisons also provide an approach to draw attention to possible errors or inconsistencies in the surveyors' land descriptions, as shown in the previously described situation where GLO bottomland timber (Timber-Bottom) was sometimes not differentiated from upland timber (Timber). Further GLO mapping efforts of other Montana valleys would provide comparable reference areas that may offer insight into the usefulness of the Bitterroot Valley GLO landscape descriptions.

DISCUSSION

The purpose of this project was to determine an effective GIS approach for collecting, categorizing and mapping General Land Office survey information. All historic information provided in the General Land Office survey field notes was recorded in the geodatabase and many of those aspects were mapped, summarized and compared. This discourse assesses the degree to which the project objectives were accomplished. The effectiveness of the ArcGIS geodatabase and aspects of the initial point collection feature class design are discussed. Advantages and limitations of using the GLO to map elements of Euro-American settlement-era vegetation in the Bitterroot Valley are assessed. The challenges of relating GLO vegetation maps and summaries to current conditions are presented, and visual observations from the two time periods are compared.

Effectiveness of the Geodatabase and Feature Class Design

A Geographic Information System geodatabase framework was valuable for the completion of this study. Appropriate interpretation of the GLO survey is dependent upon how its contents are collected, stored, and represented. When designing an effective ArcGIS geodatabase, its applications must be pre-determined in order to assemble the appropriate data layers and elements. The intended uses of the geodatabase, for this project, were essentially GLO data collection and storage, feature class creation and editing, base map data organization and GLO attribute summarization and display for a specific area. Map products were designed at the scale of the six-township study area and the single township with the geodatabase structure in mind. Other key products were summary tables for all GLO categories. Thematic base layers necessary to provide map outputs were all available through state or federal GIS sources (Table 1). Data acquired in shapefile format at the state and county levels were easily processed and converted to feature classes at the study area scale and spatially referenced within feature datasets in the geodatabase. Topologies, or spatial rules, which are important functions of the geodatabase model for managing shared border locations, were implemented for the Vegetation Polygons Feature Class. Topology rules enforced appropriate spatial adjacency of vegetation boundaries. Overall, the geodatabase structure provided the foundation for this project's organization and implementation. GLO field notes were just facts on paper until they were transformed into organized spatial entities—point, line and polygon feature classes with accurate geographic coordinates and meaningful descriptive attributes—by the successful use of the geodatabase design.

If this project were to be continued in other areas of Montana, the current geodatabase design could be expanded. Feature datasets for additional counties could be added to the current geodatabase. The state-level data could be clipped to new areas of interest. Alternatively, the Bitterroot Valley geodatabase could be replicated, creating a new geodatabase of matching design for each new study area. Consideration of the usefulness of updated versions of base data layers, especially an updated GCDB, housed in the current geodatabase may be important in determining the preferable future design structure. In both alternatives, whether the geodatabase is expanded or replicated, feature datasets housing local GLO data would require different local area map projections for different geographies.

The geographic information held within the GLO notes was a systematic collection of historic data items recorded in surveyors' language. The database design of the initial point data collection feature class allowed collection of all the types of GLO data at once, with the expectation of ordering and classification of the different types of information to follow. At the outset of the GLO data collection process, expectations of the potential land information to be collected were perceived from examining the GLO literature. Also, information from the Oregon Natural Heritage Program, on whose design the initial feature class was based, provided examples of surveyors’ vegetation descriptors (Christy *et al*., 2011). One does not know the specific nature of information that will be gathered for the chosen study area until the various descriptors are actually encountered in the notes. For example, it was unknown at the start what descriptors of open, non-forested land would be used—would the terms “prairie,” “grass,” “openings,” “agricultural land,” “marshes” or other terms for these ecological areas be documented? The data collection process required not only gathering information, but also learning the surveyors’ system of recording data and interpreting the surveyors’ language. The attribute fields of the original point feature class required flexibility so that the data could be categorized effectively. The attribute field, “Veg_Code,” was used to organize new types of vegetation data as it appeared in the notes (Table 3). New vegetation codes had to be continuously added when a previously undescribed vegetation type was encountered (Appendix VIII). Because codes were added over the course of data collection, attribute domains were not created for this field. A domain is a list of acceptable attribute values. Domains function to limit information to specific values that represent a range of valid values for that attribute field, maintaining data quality and consistency. Domains were used for consistency and expediency in entering data into township/range, direction and quadrant fields.

Several fields in the initial point feature class were devoted to relocating a GCDB corner point to the point the surveyor described along the line (Methods, page 31; Appendix VII). Now that the coordinate geometry formulas for moving points from the GCDB framework to correct section line locations have been determined, a Python program could be written or a model could be developed to automate the process for future projects. Moving points with the use of a program or model instead of the Field Calculator method may eliminate the need for several attribute fields in the point feature class.

Because of map projection limitations, in this case the inability of the local Albers Equal Area projection to represent the Earth's surface on a two-dimensional plane without some distortion of direction, the accuracy of the moved GLO points will be diminished at some unknown distance beyond the study area. The projected section lines will eventually not follow true directions; so when bearing directions are used to relocate GCDB points as new GLO points along section lines with coordinate geometry, the moved points will appear in incorrect locations. This study did not determine how large of an area can be involved in the GCDB point relocation for the local projection used. Relocated GCDB points within the study area were measured to assure that they were plotted within one meter of the surveyors' recorded locations.

Advantages and Limitations of Bitterroot Valley GLO Data

As a result of this study, hand-written archived information describing the historic character of the Bitterroot Valley landscape was made available in a spatial format. Justifications and advantages for using GLO survey data to describe pre- or early settlement conditions and applying the information to ecological studies have been reviewed in many papers (Wang, 2005; Galatowitsch, 1990, and numerous others). The distinct usefulness of GLO information stems from it being the primary available source of geographically-extensive historic vegetation and settlement descriptions for much of the United States. The use of GLO survey records to understand historic land conditions in the Bitterroot Valley has similar advantages to its utility in other locations where GLO notes are available. In addition to providing continuous coverage at an appropriate scale for land description, the GLO data can provide a record of human influences on a study area. At the time of the Bitterroot Valley survey, the majority of the land had been impacted by Indian or Euro-American occupation. Inclusion of the cultural influence provides additional context to the land description, creating a more comprehensive land cover interpretation beyond an estimation based solely on ecological information.

The general descriptions that concluded each separate township survey contract provided narratives of the diversity of land usage, streams and rivers, vegetation and settlement within that contract area. These accounts often provided additional, qualitative perspectives beyond that of the systematic subdivision point and section line records. All three different types of data contribute uniquely to the representation of the GLO landscape.

The deficiency of presettlement information for this area is a shortcoming for researchers seeking ecological data from a time before Euro-American disturbances. Adding to this disadvantage is the temporal complexity associated with the survey completion over the entire study area. The Bitterroot Valley original surveys were conducted from 1870 to 1924. Consequently, the GLO representation spans a 54-year time period when great changes were occurring. Valleys, where settlement could occur or had already occurred, were surveyed first. The more rugged landscapes, less appealing to settlers, were attended to later. This lapse between surveys allowed time for timber harvest to occur in the mountainous areas, so that when the survey was conducted the vegetation had changed from its former condition. In the valley, a continuing increase in land conversion to cropland and pasture altered the landscape as the survey was being conducted. These transformations complicated the process of land subdivision and description, perhaps to the point of diverting attention away from surveyors' vegetation descriptions. Township plat maps of the valley drawn from the field notes show minimal land description, only portraying agricultural and mountainous areas.

Several sections on the west side of study area have no completed survey. Extremely mountainous terrain prohibited survey completion in T08N R21W and T07N R21W. These areas were within the Department of the Interior forest reserve system which became the U.S. Forest Service Bitterroot National Forest (Muhn, 1992). Additional survey lines are missing for unknown reasons in the southern portion of T06N R21W.

The overall inexplicit quality of information provided was the most limiting feature of the data. As stated in previous sections, only general tree names were recorded. Classification of forest types by specific species associations could not be accomplished without referring to other botanical sources. Taxonomic ambiguity of tree species was present in the line descriptions as expected (Almendinger, 1997), but also occurred in the bearing tree data. The tree point data was not specific enough for mapping at the species level. Very few common names of trees were provided that would support species identification (Table 8). Depending upon elevation and landscape situation, surveyors' “fir” trees could be Douglas fir, grand fir, or subalpine fir. “Pine” could potentially equate to ponderosa, lodgepole, western white or whitebark pines. Tree species ambiguity also restricted bias checking and crosswalking GLO to current vegetation.

Data omission further limited the reliability of GLO data. Land descriptions were extremely rare for non-timbered areas in the Bitterroot Valley. The terms “prairie,” “meadow,” “brush” and “field” were used sparingly. Since topographic and aquatic locations appeared correctly positioned when checked on digitized USGS 7.5 minute topographic quadrangles, it was also expected that the limited vegetation descriptions were truthful. The majority of section lines in the valley were described simply as “No Timber.” Notes lacked any differentiation between various grassland cover types ranging from river bottom to foothills. Specifications of the survey after 1850 required the kind of grass “or other herbage” produced in prairie landscapes to be reported (Bourdo, 1956). The general description that followed the survey notes of an entire township mentioned occurrence of sagebrush and bunchgrasses, but section line descriptions were deficient in these details. Similarly, undergrowth within timbered areas was to be recorded according to guidelines. Since it was not described by most Bitterroot Valley surveyors the true absence of undergrowth is assumed. Although undergrowth was either absent or undescribed in most of the study area, it was included in the 1924 survey of several mountainous sections. Rarely described wet areas delineated in the notes as “swampy” may have been truly uncommon, or since the area was surveyed mainly in July and August, wet areas may have dried to the point of insignificance and were omitted from the record. Also, with the extensive ditching infrastructure in place, some wet areas could have been drained and reduced in size. Distinction between surveyors’ omission or inadequate documentation of existing vegetation occurrences, and the true absence of those occurrences, was not possible in non-timbered areas. While it may be possible to relocate old bearing trees at a timbered section corner to confirm true presence of a species in question, it is not as likely that a contemporary field investigation in an open area could discern features present at the time of the GLO survey.

Many GLO research projects utilize either the bearing tree point data or the section line descriptions, and occasionally include the qualitative general township descriptions. Depending on the objectives of a study, point, line and general township description data used together may provide a more informed interpretation of the data. Three examples stand out in this study:

1. The valley's ambiguous non-timbered vegetation line descriptions are expanded by the hundreds of added cultural and aquatic points (Figure 13). The well-developed infrastructure of roads, fences, ditches and houses and the presence of multiple sloughs associated with the Bitterroot River illustrate a more comprehensive appearance of the locality. When considered along with the general township description of the non-timbered valley area, these locations may be characterized as prairie, meadow, prairie with sagebrush or bunchgrass or blue joint grass, or fields that were formerly prairie, with scattered settlements of several hundred white settlers.
2. When determining overall tree distribution, tree types mentioned in line descriptions were not always the same as bearing trees (Figures 11 and 12). By concurrently viewing both types of data, a more comprehensive GLO description of tree locations is seen.

3. By categorizing attributes of section corner points (“Number of trees per corner” and “Average distance from corner” fields), differences between surveyor line descriptions of timber density (open, scattering, heavy, dense) can be explored (Figures 2 and 3).

Use of GLO data for defining ecological history in the Bitterroot Valley requires caution because of its ambiguity. The information is variable by surveyor, time of survey and the geography of the area. Care should be taken that its use does not extend to inappropriate extrapolations. For example, in the Bitterroot Valley, interpretation of fire-maintained ecosystems or sagebrush distribution could not be easily accomplished. Burned timber was only described in a few small areas. Burned areas were not described in township general descriptions. Surveyor descriptions of Scattering Timber and Open Timber classes may suggest possible locations of past fires. Dense, young timbered areas may have burned prior to the survey. While “probable” burned locations could potentially be quantified, areas of sagebrush were not recorded in a quantifiable manner. Additional data sources are necessary to establish sagebrush locations. Used in conjunction with early explorers’ land descriptions, pollen records, dendrochronology studies, soil surveys, and historic aerial photography, GLO information may contribute to a better understanding of an area’s historic vegetation distribution and disturbance factors. However, in the Bitterroot Valley exclusive dependence on GLO data for reliable spatial representation of fire-maintained landscapes and sagebrush distribution proves ineffective.

Challenges of Section Line GLO to Current Land Cover Comparison

Comparison of GLO to current vegetation section lines was conducted with the assumption that the two datasets were of comparable scales. A discussion of the fine points of the GLO data is needed to arrive at an estimated level of location accuracy, data resolution and map scale. Location accuracy (the degree to which mapped information matches true values) of historic vegetation descriptions along section lines cannot be easily tested and is estimated to be within 10 meters (one half chain). Accuracy estimation is based on verification of surveyors' locations of topographic features such as ridges, ravines and streams, corresponding to USGS 7.5 minute topographic quadrangle locations of those features. Additionally, Christy and Alverson (2011a) reported similar GLO accuracy estimates for the Willamette Valley, Oregon. Vegetation position along the section line is also dependent upon its related GCDB point. GCDB x- and y-coordinate errors at corners within the study area range from 0 to 86 meters. The high error distances occur at a few corners in steep mountainous areas. The average error is 16 meters. By adding the GLO accuracy estimate (10 meters) and the GCDB average error value (16 meters), and doubling this value ([10 + 16] * 2) to account for maximum estimated error in opposite directions of the true location, an average location accuracy for the GLO vegetation lines is approximately 52 meters.

Surveyor precision (the level of measurement and exactness of description) of GLO vegetation breaks along section lines, was variable throughout the study area. Some vegetation measurements were recorded to within 5 to 10 links (approximately 1 to 2 meters) and others were more routinely documented with less precision—to the half chain (50 links or approximately 10 meters) or chain (100 links or approximately 20 meters). If it is estimated that the surveyor-described vegetation extends perpendicular from the section lines by at least one chain (20 meters) (the least precise measurement used along the section line), a perceived resolution for GLO vegetation line data could be interpreted as 20 x 20 meters.

The approximate relationship between spatial resolution and map scale was determined by Tobler (1988). A known resolution is doubled to determine the approximate feature detection size or accuracy. The detection size is multiplied by 1000 to give the approximate map scale. Using this formula, map scales for correct viewing of GLO (along section lines) and 2010 land cover are calculated as:

GLO map scale: 20 meters * 2 * 1000 = 1:40,000

2010 land cover map scale: 30 meters * 2 * 1000 = 1:60,000

Robinson (1995) cautions that great care should be taken when relating data sets of varying resolution and accuracy. Comparison between these datasets is not optimal, but is what could be attempted for the scope of this study. The best available land cover dataset for this study area was compared to the GLO data—the best known historic data—for the study area's extent. The 30 x 30 meter resolution of the 2010 Montana land cover is assumed to be close enough to GLO line resolution for illustrating large differences between historic and current vegetation along section lines. This readily available land cover was chosen not only for its accessibility but its detailed, Northwest region-specific classification process. The dataset was classified using Montana ecological systems, integrating Montana Department of Revenue Final Land Unit (FLU) data, NAIP imagery, the National Hydrology dataset, wetland data and using field plots. No accuracy assessment of land cover was available. A drive-through of a portion of the study area in T06N R21W on several roads that followed section lines was conducted for overall quality assurance. Visual assessment indicated that the land cover classification along section line roads generally matched ground observations enough for a comparison to ensue. However, some inconsistencies between ground conditions and land cover categories were observed. Land cover-delineated Alpine-Montane Wet Meadows may be over-represented in certain localities. On the ground, a number of areas near section lines classified as Wet Meadow were agricultural. Several of these areas were hayfields dominated by introduced timothy (*Phleum pratense*) with some scattered *Juncus* (rush) and *Carex* (sedge) species in wetter locations of fields. Additionally, Lower Montane Riparian Woodland and Shrubland abundance may also be elevated as a land cover class compared to actual ground occurrence. Land cover classified as Montane Grassland was a combination of non-native grass/agricultural fields, open developed areas, native grassland and open areas within woodlands. Finally, land cover classification in general may under-represent the Development class. Small acreages or ranchettes, surrounded by heavily grazed, mowed or eroded grass or trees are essentially developed but are classified as mostly grass or forested classes because buildings are hidden by trees or are small in size in relationship to the surrounding cleared landscape. These impressions suggest the need for further investigation and should not be considered a comprehensive evaluation.

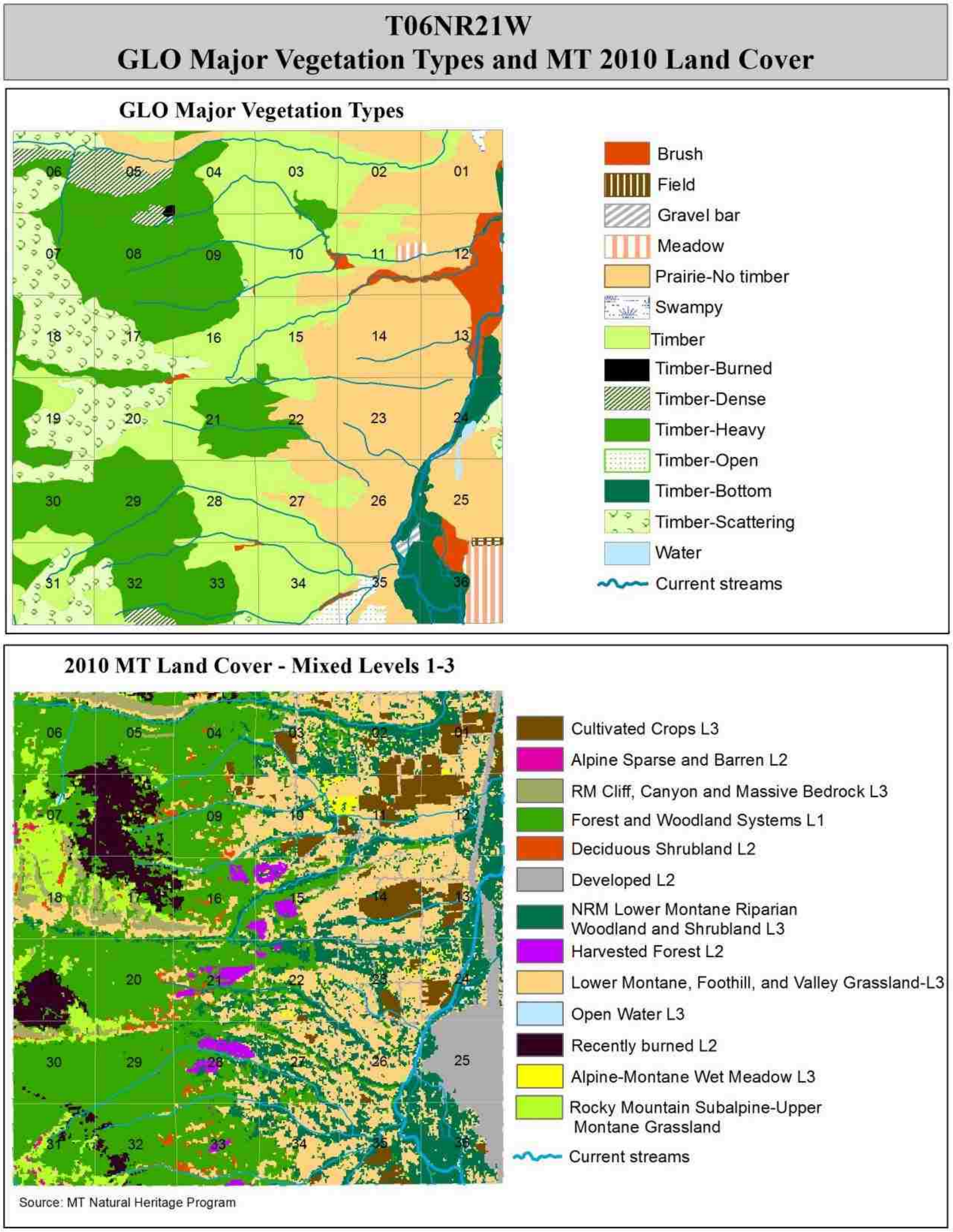
In this study’s GLO to current land cover comparison, the largest variations between historic and current conditions occurred in GLO Upland Timber (24.2 percent decrease), Field (16.2 percent increase) and Prairie-NoTimber (11.5 percent decrease) and their near-equivalent land cover classes (Results, pages 86-87). Changes such as these certainly would be predictable as population grows within a region. Differences revealed by this study's methodology seem likely to be attributed to actual change in land cover over time, but also could have arisen from other explanations. True differences between the historic and current land cover depend on several assumptions including the accuracies of GLO surveyors' descriptions and the data entry process of those reports. The GCDB data to which the GLO is attached has known x- and y- coordinate errors that must be considered. The GLO vegetation and the current land cover classification systems must reflect vegetation and land use conditions as accurately as possible. The GLO-current land cover crosswalk must correctly link corresponding GLO and current land cover as near-equivalent types. Given the potential inadequacies in some or all of these considerations, only large variations between GLO and land cover can be perceived as possible important differences.

This comparison reveals conceivable changes only along section lines and does not predict changes within the section interiors. Additionally, these cursory examinations were not meant to comprehensively explore the locations or meanings of perceived changes, but to bring attention to conceivably noticable differences between overall conditions of the two time frames spanning approximately 90-140 years.

GLO/Land Cover Differences in T06N R21W

The Major Vegetation Type polygons of T06N R21W estimate overall historic vegetation structure by combining the GLO and best available current data sources (Figure 17). However, this landscape interpretation conveys accuracy uncertainties within section interiors, making quantitative comparison to current map products untenable at the township scale. Mapping accuracy of polygon boundaries along section lines, as discussed previously, is estimated to be approximately 52 meters. Accuracy cannot be measured within section interiors as boundaries are interpretations that are based collectively on GLO vegetation lines and soils, contours and/or NAIP imagery. Each interior vegetation boundary is subjectively determined using one or more of the supporting layers deemed advantageous for producing the most appropriate vegetation boundary. For example, when a GLO Prairie-No Timber vegetation line overlays a prairie soil map unit (Mollisol order, Ustoll suborder), the interior vegetaton boundary would follow the soil boundary. If that prairie soil extends to another section line that is GLO Timber, a delineation between Prairie-No Timber and Timber somewhere within the section interior depends on other data. A line following rapidly increasing contours or a location on aerial imagery with scattered large canopy trees (old trees likely present during the survey), or both situations used together, could provide potential boundaries. The different scale and spatial resolution of each supporting layer, and the variable effectiveness of these layers to delineate the most appropriate vegetation boundary, potentially cause every point of the GLO interpretation of this township to be mapped at different, undeterminable accuracies.

Visual evaluation illustrates the problems with comparing these datasets, mapped from different time periods, using different data types (vector and raster),with varying precision levels and accuracies (Figure 21). However, several observations and interpretations of land changes may be perceived by visual comparison, including this partial list:



Source: MT Natural Heritage Program

Figure 21. T06N R21W GLO Major Vegetation Types and 2010 Montana Land Cover (Levels 1 to 3). Developed areas, wet meadows and harvested forest were not present or documented in the GLO survey in this township.

1. A noticably higher level of human-related activities—Cultivated Crops, Harvested Forest, and Development—appear on current land cover, compared to equivalent areas mapped by surveyors.
2. The increase in current Recently Burned and Harvested Forest areas likely contributed to decline in the Upland Timber/Forest and Woodland Systems equivalent class.
3. The presence of the current Lower Montane Riparian Woodland and Shrubland class, along streams draining into the Bitterroot River indicates a possible increase of woody vegetation along drainages from GLO to current periods.
4. The GLO Prairie-No Timber corresponds to the location of current Lower Montane, Foothill and Valley Grassland L3 (within Montane Grassland L2), but appears displaced by current Riparian Woodland and Shrubland along many drainages.
5. Deciduous Shrubland is noticable in mid-elevations where its near-equivalent, Brush, was not recorded as frequently by surveyors.
6. Subalpine-Upper Montane Grassland (Montane Grassland L2) is mapped in higher elevations in the vicinity of GLO Scattering Timber.
7. Cliff, Canyon and Massive Bedrock occurs as current land cover, but is not recorded in the GLO description for this township.
8. The GLO timber types (Timber, Scattering, Heavy, Open, Dense) do not easily correspond to the current Forest and Woodland classification.

Some of these interpretations seem obvious and others may be reasonably perceived, but these or any other observations or differences defy quantification, even if both datasets were of the same data type. The maps are not directly comparable, realizing the incongruity of accuracies, resolution, and scales of the two sets of information. The GLO vegetation map is unavoidably generalized because of the unknown elements within section interiors, while the current land cover evenly approximates cover types in 30-meter pixels. In addition to accuracy, resolution and scale incompatibilities, differences are also influenced by imperfect classification systems and classification crosswalks.

These and further interpretations of possible differences that may or may not seem straightforward are the starting points for further inquiry. Visual comparison is useful for gaining a general understanding of the historic and current landscape conditions and potential differences, and determining relevant questions that may be asked of the GLO dataset. Further evaluation of differences between GLO and current land cover focused on T06N R21W could involve comparison of section line data using the previously demonstrated GLO-land cover line intersection methodology (Methods, pages 53-55). GLO data could also be compared to actual ground data to determine changes. Consideration was given to comparing GLO to a more generalized current land cover polygon layer that could be created using the methods of GLO vegetation polygon mapping (Methods, pages 42-44). A new current land cover map could be created by using land cover data points along section lines with SSURGO soils, NAIP imagery, etc., to map land cover polygons. The remapped land cover polygons with generalized section interiors and GLO polygons could hypothetically be compared. Differentiation between true changes and deviations due to section interior accuracy uncertainties could still be unmanageable so this method was not pursued.

CONCLUSION

The purpose of this project was to determine an approach to document and map historic vegetation and related geographic information using General Land Office Survey records. The methodology produced for this thesis provided the means for an effective recording of the late 1800s Bitterroot Valley, Montana land and settlement patterns and surveyor information. The principal achievement was the creation of historic land cover spatial data layers that can be used to improve understanding of the circa Euro-American settlement landscape. Vegetation composition and spatial structure, tree abundance, and distribution of vegetation types were characterized in a multi-part historic data assemblage of point, line and polygon feature classes within a geodatabase, and in qualitative landscape descriptions. Documented aquatic, topographic and cultural aspects of the area contributed to the historic landscape data compilation. Historic ecological and geographic information at this level of systematic detail is not known to have been collected for this location prior to this work. This methodology, now tested, may be further used to create a multi-scale (local, state or region-wide) GLO survey data repository for use in ecological planning, management and research. Another key accomplishment of the study was the construction of the series of Bitterroot Valley historic landscape maps. The map products, evaluations and summaries provide templates for similar work in other geographic areas. If the method were applied to other mountain valleys the awareness of temporal differences between valley and adjacent mountain area surveys, gained from this project, may be useful, depending upon the objectives for acquiring the information. A fundamental observation concluded from GLO data inspection is that the combination of all GLO data types used together—tree types and locations, vegetation, land, soil, cultural and aquatic data, and narrative township descriptions—provide the most comprehensive representation of the historic landscape. If certain data types are overlooked the GLO interpretation loses accuracy, and the most complete picture is not known.

The methodology of assembling GLO information expanded into an exploration of surveyor language and procedure. Several studies using GLO data have documented historic vegetation, determined methods to overcome surveyor bias, compared historic to current land cover, and predicted disturbances such as fire regimes. In some studies, GLO information has been "translated" into another language, the language of the ecologist. This study presents a minimally interpreted version of historic geographic data for the Bitterroot Valley in the surveyors' language.The ambiguity and gaps in the information are made visible so that future researchers might see a less-adulterated example of the information available if they attempt to study a region's historical ecology using survey information. However, the mapped information is not entirely raw survey data because of the necessity to concisely categorize vegetation descriptions.

The General Land Office survey described the Bitterroot Valley landscape at different precision levels. Near-exact locations of bearing trees marking section corners, and points along each section line marking vegetation changes and geographic conditions, provided quantitative information, while township-level descriptions conveyed qualitative accounts. The combined descriptions of this study area gave a reasonable estimate of historic vegetation in the context of human occupation, without excessive bias, that can be corroborated with other published historic maps. The most numerous bearing tree types were pine, fir, cottonwood and aspen. Section line Major

Vegetation Types were most often described with Prairie-No Timber (45.7 %), followed by Timber (17.1 %), Heavy Timber (12.5 %), Scattering Timber (7.8 %) and Timber-Bottom (7.2 %) types. The most abundant section line Tree Association/ Land Classes were No Timber (41.6 %), Pine (18.8 %), Pine-fir (11.6 %), Pine-fir-larch (6.7 %) and Prairie (4.1 %). Although the most abundant section line vegetation class—No Timber—has the most ambiguous depiction, the associated qualitative township descriptions provided assurance that this vegetation was most likely prairie, prairie associated with sagebrush or former prairie converted to agricultural land. Forest descriptions including Scattering Timber and Open Timber with very limited descriptions of undergrowth suggest that these areas may have possibly been maintained historically by fire, grazing or other disturbances. However, rocky or poor soil conditions could also have produced open timbered conditions.

The most abundant current land cover types along section lines are Montane Grassland (34.2 %), Cultivated Crops (17.8 %), Forest and Woodland Systems (17.0 %), Lower Montane Riparian Woodland and Shrubland (15.8 %), and Developed (9.7 %). Similar tree species and forest vegetation types have persisted from the GLO period. However, historic forests may be generally interpreted as more open structurally than current forests containing similar species compositions, due to lack of undergrowth according to GLO descriptions.

Determination of species differences between past and current grassland and sagebrush conditions in the Bitterroot Valley cannot be interpreted through the GLO–land cover comparison. However, it was calculated that an estimated 44 percent of section lines classified as GLO Prairie-No Timber have remained in a contemporary grassland state. Over half of the historic Prairie-No Timber has been converted, mostly to cropland and developed areas.

It was realized early in this project that time would not allow for intensive GLO analyses and comparisons. Establishing the data foundation for the entirety of possible GLO questions and developing a suitable organization and representation of the original survey was the foremost intent. The effort to determine overall differences between historic and current land cover was considered a preliminary exploration that needs further attention. Large land cover differences found during this inquiry—general declines in native forest and non-forest vegetation and increases in disturbed, developed areas—are logical given the extent of development. Vegetation differences in small classes are inconclusive due to the level of mapping accuracy in historic data and potential land cover inaccuracies discovered during the field drive-through. The results of the comparison provide a baseline for further steps in improvement of calculating Bitterroot Valley landscape changes related to time and development. The limited quantitative outputs of this research could be refined with the incorporation of other ecological and historic data into the GLO dataset. A local land cover reclassification enhanced by further ground reconnaissance and an improved historic–current land cover crosswalk would benefit future analysis.

GLO survey data provide a unique framework for evaluating the historic landscape at multiple scales. The usefulness of the information may depend upon the research questions or land management objectives or other specific endeavors to which the data are applied. The results from the Bitterroot Valley may indicate what to expect from other mountain valley GLO descriptions. Knowing possible data capabilities and limits in similar geographic locations may help determine whether the GLO data deserve further investigation for future research projects. Bitterroot Valley results also provide mapped locations that may assist in investigation and prioritization of conservation goals and ecological or historical restoration projects. General Land Office survey data provide the most extensive pre-aerial photograph representation of Rocky Mountain valleys known to exist. The information is one potential resource for answering historical ecology and human settlement questions. By making it available in a spatial format to more potential users, its utility and limits will become more widely understood.

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Appendix I. Map Projection

The 2009 GCDB data was transformed from MT State Plane NAD83 back to NAD27 Geographic Coordinates (as they were in original format from BLM). These were projected to a local Ravalli County Albers equal area projection.

Projection: Albers Ravalli

False_Easting: 12000

False_Northing: 25000

Central_Meridian: -114.149500

Standard_Parallel_1: 46.192300

Standard_Parallel_2: 46.339700

Latitude_Of_Origin: 46.266000

Linear Unit: Meter

GCS_North_American_1927

Datum: North_American_1927

Appendix II. SSURGO Soils Information

Study area vegetation by soil orders and suborders.

Order	Suborder	Total Acres	Vegetation
Mollisol	Ustolls	92761.8	mostly grass
Inceptisol	Cryepts	36559.5	mountains, conifers or mixed conifer hardwood
Entisol	Fluvents	18526.6	frequent floods, organic clay or loam, any veg.
Inceptisol	Ustepts	18412.9	free draining, ustic (dry), grass, trees, pasture
Mollisol	Cryolls	4013.7	cold, grasses or forest
Alfisol	Ustalfs	608.3	frigid, mesic, deciduous trees, savanna or grass
Histosol	Hemists	503.5	wet, organic, woodland or range
Mollisol	Aquolls	173.1	wet, low, seepy, grasses, sedges, few forests
Undescribed		333.6	

Microsoft Access soils query for assigning the dominant suborder to each map unit.

The query aggregates and sums component percentages for each mapunit by suborder, then takes the component suborder with the highest total percent composition to limit the data to a one to one dominant condition suborder for each mapunit. It was modified from a query written by Jay Skovlin, Soil Scientist Missoula County NRCS.

In Access paste the following string into the SQL view of a new query:

```
SELECT mapunit.musym, Sum(component.comppct_r) AS SumOfcomppct_r,
Left([taxsuborder],50) AS soil_so
FROM (mapunit INNER JOIN component ON mapunit.mukey=component.mukey)
GROUP BY mapunit.musym, Left([taxsuborder],50)
ORDER BY mapunit.musym, Sum(component.comppct_r) DESC;
```

Save the query with the name "MT645_so".

Paste this second string into another new query:

```
SELECT MT645_so.musym, Max(MT645_so.SumOfcomppct_r) AS
MaxOfSumOfcomppct_r, Max(MT645__so.soil.so) AS MaxOfsoil_so INTO
MT645_so_agg FROM MT645_so GROUP BY MT645_so.musym;
```

Save this query as a Make Table Query with the name "MT645_so_agg_query". Re-open the query and run it to make the table.

In ArcMap, add this table to the project and join it to MT645 spatial data and change the symbology for the display.

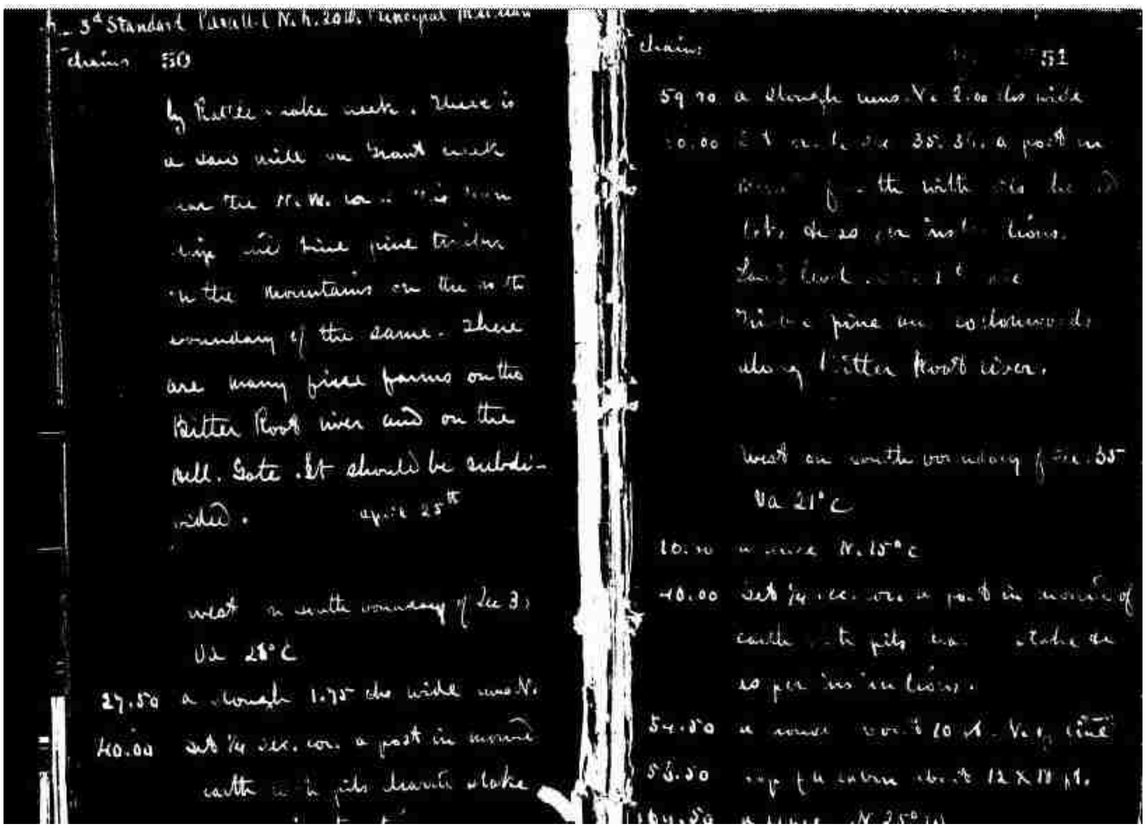
Appendix III. 2010 Montana Land Cover Levels

Level1	Level2	Level3
Human Land Use	Developed	Developed, Open Space
Human Land Use	Developed	Developed, Low Intensity
Human Land Use	Developed	Developed, Medium Intensity
Human Land Use	Mining	Quarries, Strip Mines and Gravel Pits
Human Land Use	Agriculture	Pasture/Hay
Human Land Use	Agriculture	Cultivated Crops
Sparse and Barren Systems	Bluff, Badland and Dune	Great Plains Badlands
Sparse and Barren Systems	Cliff, Canyon and Talus	Rocky Mountain Cliff, Canyon and Massive Bedrock
Alpine Systems	Alpine Sparse and Barren	Alpine Ice Field
Alpine Systems	Alpine Sparse and Barren	Alpine Bedrock and Scree
Sparse and Barren Systems	Bluff, Badland and Dune	Shale Badland
Sparse and Barren Systems	Cliff, Canyon and Talus	Great Plains Cliff and Outcrop
Sparse and Barren Systems	Bluff, Badland and Dune	Active and Stabilized Dune
Sparse and Barren Systems	Cliff, Canyon and Talus	Wyoming Basin Cliff and Canyon
Forest and Woodland Systems	Deciduous dominated forest and woodland	Aspen Forest and Woodland
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Subalpine Woodland and Parkland
Forest and Woodland Systems	Conifer-dominated forest and woodland (mesic-wet)	Rocky Mountain Mesic Montane Mixed Conifer Forest
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Foothill Limber Pine - Juniper Woodland
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Lodgepole Pine Forest
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Ponderosa Pine Woodland and Savanna
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
Forest and Woodland Systems	Conifer-dominated forest and woodland (mesic-wet)	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Montane Douglas fir Forest and Woodland
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Poor Site Lodgepole Pine Forest
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Great Plains Ponderosa Pine Woodland and Savanna
Forest and Woodland Systems	Mixed deciduous/coniferous forest and woodland	Aspen and Mixed Conifer Forest

Forest and Woodland Systems	Deciduous dominated forest and woodland	Mountain Mahogany Woodland and Shrubland
Forest and Woodland Systems	Deciduous dominated forest and woodland	Great Plains Wooded Draw and Ravine
Open Water / Wetland and Riparian Systems	Open Water	Geysers and Hot Springs
Shrubland, Steppe and Savanna Systems	Scrub and Dwarf Shrubland	Mat Saltbush Shrubland
Alpine Systems	Alpine Grassland and Shrubland	Alpine Dwarf-Shrubland
Shrubland, Steppe and Savanna Systems	Sagebrush-dominated Shrubland	Low Sagebrush Shrubland
Shrubland, Steppe and Savanna Systems	Sagebrush-dominated Shrubland	Big Sagebrush Shrubland
Shrubland, Steppe and Savanna Systems	Scrub and Dwarf Shrubland	Mixed Salt Desert Scrub
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Great Plains Shrubland
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Rocky Mountain Lower Montane-Foothill Shrubland
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Rocky Mountain Montane-Foothill Deciduous Shrubland
Shrubland, Steppe and Savanna Systems	Deciduous Shrubland	Rocky Mountain Subalpine Deciduous Shrubland
Forest and Woodland Systems	Conifer-dominated forest and woodland (xeric-mesic)	Rocky Mountain Foothill Woodland-Steppe Transition
Shrubland, Steppe and Savanna Systems	Sagebrush Steppe	Big Sagebrush Steppe
Shrubland, Steppe and Savanna Systems	Sagebrush Steppe	Montane Sagebrush Steppe
Grassland Systems	Montane Grassland	Rocky Mountain Lower Montane, Foothill, and Valley Grassland
Grassland Systems	Montane Grassland	Rocky Mountain Subalpine-Upper Montane Grassland
Grassland Systems	Lowland/Prairie Grassland	Great Plains Mixedgrass Prairie
Alpine Systems	Alpine Sparse and Barren	Alpine Fell-Field
Alpine Systems	Alpine Grassland and Shrubland	Alpine Turf
Grassland Systems	Montane Grassland	Rocky Mountain Subalpine-Montane Mesic Meadow
Grassland Systems	Lowland/Prairie Grassland	Great Plains Sand Prairie
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Shrub
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Annual and Biennial Forbland
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Annual Grassland
Recently Disturbed or Modified	Introduced Vegetation	Introduced Upland Vegetation - Perennial Grassland and Forbland
Recently Disturbed or Modified	Introduced Vegetation	Introduced Riparian and Wetland Vegetation
Recently Disturbed or Modified	Recently burned	Recently burned forest

Recently Disturbed or Modified	Recently burned	Recently burned grassland
Recently Disturbed or Modified	Recently burned	Recently burned shrubland
Recently Disturbed or Modified	Harvested Forest	Harvested forest-tree regeneration
Recently Disturbed or Modified	Harvested Forest	Harvested forest-shrub regeneration
Recently Disturbed or Modified	Harvested Forest	Harvested forest-grass regeneration
Open Water / Wetland and Riparian Systems	Open Water	Open Water
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Greasewood Flat
Open Water / Wetland and Riparian Systems	Forested Marsh	Rocky Mountain Conifer Swamp
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Great Plains Floodplain
Open Water / Wetland and Riparian Systems	Depressional Wetland	Rocky Mountain Wooded Vernal Pool
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Rocky Mountain Subalpine-Montane Riparian Woodland
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Rocky Mountain Subalpine-Montane Riparian Shrubland
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Prairie Pothole
Open Water / Wetland and Riparian Systems	Wet meadow	Alpine-Montane Wet Meadow
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Open Freshwater Depression Wetland
Open Water / Wetland and Riparian Systems	Herbaceous Marsh	Emergent Marsh
Open Water / Wetland and Riparian Systems	Bog or Fen	Rocky Mountain Subalpine-Montane Fen
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Closed Depressional Wetland
Open Water / Wetland and Riparian Systems	Depressional Wetland	Great Plains Saline Depression Wetland
Open Water / Wetland and Riparian Systems	Floodplain and Riparian	Great Plains Riparian

Appendix IV. Example of GLO field notes from the Bitterroot Valley.



3d Standard Parallel N. [illegible] Principal Meridian

chains 50

by Rattle snake creek. There is a saw mill on Grant creek near the N.W. cor. of this town ship and fine pine timber on the mountains on the north boundary of the same. There are many fine farms on the Bitter Root river and on the Hell Gate. It should be subdivided. April 25th

West on south boundary of Sec 31

Va 28° E

27.50 a slough 1.75 chs wide runs N.

40.00 Set 1/4 sec. cor. a post in mound earth with pits [illegible] stake

chains 51

59.70 a slough runs N. 2.00 chs wide

80.00 Set cor. to secs 35. 36. a post in mound of earth with pits [illegible] as per instructions.

Land level [illegible] rate

Timber pine and cottonwoods along Bitter Root river.

West on south boundary of Sec. 35

Va 21° E

10.00 a course N. 15° E

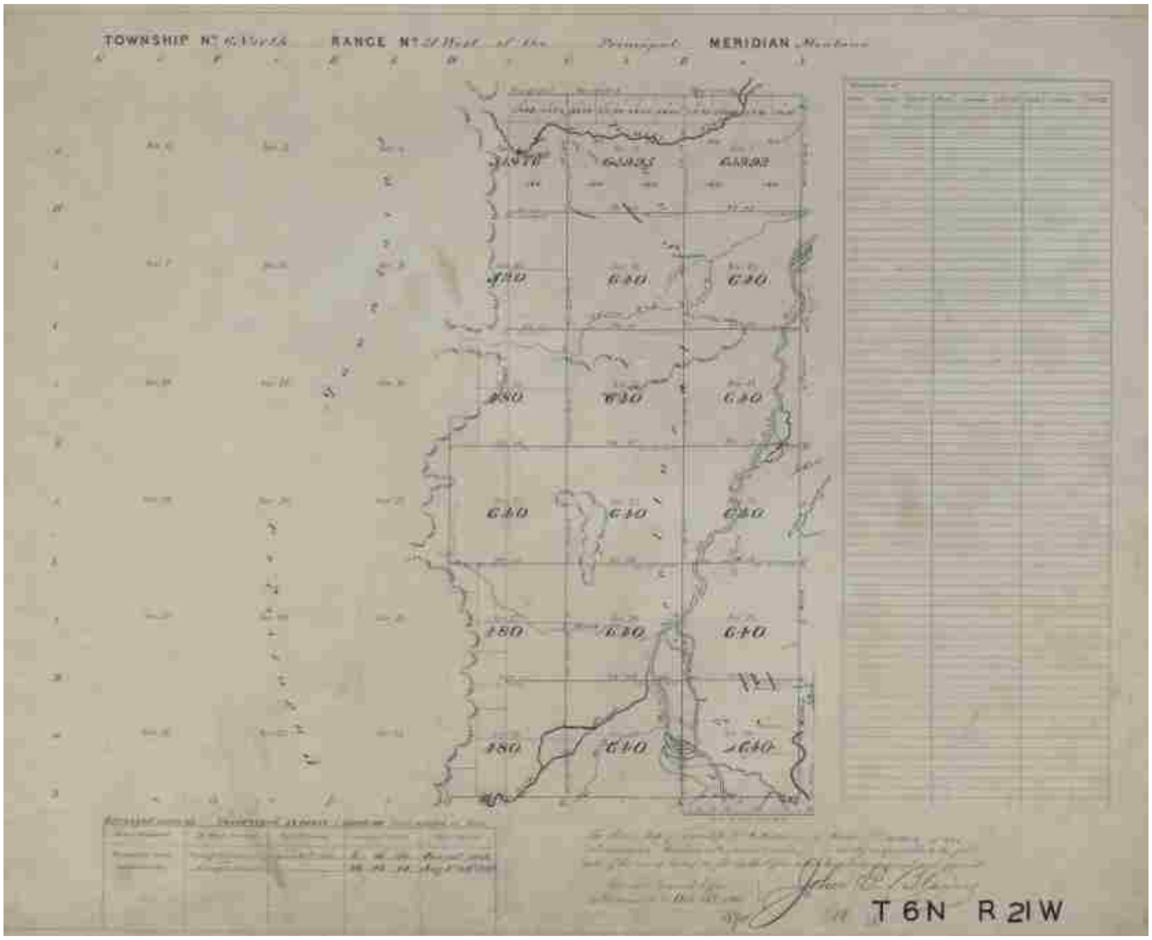
40.00 Set 1/4 sec. cor. a post in mound of earth with pits and stake as per instructions.

54.50 a course [illegible] 10 [illegible] line

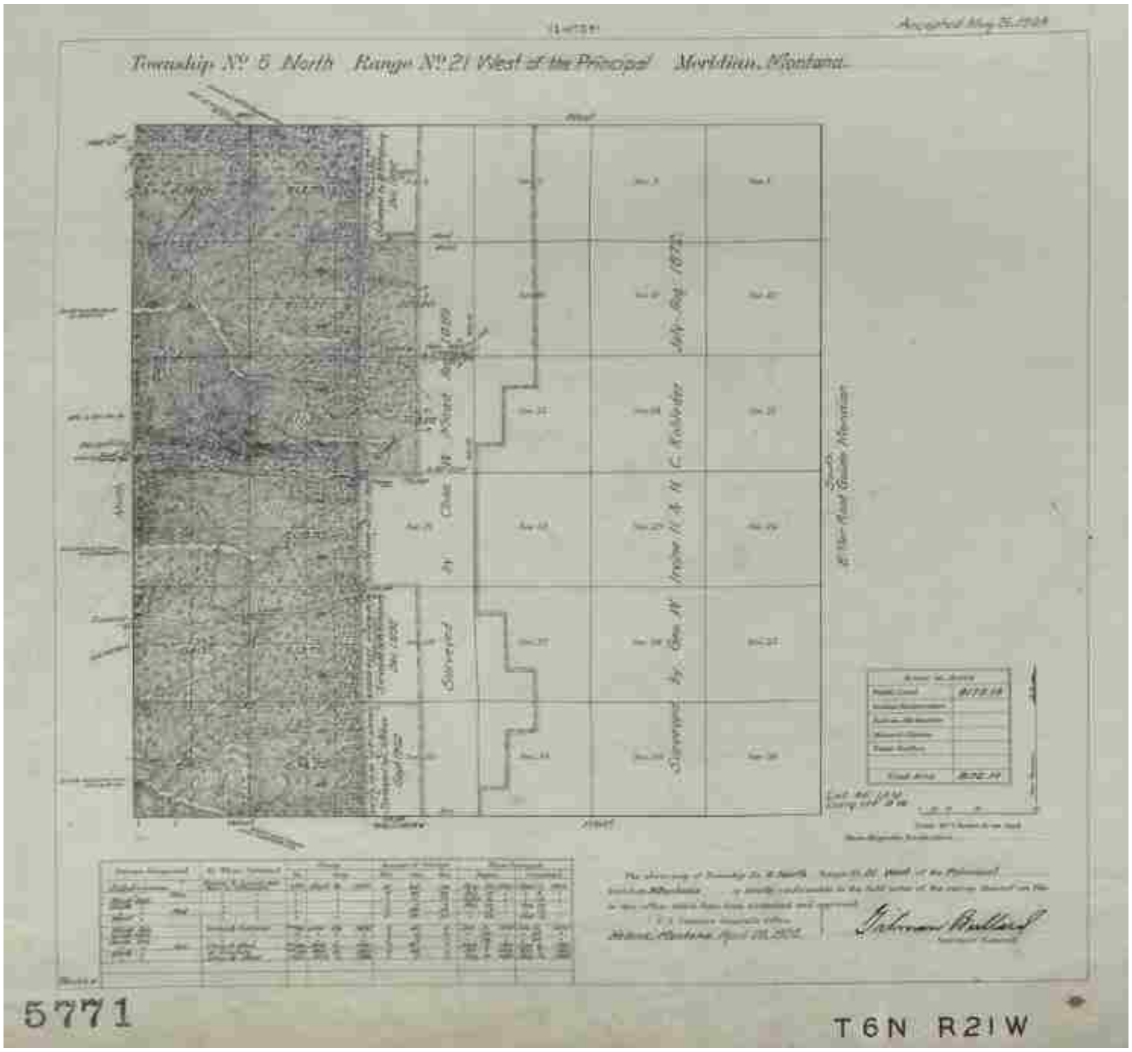
58.50 top of [illegible] about 12 x 10 ft.

Appendix V. Plats of T06N R21W original surveys (1873 and 1924)

1873



1924


Accepted May 15, 1924
Township No 6 North Range No 21 West of the Principal Meridian, Montana
Surveyed by Geo. W. Irvine, H. A. & H. C. Kolbeder July-Aug. 1872
Helena, Montana April 28, 1924
5771
T6N R21W

Appendix VI. General Descriptions of Township Boundaries and Subdivisions

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T08NR20W	Johnson, Walter W.	The Bitter Root Valley south of this parallel has a width of from 12 to 18 miles and is settled on Willow Creek 10 mi. Skalkaho. 17 m. Weeping Child which are tributaries on the east, and there are also farms on the numerous streams which flow from the rugged range of mountains which border the valley on the west. This valley has the mildest climate of any valley in the territory and the crops are luxuriant. There are some 300 whites already located in it. July 18,1870	Vol R 13 p. 112-120	7/28/1870	North
T08NR20W	Rohleder, Henry C.	Bitter Root Valley, one of the finest Agricultural Districts in the Territory of Montana is situated in the South Western portion of the Territory and is divided from South to North by the Bitter Root River a beautiful stream of pure clear water with an average width of 300 links, well stocked with fine fish and skirted with pine and cottonwood timber which abound in game. Along the Bitter Root River the surface on the east is chiefly bottom but gradually rises into tableland. The west is bottom and high rolling prairie. The soil is a deep sandy loam of inexhaustible fertility and admirably adapted to the raising of grain and vegetables and for grazing purposes. The east side is watered by Weeping Child, Ska Ka ho, Gird's and Willow Creek and the west by Komos, Mill, Fred Burr, Dry, Sweathouse, and Big Creek all of which are tributaries of the Bitter Root river and upon whose borders are many well improved ranches. This valley contains a population of probably more than eight hundred at the present time and is rapidly increasing. An excellent wagon road traverses the valley from north to south passing through the Village of Stevensville and Corvallis both of which are in the valley east of the river. The valley farther [?] south to the 1st Standard Parallel north, is of inconsiderable width, say one and a half miles and is valuable for grazing purposes only.	Vol R 29 p. 35-37	10/21/1872	North

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T08NR20W	Irvine, G.	This township lies directly West of the Bitter Root River and between that and the Bitter Root range of mountains which forms its western boundary, and from out the canons of which range flour--- [?flourishes] Mill, Fred Burr, and Dry Creeks running in a north easterly direction through the township emptying their waters into Bitter Root river. The surface of this Township is chiefly high rolling prairie terminating in the west in the foot hills whilst a portion on the east is river bottom. The Township is well watered by the various creeks which run through the Township. Timber is abundant. The soil is good 1st and 2nd rate land. Upon Mill [?] Creek is a good saw mill and also several Ranches on Fred Burr and Dry Creek	Vol R 29 p. 320-332	10/21/1872	North
T08NR20W	Johnson, Walter W.	This township contains a fine body of first class land on Burnt Fork as well as along the Bitter Root river and the rivulets flowing from the mountains on the west side of the valley [?]. The village of Stevensville contains about 20 houses. The St. Mary's Mission is about a quarter mile W. of Stevensville. Fort Owen is about a mile N.W. and a fine flouring mill is run by the water power of Burnt Fork. There are some 10 farms already settled and a fine body of pine timber is seen on the west side of the Bitter Root river.	Vol R 13 Pages 102-103	7/28/1870	North
T08NR20W	Rohleder, Henry C.	This township is an excellent body of land, thickly settled and should therefore be subdivided. Growth of rich bunch grass, leaving this township unsurpassed by any in the valley for grazing purposes. There is a sawmill in Sweathouse Creek canyon. The lands are agricultural.	Vol. R 29 p. 389	10/21/1872	South
T08NR20W	Rohleder, Henry C.	This township is fractional consisting of sections of land, which is of good quality, and is partially settled and should therefore be sub-divided.	Vol. R 29 p. 466	12/21/1872	North, East

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T08NR20W	Rohleder, Henry C.; Irvine, George	This township is known in Bitter Root Valley as the sagebrush country. It lies chiefly east of the Bitter Root River. One tier of Sections however lie upon an Island in the river, and in the finest body of meadow land in the Bitter Root Valley. The remaining portion of the township away from the river bottom is a level plateau, the soil of which is a rich alluvium. Timber is abundant along the Bitter Root River and Sweathouse and Lower Big Creek by which streams the township is well watered. This township is thickly settled, fine large, well cultivated and highly improved farms are on every land, and splendid crops of grain and vegetables are raised. The lands are agricultural.	Vol. R 29 pp. 586-87	12/21/1872	Subdivision
T08NR21W	Roleder, Henry C.	This township is fractional but containing, as it does, a considerable amount of splendid farming land a portion of which is already occupied. Should therefore be subdivided.	Vol. R 29 p. 282	10/21/1872	South
T08NR21W	Mead, Charles	The portion of this township which I subdivided is very rough and mostly worthless. It has been nearly stripped of its valuable timber, Sweathouse Creek runs through the township and affords water for irrigating the valley and bench lands below. I saw many indications of mineral bearing quartz lodes and I believe that by thorough prospecting good leads would be discovered.	Vol.R 168 p. 188	6/2/1891	Subdivision
T08NR21W	Rohleder, Henry C.	This township lies west of the Bitter Root river and is bounded on the west by the Bitter Root Range on mountains which render it fractional. It is watered north by Lower Big Creek and it southern portion by Sweathouse Creek. Timber is abundant. The surface consisting of bottoms and uplands comprise an agricultural district unsurpassed of location or variety, depth and richness of soil. It is known as the garden spot of the valley, and the splendid crops of grain and vegetables raised thereon testify to the appropriateness of the term, whilst the adjacent foot hills are covered with a luxuriant growth of rich bunch grasses leaving this township unsurpassed by any in the valley for grazing purposes. There is a sawmill in Sweathouse Creek canyon. The lands are agricultural.	Vol R 29 pp. 608-610	12/21/1872	Subdivision

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T08NR21W	Scott, R.	All the land in sec. 28 with the exception of a few acres in the SE cor. Is mountainous and covered with a heavy growth of fir and pine timber of good quality. Sweathouse Creek a swift mountain stream flows from West to East, through the sec. The W 1/2 of sec. 33 is also mountainous land, covered with an abundant growth of pine and fir timber and some tamarack. The east 1/2 of sec. 33 is bench land, mostly covered with timber and undergrowth. This section is well watered by Gash Creek and its timbered. Robert F. Scott	Vol. R 287 pp. 12-14	1/3/1902	Subdivision
T08NR21W	Lord, H.	The fractional S. and W. boundaries surveyed by me, traverse high and rugged mountains on the slopes of which is a fair growth of pine, fir and spruce. The soil is generally very rocky. The west boundary was not extended farther north because it encountered very high and rugged mountains on the slopes of which there was no timber of marketable value. 9/19/1911	Vol.R. 582 p. 62	1/16/1912	South, West
T08NR21W	Lord, H.	That portion of this township surveyed by me consists of high rugged mountains having a general trend of E. and W. and is well drained by the numerous streams which flow generally easterly. The principal creeks crossed by the lines of this survey are, Gash Creek, Sweathouse Creek, Smith Creek, and McCalla Creek, all flowing easterly. The slopes of the mountains are covered with a fair growth of heavy timber; the soil is very poor being composed of a light loam mixed in with stone and rock. There are no settlers in the sections closed by this survey. The lines were not extended or surveyed farther because they would encounter high rugged and practically impassable mountains, the slopes of which are covered with small scrubby timber of a very inferior quality of no market value.	Vol. R 582 p. 90	1/16/1912	Subdivision
T07NR20W	Rohleder, Henry C.	This township contains a body of most excellent land, is well settled and therefore should be subdivided.	Vol R029 p.210	10/21/1872	South

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T07NR20W	Irvine, George	This township is divided from south to north by the Bitter Root river lying chiefly east of that stream. The southern portion of the township is watered by Willow Creek which after flowing through the township from east to west empties into Bitter Root River. The surface is bottom land, gradually rising into bench and table land and high rolling prairie. The soil is a deep sandy loam of inexhaustible fertility admirably adapted to the raising of grain and to grazing purposes. Timber is found along the Bitter Root River and in Sections 24,25 and 36. The township is traversed from north to south by an excellent road which passes through the village of Corvallis, in Section 32 of this township consisting of two stores, a blacksmith shop, post office and a number of neat dwellings. Besides this village there are numberous fine ranches in excellent condition in the township. The lands are agricultural.	Vol R029 p. 455-456	12/21/1872	North
T07NR21W	Rohleder, Henry C.	This is a fractional township containing some excellent farming land, which being partially settled should be subdivided.	Vol R 29 p. 102	10/21/1872	South
T07NR21W	Irvine, Geo. W.	This township lies directly west of the Bitter Root River, and between that and the Bitter Root Range of mountains, which forms its western boundary, and from out of the canyons of which range, flow Mill, Fred Burr, and Dry Creeks running in a north easterly direction through the township emptying their waters into Bitter Root River. The surface of this township is chiefly high rolling prairie terminating in the west in the foot hills whilst a portion on the east is river bottom. The township is well watered by the various creeks which run through the township. Timber is abundant. The soil is good 1st and 2nd rate land. Upon Mill Creek is a good saw mill and several ranches and also several ranches on Fred Burr and Dry Creek.	Vol R 29 p. 320-321	10/21/1872	North
T07NR21W	Klingberg, W.	This line is over very rough and mountainous land. The soil is rocky 4th rate. The timber Pine and Fir 1st quality valuable for saw timber. There are about 5 settlers in this township. The west boundary falling altogether on very high and rugged mountains the survey thereof is impracticable. 12/07/1892	Vol R 200 p. 542-543	5/25/1893	South

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T07NR21W	Mead, Charles W.	The portion of this township which I subdivided was well timbered and much of it has been cut off. It is nearly all ----- ed by a ------ or --------- settlers. It is well watered by Fred Burr and Bear Creeks and by small streams.	Vol R 168 p. 167	6/2/1891	Subdivision
T07NR21W	Klingberg, Willgott	This township is rough and broken land. Soil is sandy loam and rocky. 3rd and 4th rate. No indications of any valuable mineral deposits. Timber of 1st quality, pine, fir, and tamarac, suitable for saw timber. There are several springs and small creeks in this township especially the Fred Burr Creek, which has a capacity of 4000 min[?]rs inches and flows through sec. 20. There are a few settlers but names are unknown as their improvements are all in the interior of the secs. 12/14/1892	Vol R 201 p. 613	10/10/1893	South
T06NR20W	Rohleder, Henry C.	This township is fractional yet contains a considerable amount of excellent farming land which is well settled and should be subdivided.	Vol R 29 p 147	10/21/1872	South
T06NR20W	Irvine, George	This township consists of level prairie, with bottom land near the Bitter Root River, on Girds and Willow Creeks. On the east it is shut in by the Rock Creek range of mountains. It is watered by the Bitter Root River, Girds and Willow Creeks. Along the streams the land for agricultural purposes is unsurpassed. The bank of the Bitter Root is well wooded and there is also an abundant supply of wood for fuel on the eastern border of the township. there are many well cultivated farms which produce splendid crops of wheat, oats and barley.	Vol R 29 p. 272	10/21/1872	East
T06NR20W	Bickel, Paul A.	[east township line survey] The land along this township line is mountainous all the way along the south end. On the south end it is heavily covered with timber Along Skalkaho Creek there is excellent range for stock and many places blue joint hay grows wild. Marcus Daly has a ranch just East of line in Sec 6 T5NR19W. 08/18/1893	Vol R 210 p. 431	5/31/1894	East, South

TOWNSHIP	SURVEYOR	GENERAL DESCRIPTION	VOL	APPROVED DATE	BOUNDARY
T06NR21W	Irvine, George	The greater portion of this township lies west of the Bitter Root River and extends to the foothills of the Bitter Root Range of mountains. The surface of the country is bottom and high bench land, all of which can be well watered by the various streams that run through them. The soil is of an excellent quality well adapted to the raising of grain and for meadow and grazing purposes. Timber is abundant and of good quality for building and farming purposes. The bottomland is principally settled. 08/06/1872	Vol R 29 p. 139	10/21/1872	Subdivision of east part
T06NR21W	Mead, Charles	The portion of this township which I subdivided is thickly covered with pine timber and is well watered by several little streams. There are a number of alleged settlers who have cabins built as claim holders but do not live in them and a few other bona fide settlers. 08/12/1891	Vol R168 p. 110	11/21/1891	South
T06NR21W	Lyman	The two west tiers of sections of this township, surveyed under this assignment, are located about five miles west of Hamilton Montana. They lie on rugged montainous land, draining directly into the valley of the Bitter Root River. The south boundary crosses the high divide between Saw Tooth and Canon Creeks about 1 3/4 miles south of the point where Canon Creek leaves the mountains. The west boundary crosses Canon, Blodgett and Mill Creeks leaving the NW. corner of the township on the north side of Mill Creek. The north boundary lies along the north wall of the canon of Mill Creek. The elevation ranges from about 4000 ft. above sea level, where Blodgett and Mill Creeks leave their canons, to about 8400 ft. on the high divide between Blodgett and Mill Creeks. Very good timber is found on the lower slopes along the canons, especially in the fifth tier of sections. No agricultural areas are found in the two west tiers. some high bench land in sections 9 and 16 may be utilized for fruit and grain raising but it is very stony. The canons are remarkably scenic on account of the peculiar cliff formations and the precipitous walls extending transversely from the main canon walls, these formations are confined largely to the north walls of the canons.	Vol R0 775 p. 508-509	4/29/1924	Subdivision

Appendix VII. Procedure and Formulas for New Point Creation

In Arc GIS 10 using the GCDB attribute table, new points representing bearing and line trees, vegetation, cultural and aquatic features were created from a known GCDB point location (a section corner or quarter corner) and a distance and bearing from that point.

Fields:
Point_X_M is the original GCDB X coordinate in meters (a section corner or quarter corner).
Point_Y_M is original GCDB Y coordinate in meters.
DIST_M is distance from known point.
BEAR_DEG is the bearing.
QUADRANT is one of four quadrants—NE, SE, SW, and NW

Formulas:
In ArcGIS10 (Field Calculator on NE_x, NE_y, SE_x, SE_y, SW_x, SW_y, and NW_x, NW_y):
NE_x = Point_X_M + DIST_M * SIN(BEAR_DEG * Atn(1)/45)
NE_y = Point_Y_M + DIST_M * COS(BEAR_DEG * Atn(1)/45)

SE_x = Point_X_M + DIST_M * SIN(BEAR_DEG * Atn(1)/45)
SE_y = Point_Y_M - DIST_M * COS(BEAR_DEG * Atn(1)/45)

SW_x = Point_X_M - DIST_M * SIN(BEAR_DEG * Atn(1)/45)
SW_y = Point_Y_M - DIST_M * COS(BEAR_DEG * Atn(1)/45)

NW_x = Point_X_M - DIST_M * SIN(BEAR_DEG * Atn(1)/45)
NW_y = Point_Y_M + DIST_M * COS(BEAR_DEG * Atn(1)/45)

The Atn (inverse tangent) portion of the formula converts degrees to radians. (ArcGIS computes in radians).

To create two new X and Y fields containing all the GLO points, these new point coordinates were selected by attribute–by Quadrant— NE_X, NE_Y, SE_X, etc., and were copied and pasted into new fields: New_x, and New_y fields.

Appendix VIII. Codes for classifying survey points

The Section_Points CODE field Table 2. includes: C, I, M, Q, R, S, T, V, and W point description codes.

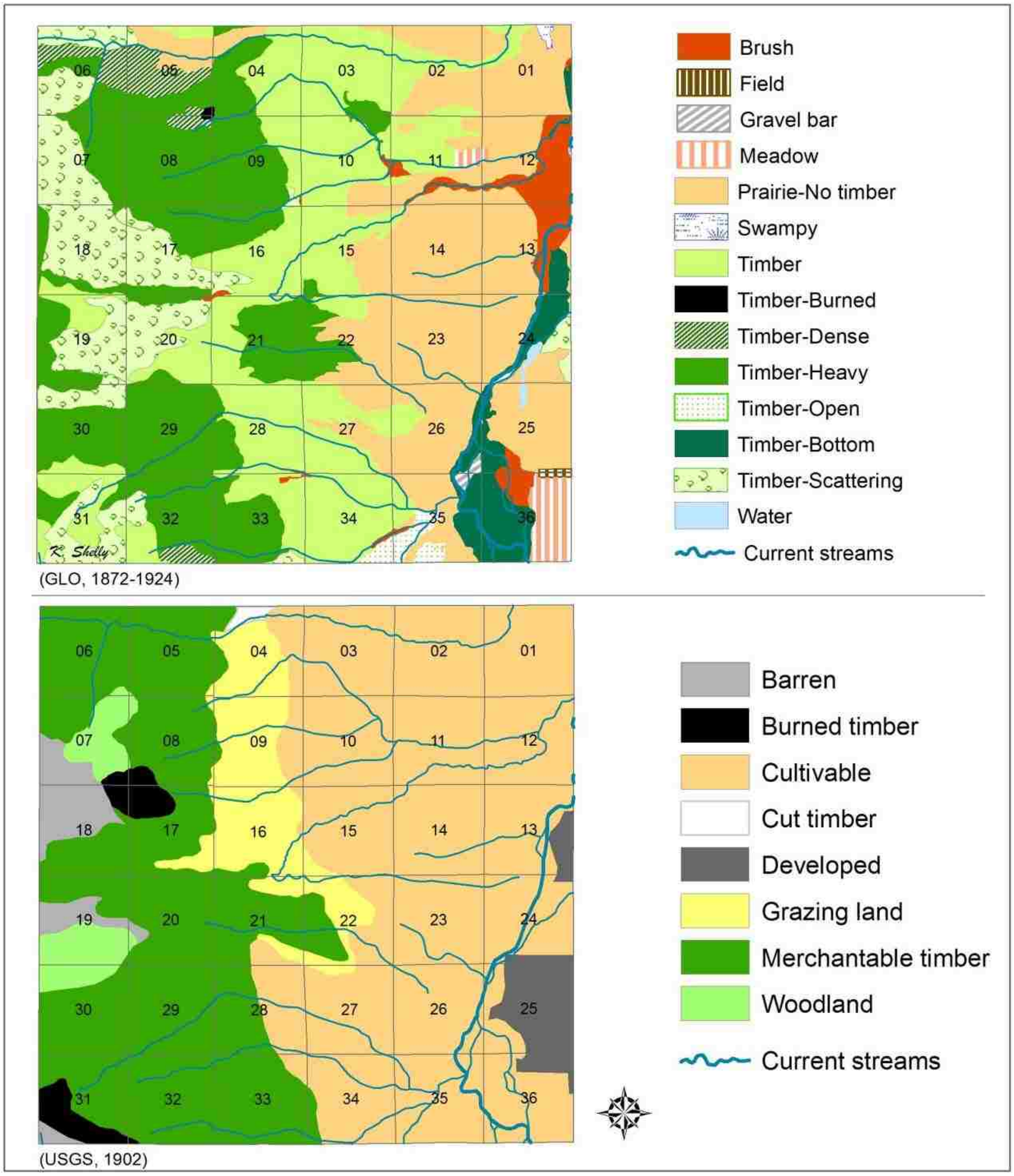
C	Section corner where four sections intersect marked by posts, rocks, mounds or trenches. All data recorded at section corner including bearing trees are coded C.
I	Intercept of a tree or other object in the direct survey path along line, not at corners. Record the name in the SPECIES field, and diameter in the TREE_DIAM field.
M	Manmade feature, buildings, road or trail crossings, cattle trails, fences, irrigation ditches, crops, orchards, old village sites, mill ponds and reservoirs.
Q	Quarter section corner set halfway between two section corners usually at 40 chains; includes witness trees, trenches, pits and mounds.
R	River, flowing or sluggishly moving water with separate entry and exit points.
S	Stream, flowing water without separate entry and exit points; includes smaller creeks, streams, brooks, branches, and springs.
T	Topographic features including hills, slopes, ravines, dry swales, bottoms.
V	Vegetation changes. Examples: Enter prairie. Enter pine timber, Leave marsh.
W	Water, non-flowing or still water without separate entry and exit points. Includes small sloughs, backwaters, bayous, lakes, ponds.

Table 2. Section_Points VEG_CODE field includes the following categories:

a	open, heavy timber
c	field, plowed field
d	dead timber
e	meadow
f	timber
g	gravel bar
h	bottom
i	open pine timber, few pine
j	pine grove, grove of small timber
k	scattering timber, scattering pine
l	lake, slough, pond
m	marsh
n	small timber
o	cut timber
p	prairie
q	no timber
r	timber bottom
s	swamp, swampy ground
t	thicket, brush, dense undergrowth, aspen brush
u	burned area

Appendix IX. Visual Comparison of Major Vegetation Types and 1902 Timber Density.

T06NR21W
GLO Major Vegetation Types and
1902 Land Classification and Timber Density



(GLO, 1872-1924)

(USGS, 1902)