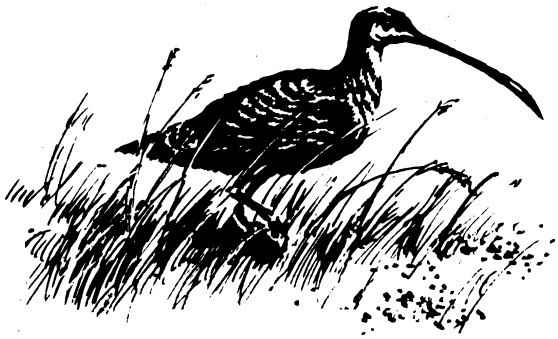
Appendix C: Hanford Biological Resources in a Regional Context



Appendix C

Hanford's Biological Resources in a Regional Context

The purpose of Appendix C is to place Hanford Site biological resources into a regional context and, within that context, to describe the significance of Hanford's resources. Section C.1 introduces the concept of an ecoregion and briefly describes how the concept has been applied to the Columbia Basin. Section C.2 describes the characteristic physical and biological features of the Columbia Basin Ecoregion. Section C.3 provides a similar description of the Hanford Site. Within the framework established by Sections C.2 and C.3, Section C.4 then discusses Hanford's regionally and nationally significant biological resources.

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C.1 Ecoregion Concept and Historic Depictions of the Columbia Basin Area

The ecoregion concept is a special method of regionalization[1] for subdividing a geographic area into regions of relative homogeneity with respect to ecological systems or the relationships between organisms and their environments (SAB 1991; Omernick 1987). The subdivisions that result can provide a valuable framework for environmental resource managers to use for monitoring, impact assessment, and resource management (SAB 1991). Also, the framework enables an evaluation of the relative significance of the characteristics that define geographic subdivisions. Although subdivision can occur at a variety of scales, as a particular level of geographic subdivision an ecoregion may be defined as a continuous geographic area within which the environment resulting from the interplay of variables such as climate, topography, and soils is sufficiently uniform to develop characteristic potential major vegetative communities. The interplay of environmental variables determine which biota can exist in an ecoregion (SAB 1991). Extreme changes in the characteristic vegetative communities define ecoregion boundaries.

Formulating definitions of geographic areas based on ecological characteristics has been an evolving process. A number of different approaches have been used in the past that have a bearing on determining Hanford's regional ecological context. Some methods for defining ecoregions have been applied across the entire United States. These are ecoregions as defined by Bailey (1976, 1980, 1995), Bailey et al. (1994), and Omernick (1987). The portions of the resultant maps produced from these methods applicable to the Pacific Northwest (in their latest versions) are portrayed in Figures C.1 (Omernick 1987) and C.2 (Bailey et al. 1994), respectively.

C.1.1 A First Attempt: Bailey 1976

Bailey's (1976, 1980) earlier framework for ecological classification was prepared as an aid for the U.S. Fish and Wildlife Service and its National Wetlands Inventory effort (Bailey 1980). The classification used a hierarchy of four levels. The broadest levels of the classification (i.e., domain and division) were based on climate. Based on the classification scheme, the Hanford Site is located within the dry domain and steppe division. Such an area is characterized by cold winters, rainfall less than 50 cm/yr (about 20 in./yr), and shrubs or sparse grasses. The next two levels, province and section, were defined by macro-features of the potential vegetation. The Hanford Site is located within the intermountain sagebrush (*Artemisia*) province, an area that encompasses southcentral Washington, a strip through central Oregon, southeastern Oregon, southern Idaho, northeastern California, most of Nevada, and western Utah. At the section level of Bailey's classification, Hanford is within the sagebrush/(bluebunch) wheatgrass [*Agropyron* (= *Pseudoroegneria*) *spicatum*] section. The area covered was a subset of the province that excludes a western strip of ponderosa shrub forest and most of the Nevada and Utah portions of the province. Thus, in Bailey's 1976 map, Hanford maintained ecological continuity with the Snake River Plain and the high elevation shrub-steppe (i.e., steppe containing conspicuous shrubs; see below) of central Oregon. Such a depiction implied a close ecological association between shrub-steppe of the Columbia Basin and shrub-steppe of the Great Basin.

C.1.2 A Different Perspective: Omernick 1987

Omernick's (1987) framework was developed in response to a need to assess existing and attainable surface water quality (Omernick and Griffith 1991). Because surface waters generally reflect the characteristics of areas they drain, Omernick based his approach on patterns of terrestrial characteristics (Omernick 1987; Omernick and Griffith 1991). For Omernick's purposes, Bailey's (1976, 1980) ecoregion sections were inadequate at most locations, because at this level of classification Bailey relied on a single mapped characteristic [i.e., potential natural vegetation from Küchler (1970)] to define an area (Omernick 1987). Omernick's approach was to instead simultaneously analyze a combination of causal factors, that included climate, soils and geology, vegetation, and physiography to define different ecoregions. Omernick also considered integrative factors, such as land use, to discern regional patterns.

[1] Regionalization is a mapping procedure by which a portion of the landscape is recognized as having a degree of internal homogeneity as well as features that contrast with those of an adjacent area (Bailey et al. 1978).

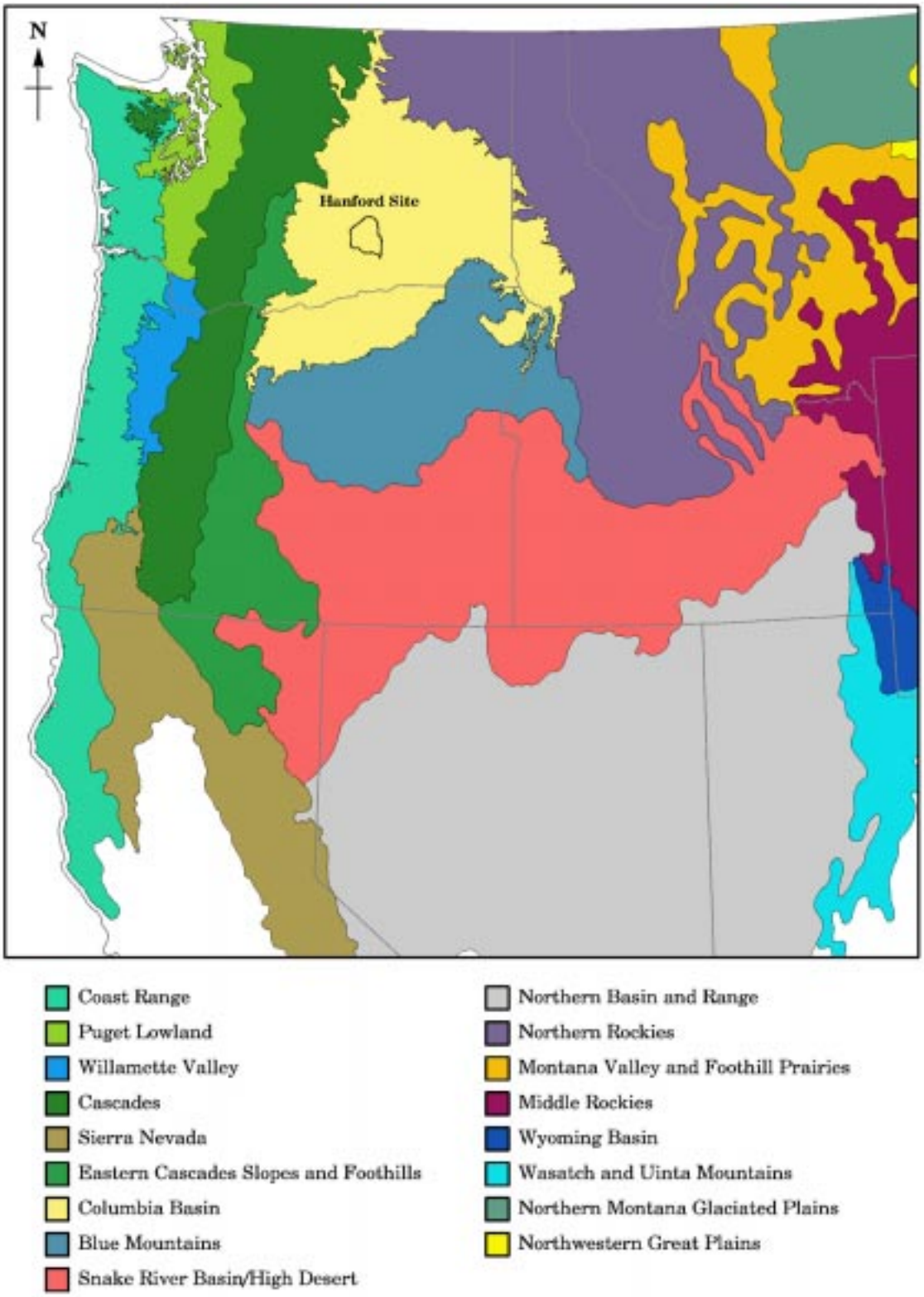
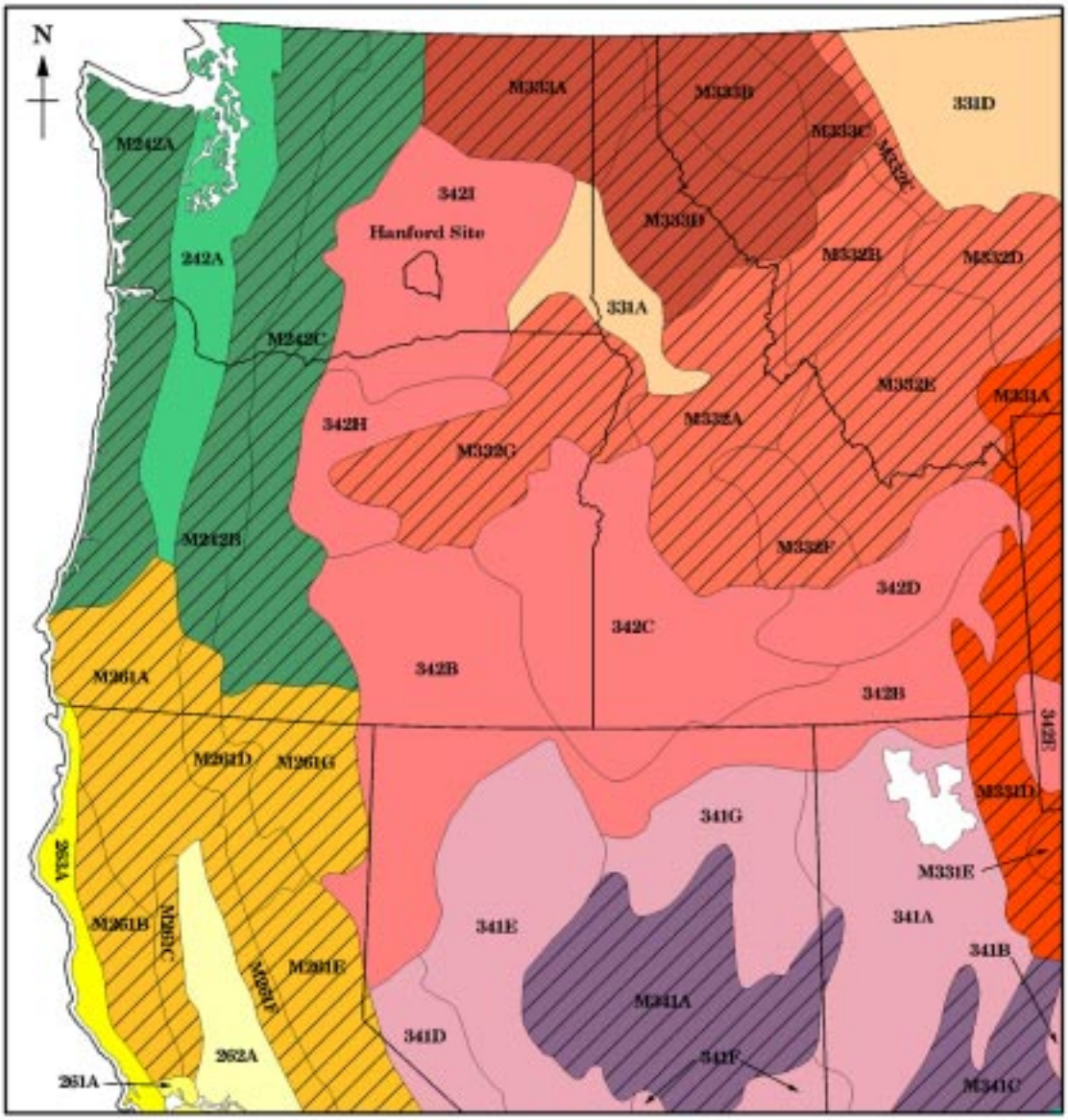


Figure C.1 Omernick's Ecoregions for the Northwest Portion of the United States (Original source: Omernick [1987]. Electronic version obtained from the Interior Columbia Basin Ecosystem Management Project.)



331A Palouse Prairie Section
342B Northwestern Basin and Range Section
342C Owyhee Uplands Section
342D Snake River Basalts Section
342H High Lava Plains Section
342I Columbia Basin Section

M242C Eastern Cascades Section
M332A Idaho Batholith Section
M332G Blue Mountains Section
M333A Okanogan Highlands Section
M333D Bitterroot Mountains Section

Figure C.2 Bailey's Ecoregions for the Northwest Portion of the United States (Original source: Bailey et al. [1994]. Electronic version obtained from the Interior Columbia Basin Ecosystem Management Project.)

Omernick's (1987) resulting map (Figure C.1) also used a hierarchical approach. At the broadest levels of classification, Omernick divided the United States into regions and sections (classifications that encompass areas not necessarily contiguous). The most detailed level, essentially equivalent to Bailey's (1976, 1980) section level and what is shown in Figure C.1, identified specific, integral geographic areas. The Hanford Site is located within Omernick's (1987) western xeric region, semi-arid section, and Columbia Basin Ecoregion. The major differences between Omernick's 1987 depiction and Bailey's 1976 map were Omernick's inclusion of Bailey's Palouse grassland province as part of the Columbia Basin Ecoregion and his limiting of the southern extent of the ecoregion to include only northcentral Oregon. Thus, in Omernick's depiction, the Columbia Basin shrub-steppe was not in ecological continuity with Great Basin shrub-steppe, including the Snake River Plain. Of lesser importance, Omernick included portions of the Methow and Okanogan river drainages within the Columbia Basin Ecoregion.

C.1.3 A Modification of Earlier Efforts: Bailey and Others 1994

Subsequent to the efforts described in the preceding paragraphs, the U.S. Forest Service developed a hierarchical framework of ecological units as a means to provide a consistent framework for agency implementation of ecosystem management at different planning levels (ECOMAP 1993). Thus, for the Forest Service, the primary purpose for delineating ecological units was to identify land and water areas at different levels of resolution that have similar capabilities and potentials for management (ECOMAP 1993). The different mapping units are differentiated by considering multiple factors, such as climate, physiography, geology, soils, water, and potential natural communities (animal as well as vegetation).

The resultant classification has hierarchies of scale, as well as levels within scales (ECOMAP 1993). At the ecoregion scale, the three ecological units included are adapted from Bailey (1976, 1980): domains, divisions, and provinces. At the subregion scale, two ecological units are included: sections and subsections. Two other scales complete the hierarchy: landscape scale and land unit scale. At coarse scales, abiotic factors dominate the basis of delineation; whereas, at finer scales of resolution, both biotic and abiotic factors are important. The section ecological unit best approximates Omernick's (1987) ecoregion level of classification and Bailey's (1976, 1980) section level; whereas, the Hanford Site (or significant portions of it) approximates the landscape scale and project-level activities at Hanford approximate the land unit scale.

Bailey's latest revision of his ecoregion framework for the United States (Bailey 1995) retains the first three levels of the hierarchy (i.e., domain, division, and province) but, in some cases, redefines their geographic representation. At the division level, the Hanford Site is now considered to be in an area defined as temperate desert. At the province level, to the east Bailey's Great Plains-Palouse Dry Steppe Province is now restricted to extreme southeastern Washington and portions of westcentral Idaho (In Bailey's 1976 map the Palouse extended northwest to central Washington and southwest to Oregon.). The Hanford Site is located within the Intermountain Semi-Desert Province, a province that still includes the Snake River Plain area as contiguous ecologically with the Columbia Basin.

If Bailey's revision had stopped at the province level, there still would remain significant differences between Omernick (1987) and Bailey's (1995) ecoregion depictions; however, Bailey et al. (1994) further modified Bailey's 1995 map. (The discrepancy in dates is probably due to differences in publication schedules.) These authors subdivided the provinces into subregions (again referred to as sections) in accordance with the Forest Service's hierarchical framework (ECOMAP 1993). The resultant map is shown in Figure C.2. At the higher levels of the classification hierarchy, climate (domain and division) and macro-features of the vegetation (province) dominate the basis for subdivision. Because physiography exerts the major influence over ecosystem characteristics within climatic-vegetation zones, physiography is used as the basis for defining sections (Bailey et al. 1994). Of note is that now at the section level, the Hanford Site, located within the Columbia Basin Section, is identified separately from the remainder of the Great Basin.

C.1.4 Contributions of a More Regional Focus: Franklin and Dyrness 1973

A final source of information that can be useful for defining Hanford's ecological context is Franklin and Dyrness (1973). This work is a regional effort that covered ecological characteristics, principally

major vegetation types, within the states of Washington and Oregon. Franklin and Dyrness attempted to outline the major phytogeographic units of the two-state region and to suggest how these units related to each other and to environmental factors. As a basis for discussion, they subdivided the region into relatively homogeneous areas (i.e., provinces) based on physiography (similar to the Bailey et al. 1994 section level designation criterion) (Figure C.3). Their Columbia Basin Province compares favorably with Omernick's (1987) Columbia Basin Ecoregion and Bailey et al.'s (1994) Columbia Basin Section.

C.1.5 A Synthesis of Available Information: Hanford's Relevant Ecological Context—The Columbia Basin Ecoregion Defined

Although the three depictions of the Columbia Basin area (i.e., Bailey et al. 1994; Franklin and Dyrness 1973; Omernick 1987; Figures C.2, C.1, and C.3, respectively) are not congruent, they overlap sufficiently to enable defining an area that provides the appropriate ecological context for Hanford's biological resources. First, it does seem necessary to define a southern ecological boundary that separates the Columbia Basin from the Great Basin, though the community dominants are often similar. Franklin and Dyrness (1973) offer several reasons to contrast the Columbia Basin steppes from the steppes of the southeastern Oregon portion of the Great Basin.[2] As compared with the Columbia Basin area:

1. Southeastern Oregon shrub-steppes average much higher in elevation.
2. Deep, loamy soils are not common in southeastern Oregon.
3. Desert or salt desert shrub communities are common enough in southeastern Oregon to show up on regional vegetation maps.
4. Western juniper (*Juniperus occidentalis*) and curl-leaf mountain mahogany (*Cercocarpus ledifolius*) occur in association with shrub-steppe in southeastern Oregon.
5. Meadow-steppes of sod-forming grasses and dicotyledonous herbs, which ring much of the Columbia Basin Province, are nearly absent in southeastern Oregon (Franklin and Dyrness 1973).

Based on a recent vegetation mapping of Oregon (O'Neil et al. 1995), the most appropriate southern boundary seems to be that of Omernick (1987). South of this boundary, western juniper becomes a community dominant (O'Neil et al. 1995). Franklin and Dyrness (1973) did not show western juniper as the dominant vegetation type until south of the Blue Mountains (High Lava Plains Province), and thus, extended the Columbia Basin Province south along the Deschutes River corridor. Omernick's boundary represents this vegetation transition better than do Bailey et al. (1994). Another reason for choosing Omernick's southern boundary is that the dominant land use within this portion of Oregon is agriculture, just as it is in the Columbia Basin portion of eastern Washington.

How to address the transition between the meadow-steppe of the Palouse and the remainder of the steppe region of eastern Washington is more problematic. Omernick (1987) did not differentiate the two and included the Bailey et al. (1994) Palouse Prairie within his Columbia Basin Ecoregion. Conversely, Bailey (1976, 1980, 1995) and Bailey et al.

[2] The following discussion on steppe and shrub-steppe is taken from Daubenmire (1970). In contrast to a desert, steppe has moisture relations adequate to support an appreciable cover of perennial grasses on zonal soils (i.e., deep loams on gentle upland slopes), yet not enough to support arborescent vegetation (i.e., trees). Thus, Daubenmire considered eastern Washington to be better classified as steppe rather than desert. Steppe includes a physiognomic subdivision—shrub-steppe—and two ecological subdivisions: meadow-steppe and true-steppe. Shrub-steppe communities are plant communities consisting of one or more layers of perennial grass above which there rises a conspicuous but discontinuous layer of shrubs. Communities with bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*), and perhaps threetip sagebrush (*A. tripartita*) illustrate shrub-steppe physiognomy in Washington. Meadow-steppe communities always reflect maximal water supplies for steppe vegetation as compared with true-steppe in which conditions are drier. Although not a physiognomic classification, meadow-steppe has a substantial measure of physiognomic homogeneity (i.e., a very dense plant cover with a rich component of broad-leaved forbs). Thus, meadow-steppe can be distinguished from true-steppe communities in which the grass cover is sparser, more narrow-leaved, and accompanied by few broad-leaved forbs.

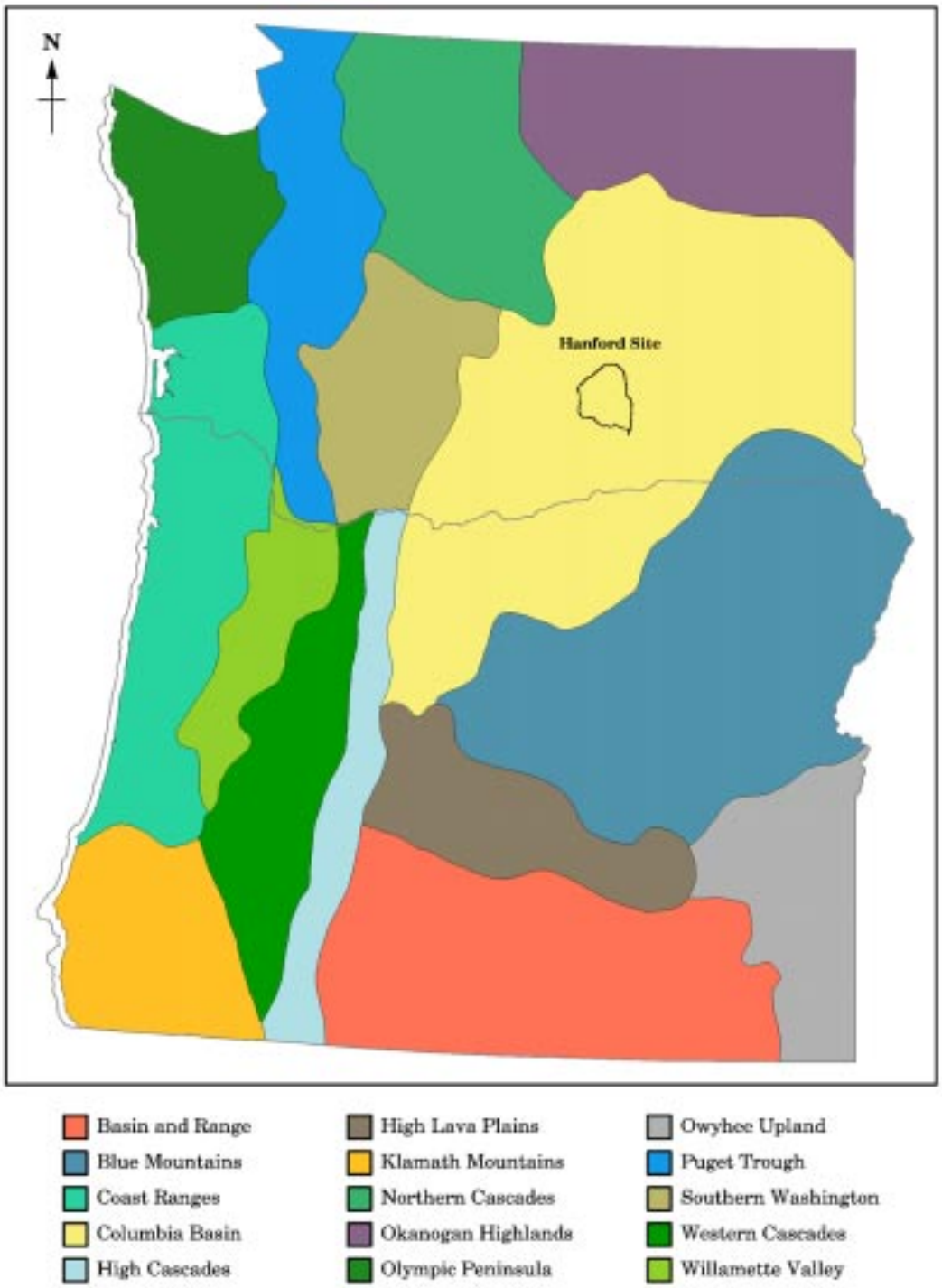


Figure C.3 Physiographic Provinces of Oregon and Washington (Original source: Franklin and Dyrness 1973. Electronic version obtained from the Interior Columbia Basin Ecosystem Management Project.)

(1994) separated the meadow-steppe of the Palouse Prairie of eastern Washington and westcentral Idaho from the drier, sagebrush-dominated areas to the west at as high a level of classification as the division.[3] Recent vegetation mapping of the state of Washington indicates, however, that similar to Franklin and Dyrness (1973) suggested, meadow-steppe rims the Columbia Basin and is not just restricted to the Palouse.[4] Additionally, there is no major physiographic break between the Palouse and the steppe regions to the west (Franklin and Dyrness 1973; Omernick 1987).

Currently, the Palouse Prairie is only a remnant ecosystem. Since European settlement, it has experienced greater than a 98% decline (Noss et al. 1995). The only remaining connection of steppe areas between Washington and Idaho is along the Snake River drainage. For all practical purposes, there remains little ecological connection between Washington and Idaho steppe areas (and through Idaho, extreme northeastern Oregon). Thus, based on the preceding discussion, the choice of an ecological boundary for the eastern portion of the Columbia Basin is somewhat arbitrary.

Bailey et al.'s (1994) suggested boundary does not accurately depict the ecological transition in steppe vegetation zones. Instead, Daubenmire's (1970) vegetation zone map for eastern Washington will be used to set the eastern boundary (Figure C.4). The Idaho fescue/snowberry (*Festuca idahoensis/Symphoricarpos albus*) and Idaho fescue/rose (*Festuca idahoensis/Rosa nutkana*) vegetation zones are considered here to be ecologically distinct from the remainder of the Columbia Basin steppe vegetation zones. The remaining meadow-steppe communities of eastern Washington—those that contain threetip sagebrush or bluebunch wheatgrass as ecological dominants—are conspicuous components of the remainder of the steppe region of Washington. Thus, these vegetation zones are considered here to be ecologically allied with the big sagebrush-dominated vegetation zones. Also, unlike the other zonal steppe communities, the fescue-dominated vegetation zones are not subject to invasion by cheatgrass (*Bromus tectorum*) when they are grazed excessively or when they are abandoned after cultivation (Daubenmire 1970). It follows that the eastern boundary will be delineated by what was the historic edge of the *festuca*-dominated vegetation zones. The Snake River corridor up to the Idaho border, as it includes bluebunch wheatgrass as a dominant, also is considered here to be ecologically connected to the drier portions of the Washington steppe.

The final major difference between the different depictions of the Columbia Basin area concerns the northern boundary. Both Bailey et al. (1994) and Franklin and Dyrness (1973) make the Columbia river the northern boundary. Conversely, Omernick (1987) includes both the Methow and Okanogan River corridors. The Okanogan River corridor, especially, provides a connection with steppe areas of southern British Columbia. This is not well represented by either the Bailey et al. (1994) or Franklin and Dyrness (1973) portrayals.

In summary, the Omernick (1987) ecoregion map, with the exception of the eastern boundary, provides the best ecological context for the Columbia Basin area at a scale appropriate for management decisions. As described above, Daubenmire's (1970) vegetation zone map is used to establish the eastern boundary. Thus, with the one modification, the regional ecological context for Hanford Site will reflect the Omernick (1987) boundaries and will be referred to, henceforth, as the Columbia Basin Ecoregion. Figure C.5 shows an outline of this area and its relationship to the Hanford Site.

C.2 Columbia Basin Ecoregion

The Columbia Basin Ecoregion occupies an extensive area south of the Columbia River between the Cascade Range and Blue Mountains in Oregon and roughly two-thirds of the area east of the Cascades in Washington State (Figure C.5). Although the

[3] Bailey et al. (1994) do not show northeastern Oregon as containing characteristic Palouse (i.e., meadow-steppe) vegetation (Figure C.2). In contrast, Omernick (1987) includes this area (Figure C.1).

[4] Washington State GAP Analysis, Land Cover Map, Version 4. 1996. Prepared by the Washington Cooperative Fish and Wildlife Research Unit at the University of Washington. Although these marginal areas of the Basin can be classified as meadow-steppe because of moisture regimes, to the north and west they also represent shrub-steppe because they include threetip sagebrush (*Artemisia tripartita*) as a dominant (Daubenmire 1970). This overlap in steppe characteristics makes it difficult to draw distinctions between the Palouse Prairie (meadow-steppe) and the remainder of the steppe regions of Oregon and Washington.

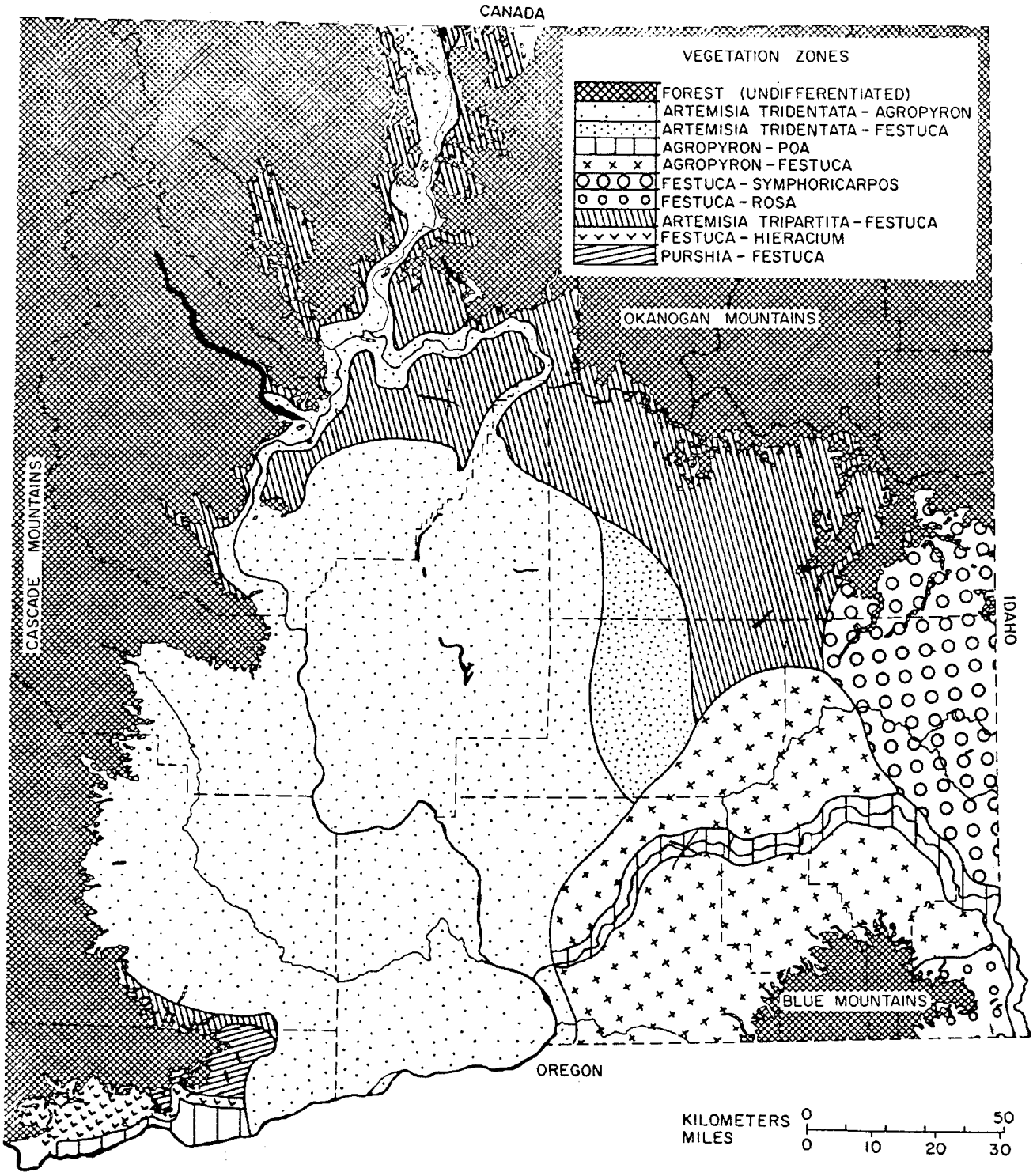


Figure C.4 Vegetation Zones of the Steppe Region of Eastern Washington (Source: Daubenmire 1970)

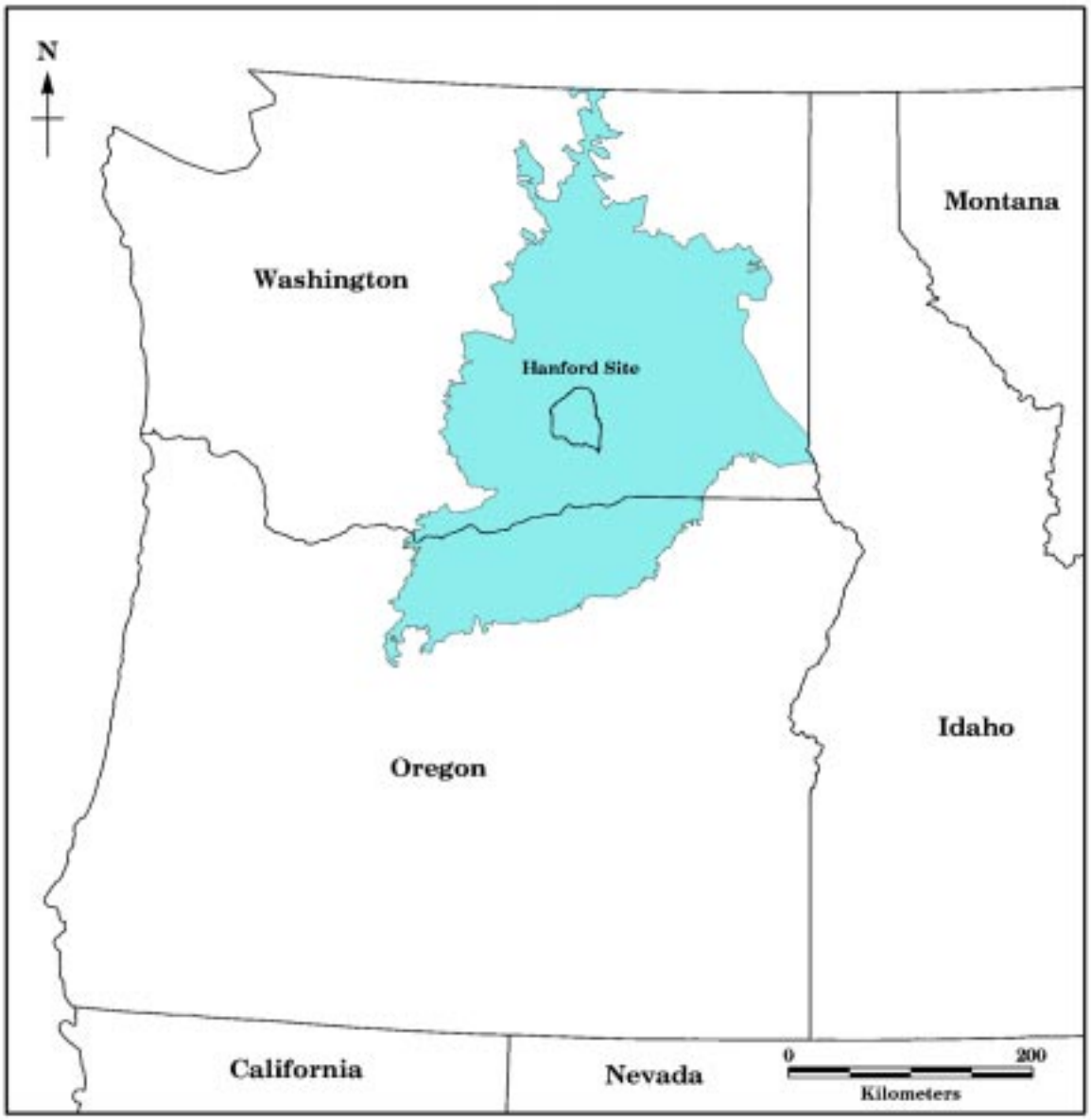


Figure C.5 Hanford's Ecological Context, the Columbia Basin Ecoregion

precise boundaries offered by Franklin and Dyrness (1973) are not used to define the Columbia Basin Ecoregion, these authors still provide the best reference for general information about the topography, geology, climate, and soils for the area. These characteristics are described in Section C.2.1 using Franklin and Dyrness (1973) as the source of information, unless otherwise indicated. This section also includes a description of the Columbia River watershed. Vegetation characteristic of the ecoregion is described in Section C.2.2, and characteristic fauna is covered in Section C.2.3. Section C.2.2 also includes a comparative analysis of historic and current ecoregion vegetation.

C.2.1 Abiotic Characteristics

Topography—Topography within the Columbia Basin Ecoregion varies from gently undulating to moderately hilly land. Steep slopes are limited and are largely restricted to isolated basaltic buttes or canyons, such as those cut by major rivers. Over most of the area, elevations range from 300 to 600 m (about 1000 to 2000 ft) above sea level, though adjacent to the Columbia River they are less than 150 m (about 500 ft).

Geology—The important geologic event in the Columbia Basin Ecoregion began during the Miocene epoch with the vast outpouring of lavas that constitute the Columbia River Basalt formation. This enormous basalt layer underlies virtually the entire ecoregion. The Columbia River Basalt formation ranges in total thickness from 600 to over 1500 m (about 2000 to 5000 ft) and is made up of numerous individual flows about 8 to 30 m (about 25 to 100 ft) thick. Within the past 15,000 years, glacial action also has shaped the ecoregion by creating the Methow and Okanogan valleys. Flooding from Lake Missoula scoured lava beds creating the Channeled Scablands over 12,000 years ago. This flooding also created islands of deep soil as the water receded, the location of much of today's agriculture in the region (Bretz 1959).

Climate—Climatically, the Columbia Basin Ecoregion can be typified as arid to semi-arid with low precipitation, warm-to-hot dry summers, and relatively cold winters. Some marine influences are present; however, continental-type climatic conditions prevail. Precipitation is heaviest along the margins of the ecoregion [40 to 60 cm annually (about 16 to 24 in./yr)] and gradually decreases toward the central portion [10 to 23 cm annually (about 4 to 9 in./yr)].

Soils—A wide variety of soils occurs in the Columbia Basin Ecoregion. Most of the broad soil differences correlate with annual precipitation. Table C.1 depicts a zonal sequence of four soil regions that correspond to a gradient from the hottest, driest sites in the central portion of the ecoregion to the coolest, wettest sites along the periphery of the ecoregion. The regions form a roughly concentric circular pattern. Only the dominant soil group within a region is described.

In general, these great soil groups range from relatively poorly developed soils with lightly colored, thin A (surface) horizons and low organic matter, in which calcium carbonate accumulations are high in the profile (Camborthids), to well-developed soils with thick, very dark-brown to black A horizons and high organic matter, in which calcium accumulations may be deep in the profile or absent (Argixerolls).

Columbia River Watershed—The Columbia River originates in the mountains of eastern British Columbia, Canada, and drains a total area of approximately 668,000 km^2 (258,000 mi^2) (van der Leen et al. 1990). The Hanford Site is located within the Pasco Basin portion of the Columbia River's watershed. The Columbia River enters the Pasco Basin at Sentinel Gap in the Saddle Mountains and leaves via the Wallula Gap upstream of McNary Dam. There are no perennial streams that feed the Columbia River and originate within the Pasco Basin. The Yakima, Snake, and Walla Walla rivers join the Columbia River downstream of the Hanford Site. Beginning with Bonneville Dam in 1938 and ending with John Day Dam in 1967, 11 hydroelectric dams have been constructed on the Columbia River within the United States. Operation of these dams has affected seasonal and daily flow regimes and eliminated most of the lotic habitat formerly present within the Columbia River system.

C.2.2 Vegetation

General Description—Information on vegetation characteristic of the Columbia Basin Ecoregion is taken from Daubenmire (1970) and Franklin and Dyrness (1973). In general, no single sequence of zonal belts of vegetation applies throughout the Columbia Basin Ecoregion. The following seven

Table C.1 Soil Regions of the Columbia Basin Ecoregion

Order	Suborder	Great Soil Group	Characteristics	Remarks
Hot, dry				
Aridisol	Orthid	Camborthids (Region 1)	Pedogenic horizons low in organic matter; surface horizons are thin; no large accumulations of calcium carbonate or gypsum, though when a carbonate-enriched horizon occurs it may be cemented; no horizon of significant clay accumulation, though clay content may be higher in subsurface horizons.	Soils never moist for as long as three months; arid climate; used mostly for range and some irrigated crops.
Mollisol	Xeroll	Haploxerolls (Region 2)[a]	Soils derived from loess; poorly developed; moderately thick, dark grayish-brown, loam-textured surface horizons containing low amounts of organic matter; subsurface horizons high in bases but lacking large accumulations of clay, calcium carbonate, or gypsum.	Formed in climates with rainy winters and dry summers; semiarid climate; used for wheat, range, and irrigated crops.
Mollisol	Xeroll	Haploxerolls (Region 3)	Soils derived from loess but with less sandier windblown materials than region 2; moderately thick, brown silt loam surface horizons containing moderate amounts of organic matter over a light-brown silt loam horizons; zone of calcium carbonate accumulation commonly present.	Formed in climates with rainy winters and dry summers; semiarid climate; used for wheat, range, and irrigated crops.
Mollisol	Xeroll	Argixerolls (Region 4)	Soils with nearly black, friable (i.e., silt loam texture), organic-rich surface horizons high in bases; subsurface horizon of clay accumulation that is relatively thin or brownish.	Absent in the western part of the Basin; formed in climates with rainy winters and dry summers; subhumid climate; used for wheat, range, and irrigated crops.
Wet				

[a]Lithosols (i.e.,well drained, shallow, generally stony soils over bedrock Ñazonal soil) also are common in Region 2 because it encompasses a large portion of the Channeled Scablands.

zonal plant associations, which can occur as climatic climaxes, occur in the Columbia Basin Ecoregion within Washington (Figure C.4):[5]

1. Big sagebrush/bluebunch wheatgrass
2. Big sagebrush/Idaho fescue
3. Bluebunch wheatgrass-Sandberg's bluegrass (*Poa sandbergii* [=*P. secunda*])
4. Bluebunch wheatgrass-Idaho fescue
5. Threetip sagebrush/Idaho fescue
6. Idaho fescue/tongue hawkweed (*Hieracium cynoglossoides*)
7. Bitterbrush/Idaho fescue.

These seven associations have differentiated in response to differences in temperature and total and seasonal distribution of precipitation in the ecoregion. The last three associations are found on the periphery of the ecoregion near its contact with

[5] Daubenmire (1970) recognizes two additional zonal plant associations as occurring in the steppes of eastern Washington: Idaho fescue/snowberry and Idaho fescue/rose. As discussed previously, these zones are considered outside the Columbia Basin Ecoregion.

forest vegetation. These tend to be lush, meadow-like communities with conspicuous amounts of large perennial grasses and broad-leaved forbs. The other four zonal associations lie in the more arid interior of the ecoregion where vegetation is more sparse and forbs are less conspicuous.

The driest and largest of these four zones [approximately 3.3 million ha (8.2 million acres)] has as a climatic climax the big sagebrush/bluebunch wheatgrass association. This association occupies the center of the Columbia Basin Ecoregion, extends west to the Cascade Mountains, north into the Okanogan Valley, south into portions of northcentral Oregon, and also encompasses all of the Hanford Site (Figure C.4 illustrates the Washington portion of this zone). In general, the big sagebrush/bluebunch wheatgrass association is characterized by four canopy layers that include an overstory layer composed mostly of big sagebrush, a tall understory layer of bluebunch wheatgrass, a short understory layer dominated by Sandberg's bluegrass, and a cryptogam layer of crustose lichens and acrocarpous mosses. Other shrub dominants include gray rabbitbrush (*Chrysothamnus nauseosus*), green rabbitbrush (*C. viscidiflorus*), bitterbrush, spiny hopsage (*Grayia spinosa*), threetip sagebrush, and horsebrush (*Tetradymia canescens*). Additional locally abundant bunchgrasses include needle-and-thread grass (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), Cusick's bluegrass (*Poa cusickii*), and Idaho fescue.

The other three zonal associations: big sagebrush/Idaho fescue, bluebunch wheatgrass/Sandberg's bluegrass, and bluebunch wheatgrass/Idaho fescue, can occur as topographic climaxes on moister sites within the big sagebrush/bluebunch wheatgrass association. Conversely, the big sagebrush/bluebunch wheatgrass association may occur as a topographic climax on drier sites within these three adjacent zones.

Certain edaphic (soil-related) and zootic (animal-related) plant associations are of ecological importance within the ecoregion. On deep soils dominated by gravel, sand, or strongly weathered volcanic ash, needle-and-thread grass replaces bluebunch wheatgrass as the dominant grass in several associations. This shift seems to be related to needle-and-thread grass's ability to tolerate lower fertility soils than does bluebunch wheatgrass. The dominant shrub in these associations can be either big or threetip sagebrush or bitterbrush. On stony soils or extremely shallow soils over bedrock (lithosols), various species of buckwheat (*Eriogonum*) and/or stiff sage (*Artemisia rigida*) dominate the shrub layer, and Sandberg's bluegrass dominates the understory.

Within the hottest, driest, and elevationally lowest part of the ecoregion (e.g., the Hanford Site) is a series of three associations found on reasonably deep, loamy soils that are drier than those found on associated zonal associations. These are the big sagebrush/Sandberg's bluegrass, spiny hopsage/Sandberg's bluegrass, and winterfat (*Ceratoides* [=*Eurotia*] *lanata*)/Sandberg's bluegrass associations. Each of these associations is characterized by the lack of large perennial grasses and low overall plant species diversity. At one time, the big sagebrush/Sandberg's bluegrass plant association was thought to have been derived from the effects of livestock overgrazing within big sagebrush/bluebunch wheatgrass communities. Daubenmire (1970), however, provides persuasive evidence that this community exists as a natural community. Big sagebrush has a higher density (average cover, 24%; range, 8–35%) in this association than in any other type of undisturbed vegetation in the Columbia Basin Ecoregion.

Cheatgrass, introduced to Washington about 1890, is the most important invading species in the drier areas of the Columbia Basin Ecoregion following overgrazing or cultivation. On abandoned fields, a brief 1-2 year stage of dominance by the non-native annuals Russian thistle (*Salsoa kali*) and tumble mustard (*Sisymbrium altissimum*) is followed by cheatgrass dominance. Once established, there is no strong evidence that cheatgrass ever relinquishes an area to native grasses and forbs. Partial invasion by gray rabbitbrush into a mostly pure cheatgrass stand may occur as a result of grazing and represents another stage of degradation of the community.

Communities dominated by cheatgrass are a permanent and widespread feature of the Columbia Basin landscape. Wherever a major shrub dominant is removed by cultivation, fire, or gazing, a shrub-cheatgrass community may result. Indeed, the high flammability of cheatgrass increases the likelihood of fire in cheatgrass-dominated communities and replacement by cheatgrass in adjacent burned communities. Although a non-native species, in small quantities cheatgrass also must be considered an element of most climax steppe communities even on undisturbed sites (see also Brandt and Rickard 1994).

Response of Steppe Vegetation to Grazing—The Columbia Basin Ecoregion's shrub-steppe and meadow-steppe communities developed over the past several thousand years without the influence of large herds of ungulates (Daubenmire 1970; Mack and Thompson 1982). Before European settlement, grazing was limited to small numbers of deer, wapiti (elk), and antelope; buffalo were never a factor in grazing. Cattle and sheep were introduced in the Columbia Basin in 1834 (Daubenmire 1970) and about 1860, respectively, with peak numbers occurring from 1860–1900. Their introduction drastically altered much of the native shrub-steppe vegetation. The ecoregion's range was likely in its poorest condition around 1900 and has improved since (Daubenmire 1970; Franklin and Dyrness 1973) by a reduction in livestock grazing pressure. The native bunchgrass understory of shrub-steppe is easily damaged by heavy grazing and often is unable to recover; such conditions accelerate the invasion of non-native Eurasian annual plant species, such as cheatgrass and tumble mustard. Livestock trampling, which frequently occurs near water, and plowing, or any other severe mechanical disturbance of the soil, tends to eradicate native vegetation, opening the soil to invasion by these non-native annuals.

Response of Steppe Vegetation to Fire—Wildfire has played a relatively minor role in the ecology of the Columbia Basin Ecoregion. Wildfires are naturally recurring historic components of steppe plant communities. Natural wildfires are typically initiated by lightning and occur primarily during the summer months when most plants are mature and dried from summer drought (Uresk et al. 1980). Most shrub species (e.g., big sagebrush, bitterbrush, and spiny hopsage) are easily killed by burning. Shrubs may recolonize fire-scarred areas in the following ways: (1) by resprouting following burning [illustrated by greasewood (*Sarcobatus vermiculatus*) and threetip sagebrush], (2) from buried seed, and (3) by seed dispersal from unburned shrubs.

The understory comprises primarily grasses and forbs, is generally resistant to fire damage, and resumes vegetative growth during the following growing season (Uresk et al. 1980). In general, the dominant understory species on a site before burning, whether native or non-native, dominate the site following a fire; however, if the site is occupied by a native understory that is both burned and grazed, it may be colonized by non-native species, such as cheatgrass, tumble mustard, and Russian thistle, after a fire. Figure C.6 shows the major pathways of succession in sagebrush-steppe plant communities that may experience fire and grazing in the presence of non-native species. The successional model applies to sagebrush-steppe communities both within and outside of the Columbia Basin Ecoregion (West 1983a, b).

Comparison of Historic and Current Ecoregion Vegetation—The preceding sections provided both a description of the native and non-native vegetation that characterizes the Columbia Basin Ecoregion and an overview of some of the natural and human-related processes that affect the vegetation. This section provides a coarse-scale analysis of changes in the vegetation patterns that have occurred within the ecoregion since European settlement. Such an analysis is useful for two reasons. It: (1) provides an indication of how ecological conditions have changed in the ecoregion, and (2) enables resource managers and land administrators to better plan resource conservation strategies for the future.

The data used to depict historic and current Columbia Basin Ecoregion vegetation were obtained from the Interior Columbia Basin Ecosystem Management Project (ICBEMP)[6]. The ICBEMP has collected and developed large amounts of spatial data that cover a large portion of the Columbia Basin watershed east of the crest of the Cascade Mountains. Depicted and analyzed here are only those data that fall within the boundaries of the Columbia Basin Ecoregion. Two ICBEMP data sets are used here: "Historical Potential Vegetation Types" (September 8, 1995) and "Current Vegetation Cover Types" (as of April 14, 1995). Both ICBEMP data sets rely on successional models as an aid to their classification of vegetation in specific areas. The scale of resolution (i.e., pixel size) is 1 km^2 for both data sets.

The historic potential vegetation type classes are composed of broad groups of plant associations and habitat types that regional ecologists judged to

[6] The ICBEMP is a joint venture of the U.S. Forest Service and Bureau of Land Management. Together they are attempting to develop, through an open public process, a new management strategy for public land administered by the two agencies in eastern Oregon and Washington, Idaho, western Wyoming, and portions of northern Utah and northern Nevada.

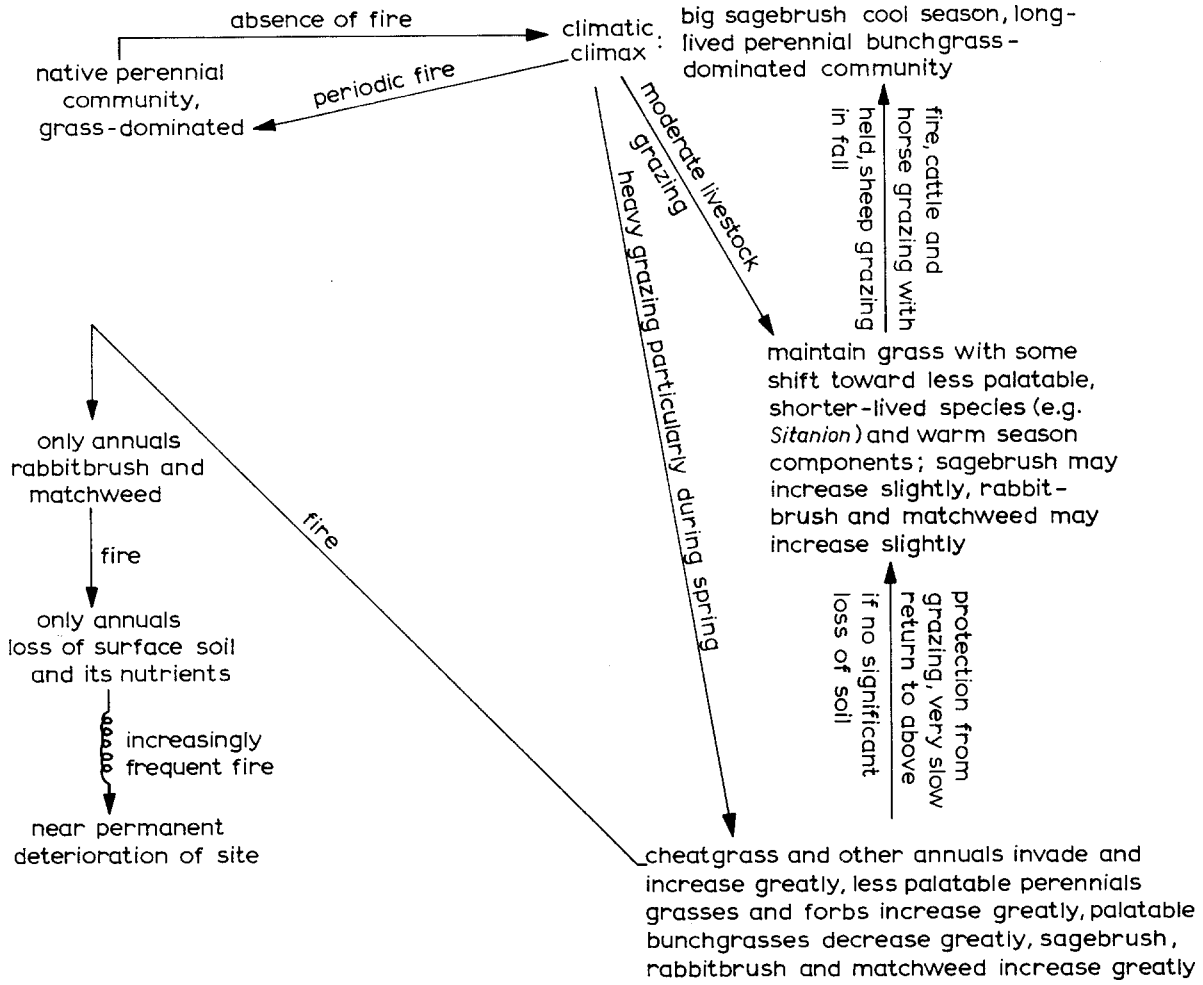


Figure C.6 Major Pathways of Succession in Sagebrush-Steppe Plant Communities (Source: West 1983a. Matchweed: *Xanthocephalum* spp.)

be present at a coarse scale of vegetation mapping. The mapped potential vegetation types were derived from overlaying current and earlier existing cover type base maps and a map depicting regional biophysical settings. Inconsistencies were corrected and the resultant map reclassified to match the successional models.

The current cover type classes are a classification of existing vegetation by broad vegetative communities that regional ecologists judged to be present at a coarse scale of vegetation mapping. For the Columbia Basin Ecoregion area, the cover type classes were selected in accordance with Shiflet (1994); however, additional cover types were created for unique types. The mapped cover types were derived in a manner similar to the historic potential vegetation type map through the use of cover type base maps, a biophysical settings map, and the successional models. The current cover type base map is taken from the conterminous U.S. Land Cover Characteristics (LCC) map developed in 1991 by the Engineering and Remote Sensing Data Center of the U.S. Geological Survey.

Although the LCC map is itself a continuous layer of spatial information data for the entire United States, it is based on several remotely sensed image scenes. The data were obtained near the end of 1990 from the Advanced High Resolution Radiometer (AVHRR) sensor on the National Oceanographic and Atmospheric Administration's TIROS series satellites. The spectral data obtained were classified into 159 land-cover classes (without ground-truthing) that the ICBEMP's assembled regional ecologists merged or split to arrive at the cover type classes used in the current vegetation cover type map. A general overview of some remote sensing image sources and their characteristics is provided in the box on the next page.

Not all the cover classes used for the ICBEMP historic potential vegetation type and current vegetation cover type data sets occur within the Columbia Basin Ecoregion. Moreover, a generalized cover class, such as *Agropyren* steppe, can be reclassified as bluebunch wheatgrass steppe to reflect that this is the only wheatgrass species that will occur as a dominant within the Columbia Basin Ecoregion. Thus, to make the cover class classifications more useful at the ecoregion level, the original ICBEMP cover classes were reclassified (Table C.2). An added advantage to reclassification was that it enables, at least, a coarse comparison between the historic and current vegetation data sets (i.e., ICBEMP did not use consistent cover class delineations for their two data sets).

Figures C.7 and C.8 provide depictions of the historic and current distribution and extent of land cover classes within the Columbia Basin Ecoregion, respectively. Table C.3 provides data on absolute area covered and percentage area covered within the ecoregion for each cover class. The Hanford Site data will be discussed in Section C.4.2.

To keep the relevance of the data presented in Figures C.7 and C.8 and Table C.3 in the proper perspective, several considerations bear mentioning before proceeding with further discussion of the data. These are:

- The historic vegetation data are based on potential vegetation (i.e., that vegetation predicted to be present at the end of plant succession in the absence of human-induced change). The current vegetation data are based on what actually is present, not what potentially could be present were the effects of humans to be removed. The generalized reclassification scheme used here (Table C.2) should accommodate these differences. With respect to steppe vegetation, especially, there are only a few regionally dominant shrubs and bunchgrasses that could occur within the ecoregion. Moreover, at the scale of resolution used for mapping, it seems unlikely that the current vegetation mapping of steppe vegetation could reflect early successional stages.
- Because of the scale of resolution and the use of generalized cover classes, analysis should be attempted at only large regional scales. At the level of the Columbia Basin Ecoregion, this

Remote Sensing Image Sources

Remote sensing technologies provide images of land surfaces and existing vegetation cover that enable researchers to map land cover classes over large areas. Although several sources of remote sensing images exist, the two sources commonly used to classify vegetation are the Advanced Very High Resolution Radiometer (AVHRR) and the Landsat Thematic Mapper (TM). These two sources, which are described below, are used because they collect spectral data sensitive to vegetative properties such as chlorophyll or moisture content. To map vegetation using spectral data from remote sensing images, the spectral data must first be classified. In a supervised classification (i.e., in which previous knowledge of vegetation classes at known locations is used to calibrate the data), the spectral signature of areas of known vegetative classes are used to define the decision space for those classes. After each class has been defined, a computer program is used to classify all the remaining areas in a scene.

AVHRR. This multispectral scanner travels aboard polar orbiting satellites that are in sunsynchronous orbits. The satellites circle the earth 14 times daily and acquire complete coverage of the globe every 24 hours. Images are acquired in a swath of 2700 km with a ground resolution of approximately 1 km^2. There are 5 spectral bands with the following band widths: 1: 0.55-0.68 μm (red); 2: 0.73-1.10 (reflected IR); 3: 3.55-3.93 (thermal IR); 4: 10.50-11.50 (thermal IR); and 5: 11.50-12.50 (thermal IR).

TM. A Thematic Mapper imaging platform is carried aboard the Landsat satellites and is usually referred to as Landsat TM. Complete earth coverage requires 16 days. Coverage is 185 km in east-west direction and ground resolution is 30 m^2 (approx.). There are 7 TM bands with band widths of: 1: 0.45-0.52 μm (blue-green); 2: 0.52-0.60 (green); 3: 0.63-0.69 (red); 4: 0.76-0.90 (reflected IR); 5: 1.55-1.75 (reflected IR); 6: 10.40-12.50 (thermal IR); 7: 2.08-2.35 (reflected IR).

Table C.2 Comparison of Land Cover Classes Used for the Columbia Basin Ecoregion Maps Versus the Original Classifications Used by the Interior Columbia Basin Ecosystem Management Project

BRMaP Historic	ICBEMP Historic	BRMaP Current	ICBEMP Current
Bluebunch wheatgrass steppe	Agropyren steppe	Bluebunch wheatgrass steppe	Agropyren bunchgrass
Idaho fescue steppe	Fescue grassland	Idaho fescue steppe	Fescue bunchgrass
Bitterbrush steppe	Antelope bitterbrush	Bitterbrush steppe	Antelope bitterbrush/ bluebunch wheatgrass
Big sagebrush steppe	Big sage steppe Big sage - warm Big sage - cool Low sage - mesic Mountain big sage - mesic - East Mountain big sage - mesic - East with conifer Mountain big sage - mesic - West	Big sagebrush steppe	Big sagebrush Mountain big sagebrush
Juniper/sagebrush	Mountain big sage - mesic - West	Juniper/sagebrush	Juniper/sagebrush
Threetip sagebrush	Threetip sage		
Black greasewood	Saltbrush riparian[a]		
Conifers/Idaho fescue	Fescue grassland with conifer		
Ponderosa pine	Interior ponderosa pine	Ponderosa pine	Interior ponderosa pine
Water	Water	Water	Water
		Urban	Urban
		Crop/hay/pasture	Crop/hay/pasture
Other	All other clover classes that occur in low amounts in the Columbia Basin Ecoregion.	Other[b]	All other clover classes that occur in low amounts in the Columbia Basin Ecoregion (i.e., less than 1.5% by area and not occurring within Hanford's geographic location).

[a]Includes black greasewood/ryegrass and black greasewood/saltgrass.
[b]The ICBEMP data showed low sage (*Artemisia arbuscula*) as occurring on Hanford in the general area occupied by 200 East and 200 West Areas. Because low sage does not occur on Hanford, these areas were reclassified as other.

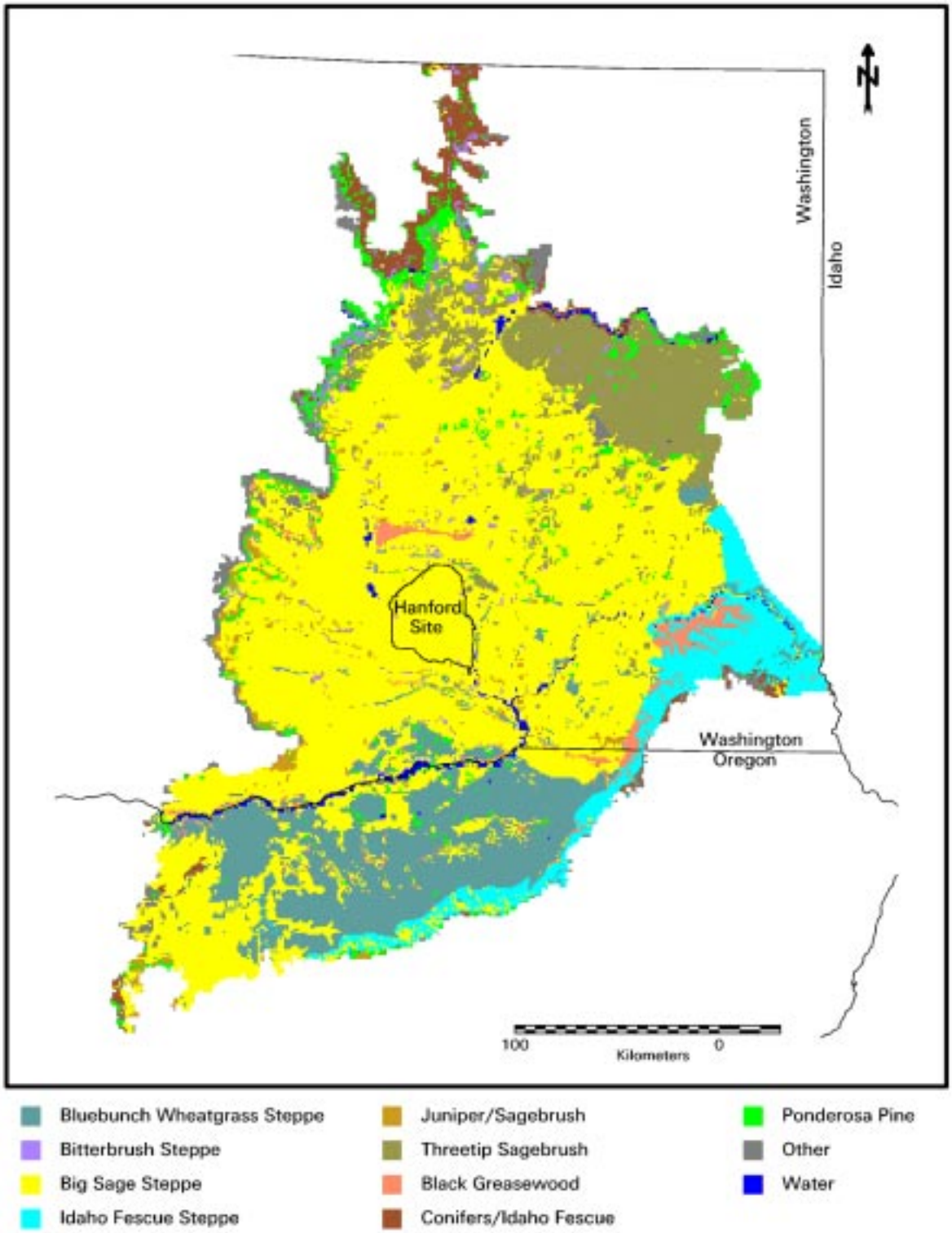


Figure C.7 Historic Distribution and Extent of Land Cover Classes Within the Columbia Basin Ecoregion (Source: Electronic version obtained from the Interior Columbia Basin Ecosystem Management Project.)

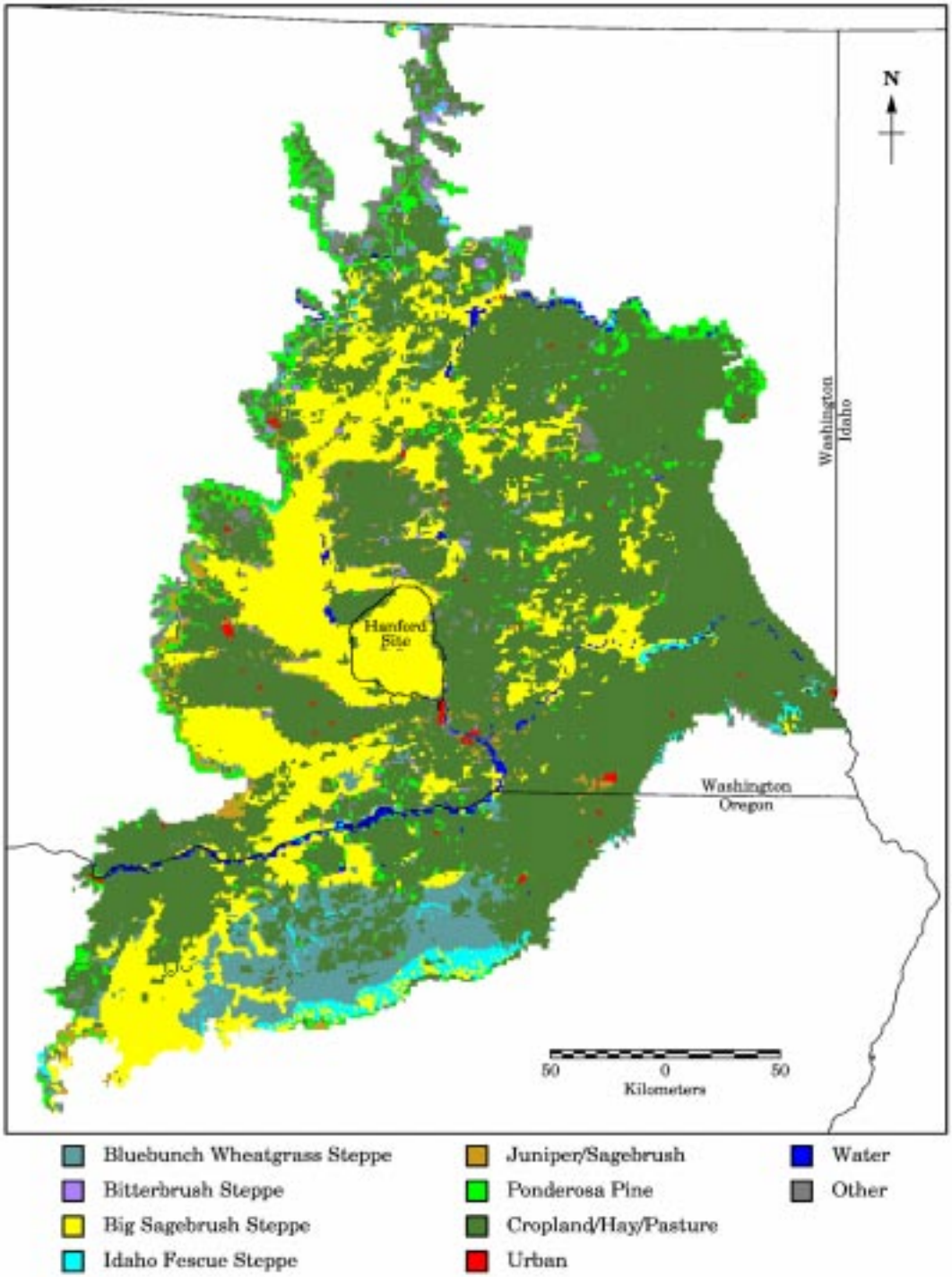


Figure C.8 Current Distribution and Extent of Land Cover Classes Within the Columbia Basin Ecoregion (Source: Electronic version obtained from the Interior Columbia Basin Ecosystem Management Project.)

Table C.3 Percentage of Area Covered and Actual Area Covered by the Different Land Cover Classes Within the Columbia Basin Ecoregion

Cover Class	Ecoregion Area (ha)	% Area of Ecoregion	Hanford Site Area (ha)	% of Cover Class by Area in Ecoregion at Hanford
Historic				
Bluebunch wheatgrass steppe	1,028,900	13.76	612	0.06
Idaho fescue steppe	436,700	5.84	0	0.00
Bitterbrush steppe	118,600	1.59	915	0.77
Big sagebrush steppe	4,096,900	54.79	148.902	3.63
Juniper/sagebrush	110,300	1.48	508	0.46
Threetip sagebrush	746,000	9.98	16	<0.01
Black greasewood	134,900	1.80	506	0.37
Conifers/Idaho fescue	225,000	3.01	0	0.00
Ponderosa pine	302,900	4.05	102	0.03
Water	71,100	0.95	25	0.04
Other	205,500	2.75	0	0.00
Total	7,476,800	100.00	151,585	2.03
Current				
Bluebunch wheatgrass steppe	431,400	5.77	1,602	0.37
Idaho fescue steppe	122,200	1.63	0	0.00
Bitterbrush steppe	78,100	1.04	904	1.16
Big sagebrush steppe	1,662,400	22.23	137,834	8.29
Juniper/sagebrush	109,100	1.46	508	0.47
Ponderosa pine	335,100	4.48	102	0.03
Water	71,100	0.95	25	0.04
Urban	22,200	0.30	156	0.70
Crop/hay/pasture	4,443,400	59.43	9,644	0.22
Other	201,800	2.70	812	0.40
Total	7,476,800	100.0	151,585	2.03

should not pose a problem; however, the Hanford data may need to be evaluated with caution (see Section C.4.2).

- Although both the historic and current vegetation data sets are modified by successional models, the current vegetation data set is, at least in part, based on real-time data (i.e., the LCC data base). Thus, there may be accuracy differences between the two data sets; however, again, provided the geographic scale of analysis is large, this should not be problematic.
- A complete matching of reclassified cover classes between the historic and current vegetation data sets was not possible. Ideally, other than human-activity derived cover classes there should be no differences in the types of cover classes used. Three reclassified cover classes that occur as a part of the historic vegetation data set—threetip sagebrush, black greasewood, and conifers/Idaho fescue—do not occur in the current vegetation data set. The areas occupied by the threetip sagebrush and black greasewood cover classes in the historic land cover map (Figure C.7) seem to have been replaced in the current cover class map (Figure C.8) by either human-altered areas or by being reclassified as big sagebrush steppe. At higher levels of analysis (i.e., combining cover classes to form even more generalized classifications), these potential overlap errors in classification should have minimal effect on the analysis. The conifers/Idaho fescue cover class occurs predominantly at the northern extent of the ecoregion and generally outside what either data set seems to classify as steppe vegetation. Thus, the lack of overlap here should have little effect on an analysis of changes in steppe vegetation.

Table C.4 provides comparison data associated with the historic and current vegetation data sets (The Columbia Basin Ecoregion data will be discussed here and the Hanford-specific data in Section C.4.2). Whether looked at from the standpoint of big sagebrush steppe alone or when combined with other cover classes to form more generalized classifications (i.e., sagebrush steppe, shrub-steppe, or steppe with and without shrubs), about 35–40% of the steppe vegetation remains from what was present historically in the Columbia Basin Ecoregion. Historically, steppe vegetation accounted for about 89.2% of the ecoregion; today, it occupies only about 32.1%. In its place, human-altered areas today occupy about 59.7% of the ecoregion. About 99.5% of this land use is related to agriculture.

The distribution of the loss in steppe vegetation is not uniform across the ecoregion. The most extensive losses of steppe vegetation are concentrated in the eastern portion of the ecoregion (Figure C.8) (A fate that also has befallen the Idaho fescue/snowberry plant associations east of the ecoregion in Washington.). Although more extensive amounts of steppe vegetation remain in the western and southern portions of the ecoregion, the distribution of what remains is fragmented. Also, much of the remaining large blocks are administered by federal agencies (e.g., DOE and DoD) that are not traditional resource management agencies.

C.2.3 Terrestrial Fauna

No single review publication or collection of studies focuses on characterizing the fauna of the Columbia Basin Ecoregion. Previous faunal characterizations have either treated the Columbia Basin area as a part of a larger biogeographic area [e.g., western intermountain sagebrush-steppe (West 1983b)] or have focused on a particular portion of the Columbia Basin Ecoregion [e.g., ALE Unit on Hanford (Rickard et al. 1988)]. Most studies have concentrated on the shrub-dominated aspects of the ecoregion's ecology and not on the significance, in regard to faunal diversity, of the mosaic of shrub-dominated and bunchgrass-dominated lands within the ecoregion. With respect to shrubs, big sagebrush communities are those that have received most of the attention.

In contrast to the general studies, certain taxa are fairly well-characterized for the ecoregion. For example, although they did not use exactly the same boundaries for the Columbia Basin Ecoregion as defined here, Nussbaum et al. (1983) provided information on the characteristic amphibians and reptiles found in the area. Also, as part of a larger study that examined non-game bird communities in northwestern rangelands (essentially encompassing the sagebrush-steppe communities of southeastern Washington, eastern Oregon, and southern Idaho), Rotenberry and Wiens (1978) provided evidence that distinct avian communities are present within the sagebrush-steppe. They identified one such distinct community as occurring within the Columbia Basin Ecoregion. As is probably true for other taxa, Rotenberry and Wiens's

Table C.4 Comparison of Historic and Current Land Cover Classes Within the Columbia Basin Ecoregion

Cover Class	Ecoregion Area (ha)		% Change in Area Covered in Ecoregion	% of Cover Class by Area in Ecoregion at Hanford		% Change in Area Covered at Hanford Relative to Ecoregion
	Historic	Current		Historic	Current	
Big sagebrush steppe	4,096,900	1,662,400	40.6	3.63	8.29	228.4
Sagebrush steppe[a]	4,953,200	1,771,500	35.8	3.02	7.81	258.6
Shrub-steppe[b]	5,206,700	1,849,600	35.5	2.90	7.53	259.7
Steppe without shrubs[c]	1,465,600	553,600	37.8	0.04	0.29	725.0
Steppe: with and without shrubs[d]	6,672,300	2,403,200	36.0	2.27	5.86	258.1
Conifers[e]	527,900	335,100	63.5	0.02	0.03	150.0
Human-altered areas[f]	0	4,465,600	--	--	0.22	--
Water	71,100	71,100	100.0	0.04	0.04	100.0
Other	205,500	201,800	98.2	0.00	0.40	--

[a]Includes *big sagebrush steppe, threetip sagebrush, and *juniper/sagebrush.
[b]Includes *big sagebrush steppe, threetip sagebrush, *juniper/sagebrush, *bitterbrush steppe, and black greasewood.
[c]Includes *bluebunch wheatgrass steppe and *Idaho fescue steppe.
[d]Includes *big sagebrush steppe, threetip sagebrush, *juniper/sagebrush, *bitterbrush steppe, black greasewood, *bluebunch wheatgrass steppe, and *Idaho fescue steppe.
[e]Includes *Ponderosa pine and conifers/Idaho fescue.
[f]Includes cropland/hay/pasture and urban.
*Indicates a cover class common to both historic and current land cover designations.

study indicates that, although individual bird species are not unique (i.e., endemic) to the Columbia Basin Ecoregion, what typifies the ecoregion are the characteristic species assemblages.[7] Finally, Rotenberry and Wiens is one of the few studies to examine changes in faunal species abundance (again for birds) between sagebrush-dominated areas and bunchgrass-dominated areas within the sagebrush-steppe.

The following sections provide an overview of those species considered dependant within the ecoregion on native steppe and shrub-steppe communities for continued population viability. An overview of species characteristic of the uplands within the Columbia Basin Ecoregion by taxa also is provided.

Steppe and Shrub-Steppe Obligate Species—Because much of the Columbia Basin Ecoregion is composed of sagebrush-dominated vegetation zones, much attention paid to species dependency has focused on identifying those species that are highly dependent (i.e., obligates) on sagebrush-dominated communities for at least portions of their life cycle. A more limited amount of information is available for non-sagebrush dependent species that are still

[7] Although endemic species as a rule do not characterize the Columbia Basin Ecoregion, plants and insects may be an exception; for example The Nature Conservancy biodiversity studies on Hanford have documented previously unknown plant and insect species not found elsewhere (TNC 1995, 1996, 1998, and 1999).

generally confined to the Columbia Basin Ecoregion. Table C.5 provides a summary of steppe and shrub-steppe obligate species, their listing status, and their Hanford abundance with an emphasis on sagebrush-obligate species. Information as to what constitutes an obligate species is taken from Braun et al. (1976), Dobler (1992), Pyle (1989), and Rotenberry and Wiens (1978).

Other species, although perhaps found in other types of habitat, are generally associated with steppe and shrub-steppe habitats within the Columbia Basin Ecoregion. These species include sagebrush lizard (*Sceloporus graciosus*), burrowing owl (*Athene cunicularia*), loggerhead shrike (*Lanius ludovicianus*), lark sparrow, (*Chondestes grammacus*), vesper sparrow (*Pooecetes gramineus*), Townsend's ground squirrel (*Spermophilus townsendii*), northern grasshopper mouse, (*Onychomys leucogaster*), and Merriam's shrew (*Sorex merriami*). Additionally, species such as the Great Basin spadefoot toad (*Scaphiopus intermontanus*), though they rely on the proximity of at least ephemeral water supplies, also are highly characteristic of shrub-steppe habitats.

Invertebrates—Insects and their close invertebrate relatives, such as mites, spiders, and scorpions, are widely distributed in the steppe and shrub-steppe of the Columbia Basin, as well as in other arid land ecosystems throughout the world. Certain insect groups, such as locusts and beetles, are well known for their periodic population eruptions. Such eruptions often result in damage to range land vegetation and nearby croplands. Consequently, pest species such as Orthoptera (grasshoppers, crickets, and katydids) (Mulkern et al. 1964; Rogers

Table C.5 Steppe and Shrub-Steppe Obligate Species of the Columbia Basin Ecoregion

Scientific Name	Common Name	Federal Status	State Status	Sagebrush Obligate	Hanford Abundance
Insects					
Callophrys sheridanii neoperplexa	Sheridan's green hairstreak		Monitor		Rare
Reptiles					
Masticophis taeniatus	Striped whipsnake		Candidate	Yes	Rare
Birds					
Spizella breweri	Brewer's sparrow			Yes	Common
Centrocercus urophasianus	Sage grouse	Former candidate	Candidate	Yes	Rare
Oreoscoptes montanus	Sage thrasher		Candidate	Yes	Rare
Amphispiza belli	Sage sparrow		Candidate	Yes	Common
Mammals					
Brachylagus (=Sylvilagus) idahoensis	Pygmy rabbit	Former candidate	Endangered	Yes	Extirpated
Lagurus (=Lemmiscus) curtatus	Sagebrush vole		Monitor	Yes	Uncommon
Spermophilus (=Citellus) washingtoni	Washington ground squirrel		Monitor		Undocumented

and Uresk 1974); Hymenoptera (sawflies, parasitic wasps, ants, wasps, and bees) (Hewitt et al. 1974; Lavigne 1969); Coleoptera (beetles) (Graber et al. 1931; Rickard 1970); and Lepidoptera (butterflies and moths) (Wildermuth and Caffrey 1916; Walkden 1950) have been the focus of much research in the shrub-steppe.

The majority of insects in the shrub-steppe are primary consumers. Sometimes they may become so numerous as to completely defoliate sagebrush [e.g., the sagebrush moth (*Aroga websteri*)] or to compete with domestic livestock for forage, as do the migratory grasshopper (*Melanoplus sanguinipes*) and Mormon cricket (*Anabrus simplex*). Insects are an important food base for birds, especially horned larks, meadowlarks, sage sparrows (Rotenberry and Wiens 1978), and small raptors (Green et al. 1993).

Many insects in the shrub-steppe burrow in the soil during at least some part of their life cycle and, consequently, influence the development of shrub-steppe soils. These include various taxa such as ants, wasps, solitary bees, and beetles. In general, the activities of these groups are not well documented (Gano and Rogers 1983).

Herpetofauna—Information on the herpetofauna of the Columbia Basin Ecoregion is taken from Nusbaum et al. (1983). Amphibian diversity in the Columbia Basin Ecoregion is lower than in more mesic areas of the Pacific Northwest. Reptile diversity in the ecoregion is lower than in the southwestern United States. None of the herpetofauna in the ecoregion are endemic. Most species seem to have colonized the ecoregion relatively recently from the centers of their distributions to the south.

Several species are common throughout the ecoregion. The Great Basin spadefoot uses ephemeral habitats; the larvae are especially adapted to such conditions. Adult spadefoots also have numerous adaptations for life in a xeric environment. Painted turtles (*Chrysemys picta*) occur in marshy ponds or small lakes, as well as in the quiet backwaters of rivers. The sagebrush lizard (*Sceloporus graciosus*), side-blotched lizard (*Uta stansburiana*), and short-horned lizard (*Phrynosoma douglassii*) occur throughout the ecoregion. In appropriate habitat, sagebrush lizards and side-blotched lizards are locally common but seldom co-occur (Nussbaum et al. 1983). All three lizard species occur at lower elevations in the ecoregion than they do in the more southern portions of their ranges. Common snake species that occur in a variety of habitats throughout the ecoregion include the racer (*Coluber constrictor*), gopher snake (*Pituophis melanoleucus*), and western rattlesnake (*Crotalus viridis*).

Other herpetofauna, while characteristic of the ecoregion, are not so widely distributed. The pond-breeding tiger salamander (*Ambystoma tigrinum*), for example, is generally absent from drier areas of the ecoregion. Two ranid frogs, the bullfrog (*Rana catesbeiana*) and northern leopard frog (*R. pipiens*), occur in scattered locations throughout the ecoregion close to permanent ponds and lakes. The bullfrog was introduced to the Pacific Northwest in the late 1920s or early 1930s and has rapidly expanded its range. One bufonid species, Woodhouse's toad (*Bufo woodhousii*), occurs in the vicinity of the Snake and Columbia rivers. Both Woodhouse's toad and the northern leopard frog possibly recently colonized the ecoregion from the East by using the Snake and Columbia rivers as avenues of dispersal. Two snake species, the western terrestrial garter snake (*Thamnophis elegans*) and common garter snake (*T. sirtalis*), are widely distributed throughout the ecoregion, but generally occur near permanent water.

Other species such as the long-toed salamander (*Ambystoma macrodactylum*), Pacific treefrog [*Hyla* (=*Pseudacris*) *regilla*], and spotted frog (*R. pretiosa*) may be considered typical of the Pacific Northwest (i.e., 50% or more of their entire range occurs within the Pacific Northwest), but not of the ecoregion. These species tend to be more common and more widely distributed outside of the ecoregion than within it. Nonetheless, the Pacific treefrog is still considered one of the more common frogs of the ecoregion. Similar to the Great Basin spadefoot, it will make use of empheral habitats. Both the long-toed salamander and spotted frog are absent from drier areas of the ecoregion.

Some species are relatively uncommon or occur only at specific locations within the ecoregion. The western skink (*Eumeces skiltonianus*) occurs mostly in the northern portion of the ecoregion where conditions are more mesic; it prefers rocky habitats with some moisture. Two snakes, the night snake (*Hypsiglena torquata*) and striped whipsnake (*Masticophis taeniatus*), are relatively uncommon. The northern extent of the striped whipsnake's range occurs in approximately the center of the ecoregion. The night snake tends to be found only in association with rocky outcrops and slopes. Several other amphibian and reptile species occur at

the margins of the ecoregion or at isolated locations within the ecoregion. These include the western toad (*Bufo boreas*), southern alligator lizard [*Elgaria* (=*Gerrhonotus*) *multicarinata*], rubber boa (*Charina bottae*), sharptail snake (*Contia tenuis*), and ringneck snake (*Diadophis punctatus*).

Birds—Table C.6 provides a list of native birds that use steppe and/or shrub-steppe habitats within the Columbia Basin Ecoregion for at least a portion of their life cycle. The information in the table is taken from Andelman and Stock (1994a, 1994b), who draw heavily on U.S. Fish and Wildlife Service Breeding Bird Survey survey data on breeding neotropical migrants in various habitats in Washington and Oregon, and from Rotenberry and Wiens (1978).

Four sagebrush nesting birds, generally migratory, are characteristic of the shrub-steppe birds in the ecoregion in both Washington and Oregon. These are the loggerhead shrike, Brewer's sparrow, sage thrasher, and sage sparrow (Andelman and Stock 1994a, 1994b). The loggerhead shrike and Brewer's sparrow are habitat specialists (species that use only one or two habitats for nesting and foraging) that are considered to be declining significantly in the Oregon shrub-steppe (Andelman and Stock 1994b). Insufficient data exist to establish a trend for loggerhead shrike and Brewer's sparrow in Washington. The sage thrasher and sage sparrow are considered species of management concern in Washington because they are habitat specialists that have localized breeding distributions (Andelman and Stock 1994a). The sage grouse, a non-migrant, also is a sagebrush obligate. It is known to breed in two locations in the ecoregion, one on the Yakima Training Center (managed by the U.S. Department of the Army) and the other in Douglas County.

Most species that occur in shrub-steppe habitats also can be found in steppe habitats. Six species best characterize steppe habitats in both Washington and Oregon. These are the long-billed curlew, vesper sparrow, grasshopper sparrow, lark sparrow, savannah sparrow, and western meadowlark (Andelman and Stock 1994a, 1994b). The sharp-tailed grouse, a non-migrant resident of the ecoregion, also is a species that uses bunchgrass areas for nesting.

A number of raptors are characteristic of both shrub-steppe and steppe in the ecoregion. The most conspicuous of these are the American kestrel, prairie falcon, red-tailed hawk, ferruginous hawk, turkey vulture, northern harrier, and golden eagle.

Several introduced game species also use steppe and shrub-steppe habitats within the Columbia Basin Ecoregion. These include the chukar (*Alectoris chukar*), ring-necked pheasant (*Phasianus colchicus*), and gray partridge (*Perdix perdix*) (Rotenberry and Wiens 1978).

Rotenberry and Weins (1978) drew several conclusions from their analysis of non-game bird communities in northwestern rangelands (As described in the introductory paragraphs to Section C.2.3, these rangelands include more than the Columbia Basin Ecoregion.). They concluded that:

1. Shrub-steppe avian communities are distinctly different from the surrounding forest communities. Only 3-6 species are recorded usually in any local area. This number ranges from 20-33% of that reported for various forest bird censuses.

2. Shrub-steppe is not avifaunally homogenous itself. There are different species assemblages in different areas. The Columbia Basin Ecoregion is one of these distinct areas.

3. There are indeed species that are characteristic of the shrub-steppe.

4. Wintering avifaunas are sparse, both in terms of species occurrence and abundance.

Mammals—Mammal diversity in the Columbia Basin Ecoregion is lower than in more mesic areas of the Pacific Northwest. Mammals in the Columbia Basin Ecoregion must either be adapted to the to semi-arid climate or live close to a permanent water source. The ecoregion has only one endemic species. Many species that occur in the ecoregion range far beyond the ecoregion's borders and most exist in greater numbers outside the ecoregion.

The Washington ground squirrel is the only mammal endemic to the Columbia Basin Ecoregion. It is found only in the grasslands, low sagebrush, wheat fields, and rocky hillsides of central Washington and northeastern Oregon. It seems to prefer steppe habitats with high grass and forb cover, deep and loose soil, and soil without a high clay content (Betts 1990).

Species within a number of groups might be considered typical of the ecoregion, as their ranges overlap it entirely. These include shrews, pocket gophers, rabbits, ground squirrels, mice, woodrats, bats,

Table C.6 Native Avian Species that Use Steppe and/or Shrub-Steppe Habitats for Some Portion of Their Life Cycle Within the Columbia Basin Ecoregion

Scientific Name	Species	Shrub-Steppe	Steppe[a]
Year-Round Residents (at least some members of the population)			
Corvus brachyrhynchos	American crow	X	X
Falco sparverius	American kestrel	X	X
Pica pica	Black-billed magpie	X	X
Athene cunicularia	Burrowing owl	X	X
Corvus corax	Common raven	X	
Eremophila alpestris	Horned lark	X	X
Lanius ludovicianus	Loggerhead shrike	X	X
Zenaida macroura	Mourning dove	X	X
Circus cyaneus	Northern harrier	X	X
Falco mexicanus	Prairie falcon	X	X
Buteo jamaicensis	Red-tailed hawk	X	X
Centrocercus urophasianus	Sage grouse	X	
Tympanuchus phasianellus	Sharp-tailed grouse	X	X
Asio flammeus	Short-eared owl		X
Sturnella neglecta	Western meadowlark	X	X
Summer Residents			
Hirundo rustica	Barn swallow	X	X
Dolichonyx oryzivorus	Bobolink		X
Euphagus cyanocephalus	Brewer's blackbird	X	
Spizella breweri	Brewer's sparrow	X	
Hirundo pyrrhonota	Cliff swallow	X	X
Chordeiles minor	Common nighthawk	X	X
Phalaenoptilus nuttallii	Common poorwill	X	X
Buteo regalis	Ferruginous hawk	X	X
Aquila chrysaetos	Golden eagle	X	X
Ammodramus savannarum	Grasshopper sparrow	X	X

[a]Steppe here refers not only to vegetation zones that are characteristically without sagebrush or bitterbrush, but also to areas within the shrub-steppe vegetation zones that are in a successional stage and lack a significant shrub cover.

Table C.6 Native Avian Species that Use Steppe and/or Shrub-Steppe Habitats for Some Portion of Their Life Cycle Within the Columbia Basin Ecoregion (continued)

Scientific Name	Species	Shrub-Steppe	Steppe[a]
Summer Residents (Continued)			
Empidonax wrightii	Gray flycatcher	X	
Chondestes grammacus	Lark sparrow	X	X
Numenius americanus	Long-billed curlew		X
Sialia currucoides	Mountain bluebird		X
Salpinctes obsoletus	Rock wren	X	X
Amphispiza belli	Sage sparrow	X	X
Oreoscoptes montanus	Sage thrasher	X	X
Passerculus sandwichensis	Savannah sparrow		X
Sayornis saya	Say's phoebe	X	X
Buteo swainsoni	Swainson's hawk	X	X
Cathartes aura	Turkey vulture	X	X
Pooecetes gramineus	Vesper sparrow	X	X
Tyrannus verticalis	Western kingbird	X	X
Aeronautes saxatalis	White-throated swift	X	X
Winter Residents			
Lanius excubitor	Northern shrike	X	X
Buteo lagopus	Rough-legged hawk	X	X

[a]Steppe here refers not only to vegetation zones that are characteristically without sagebrush or bitterbrush, but also to areas within the shrub-steppe vegetation zones that are in a successional stage and lack a significant shrub cover.

weasels, coyote (*Canis latrans*), bobcat (*Lynx rufous*), mule deer (*Odocoileus hemonionus*), beaver (*Castor canadensis*), and muskrat (*Ondatra zibethica*) (Burt and Grossenheider 1976).

Some of these species are widely distributed throughout the sagebrush-steppe. The Great Basin pocket mouse (*Perognathus parvus*), for example, is granivorous and likely obtains its water entirely from its food (Ingles 1965). Others that have a strong association with sagebrush-steppe are the northern pocket gopher (*Thomomys talpoides*), black-tailed jack rabbit (*Lepus californicus*), and northern grasshopper mouse. In contrast, other species, such as the long-tailed weasel (*Mustela frenata*), beaver, and muskrat, are found only in areas near a permanent water source, where they find much of their food. Other species typical of the ecoregion's shrub-steppe also occur in more mesic environments elsewhere outside the ecoregion. These mammals include Merriam's shrew, Nuttall's cottontail (*Sylvilagus nuttalli*), deer mouse (*Peromyscus maniculatus*), striped skunk (*Mephitis mephitis*), bushy-tailed woodrat (*Neotoma cinerea*), and badger (*Taxidea taxus*). A number of bats species that are typical of the ecoregion, as well as more mesic environments elsewhere, include the little brown myotis (*Myotis lucifugus*), California myotis (*M. californicus*), Yuma myotis (*M. yumanensis*), silver-haired bat (*Lasionycteris noctivagans*), big brown bat (*Eptesicus fuscus*), pale Townsend's (=western) big-eared bat (*Plecotus townsendii pallescens*), and pallid bat (*Antrozous pallidus*). Riparian zones provide suitable foraging habitat for these insectivores.

Other species, while characteristic of the ecoregion, are not so widely distributed. Several rely on forested or riparian vegetation for food and cover. These include the vagrant shrew (*Sorex vagrans*), white-tailed jack rabbit (*Lepus townsendii*), long-eared myotis (*Myotis evotis*), long-legged myotis (*M. volans*), and small-footed myotis [*M. ciliolabrum* (split from *M. leibii*)]. Other species that are associated with sagebrush steppe, but are not common throughout the entire Columbia Basin Ecoregion, include the pygmy rabbit, Townsend's ground squirrel, least chipmunk (*Eutamias minimus*), sagebrush vole, western harvest mouse *(Reithrodontomys megalotis*), western pipistrel (*Pipistrellus hesperus*), and badger.

The pygmy rabbit, for example, is found in Washington only within the Columbia Basin Ecoregion. These Washington populations are disjunct from the core of the species's range to the south, and apparently, have been separated for thousands of years. The pygmy rabbit requires dense rabbitbrush or clumps of sagebrush to provide necessary cover from predators such as the coyote and long-eared owl (*Asio otus*). The pygmy rabbit is highly dependent on sagebrush, which composes up to 99% of its diet. It also requires relatively deep, loose soil for digging its burrows (WDFW 1993). Such habitat has largely been converted to agriculture and is now relatively scarce in the ecoregion. The pygmy rabbit's numbers are few in Washington. The sagebrush vole has a close association with big sagebrush (Rickard 1960).

A number of other species are less characteristic of the ecoregion, as they occur within the ecoregion but on its periphery. These peripheral species include the fringed myotis (*M. thysanodes*), hoary bat (*Lasiurus cinereus*), shorttail weasel (*Mustela erminea*), mink (*Mustela vison*), spotted skunk *(Spilogale putorius),* raccoon (*Procyon lotor*), river otter (*Lutra canadensis*), and red fox (*Vulpes fulva*), all of which are confined to locations with permanent water. The yellow-bellied marmot (*Marmota flaviventris*), mountain lion (*Felis concolor*), Columbian ground squirrel [*Spermophilus* (=*Citellus*) *columbianus*], Ord kangaroo rat (*Dipodomys ordi*), elk (*Cervus elaphus*), and porcupine (*Erethizon dorsatum*) require other habitat characteristics that limit their range within the ecoregion. Many of these are found primarily in forested areas at the margins of the ecoregion and at higher elevations. For example, the Columbian ground squirrel is found in grassland and open timber along the eastern edge of the ecoregion; the marmot is found primarily in talus slopes bordering alpine meadows; and the porcupine is largely arboreal, frequenting conifer forests along the eastern and western fringes of the ecoregion. The Ord kangaroo rat occurs in sagebrush steppe in open sandy areas; its range extends only into the extreme southern portion of Washington (Ingles 1965).

Response of Steppe Animals to Fire—The adverse effects of fire for shrub-nesting birds [e.g., loggerhead shrike, sage sparrow, sage thrasher, and Brewer's sparrow] are typically delayed until the following spring, as most wildfires occur after the nesting season. Ground-nesting birds are generally not greatly affected by burning [e.g., horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), and long-billed curlew (*Numenius americanus*)]. The sage grouse may be adversely affected because it forages largely on sagebrush foliage. Small mammals that burrow deeply are little affected by burning (e.g., Great Basin pocket mouse and Townsend's ground squirrel). Large, highly mobile mammals usually escape wildfires (e.g., coyote, mule deer, and elk).

C.2.4 Riverine/Riparian Communities Within the Ecoregion

The presence of dams has significantly altered the physical characteristics of the riverine environment of the Columbia Basin Ecoregion's major rivers, the Columbia and Snake. What was once a free-flowing system with significant seasonal changes is now mostly slackwater confined within a reservoir system. These physical changes have altered the amount and diversity of habitats available to aquatic organisms. Slackwater-adapted species are now favored over those that rely on free-flow conditions. Resident fish species for different segments of the Columbia River are described in a number of sources (see Gray and Dauble 1977 for citations). Some of these may describe pre-dam populations. As one of the last free-flowing stretches of the Columbia/Snake river system, the Hanford Reach may retain remnants of the pre-dam native fish species assemblages for this system (see Section C.3.6).

During the 1970s, the U.S. Army Corps of Engineers undertook an inventory of riparian habitats and associated wildlife along the Columbia and Snake rivers as part of an effort to evaluate the impacts of river regulation for maximum power production (i.e., power peaking) on key riparian habitats and

wildlife. Payne et al. (1976) inventoried the approximately 400-mile segment of the Columbia River from just north of Richland, Washington, to the Canadian border. The portion of the study conducted downstream of Chief Joseph Dam will be used to represent the riverine/riparian communities of the Columbia Basin Ecoregion, although it should be realized that many of these communities are still in a state of development following impoundment.

The main vegetation types identified by Payne et al. (1976) that occurred along the river shoreline included cobble and shoreline gravel, sand dune, shrub-steppe, steppe (without shrubs), riparian shrub [e.g., willow (*Salix* spp.)], and riparian tree [e.g., black cottonwood (*Populus trichocarpa*)]. Riparian shrub and tree communities were the most limited in occurrence, yet the most valuable in regard to wildlife usage. Before impoundment, narrow bands of willow may have typified the river floodplain where stream bank gradients were not steep.

Riparian habitat was important for passerine birds both for nesting and as resting areas during migration. Bird species diversity increased with vegetation type in the order: sand dune, cobble, shrub-steppe, riparian shrub, and riparian tree. The ranking probably reflects a similar increase in habitat complexity. Deer mice were the most abundant small mammal detected. When shrub-steppe occurred adjacent to the river, Great Basin pocket mice occupied as many transects as the deer mice; however, they were always at lower densities. Small mammal diversity never exceeded seven species at any particular location. Payne et al. (1976) had minimal sampling records for amphibians and reptiles, though they recorded nine different species along the Hanford Reach. Larger mammals and raptorial birds use the riparian habitat, but are not as tied to it as the smaller species.

C.3 Hanford Site and Immediate Surrounding Areas

C.3.1 Physical Features

The current Hanford Site occupies about 1517 km^2 (586 mi^2) of shrub-steppe in semi-arid south-central Washington. Figure C.9 shows the major physical features of the Hanford Site. Additional detail about the physical features of the Hanford Site can be found in Neitzel (2000).

A stretch of the Columbia River (the Hanford Reach) runs through the northern part of the Site and forms part of its eastern boundary. Specific abiotic characteristics of the Hanford Reach are described as part of Section C.3.6. Other than the Columbia River, little surface water is present on the Hanford Site—mostly a few spring and stream systems in the southwestern portion of the Site and irrigation runoff areas that have resulted in the formation of wetlands north of the Columbia River.

Hanford is located within the hottest and driest portion of the Columbia Basin Ecoregion. An almost 50-year record of climatological data is available for the central portion of the Site (Hoitink and Burk 1994). Average annual precipitation for this area is 16 cm (6.3 in.). Although the data from the central portion of the Site are representative of the general climate conditions for the region, differences in the topography of the Site contribute to relatively significant local changes in some aspects of climate (Neitzel 2000). For example, on the crest of Rattlesnake Mountain annual precipitation can reach up to 35 cm (13.8 in.) (Downs et al. 1993).

The Columbia River Plain constitutes the majority of the Hanford Site and is its lowest and most arid region. The Columbia River Plain differs somewhat from other areas of the Columbia Basin Ecoregion in that it was severely disturbed by a series of massive glacio-fluvial floods 10-20,000 years ago. As the floods subsided, the plain was newly colonized by terrestrial plant and animal populations from surrounding hills and ridges. Considering its relatively recent colonization and relatively extreme climate, it is not surprising that the native flora and fauna of the Columbia River plain differ from that of the surrounding shrub-steppe. The recent colonization of the plain also may be a factor in its vulnerability to invasion by non-native annuals (e.g., cheatgrass; see Section C.2.2 and Brandt and Rickard 1994).

Several basalt ridges traverse the Site and provide much of its topographic relief. Rattlesnake Mountain is the largest and highest ridge [1050 m (about 3450 ft)] and forms the southwestern border of the Site. Two ridges, Yakima and Umtanum, extend across Hanford's western boundary and terminate on the Site. Gable Butte and Gable Mountain, located north of the 200 Areas, are segmented extensions of Umtanum Ridge (Neitzel 2000). The Saddle Mountains form the northern border of the Site. The White Bluffs, which are formed from consolidated sediments, create a prominent cliff

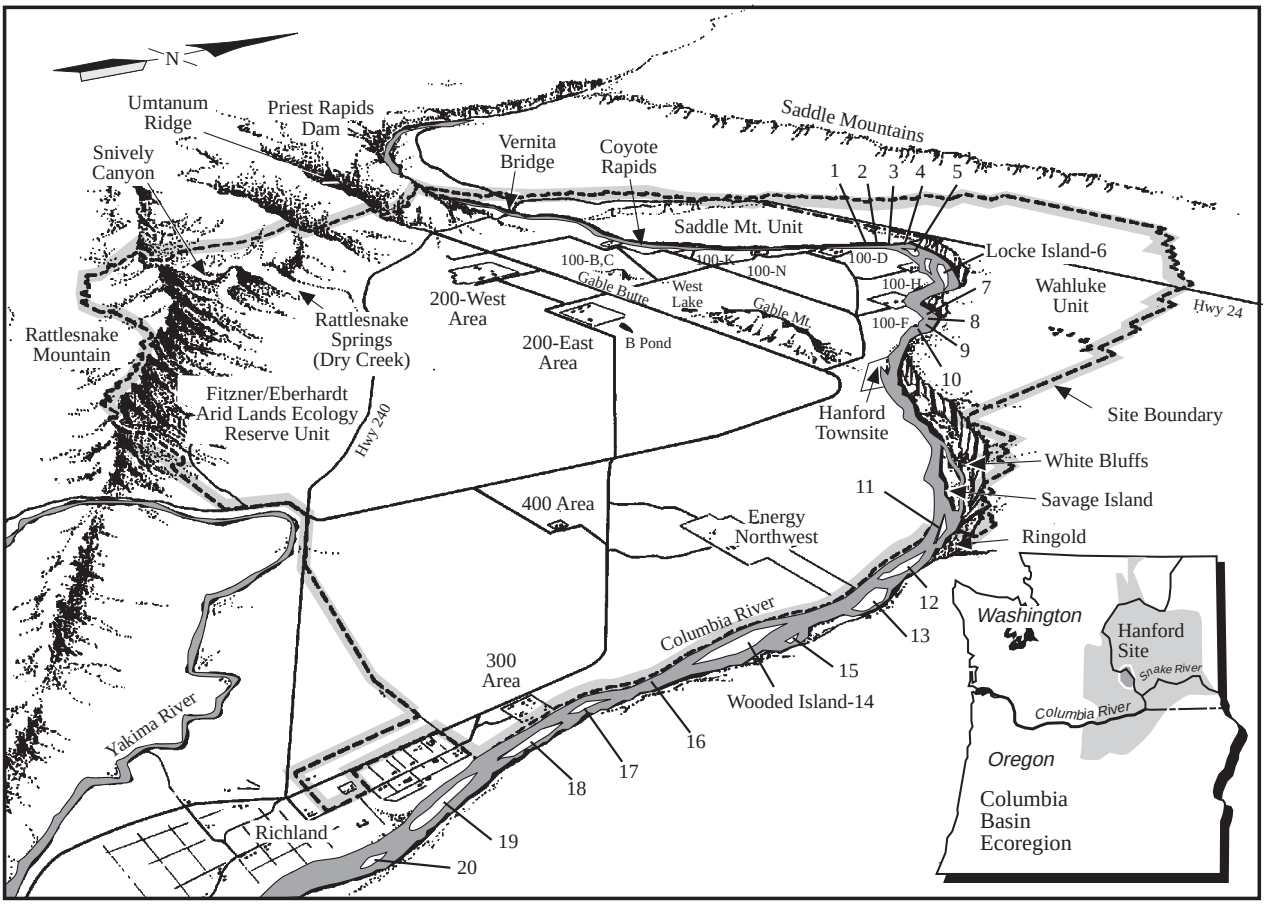


Figure C.9 Major Physical Features of the Hanford Site. Numbers refer to numbered river islands within the Hanford Reach.

along much of the eastern and northern shore of the Hanford Reach. The White Bluffs are subject to landslides as a result of irrigation activity east of the Columbia River (Neitzel 2000). The Cold Creek Valley (generally delineated by the route of state Highway 240 at the base of Rattlesnake Mountain) traverses the Site at roughly 150 m (about 500 ft) elevation.

Soils on the Hanford Site vary from sand to silty and sandy loam with 15 types in all described (Hajek 1966). The silt loam soils tend to be found on the slopes and higher elevation areas of the Site, whereas, the sandier soils are found at the lower elevations of the Columbia River Plain (see Figure 1 in Hajek 1966). Active and stabilized sand dunes are present in the eastern portion of Hanford (south and west of the Columbia River) and north of the Columbia River on the North Slope. Soil classification schemes have evolved since Hajek (1966); however, until such time the Site is resurveyed, Hajek's classification serves as the best available information (Neitzel 2000).

C.3.2 Hanford Site Operations and Land Uses

Before 1943, the recent land-use history of the Hanford Site related principally to livestock ranching, farm homesteads, and small supply and grain shipment towns (Gerber 1992). The consequences of some of these land uses are still apparent today as, for example, the abandoned town sites and old fields along the Columbia River. These areas today are composed mostly of non-native plant species that will probably not recover to a native composition without manipulation. Other areas that were grazed either retain a mix of native and non-native plant species or, if not intensively grazed, still closely resemble the original native plant communities. Even the ALE Unit experienced historic land uses (i.e., 1880–1940), such as homesteading, winter/spring sheep grazing, gas wells, and road building (Hinds and Rogers 1991). These historic non-DOE land uses also must be considered in understanding the ecological context of the Hanford Site.

The Hanford Site was established in 1943 in response to the nation's defense needs during World War II (Harvey 2000). Hanford's initial mission was to produce plutonium for use in the fabrication of nuclear weapons. Over most of its over 50 years of operation, Hanford's mission has been a combination of energy-related research and military-related material production, the apportionment of which depended on the nation's changing defense needs (Becker 1990). In the late 1980s the Site's mission changed to environmental cleanup and economic transition.

Plutonium production involved construction and operation of eight single-pass nuclear reactors, one dual-purpose nuclear reactor, and associated auxiliary facilities along the Columbia River (100 Areas); fuel reprocessing and waste management facilities in the central plateau region of the Site, all of which were at least 8 km (5 mi) from the Columbia River (200 Areas); fuel fabrication and research facilities north of the city of Richland along the Columbia River (300 Area); and support facilities north of the city of Richland inland from the Columbia River (1100 Area) (Figure C.10). Throughout much of their early operating history the 100 and 300 Areas also were used for waste management. A concise and informative summary of Hanford's history is provided by Gray and Becker (1993). Harvey (2000) and Gerber (1992) provide a more detailed overview.

The Site today also contains several other facilities and land areas that are mostly unrelated to Hanford's former defense mission. The Fast Flux Test Facility (currently deactivated) is located in the 400 Area inland from the Columbia River about 8 km (5 mi) north of the 300 Area. The 600 Area includes all other land areas not previously described. These lands are mostly undeveloped; however, they do include:

- an active commercial nuclear reactor and two unfinished commercial reactor complexes, which occupy about 4.4 km^2 (1.7 mi^2) of land and are operated by Energy Northwest (formerly the Washington Public Power Supply System), located east of the 400 Area, west of the Columbia River, and about 19 km (11.8 mi) north of the city of Richland
- a commercial, low-level radioactive-waste burial facility operated by U.S. Ecology on 0.4 km^2 (0.15 mi^2) of land leased by the state of Washington that is located south of the 200 Areas
- the Laser Interferometer Gravitational-Wave Observatory (LIGO) located west of Route 10
- the Environmental Restoration Disposal Facility (ERDF) located southeast of the 200 West Area. The ERDF receives waste resulting from the environmental cleanup of Hanford.
- an area in the southeast portion of the Site dedicated to the Hanford Patrol for training purposes.

The state also owns 2.6 km^2 (1.0 mi^2) of land just north of State Highway 240 and southeast of the 200 Areas that was acquired as a potential site for disposal of nonradioactive hazardous waste. A few hazardous and mixed waste burial sites are scattered throughout the 600 Area. A network of roads, railroads, and electrical transmission lines connect the above building complexes on Hanford.

Two new facilities were built in the southeastern corner of the Site in the 1990s. A training facility for hazardous materials handling [Hazardous Materials Management and Emergency Response Training Center (HAMMER)] and the Environmental Molecular Sciences Laboratory (EMSL). A nuclear fuel fabrication facility, which is operated by the Siemens Nuclear Power Corporation, is located adjacent to the Hanford Site near the 1100 Area and just south of HAMMER.

Scattered parcels throughout much of the Hanford Site are Bureau of Land Management-withdrawn lands that have been transferred to the control of DOE-RL. Additionally, there are Bureau of Reclamation parcels on the North Slope that DOE-RL uses under a Memorandum of Agreement with Reclamation.[8] Reclamation retains the right to construct, operate, and maintain the irrigation infrastructure on these parcels.

Much of the land surrounding Hanford is used for agriculture. Ironically, use of Hanford for the production of defense nuclear materials protected much of the Site from industrial development, agriculture, and livestock grazing (Gray and Becker 1993; Gray and Rickard 1989).

[8] Memorandum of Agreement between the Bureau of Reclamation and the then Atomic Energy Commission in regard to the transfer of rights for certain acquired and withdrawn lands on the Wahluke (North) Slope, dated February 27, 1957.

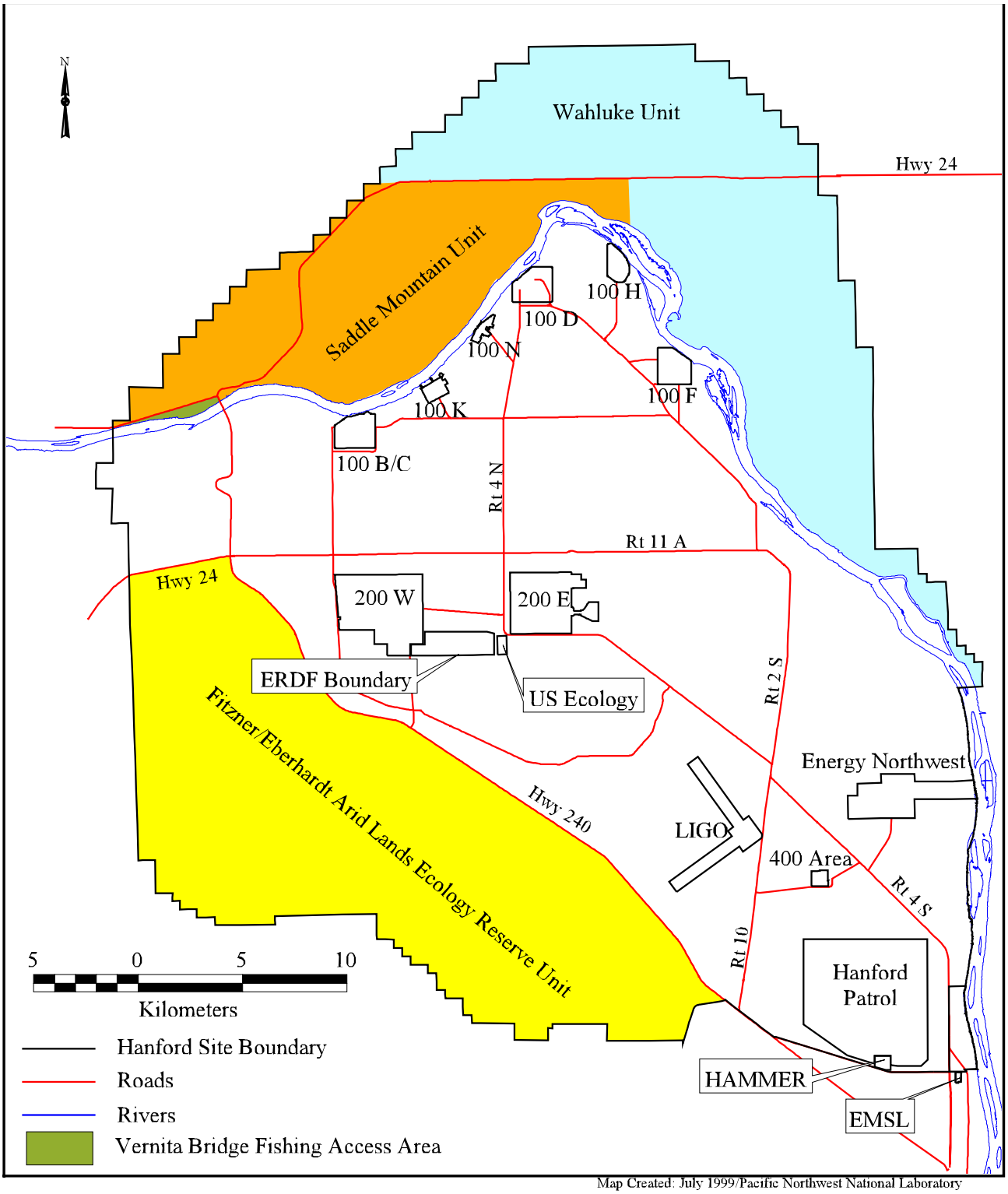


Figure C.10 Hanford Site Facilities and Land Use Areas

C.3.3 Areas Managed Principally for Their Biological Resource Values

Three land areas within the 600 Area are managed principally for their biological resource values (Figure C.10). The former ALE Reserve, now named the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument/ Saddle Mountain National Wildlife Refuge, is managed by the U.S. Fish and Wildlife Service. Property north of the Columbia River is managed by the U.S. Fish and Wildlife Service as a national wildlife refuge.

A smaller property (approximately 1.65 km^2) that lies north of the Columbia River, west of State Highway 24 and south of State Highway 223 is casually referred to as the Vernita Bridge Fishing Access Area and is currently managed by permit from DOE-RL to the Washington Department of Fish and Wildlife for recreational use. However, the long-term management of this land area, which also has biological resource value is, at the time of this writing, being negotiated among the DOE-RL, USFWS, and WDFW.

Two other wildlife areas border the Hanford Site: the Rattlesnake Slope Wildlife Area (managed by the WDFW) and the McNary National Wildlife Refuge (managed by the USFWS), which includes some islands of the Columbia River north of the city of Richland (Neitzel 1999).

C.3.4 Hanford Vegetation

The Hanford Site is located in the lowest and most arid portion of the Columbia Basin Ecoregion. The Site is located within the big sagebrush/bluebunch wheatgrass association, one of seven vegetation zones within the ecoregion (see Section C.2.2). Vegetation at higher elevations on Hanford largely typifies this association. For example, on Rattlesnake Mountain, Gable Mountain, Umtanum Ridge, and Yakima Ridge, communities with a big sagebrush overstory and a bluebunch wheatgrass understory are prevalent. In contrast, on the Columbia River Plain, communities with a big sagebrush overstory and a Sandberg's bluegrass understory are prevalent. Spiny hopsage frequently co-occurs with big sagebrush on the plain and in a few areas occurs in monotypic stands. Winterfat replaces big sagebrush and spiny hopsage in some areas, as does bitterbrush in mostly sandy soils. Appendix D provides land cover maps that delineate Hanford's vegetation. Sackschewsky et al. (1992) provides a listing of vascular plants present on the Hanford Site. Recent work by The Nature Conservancy (Caplow and Beck 1996; TNC 1995, 1996, 1998, and 1999) has added to the number of documented plant species on the Site.

The Hanford Site is unique within the Columbia Basin Ecoregion because it is the only area where irrigated agricultural fields have been permitted to naturally recolonize for as long as 50 years. After 50 years, abandoned fields in the vicinity of White Bluffs and the old Hanford Townsite remain dominated by non-native annuals [e.g., cheatgrass, tumble mustard, and jagged chickweed (*Holosteum umbellatum*)] with little evidence of recolonization by native shrubs and herbs. The persistent dominance of these species reflects the vulnerability of shrub-steppe to invasions by introduced Eurasian species and the competitive ability of these non-native species. The abandoned old fields provide nesting habitat for western meadowlarks, horned larks, and long-billed curlews, and foraging habitat for Canada geese (*Branta canadensis*), California quail (*Callipela californica*), and ring-necked pheasants, as well as for mule deer.

The Hanford populus was relocated offsite in the early 1940s. Residents' shade trees were allowed to remain. Those trees located near the Columbia River provide critical day perches and night roosts for wintering bald eagles (Eisner 1991) and nest sites for great blue herons (*Ardea herodias*). Riparian vegetation is further described in Section C.3.7. Trees located away from the river provide nest sites for Bullock's (formerly northern) orioles (*Icterus bullockii*), western kingbirds, Swainson's hawks, red-tailed hawks, American kestrels, and other tree-nesting species.

Hanson and Eberhardt (1971) provide maps of the vegetation characteristic of the islands within the Hanford Reach for areas above the littoral zone. Dominant species included northern buckwheat (*Eriogonum compositum*), absinthe (*Artemisia absinthium*), lupine (*Lupinus* sp.), and thick-spiked wheatgrass (*Agropyron dasystachyum*) (see Table 3 in Hanson and Eberhardt 1971). In a more recent study, Salstrom and Easterly (1995), describe three different island upland communities (may be seasonally flooded). Plant dominants differed from those reported by Hanson and Eberhardt (1971).

Differences could be due to different seasons of sampling or actual changes in composition during the intervening years.

C.3.5 Hanford Terrestrial Fauna

Several reviews on Hanford terrestrial fauna have been published (e.g., Downs et al. 1993; Fitzner and Gray 1991; Rickard and Poole 1989) as well as extensive treatments on particular portions of the Site (e.g., Rickard et al. 1988 on the ALE Unit). An overview of Hanford's fauna in relation to the rest of the Columbia Basin Ecoregion is provided in the paragraphs below.

Invertebrates—More than 1100 terrestrial and aquatic insect species are found on the Hanford Site (TNC 1995, 1996, 1998, and 1999). In general, bunchgrass, rabbitbrush, and sagebrush communities seem to be preferred more by insects than do cheatgrass communities. The major taxonomic groupings, as indicated by biomass estimates, are Coleoptera (beetles), Hymenoptera (ants, bees, and wasps), and Lepidoptera (moths and butterflies). Darkling beetles (Tenebrionidae) and ground beetles (Carabidae) are the most common beetles. Ants (Formicidae) are the most common family of the Hymenoptera, and moths are the most common lepidopterans (Downs et al. 1993). The above insects are an important food source for higher level consumers.

Herpetofauna—At least nine species of reptiles and three species of amphibians have been documented on the Hanford Site (Table C.7) (TNC 1999). Payne et al. (1976) reported the presence of common garter snakes within a segment of the Columbia River between Priest Rapids Dam and River Mile 345.5 (i.e., just north of Richland, Washington); however, they did not provide a precise sampling location. Compared to other taxa, amphibians and reptiles have been little studied on the Hanford Site. The side-blotched lizard is by far the most abundant reptile and can occur over the entire Site (Downs et al. 1993; Marr et al. 1988); however, in a study by Marr et al. (1988), no lizards were captured in the hopsage/Sandberg's bluegrass community. Racers and gopher snakes are the most common snakes at Hanford (Fitzner and Gray 1991). Amphibians are found primarily in close association with riparian and wetland habitats.

Birds—Various publications have estimated the number of bird species that have been observed on Hanford. Fitzner and Gray (1991) reported 187 species, Landeen et al. (1992) 238 species, and most recently for the ALE Unit, the North Slope, and central Hanford combined The Nature Conservancy reported 154 species for the ALE Unit, 152 for central Hanford, and 195 for the North Slope (TNC 1999). The shrub-steppe-dependent species that occur on the Site include virtually all of those listed in Section C.2.3 as species typical of shrub-steppe in the ecoregion. Sage thrashers occur in low numbers, and sage grouse have not been seen in recent years. Brewer's sparrows tend to be found only at high elevations on the ALE Unit within the threetip sagebrush communities. Sage sparrows and loggerhead shrikes are common. Other significant components of Hanford's upland avifauna include ferruginous hawks, bald eagles (*Haliaeetus leucocephalus*), burrowing owls, vesper sparrows, lark sparrows, grasshopper sparrows, long-billed curlews, and Swainson's hawks.

The 1997 bird survey of Central Hanford yielded 152 species, 57 of which were unique to Central Hanford in comparison to the ALE Unit (with 26 unique species) and the North Slope (with 77 unique species). The higher numbers of unique species on Central Hanford and the North Slope were attributed to the presence of the abundant riparian and wetland habitats. It was also noted that the Central Hanford surveys were of shorter overall duration and may have missed some of the winter resident species.

Additional bird survey data have been recorded from the Hanford Site Ecosystem Monitoring Project and from other occasional surveys and field studies. Those data are maintained in the Ecosystem Monitoring Project data files, but have not yet (September 1999) been integrated for the purpose of revising the Hanford Site bird species list.

Many insectivorous and piscivorous riverine and riparian species are found in riparian areas and on the shoreline of the Columbia River. Some of these, such as the bald eagle and great blue heron, use trees planted by early settlers along the Columbia River, as these provide night roosts, perches, and nest sites. Some species, such as the meadowlark and loggerhead shrike, though they occur along the river, are much more common in shrub-steppe

Table C.7 Reptiles and Amphibians Potentially Occurring on the Hanford Site

Scientific Name	Common Name
Reptiles	
Sceloporus graciosus	Sagebrush lizard
Uta stansburiana	Side-blotched lizard
Phrynosoma douglassii	Short-horned lizard
Masticophis taeniatus	Striped whipsnake
Coluber constrictor	Racer
Pituophis melanoleucus	Gopher snake
Thamnophis elegans	Western terrestrial garter snake
Hypsiglena torquata	Night snake
Crotalus viridis	Western rattlesnake
Chrysemys picta	Painted turtle
Amphibians	
Scaphiopus intermontanus	Great Basin spadefoot
Bufo woodhousii	Woodhouse's toad
Pseudacris (=Hyla) regilla	Pacific chorus (=treefrog) frog
Rana catesbeiana	Bullfrog

habitats (Downs et al. 1993). Waterfowl are abundant along the Hanford Reach where hunting is prohibited. As the Hanford Site is located in the Pacific flyway, many migratory birds use the Hanford Reach as a resting place during fall and spring migrations.

Mammals—Over 40 species of mammals species, all of which are listed in Section C.2.3 as mammals of the ecoregion [with the addition of the montane vole (*Microtus montanus*), Norway rat (*Rattus norvegicus*), and house mouse (*Mus musculus*) and the exclusion of the red fox, spotted skunk, mountain lion, and Columbian ground squirrel), have either been documented as occurring at Hanford (Fitzner and Gray 1991; Fitzner et al. 1992) or are identified by BRMaP as potential residents of the Site. Most of these species are small and primarily nocturnal and provide an abundant food source for larger predatory mammals, such as coyotes, and raptors. Large mammalian species that occur on the Site include Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) and Rocky Mountain elk (*Cervus elaphus nelsoni*). Elk are a relatively recent addition to Hanford Site wildlife, first appearing on the ALE Unit in 1972 (Rickard et al. 1977). The resident herd increased from approximately eight animals in 1975 to approximately 850 in 1999 (www.pnl.gov/ecology/ecosystem). Pygmy rabbits have not been observed on Hanford since 1984 (Fitzner and Gray 1991). Ord's kangaroo rat and the Washington ground squirrel may occur on the Hanford Site (i.e., on the North Slope). Both have yet to be documented by validated sightings (Rickard and Poole 1989); however, Payne et al. (1976) reported observing the kangaroo rat's characteristic track 3 miles downstream from Priest Rapids Dam on the Grant County side of the Columbia River. Certain species, such as Merriam's shrew, white-tailed jack rabbit, least chipmunk, yellow-bellied marmot, and sagebrush vole seem to be restricted in their distribution to the higher

elevations of the ALE Unit (Fitzner and Gray 1991); however, Payne et al. (1976) reported observing yellow-bellied marmots along the Hanford Reach.

C.3.6 The Hanford Reach

The Columbia River within the Hanford Site is atypical of the rest of the post-dam Columbia River system in the United States in that, here, the river runs through an approximately 76-km (47-mi) segment extending from the upper end of McNary Dam Reservoir to Priest Rapids Dam—known as the Hanford Reach—that remains essentially free-flowing. Except for the Columbia River estuary downstream of Bonneville Dam, this makes the Hanford Reach the only unimpounded stretch of the Columbia in the United States. As a result, the Hanford Reach provides remnant free-flowing habitat for aquatic organisms that were present before the remainder of the Columbia River system was converted to reservoir or slackwater habitat.

Although unimpounded, flows through the Hanford Reach are regulated by releases at Priest Rapids Dam and other upstream dams (primarily Grand Coulee Dam and Canadian water storage projects). Thus, the ranges of daily and seasonal flows differ from pre-dam conditions. Daily average discharges through the Hanford Reach vary seasonally and typically range from about 1140 to 7070 m^3/sec (40,000 to 250,000 cfs). Additionally, the Federal Energy Regulation Commission has established minimum licensed flows of 1020 m^3/sec (36,000 cfs) at Priest Rapids Dam.

The variability of water velocity and depth and substrate characteristics within the Reach has resulted in a diversity of riverine habitats. Some habitats may be used by a wide variety of aquatic species during all or part of their life cycles, whereas, others are species specific. The general kinds of habitat of importance are (1) main channel, (2) deepwater, and (3) backwater or slough. Within the main channel, there are areas with a relatively uniform vertical profile and flow, as well as braided sections with numerous islands, rock ledges, and gravel bars. Water velocities in the main channel vary with dam discharge and typically range from 0.6–3.0 m/s (2–10 ft/s). Reduced velocities occur near the shoreline and provide resting areas for many fish species. Maximum depth of the river channel rarely exceeds 10 m (about 33 ft) during average discharges; however, several deepwater sites [15-20 m (49–66 ft)] provide holding areas for white sturgeon and adult fall chinook salmon. Backwater areas are characterized by shallow depths and low velocities. The river bed typically consists of sand, gravel, cobble, and large rock (Chapman et al. 1983, 1986), with cobble the dominant substrate except in backwater areas.

Gray and Dauble (1977) identified 43 species of fish as occurring in the Hanford Reach. Neitzel (1999) added one more to the list: the brown bullhead [*Ameiurus* (= *Ictalurus*) nebulosis]. Several species of salmonids (i.e., salmon, trout, and whitefish) use the Reach as migration routes to and from upstream spawning areas. Both fall chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) spawn in the Reach (Downs et al. 1993). Additional information on the significance of the Hanford Reach's fisheries is provided in Section C.4.3.

The cobble substrate and free-flowing habitat of the Hanford Reach also supports a diverse benthic community. All major freshwater benthic taxa are represented in the Columbia River. The aquatic insect larvae of caddisflies (Trichoptera), midge flies (Chironomidae), and black flies (Simuliidae) are the dominant taxa. Other aquatic invertebrates include limpets, snails, sponges, and crayfish (Downs et al. 1993). The microfloral communities are composed mainly of diatoms, generally one or two taxa dominate, and benthic microfloral productivity may exceed that of the phytoplankton (Neitzel et al. 1982).

C.3.7 Riparian Communities

In general, two kinds of riparian habitats occur on the Hanford Site, the extensive narrow corridors along the Hanford Reach shoreline and the isolated, disjunct patches along the ALE Unit springs/streams. The important spring/stream communities on the ALE Unit include Rattlesnake (Dry Creek), Snively, and Bobcat. The ALE Unit springs/streams habitats consist primarily of native trees, such as black cottonwood (*Populus trichocarpa*) and chokecherry (*Prunus virginianus*); shrubs, such as willows (*Salix* spp.); and an herbaceous understory. In addition to the springs and streams on the ALE Unit, several ephemeral springs/seeps are located across the Hanford Site. For example, Cold Creek and its tributary, Dry Creek, are ephemeral springs within the Yakima River system. Such isolated springs contain small populations of land snails, including a previously undescribed species (Frest

and Johannes 1993). Because surface water is rare on Hanford, all the above springs are an important source of water for wildlife.

The riparian community on the Hanford Reach shoreline consists primarily of introduced trees, such as mulberry (*Morus alba*), Siberian elm (*Ulmus pumila*), and black locust (*Robinia pseudo-acacia*); native shrubs, such as willows; and emergent vegetation, such as reed canary grass (*Phalaris arundinacea*). In addition, a rich assemblage of perennial forbs and grasses occurs along the Hanford Reach shoreline and islands (Becker 1985; Salstrom and Easterly 1995). Substrate in the Hanford Reach riparian communities consists primarily of cobblestone. This substrate and the associated riparian plant communities are unique in the Columbia River ecosystem (Fickeisen et al. 1980a).

In the Hanford Reach, riparian vegetation is limited near the river's edge (Rickard et al. 1982). Most riparian vegetation occurs above the average annual flow line because variable discharge levels in the Hanford Reach prevent it from becoming established. Thus, the amount of shading and/or cover for aquatic organisms in the river is minimal. Riparian plant community compositions have been dynamic, which could be a response to the changing water level fluctuations resulting from the operation of Priest Rapids Dam (Rickard et al. 1982).

The ALE Unit and Hanford Reach riparian areas serve as a corridors for wildlife daily and seasonal movements and provide nesting, cover, and foraging habitat. Avifauna in these riparian areas is more diverse than in the surrounding shrub-steppe habitats (Rotenberry et al. 1979). These are valuable bird habitats, as most such stands outside of Hanford have not been protected from livestock grazing and are thus relatively scarce elsewhere in the ecoregion. By removing cattle from Rattlesnake Springs in the 1960s (Rickard and Cushing 1982), woody riparian habitat quickly expanded and now provides nest sites for many bird species, as well as forage for elk and mule deer. Additional discussion of Hanford Reach riparian habitat usage by wildlife is provided in Downs et al. (1993), Fickeisen et al. (1980b), and Rickard et al. (1982).

C.4 Regional and National Significance of Hanford's Biological Resources

C.4.1 Administrative Designations

The entirety of Hanford is designated a NERP by DOE (DOE 1994). This designation reflects the importance of Hanford in providing a "protected area for research demonstrations and education in ecology" (PNL 1977). The ALE Unit, one component of the Hanford NERP, is also designated a Research Natural Area. The ALE Unit provides opportunities for researchers, students, and educators to study and observe a relatively large and undisturbed ecosystem in which natural processes are retained (PNL 1993). The Research Natural Area designation also supports the state of Washington's Natural Heritage Plan (e.g., by providing a protected area for rare plant communities) (WDNR 1995).

In June 2000, the Hanford Reach, ALE Unit, Saddle Mountain Unit, and Wahluke Unit were proclaimed the Hanford Reach National Monument by presidential proclamation (65 FR 37253). The USFWS manages the Monument.

C.4.2 Stemming the Decline of Shrub-Steppe

Current Trends—Washington is rapidly losing much of its remaining steppe habitat and losses are projected to be high for the next 50 years (Andelman and Stock 1994a). Oregon also is losing its remaining steppe habitat, but at a slower rate (Andelman and Stock 1994b). Dobler (1992) estimates that approximately 60% of the original acreage [4.2 million ha (10.4 million acres)] of steppe vegetation in Washington has been lost, primarily to agriculture. Much of what remains is either already degraded and fragmented or is threatened by development and agricultural expansion (Noss et al. 1995). Moreover, Noss et al. (1995) recently concluded that:

- native shrub- and grassland-steppe (steppe in which the shrubs are not the most conspicuous part of the flora) within Washington and Oregon is an endangered ecosystem, in that it has experienced between an 85% to 98% decline since European settlement

- ungrazed sagebrush-steppe in the Intermountain West is a critically endangered ecosystem, in that it has experienced greater than a 98% decline since European settlement.

Dobler's (1992) estimate of steppe vegetation losses for Washington compares favorably with the ICBEMP data for vegetation losses across the entire Columbia Basin Ecoregion (see Section C.2.2 and Table C.4). Dobler's estimate is based on an analysis of Landsat Thematic Mapper (TM) data by the WDFW). The WDFW's unsupervised (i.e., ground-truthing was not used to calibrate the spectral data) land cover classification of the TM data is shown in Figure C.11. Non-potential shrub-steppe (SS) indicates that those areas classified as grass/bare are not likely shrub-steppe (WDFW's classification scheme does not distinguish areas of steppe which at the end of succession will contain large shrubs from those areas of steppe that will never contain large shrubs.).

The area shown in Figure C.11 covers only a portion of eastern Washington. To the west it includes some areas that are not part of the Columbia Basin Ecoregion and to the east, north, and south it omits some areas. The data represent portions of four satellite scenes: two scenes from June 9, 1986, and two scenes from July 18, 1986 (the latter scenes represent areas west of Hanford) (S. Snyder, WDFW, pers. comm., 1996). The advantage this data set has over the ICBEMP data is that TM data enable a mapping unit size of about 30 m^2 versus the 1 km^2 of the AVHRR data.

Where they overlap in coverage, the WDFW and ICBEMP data indicate a similar pattern of the current distribution and extent of steppe vegetation across eastern Washington (to the extent that 1986 and 1990 data are current). Overall, the WDFW data depict a higher degree of fragmentation of the remaining steppe vegetation; however, this is not unexpected given that it has a smaller mapping unit size. Both data sets (compare Figures C.8 and C.11) indicate that the Hanford Site and Yakima Training Center (located to the west of Hanford) combined contain the largest remaining remnant of steppe vegetation in the Columbia Basin Ecoregion. Moreover, the figures also indicate that these two sites still retain some degree of ecological continuity. If conversion and fragmentation of the remaining steppe outside these two sites continues unabated, the importance of this connectivity may increase over time.

The Role of Hanford—Ironically, use of Hanford for the production of defense nuclear materials has protected much of the Site from industrial development, agriculture, and livestock grazing (Gray and Becker 1993; Gray and Rickard 1989). The Hanford Site retains the largest remaining blocks of relatively undisturbed shrub-steppe in the Columbia Basin Ecoregion (Smith 1994) (Geographically, Hanford is in that portion of the Columbia Basin Ecoregion within which the potential steppe vegetation would be predominantly shrub-steppe.). Shrub-steppe plant communities on Hanford that have a high regional significance are those that are (1) extensive on Hanford relative to their extent in the rest of the ecoregion, and/or (2) of high quality on Hanford relative to their counterparts elsewhere in the ecoregion (Table C.8).

Figure C.11 shows that about 86% of Hanford can be classified as shrub-steppe. The perhaps less accurate ICBEMP data indicate that Hanford has lost only 7-8% of its historic shrub-steppe cover (Table C.3). Although at a finer scale of vegetation mapping it can be shown that significant portions of what these remotely sensed data sets identify as shrub-steppe contain extensively non-native species (e.g., cheatgrass), the estimates of remaining shrub-steppe at Hanford are reasonably accurate when only the developed portions (i.e., industrial and historic agricultural areas) are removed from the estimate. The ICBEMP data also can be used to illustrate, at least in a coarse manner, how Hanford's relative significance in regard to the presence of shrub-steppe has changed as the lands within much of the remainder of the Columbia Basin Ecoregion have been extensively converted to human use. Thus, the percentage that Hanford contributes to the existence of shrub-steppe within the ecoregion has increased by about 250% since European settlement (Table C.4).

Hanford's importance as a refuge for the shrub-steppe ecosystem is not based strictly on the ecosystem's rarity. In many places on Hanford, the shrub-steppe is relatively free of non-native plant species and/or is extensive enough to retain characteristic populations of shrub-steppe birds, mammals, and plants. In an analysis of avian diversity within eastern Washington, Smith (1994) predicted species distributions based on habitat associations.

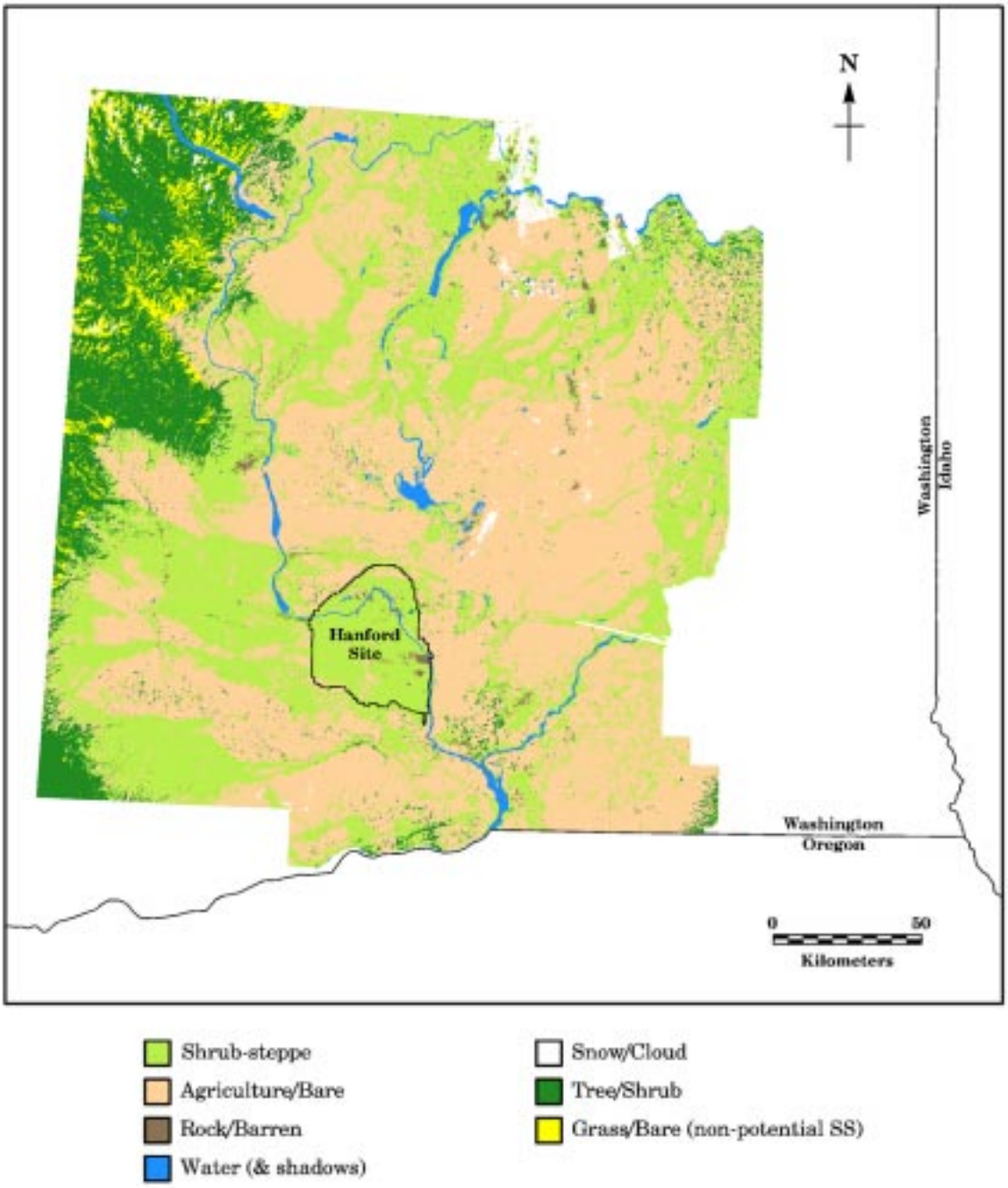


Figure C.11 Current Distribution and Extent of Land Cover Classes Within A Portion of the Columbia Basin Ecoregion (Source: Electronic version obtained from the Washington Department of Fish and Wildlife)

Table C.8 Shrub-Steppe Plant Communities on the Hanford Site in Relation to Their Status Elsewhere in the Shrub-Steppe of the Columbia Basin Ecoregion of Washington

Plant Community	Geographic Extent on Hanford	Stand Quality[a]	Regional Significance	Threat from Hanford Activities	Comments
Big sagebrush/ bluebunch wheatgrass	Major	High-Low	High	Low	Good quality stands on deep soil
Big sagebrush/ Sandberg's bluegrass	Major	High-Low	High	High	
Stiff sagebrush/ Sandberg's bluegrass	Minor	Mod.	Low	Low	Scarce on the Hanford Site
Threetip sagebrush/ bluebunch wheatgrass	Minor	High	High	Low	
Black greasewood/ alkali saltgrass (*Distichlis stricta*)	Minor	Mod	High	Low	Sodium accumulator; phreatophyte
Spiny hopsage/ Sandberg's bluegrass	Minor	Mod.	High	Mod	Potassium accumulator; relict stands
Winterfat/ Sandberg's bluegrass	Minor	Mod.	High	Low	
Rock buckwheat (*Eriogonum sphaerocephalum*)/ Sandberg's bluegrass	Minor	Mod.	High	Low	
Thyme buckwheat (*Eriogonum thymoides*)/ Sandberg's bluegrass	Minor	High	Mod.	Low	
Bitterbrush/ needle-and-thread	Major	Mod-Low	High	High	Bitterbrush is regarded as high quality forage for mule deer

[a]Stand quality judged by presence of non-natives (e.g., few non-natives = high quality).

His analysis indicates that Hanford possesses suitable habitat for the highest number of:

- species that breed within eastern Washington
- shrub-steppe species of concern (those that are listed or are candidates for listing by the federal government, Washington State, and or Oregon State governments)
- species that nest in big sagebrush.

Hanford's shrub-steppe also supports, or may potentially support, a number of obligate species (i.e., those that are dependent on a specific habitat type for at least a portion of their life cycle; for a discussion of avian obligates, see Section C.2.3), as well as other species that seem to be associated strongly with shrub-steppe. Notable examples of obligate species that have dramatically declined in Washington and Oregon, and that may occur on Hanford, but are either not currently known to occur or only rarely occur there, are the pygmy rabbit and sage grouse, respectively. The sage sparrow is also an obligate species; it is present in significant numbers on the Hanford Site. Examples of other species that seem to be associated strongly with shrub-steppe and that are known to occur on Hanford include the ferruginous hawk, loggerhead shrike, striped whipsnake, and Columbia milkvetch (*Astragalus columbianus*).

C.4.3 Last Free-Flowing Stretch of the Columbia River

The Hanford Site contains significant riparian, wetland, and riverine habitat associated with the Hanford Reach of the Columbia River. It contains riparian habitat, free-flowing riffles, gravel bars, oxbow ponds, and backwater sloughs, which are otherwise limited in occurrence in the Columbia River system (USFWS 1980; NPS 1994). In 1980, the USFWS inventoried exceptional fish and wildlife habitats within the state of Washington. Based on the USFWS criteria of nationally significant and unique ecosystems, the Hanford Reach section of the Columbia River ranked second in the state (USFWS 1980). Also, the ecological importance of the Hanford Reach and the DOE-owned (but leased) land north and of the Columbia River (Wahluke or North Slope) has contributed, in large measure, to a recent determination that these areas should be permanently protected (NPS 1994).

The river channel within much of the Hanford Reach contains islands (over 20), submerged rock ledges, and gravel bars. The resultant complex network of pools, riffles, and backwater areas supports an aquatic community unique to the Columbia River Basin. For example, native species of cyprinids (i.e., carps and minnows), catostomids (i.e., suckers), and salmonids require higher velocity areas for spawning, while adjacent low-velocity areas provide essential rearing habitat. Thus, the increased habitat complexity within the Hanford Reach supports a wider range of life stages and greater species diversity than the more uniform habitat found within the reservoir complex. In contrast to backwater habitat within the reservoir complex that accumulate sediments and may be filled over time, reach backwater areas or sloughs are periodically flushed during high flow periods. The seasonal flushing action scours the substrate, exposing gravel/cobble beds important for fish spawning and invertebrate production.

Backwater areas within the Hanford Reach provide important spawning and rearing habitat for many aquatic species, including bass (*Micropterus* spp.), sunfish (*Lepomis* spp. and *Pomoxis* spp.), and catfish (mostly the brown bullhead) that migrate from downstream areas to the Hanford Reach each year for spawning (Page et al. 1982). These backwater areas also are important nursery areas for juvenile anadromous salmonids and resident native populations of cyprinids and catostomids. Backwater areas also are likely important breeding areas for amphibians, as well as important habitat for populations of mollusks (e.g., *Anadonta* spp.).

The Hanford Reach is regionally significant in that it provides important habitat for several species of anadromous salmonids. The Hanford Reach contains the last major mainstem spawning habitat in the Columbia River system for fall chinook salmon. Hanford Reach fall chinook represent a healthy population of the most inland fall chinook salmon stock in the Pacific Northwest and California (Huntington et al. 1996). Construction of 11 hydroelectric dams on the Columbia River and 6 dams on the Snake River between 1939 and 1975 blocked access or inundated most spawning sites used historically by fall chinook salmon. Up to 80% of the total run of adult fall chinook salmon returning to the mouth of the Columbia River spawn in the Hanford Reach (Dauble and Watson 1990). In recent years, nearly 60% of the return adult fall chinook salmon that pass McNary Dam spawn naturally in the Hanford Reach (NPS 1994). The Hanford Reach also serves as a migration corridor for other species/stocks of anadromous salmonids [i.e., sockeye salmon (*Oncorhynchus nerka*) and spring/summer chinook salmon] and provides important rearing habitat for juvenile steelhead trout and sockeye salmon from upstream production areas.

In addition, the Hanford Reach provides significant breeding habitat for several resident fish, such as the white sturgeon (*Acipenser transmontanus*). The white sturgeon is a long-lived species that requires flowing water to reproduce. White sturgeon spawning habitat downstream of the Hanford Reach is limited to small areas just below each hydroelectric project. Within the Hanford Reach, white sturgeon spawning has been recently documented just below Priest Rapids Dam and at a second location above Vernita Bridge (NPS 1994). Other locations are probable (Fickeisen 1980a). The Hanford Reach and the lower Columbia River downstream of Bonneville Dam support the largest white sturgeon populations in the Columbia River system. In addition to white sturgeon, mountain whitefish (*Prosopium williamsoni*), and sandroller (*Percopsis transmontana*) are two native species that may be present in much higher numbers in the Hanford Reach than in impounded areas (NPS 1992).

A number of non-fish, species of concern from a variety of taxa occupy the Hanford Reach. For example, the native molluscs Columbia pebblesnail (*Fluminicola columbiana*) and the shortface lanx

(*Fisherola nuttalli*), both state candidate species, can be found in the Reach. The distribution of the populations of these species may now be fragmented within the Columbia River basin, and populations are typically limited to headwater streams and unimpounded areas within larger rivers. The state endangered Columbia yellowcress (*Rorippa columbiae*) occurs in scattered locations along the wet shoreline of the Reach (Downs et al. 1993). The federal and state threatened bald eagle rests and forages along the Reach during its overwinter stay. Additionally, several species of recreational importance, such as the Canada goose and other waterfowl, also use this stretch of the river, its islands, and riparian corridor for portions of their life cycle.

Surveys by The Nature Conservancy (Salstrom and Easterly 1995; TNC 1996) identified six areas along the south shore and islands of the Hanford Reach that represent regionally significant occurrences of Columbia Basin low-elevation riparian wetlands. Most comparable sites have been permanently flooded by the existing reservoir system of the Columbia and Snake rivers. The six areas are: China Bar, Wahluke Bend Islands (2 and 3; see Figure C.9) and Point Bar, Locke Island, White Bluffs Slough, 100-F Area Slough, and the Hanford Townsite Slough.

Future regulatory actions associated with the listing of aquatic species under the Endangered Species Act may impact the management of aquatic species in the Hanford Reach. For example, upper Columbia River steelhead was recently listed as endangered and Snake River Basin steelhead was listed as threatened under the Endangered Species Act. Thus, any activity along the Hanford Reach that may adversely affect Snake River populations will need to be carefully scrutinized before implementation. Because the Hanford Reach may serve as migration corridors for other salmonids of regional importance [e.g., bull trout (*Salvelinus malma*) and steelhead], new listings of species in the Columbia River watershed, particularly those upstream of the Hanford Reach, may warrant similar scrutiny of Hanford activities.

C.4.4 Rare Habitats on the Hanford Site

Other riparian and wetland areas not directly associated with the Hanford Reach are scattered across the Hanford Site. These areas include a mix of small, naturally occurring cold-desert springs and streams (see Section C.3.7), artificial wetlands created by irrigation runoff (north of the Columbia River), and a variety of other temporary water bodies that result from waste-water discharges (Neitzel 1999; Downs et al. 1993). The springs and streams and their riparian vegetation provide water, forage, cover, and breeding sites for wildlife within arid portions of the Hanford Site (Downs et al. 1993). The presence of riparian and wetland areas also is important because of the increased habitat diversity they provide. Because of their relative isolation, the springs and streams may contain previously unknown endemic species or unique genotypes (Frest and Johannes 1993).

The Hanford Site also contains a diversity of other rare terrestrial habitats such as riverine islands, bluffs/cliffs, basalt outcrops, and sand dunes (Downs et al. 1993). Sand dunes, especially, have received little investigation, and could contain several faunal and floral species of concern.

C.4.5 Endemic Plant Species

Several plant species grow on and around the Hanford Site that are not known to occur anywhere else. Most are confined to the basalt hills and ridges, such as rosy balsamroot (*Balsamorhiza rosea*), Hoover's desert parsley (*Lomatium tuberosum*), Columbia milkvetch, basalt milkvetch (*Astragalus conjunctus* var. *rickardii*) and Umtanum desert buckwheat (*Eriogonum codium*). This last species does have other varieties that occur elsewhere. The Hanford population is a northern range extension for the species (TNC 1998). White Bluffs bladderpod (*Lesguerella tuplahensis*) is apparently restricted to a narrow zone along the crest of the White Bluffs located on the east shoreline of the Columbia River. At least in some cases, the above plants seem to be uniquely adapted to the rooting substrates in the locations in which they occur (Caplow and Beck 1996).

C.4.6 Hanford Biodiversity

One of the first steps toward conserving biodiversity is to conduct floral and faunal inventories at appropriate geographic scales (Knopf and Samson 1994). Effective biodiversity conservation relies on accurate information about species richness (i.e., the number of species), how species richness changes over different spatial scales, and the relative abundance of species. In 1995, TNC, in cooperation with DOE-RL, implemented a detailed inventory

of Hanford's biodiversity. The need for such a study was described by TNC as follows (TNC 1995):

> The DOE needs an accurate account of the rare species and ecosystems present on the Hanford Site in order to make informed decisions about future land uses. Biological studies undertaken in the past at Hanford have been primarily project- or species-specific. These studies have contributed enormously to the body of knowledge on Hanford, but have not included a large-scale, detailed inventory of the rare species and ecosystems present on the Site.

The results of TNC's 1994, 1995, and 1997 inventories (TNC 1995, 1996, 1998, and 1999) are informative as to the nature of Hanford's biodiversity. Highlights of the inventories include documentation of the following:

- 48 plant community element occurrences of 17 terrestrial elements (community types)
- 6 element occurrences of wetland/aquatic communities
- 112 populations of 28 rare plant taxa, 2 species and 1 variety new to science
- 1121 taxa of invertebrates, 40 species and 2 subspecies new to science
- 368 butterfly and moth taxa
- 3 species of amphibians
- 9 species of reptiles
- approximately 200 species of birds
- 16 mammal species.

Because the inventories focused on specific taxa and geographic areas, these results provide only a partial picture of Hanford's potential biodiversity (TNC 1995, 1996, 1998, and 1999). In assessing the relevance of their findings TNC concluded (TNC 1996):

> From a conservation standpoint, the Hanford Site is a vital—and perhaps the single most important—link in preserving and sustaining the biodiversity of the Columbia Basin's shrub-steppe region.

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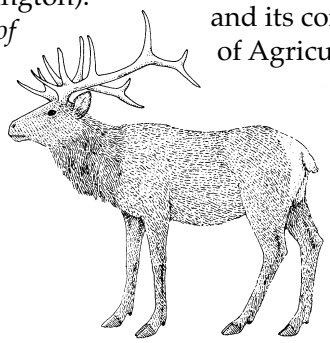
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