Washington Shrub-Steppe Ecoregion

Van R. Kane
BES 489
December 10, 2002

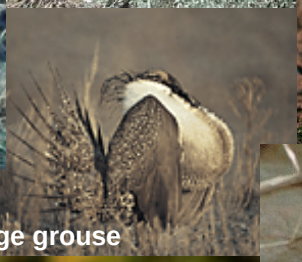
Shrub-steppe

Hanford site

Big sagebrush

Idaho fescue

Pygmy rabbit



Sage grouse

Cryptogamic crust

Northern grasshopper mouse

Grasshopper

Sources for cover photos

Hanford site - http://www.pnl.gov/ecology/Gallery/Landsc/mtns.htm

Shrub-steppe - http://www.pnl.gov/ecology/Gallery/flora/sage.htm

Big sagebrush - http://www.laspilitas.com/plants/97.htm

Idaho fescue - http://www.viarural.com.ar/viarural.com.ar/agricultura/forrajeras/festuca/variedades/festuca%20idahoensis%20subsp%20idahoensis%201.htm

Cryptogamic crust - http://www.pnl.gov/pals/resource_cards/Cryptogamic_crust.stm

Sage grouse – unable to refind original web site

Pygmy rabbit - http://www.wa.gov/wdfw/wlm/diversty/soc/pygmy.htm

Grasshopper - http://www.pnl.gov/ecology/Gallery/Animal/ghop.htm

Northern grasshopper mouse - http://www.americazoo.com/goto/index/mammals/170.htm

Tables and Figures

Preface

Note on Sources

R. Daubenmire appears to have devoted his working career to studying the shrub-steppe ecosystems of Washington State; sources used for this paper refer to his published work as far back as 1940. His technical bulletins (Daubenmire 1970 and 1988) form the basis for almost every other author's discussion of the ecoregion and its plants. This paper also depends on Daubenmire for the majority of its information. Rather than constantly cite his work, it should be assumed that the facts I present on the plant ecosystems, climate, and geology come from his bulletins unless otherwise noted.

Scientific Names

Appendix A provides the scientific names for all species discussed in this report.

Ecoregion Setting

Daubenmire (1988) defines the Washington shrub-steppe region as a 6 million hectare area of central-eastern Washington and north-central Oregon (Figure 1). It is a hot, dry region where a combination of shrubs, grasses, and herbs dominate the landscape. Several researchers consider the Washington region an extension of the shrub-steppe that extends through eastern Oregon and southern Idaho (for example, Primm 1999 and Ricketts *et al* 1999).

The Washington shrub-steppe lies in the Columbia basin. The Cascade Mountains bound the region on the west, the Okanogan plateau on the north, the Palouse Prairie on the east, and the Blue Mountains on the south. Numerous low mountains, hills, valleys, and canyons provide local vertical relief. (Figure 2) Three major rivers – the Columbia, the Snake, and the Yakima – flow through the basin.

Climate

The Washington shrub-steppe lies in the Cascade Mountains' rain shadow. Winters are moderately cold, and the summers are warm to hot. Precipitation falls primarily in the winter in the form of snow and melts by the early spring. (Daubenmire 1988) (Figure 3) Precipitation and temperature varies considerably from year to year (Rickard 1988). Records at the Hanford Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve show an average annual rainfall at the site of 12.8cm, with a low of 4.7cm and a high of 22.7cm. Temperatures similarly vary considerably from year to year.

The lowest parts of the basin (in the central and western portions) lie at the lowest elevations and receive the least amount of rain. As elevations gradually rise (Figure 2) towards the east, northeast, and south, precipitation increases and temperatures cool. (Franklin and Dyrness 1973; Daubenmire 1988) Daubenmire finds that the differences in climate caused by the gentle rise of the basin account for the major changes in plant zones.

Local topography creates microclimates that can significantly differ from the climate of the general area. Researchers at the ALE reserve (Gee *et al* 1988), for example, mapped 7 different microclimates based on elevation, exposure to the sun, and exposure to the wind. Daubenmire found that the plant cover on south and north facing hills differed, presumably because of different microclimates. Sullivan (1986) reports that this pattern extends to north and south facing railroad track banks and sides of knobs and kettles.

Even individual plants create microclimates (Gee *et al* 1988). The plant structures direct rainfall to their stem and create areas of relative dryness immediately below their canopies. They also influence soil temperatures. Soil measured 3cm below the ground around shrubs show significant differences in temperature. Sunlight reflected from the sagebrush's canopy heats the soil on the sunward side by 2° to 8°C compared to surrounding soil. Similarly, hopsage cools the soil in its shade by 10°C.

Studies (Daubenmire 1988) at one site traced the soil water availability following the snow melt. Early in the spring, the soils is dry to the 5cm level; by the end of April to the 20cm level; by the end of May to the 50cm level; and by the end of June to the 1m level.

Geology and Soils

Daubenmire (1988) summarizes the geology (Figure 4) and soils of the Washington shrub-steppe. Numerous flows of lava laid a basalt floor the basin that remains near the surface in much of the basin. Wind carried in layers of loess. During the ice age, the glaciers did not reach the basin. Floods released by the glaciers, on the other hand, carved numerous canyons and deep valleys into the loess; the floods carried outwash sediments into the newly carved valleys (Wildung and Garland 1988). Volcanic ash from the Cascades volcanoes has periodically covered portions of the basin.

Deep loams on gentle slopes cover most of the Columbia Basin. Because this soil type broadly covers the basin, differences in soils do not cause broad differences in the

vegetation zones. In places, though, the soil becomes unusually sandy, shallow, stony, or alkali, which creates local sites of different vegetation types.

A local area can have a variety of soils. The Hanford site (Soll *et al* 1988), for example, has 15 soil types. Silt loams dominate the slopes and higher elevations and sandier soils dominate on the Columbia River plain. The smaller ALE Reserve at the Hanford site has the same dominant soil patterns, but has 8 other soils types at local sites (Figure 5). Depending on the area and soil types, soil depths typically range from 25cm to 150cm before bedrock at the ALE reserve (Wildung and Garland 1988).

Ecosystem Diversity

Species of sagebrush and perennial grasses -- which evolved to survive the limited winter precipitation and the hot, dry summers -- dominate the Washington shrub-steppe ecosystems (Ricketts *et al* 1999). Just three species -- the big sagebrush, bluebunch wheatgrass, and Idaho fescue -- constitute either the primary canopy or under story plant across most of the region (Daubenmire 1988) (Figure 6). Which species prevails in any particular zone depends on its annual precipitation (Franklin and Dyrness 1973; Daubenmire 1988). The relationship between elevation and plant community holds when the elevation increase comes from local topography such as a mountain (Rickard 1988; O'Connor and Wieda 2001). (Figure 7)

The lowest portions of the Columbia basin (approximately two-thirds of the region) are dry enough to allow sagebrush to be the upper story with an under story of perennial bunchgrasses. Big sagebrush/bluebunch wheatgrass prevails in the driest areas. Idaho fescue becomes the defining under story as higher elevations increases precipitation. In the wettest sagebrush areas threetip sagebrush becomes the dominant shrub with Idaho fescue remaining the most common under story plant.

Once the precipitation increases beyond the tolerance of sagebrush, perennial grasses and herbs dominate the landscape. At the lower elevations, the bluebunch wheatgrass/Idaho fescue community replaces the sagebrush communities. Above that, at the eastern and southern extents of the basin, the Idaho fescue dominates the landscape with inclusions of shrubs such as common snowberry or Nootka rose.

While the zonal system works well to explain the broad distribution of plant communities, Daubenmire documents 33 additional specialized native communities:

- Smaller zonal communities exist on the southern margins of the basin and along the Snake and southwestern Columbia River canyons and as meadow-like parks within the lower forest zones that surround the basin.
- The edaphic communities respond to soils that are sandier, shallower, stonier, or more alkali than the norm.
- Several specialized communities grow on dunes, talus slopes or in crevices.
- A number of communities specialize in lands adjacent to or in springs, streams, rivers, and ponds.

Table 1 summarizes Daubenmire's plant communities.

The Hanford Site (Soll *et al* 2000) shows how the mix of zonal and specialized communities creates rich biodiversity at the local level. The site lies within the hottest and driest area of the big sagebrush/bluebunch wheatgrass zone. The area's topography – tall hills in the north and south with a low-lying plain in between – creates a range of temperature and precipitation zones. Specialized soils permit the existence of edaphic communities. The southern hills contain numerous springs and streams that provide riparian habitat. And the free-flowing Columbia River creates a number of communities specialized to its shores, wetlands, sloughs, islands, riffles, and ponds. A inventory of the site found a total of 48 occurrences of 17 terrestrial plant communities and 8 riparian, 3

island, and 1 wetland communities along the Columbia River (Figure 8a-d). The inventory also found 1,509 taxa of invertebrates (including 368 taxa of butterflies and moths), 221 species of birds, 22 species of mammals, 9 species of reptiles, and 4 species of amphibians.

Native and Zootic Communities

Plant Communities

This section introduces the communities by focusing on three widespread zones. (Unless otherwise cited, all information comes from Daubenmire (1988).)

The most extensive community, dominated by big sagebrush/bluebunch wheatgrass, has four layers (Figure 9). Big sagebrushes, with a scattering of other sages such as rabbit-brush and threetip sagebrush, create the upper layer. Perennial grasses such as bluebunch wheatgrass constitute the second layer. Short vascular plants such as small fescue form the third layer. A cryptogamic crust composed of lichen and mosses constitutes the final layer. Primary production of this community is low, ranging from 105 to 166 grams/m^2.

While the big sagebrush/bluebunch wheatgrass community lies at the lowest and driest portion of the basin, the Idaho fescue/common snowberry lies at some of the highest and wettest portions of the basin. In this meadow-steppe, low winter temperatures limit primary production instead of summer drought. Perennial grasses such as the Idaho fescue provide the canopy with forbs providing an under story and a cryptogamic crust on the ground. (Figure 9) The wetter climate supports more species of plants than the shrub-steppe, and a large number of perennial forbs are found. Rhizome propagation is also more common than in the lower, hotter regions. The meadow-steppe produces 2-3 times more biomass (239 to 368 grams/m^2) than does the shrub-steppe.

The plants in both of these native communities have adapted to the arid climate. Most plants confine their growth to the spring following the snowmelt and then become dormant over the summer. Mosses desiccate in late April; bluegrasses in May; and the largest grasses and forbs in June. The largest shrubs, however, have roots that tap into deep subsurface water and remain active throughout the summer. (Constrained water supplies, however, impact the big sagebrush. It typically covers just 5-26% of the surface. Experiments have shown that the use of near-surface water by other plants in the area prevents it from growing more densely.) With the return of rain in the autumn, the perennial grasses grow new leaves and grow sporadically through the winter. Most plants, however, remain dormant during the winter.

The cryptogamic crust appears to play a number of roles in the community (Soll *et al* 2000): It helps preserve the soil against wind and water erosion; it enriches the soil by providing carbon and nitrogen; and it appears to assist water in infiltrating the soil. Some research also suggests that the crust provides favorable microhabitats for native seedlings while discouraging the establishment of exotic seedlings.

The exotic cheatgrass community differs from the two communities discussed above. It is found throughout the Columbia basin where the native community has been severely disturbed (primarily through farming or grazing). Once it becomes established, it apparently has never been dislodged by natural succession -- cheatgrass has become a widespread climax community in its own right. Native plants grow sporadically in this community; the cryptogamic crust is absent (Crawford and Kagan 2001).

Cheatgrass' competes well against the native plants (Rickard and Vaughan 1988). An annual, cheatgrass sprouts at the beginning of the autumn rains. It resumes production as soon as warm spring weather permits and out competes native perennials for water and space. It produces copious seeds, overwhelming the comparatively paltry seed production

of the native perennials. After seeding, the cheatgrass dies. Cheatgrass produces 12g of biomass per centimeter of precipitation compared to 2.7g/cm in one native shrub-steppe community; total cheatgrass productivity is 225 grams/m^2 compared to 59 grams/m^2 in the native community[1].

Animal Communities

The simple trophic structure of the pure shrub-steppe reflects its limited primary production (Rogers *et al* 1988). Insects consume over 80% of the biomass. Small mammals and birds consume almost equal amounts of the rest; large native animals consume relatively little. The sparseness of primary productivity ultimately limits the number and kinds of predators. For example, the shrub-steppe supports just 3 carnivorous mammals compared to 10 commonly found in Washington forests (Vander Haegen *et al* 2001). Predatory birds consume 38% of herbivore mass, mammals 43%, and insects 18%.

Several mammal and bird species have developed specialized adaptations for life in the arid shrub-steppe. (Vander Haegen *et al* 2001). The grasshopper mouse and sage sparrow, for example, get most of their water requirements from their food and can survive without free water for long periods. Many species avoid the heat by spending the day underground or in crevices and being active only at night. Some, such as ground squirrels and pocket mice, spend the dry, hot summer months underground in a torpor. Shrub-steppe small mammals and birds typically nest either underground or nest using the structure of shrubs and tall grasses. A number of species have become so adapted to the shrub-steppe that they have become obligates, including the Sage and Brewer's sparrows, sage grouse, sage thrasher, and pygmy rabbit.

[1] The productivity numbers for the shrub-steppe from Daubenmire differ significantly from Rickard and Vaughn; the difference could come from different techniques, sample sites, or years.

The biodiversity of the shrub-steppe increases dramatically where springs or streams occur. The tree-and-shrub-lined riparian areas directly support a number of species found only in or near water such as several bird species (Rogers *et al* 1988), fish, reptiles, and amphibians (Johnson and O'Neil 2001). In addition, a number of species that primarily use the shrub-steppe also depend on riparian areas. Almost all bird species found at Hanford, for example, depend on riparian areas for water, habitat, or food during at least some part of the year (Soll *et al* 2000). Similarly, the mule deer and elk in Hanford's southern hills use the riparian areas for drinking water (Rogers *et al* 1988).

A clear relationship exists between animal biodiversity and the three plant communities described above. Structural diversity creates more habitats and supports greater animal diversity: The shrub-steppe has more animal biodiversity than does the meadow-steppe; both have more diversity than does the cheatgrass community (49 closely associated species versus 34 versus 2) (Vander Haegen *et al* 1988). While cheatgrass produces significant plant biomass, many species cannot eat it once it dies or cannot effectively use its seeds. (Vander Haegen *et al* 1988). Abundance of animals also appears to be lower in cheatgrass communities (Rogers *et al* 1988). One experiment caught over 3 times (283 versus 89) as many small burrowing mammals in a native shrub-steppe community as in a nearby cheatgrass community.

Disturbances and Succession

The native shrubs and bunchgrasses evolved in a regime with modest natural disturbance (Daubenmire 1988). Few large native ungulates existed, and they tended to cluster near the basins borders or near streams. Their numbers were low enough that they put little pressure on the native plants. Similarly, fire occurred at a modest frequency of once every 25 years (Crawford and Kagan 2001). When a large disturbance such as fire did sweep through an area, the initial recovery was swift for the perennial grasses, forbs,

and some shrubs. These species rapidly regenerated from roots that survived below ground. A few shrubs, such as the big sagebrush, would be killed outright, and their return to the area would take up to 10 years (Crawford and Kagan 2001).

European settlers dramatically changed the disturbance and succession regime. Farming and building directly disturbed a number of communities. Cattle grazed native grasses and forbs with an intensity that reduced these plants' numbers to a shadow of their former selves. The repeated trampling of the cattle also destroyed the cryptogamic crusts that were essential to retaining soil and water in the natural community.

Cheatgrass and Kentucky bluegrass brought by the settlers enhanced the damage to native communities. These annual grasses evolved in areas with heavy grazing and frequent fires. They rapidly take over areas disturbed by grazing, fire, or human activities. Once established, they out compete native seedlings by appropriating the water supply, more efficiently converting water to growth, and producing an overwhelming quantity of seeds. Fire sweeps through exotic grass communities every 3-5 years; native communities cannot cope with this frequency (Johnson and O'Neil 2001).

Human Impacts and Management

Europeans settled the Columbia Basin in the second half of the 1800s and radically remade the landscape. Daubenmire (1970) had to reconstruct the original ecosystem map through a "diligent search spanning three decades to find scraps of apparently virgin vegetation in fence-corners, road right-of-ways, old cemeteries, and in places simply too remote from water to be grazed." A federal survey (Quigley *et al* 1996) found the ecological integrity of the region low across the basin. (Figure 10) Almost 60% of the land (preferentially in the moister uplands and river valleys) has been converted to agriculture; much of the rest is used for grazing (O'Connor and Wieda 2001). (Table 2) Of Daubenmire's zonal communities, only the big sagebrush and bluebunch wheatgrass

communities survive in large expanses and these suffer extensive incursions of exotic grass communities (Daubenmire 1988; O'Connor and Wieda 2001). (Table 2 and Figure 11) Several species – such as the pygmy rabbit and the sage grouse -- dependent on healthy shrub-steppe are threatened with extinction in the region (Soll *et al* 2000).

Ownership of the land divides among several entities (Figure 12) with the majority of privately held. The Bureaus of Reclamation Land Management have numerous small holdings in the central portion of the basin. Two large, nearly intact expanses of the native shrub-steppe community exist at the Hanford National Monument and the Yakima Training Center (Ricketts *et al* 1999). The Federal government is drawing up plans to manage Hanford to preserve biological diversity (much of it has been managed as an ecology reserve or wildlife area for many years) (Federal Register 2002). The Army has undertaken extensive surveys of its training center and attempts to preserve the ecosystem while still carrying out its training mission (Environment and Natural Resource Division 2002).

Put together, farming, grazing, fragmented ownership, and invasion of exotic communities have left the Washington shrub-steppe in poor condition. On the positive side, the situation apparently has not worsened dramatically in the last 50 years (Quigley 1999) and may have improved since the early decades of the 20th century (Daubenmire 1988). On the negative side, the ecoregion enters the period of global warming in poor shape. The results of the climate change on weakened ecosystems are likely to be unpredictable. In a cautionary study, for example, researchers studying an arid shrub-grassland in Arizona found that increased rain caused increased *desertification* (Brown et al 1997). What our descendents receive of the Washington shrub-steppe 200-400 years hence may bear little resemblance to what our forefathers found just 150 years ago.

Appendix A: Plants and Animals of the Columbia Basin Shrub-Steppe

The following list combines the plants that define the plant communities identified by Daubenmire (1988) (**listed in bold type**) with common plants and animals from O'Connor and Wieda (2001).

Plants and animals common to the terrestrial shrub-steppe are listed first followed by those common to riparian and aquatic habitats within the shrub-stepped. O'Connor and Wieda focus on the Hanford site, so the list of plants and animals may be biased toward those found in the hotter and drier regions of the basin typified by the Hanford site.

(a) = introduced species

Terrestrial Shrub-steppe species

Terrestrial Shrub-steppe Species	
Shrubs	
Big sagebrush	***Artemisia tridentata***
Bitter-brush	***Purshia tridentata***
Common snowberry	***Symphoricarpos albus***
Gray rabbitbrush	*Ericamerica nauseosa*
Hackberry	***Celtis douglasii***
Nootka rose	***Rosa nutkana***
Parsnipflower Buckwheat	***Eriogonum heracleoides***
Purple sage	*Salvia dorii*
Rock buckwheat	*Eriogonum spaerocephalum*
Smooth sumac	***Rhus glabra***
Snow buckwheat	*Eriogonum niveum*
Spiny hopsage	*Grayia spinosa*
Stiff sagebrush	*Artemisia rigida*
Threetip sagebrush	***Artemisia tripartita***
Thyme buckwheat	*Eriogonum thymoides*
Winterfat	*Eurotia lanata*
Perennial Grasses	
Bluebunch wheatgrass	***Agropyron spicatum***
Alkali saltgrass	***Distachlis stricta***
Bottlebrush squirreltail	*Elymus elymoides*
Cusick's bluegrass	*Poa cusickii*
Giant wildrye	***Elymus cinereus***
Idahoe fescue	***Festuca idahoensis***
Indian rice grass	*Achmatherum hymenoides*
Needle and thread	***Stipa comata***
Prairie junegrass	*Koeleria cristata*
Red threeawn	***Aristida longiseta***
Sand dropseed	***Sporobolus cryptandrus***
Sandberg's bluegrass	***Poa secunda***
Annual grasses	
Cheatgrass	***Bromus tectorum***
Kentucky bluegrass	***Poa pratensis***
Perennial Herbs	
Common cow-parsnip	***Heracleum lanatum***
Douglas' buckwheat	***Eriogonum douglassi***
Hood's pholx	*Phlox hoodii*

Hounds-tongue hawkweed	***Hieraceum cynoglossoides***
Lance-Leaved Psoralea	***Psoralea lanceolata***
Longleaf phlox	*Phlox longifolia*
Lupine	*Lupinus spp.*
Munro's globemallow	*Sphaeralcea munroana*
Narrowleaf goldenweed	*Haplopappus stenophyllus*
Northern buckwheat	***Eriogonum compositum***
Oregon cliff fern	***Woodsia oregana***
Oregon double bladderpod	***Physaria oregana***
Pale evening primrose	*Oenothera pallida*
Penstemom	***Penstemon triphyllus***
Piper's daisy	*Erigeron piperianus*
Rosy halsamroot	*Balsamorchiza rosea*
Sand beardtongue	*Penstemon acuminatus*
Sand dock	*Rumex venosus*
Slenderbush buckwheat	***Eriogonum microthecum***
T. Moore slinder lipfern	***Cheilanthes feei***
Threadleaf fleabane	*Erigeron filifolius*
Turpentine springparsley	*Pteryxia terebinthina*
Yarrow	*Achillea millefolium*
Yellow hell	*Fritillaria pudica*

Annual Herbs

Clasping pepperweed	*Lepidium perfoliatum*
Indian wheat	*Plantago patagonica*
Jacob's ladder	*Polemonium micranthum*
Jagged chickweed	*Holosteum umbellatum*
Jimrn Hill's turnblemustard	*Sisymbrium altissiumum*
Matted crvptantha	*Cryptatha circumscissa*
Pink rnicrosteris	*Microsteris gracilis*
Prickly lettuce	*Lactuca serriola*
Rough wallflower	*Erysimum asperum*
Russiati thistle (turnhleweed)	*Salsola kali(a)*
Slender hawksbeard	*Crepis atrabarba*
Spring whitlowgrass	*Draba verna(a)*
Storksbill	*Erodium cicutarioum(a)*
Tall willowherb	*Epilobium paniculatum*
Tarweed fiddleneck	*Amsinckia lycopsoides*
Threadleaf scorpion weed	*Phacelia linearis*
Western tansymustard	*Descuraninia pinnata*
White cupseed	*Plectritis macroecera*
Whitestem stickleaf	*Mentzelia albicaulis*
Winged cryptantha	*Cryptantha pterocarya*
Yellow salsify	*Tragopogon dubious(a)*

Shrub-steppe mammals

Badgers	*Taxidea taxus*
Black-tailed jackrabbit	*Lepus californicus*
Bushy-tailed woodrat	*Neotoma cinerea*
Coyotes	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Grayish-brown montaine vole	*Microtus montanus*
Great basin pocket mouse	*Perognathus parvus*
Least chipmunk	*Eutamias minumus*
Merriam's shrew	*Sorex merriami*
Mule deer	*Odocoleus hemionus*
Northern grasshopper mouse	*Onychomys leucogaster*
Northern pocket gopher	*Thomomys talpoides*
Nuttall's cottontail	*Sylvilagus nuttallii*
Porcupine	*Erethizon doratum*
Pygmy rabbit	*Sylvilagus idahoensis*
Rocky Mountain elk	*Cervus elaphus*
Sagebrush vole	*Lagurus curtatus*
Skunk	*Mephitis mephitis*

Townsend's ground squirrel	*Spermophilus townsendii*
Vagrant shrew	*Sorex Vagrans*
Washington ground squirrel	*Spermophylus washingtonii*
White-tailed jackrabbit	*Lepus townsendi*
Yellow-bellied marmot	*Marmota flaviventris*

Shrub-steppe bats

Big brown bat	*Eptesicus fuscus*
California myotis	*Myotis californicus*
Hoary bat	*Lasiurus cinereus*
Little brown myotis	*Myotis lucifugus*
Pallid bat	*Antrozous pallidus*
Western pipistrel	*Pipistrellus hesperus*
Western small-footed myotis	*Myotis cilioabrum*
Yuma myotis	*Myotis yumanensis*

Shrub-steppe birds

Amerian crow	*Corvus brachyhynchos*
Amerian kestrel	*Falco sparverius*
Bald eagle	*Haliaeetus leucocephalus*
Barn swallow	*Hirundo rustica*
Black-billed magpie	*Pica pica*
Brewer's blackbird	*Euphagus cyanocephalus*
Brewer's sparrow	*Spizella breweri*
Burrowing owl	*Athene cunicularia*
California quail	*Callipepla californica*
Chukar	*Alectoris chukar*
Cliff swallow	*Hirundo pyrrhonota*
Common raven	*Corvus corax*
Ferruginous hawk	*Buteo reglis*
Golden eagle	*Aquila chrysaetos*
Gray partridge	*Perdix perdix*
Great horned owl	*Bubo virginianus*
Greater sage grouse	*Centrocercus urophasianus*
Horned lark	*Eremophila alpestris*
Lark sparrow	*Chondestes grammacus*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Mourning dove	*Zenaida macroura*
Northern harrier	*Circus cyaneus*
Northern flicker	*Colaptes auratus*
Prairie falcon	*Falco mexicanus*
Red-tailed hawk	*Buteo jamaicensis*
Ring-nicked pheasant	*Phasianus colchicus*
Rock wren	*Salpinctes obsoletus*
Rough-legged hawk	*Ruteo lagopus*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Say's phoebe	*Sayornis saya*
Sharp-tailed grouse	*Tympanuchis phasianellus*
Swainson's hawk	*Buteo swainsoni*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Surnella neglecta*

Reptiles

Side-botched lizard	*Uta stansburiana*
Sagebrush lizard	*Sceloporus graciosus*
Short-horned lizard	*Phrynosoma douglasii*
Night snake	*Hypsislena torquata*
Striped whipsnake	*Masticophis taeniatus*
Western terrestrial garter snake	*Thamnophis elegaus*
Western rattlesnake	*Crotalus viridis*

Riparian and Aquatic Species

Riparian & Aquatic Species	
Riparian Trees and Shurbs	
Black cottonwood	*Populus trichocarpa*
Black cottonwood	***Populus trichocrapa***
Black greasewood	***Sacobatus vermiculatus***
Black hawkthorne	***Crataegus douglasii***
Black locust	*Robinia pseudo-acacia(a)*
Blue elderberry	*Sambucus cerulea*
Chokecherry	*Prunus virginiana*
Coyote willow	*Salix exigua*
Golden currant	*Ribes aurcum*
Mock orange	*Philadelphus lewisii*
Peachleaf willow	*Salix amygdaloides*
Red osier dogwood	*Cornus stolonifera*
Russian olive	*Elaeagnus angustifolia(a)*
Serviceberry	*Amelanchier alnifolia*
Siberian elm	*Ulrnus pumila(a)*
White mulberry	*Morus alba(a)*
White poplar	*Populus alba(a)*
Willow	*Salix spp.*
Wood's rose	*Rosa woodsii*
Riparian Perennial Grasses and Flowering Plants	
Bulbous bluegrass	*Poa bulbosa(a)*
Bulrush	*Scirpus spp.*
Cattail	*Typha latifolio*
Columbia River mugwort	*Artemisia lindleyana*
Columbia tickseed	*Coreopsis atkinsoniana*
Horsetail	*Equisetum spp.*
Lovegrass	*Eragrostis spp.*
Purple loosestrife	*Lythrum salicaria*
Reed canarygrass	*Phalaris arundinacea(a)*
Rushes	*Juncus spp.*
Sedges	*Carex spp.*
Water Speedwell	*Veronica anagallis-aquatica*
Western marsh aster	*Aster hesperius*
Western water hemlock	***Cicuta douglasii***
Whild chives	*Allium schoenoprasum*
Wiregrass spikerush	*Eleocharis spp.*
Wormwood	*Artemisia campestris*
Aquatic Plants	
Duckweed	*Lemna minor*
Pondweed	*Potamogeton spp.*
Columbia yellowcress	*Rorippa columbiae*
Spiked water milfoil	*Myriophyllum spicatum*
Watercress	*Rorippa nasturtium-aquatica(a)*
Fish species	
American shad	*Alosa sapidissima*
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lopomis macrochirus*
Bridgelip sucker	*Castostomus columbianus*
Brown bullhead	*Ictalurus nebulosus*
Burbot	*Lota lota*
Carp	*Cyprinus carpio*
Channel catfish	*Ictalurus punctatus*
Chinook salmon	*Oncorhynchus tshawytscha*
Chiselmouth	*Acrocheilus alutaceus*
Coho salmon	*Oncorhynchus kisutch*
Cutthroat trout	*Oncorhynchus clarki*
Dolly Varden	*Salvelinus malma*
Lake whitefish	*Coregonus clupeaformis*
Largemouth bass	*Micropterus salmoides*
Largescale sucker	*Catostomus macrocheilus*

Leopard dace	*Rhinichthys falcatus*
Longnose dace	*Rhinichthys cataractae*
Mottled sculpin	*Cottus bairdi*
Mountain sucker	*Catostomus platyrhynchus*
Mountain whitefish	*Prosopium williamsoni*
Northern pike minnow (squawfish)	*Ptychocheilus oregonensis*
Pacific lamprey	*Entosphenus tridentatus*
Peamouth	*Mylocheilus caurinus*
Paiute sculpin	*Cottus beldingi*
Prickly sculpin	*Cottus asper*
Pumpkinseed	*Lepomis gibbosus*
Rainbow trout (steelhead)	*Oncorhynchus mykiss*
Redside shiner	*Richardsonius balteatus*
Reticulate sculpin	*Cottus perplexus*
River lamprey	*Lampetra ayresi*
Sandroller	*Percopsis transmontana*
Smallmouth bass	*Micropterus dolomieui*
Sockeye salmon	*Oncorhynchus nerka*
Speckled dace	*Rhinichthys osculus*
Tench	*Tinca tinca*
Threespine stickleback	*Gasterosteus aculeatus*
Torrent sculpin	*Cottus rhotheus*
Walley	*Stizostedion betreum*
White crappie	*Pomoxis annularis*
White sturgeon	*Acipenser transmontanus*
Yellow perch	*Perca flavescens*
Yellow bullhead	*Ameiurus natalis*

Riparian and Riverine Bird Species

American coot	*Fulica americanus*
American white pelican	*Pelecanus crythrorhynchos*
Bank swallow	*Riparia reparia*
Black-crowned night-heron	*Nycticorax nycticorax*
Blue-winged teal	*Anas discors*
Bufflehead	*Bucephala albedo*
Canada goose	*Branta candensis*
California gull	*Larus californicus*
Caspian tern	*Sterna caspia*
Common goldeneye	*Bucephala clangula*
Common loon	*Gavia immer*
Common merganser	*Mergus merganser*
Forster's tern	*Sterna forsteri*
Great blue heron	*Ardea herodias*
Horned grebe	*Podiceps auritus*
Mallard	*Anas Platyrhynchos*
Ring-billed gull	*Larus delawarensis*
Western grebe	*Aechmorphous occidentalis*
Western sandpiper	*Calidris mauri*

Riparian Mammals

Muskrat	
Beavers	*Castor canadenis*
River otters	*Lutra canadensis*
Raccoon	*Procyon lotor*
White-tailed deer	*Odocoileus virginianus*

Amphibians & Riparian Reptiles

Painted turtle	*Chrysemus picta*
Great Basin spadefoot toad	*Scaphiopus intermontanus*
Woodhouses toad	*Bafo woodhousei*
Pacific tree frog	*Hyla regilla*
Bullfrog	*Cates beiana*

References

Brown JH, Valone TJ, and Curtin CG. 1997. Reorganization of an arid ecosystem in response to recent climate change. *Proceedings of the National Academy of Sciences, USA*. 94: 9729-33.

Crawford RC and Kagan J. 2001. Pages 50-1 in Johnson, D.H. and T.A. O'Neil editors. *Wildlife-Habitat Relationships in Oregon and Washington*. Oregon State University Press

Cushing CE and Vaughan BE. 1988. Springs and streams. Pages 85-181 in Rickard WH, Rogers LE, Vaughan BE, and Liebetrau SF editors. *Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem*. Elsevier. New York, USA.

Daubenmire. R. 1970. *Steppe vegetation of Washington*. Washington Agricultural Experiment Station Technical Bulletin.

Daubenmire. R. 1988. *Steppe vegetation of Washington*. Washington Agricultural Experiment Station Technical Bulletin.

Environment and Natural Resource Division, Directorate of Public Works. 2002. Management of sage grouse on the Yakima Training Center. www.lewis.army.mil/yakima/pamphlet.pdf.

Federal register. 2002. Notice of intent to prepare a comprehensive conservation plan and associated environmental impact statement for Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge. *Federal Register*. 67(113): 40333-7.

Franklin, J.F. and C.T. Dyrness. 1973. *Natural vegetation of Oregon and Washington*. USDA Forest Service General Technical Report PNW-8. Reprinted with new bibliographic supplement by Oregon State University Press in 1988.

Gee GW, Beedlow PA, and Skaggs RL. 1988. Water balance. Pages 61-84 in Rickard WH, Rogers LE, Vaughan BE, and Liebetrau SF editors. *Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem*. Elsevier. New York, USA.

Johnson, D.H. and T.A. O'Neil. 2001.*Wildlife Habitat Relationships in Oregon and Washington*. Oregon State University Press.

O'Connor G and Wieda K. 2001. *Northwest arid lands: an introduction to the Columbia basin shrub-steppe*. Battelle Press. Columbus, OH, USA.

Quigley TM editor. 1999. *Historical and Current Forest and Range Landscapes in the Interior Columbia River Basin and Portions of the Klamath and Great Basins* General technical report PNW-GTR-458. US Department of Agriculture. Portland, Oregon.

Quigley TM, Haynes RW, Graham RT editors. 1996. *Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath*

and Great Basins. United States Department of Agriculture. Portland, Oregon.

Rickard WH and Vaughan BE. 1988. Plant communities: characteristics and responses. Pages 109-181 in Rickard WH, Rogers LE, Vaughan BE, and Liebetrau SF editors. *Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem*. Elsevier. New York, USA.

Rickard WH. 1988. Climate of the Hanford site. Pages 14-22 in Rickard WH, Rogers LE, Vaughan BE, and Liebetrau SF editors. *Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem*. Elsevier. New York, USA.

Ricketts TH, Dinerstein E, Olson DM, Loucks CJ, Eichbaum W, DellaSala D, Kavanagh K, Hedao P, Hurley PT, Carney KM, Abell R, Walters S. 1999. *Terrestrial ecoregions of North America: a conservation assessment*. Island Press. Washington, D.C., USA.

Rogers LE, Fitzner RE, Cadwell LL, and Vaughan BE. 1988. Terrestrial animal habitats and population responses. Pages 182-257 in Rickard WH, Rogers LE, Vaughan BE, and Liebetrau SF editors. *Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem*. Elsevier. New York, USA.

Soll J, Hall JA, Pabst R, and Soper C editors. 2000. *Biodiversity Inventory and Analysis of the Hanford Site Final Report: 1994-1999*. The Nature Conservancy of Washington. Seattle, WA, USA.

Sullivan S. 1986. *Plant ecology of Washington's steppe and shrubsteppe habitats*. Washington Department of Game. Olympia, WA.

Vander Haegen WM, McCorquodale SM, Peterson CR, Green GA, and Yensen E. 2001. Wildlife of eastside shrubland and grassland habitats. Pages 292-316 in Johnson, D.H. and T.A. O'Neil editors. *Wildlife-Habitat Relationships in Oregon and Washington*. Oregon State University Press

Wildung RE and Garland TR. 1988. Soils: carbon and mineral cycling processes. Pages 23-60 in Rickard WH, Rogers LE, Vaughan BE, and Liebetrau SF editors. *Shrub-steppe: balance and change in a semi-arid terrestrial ecosystem*. Elsevier. New York, USA.

Zonal Series		Plant communities determined by amount of precipitation and temperature of area. Generally listed from driest/hottest community to wettest/coolest.
Artemisia tridentata	*Agropyron spicatum*	Most extensive; widely distribted outside of state. Includes Hanford site. Species diversity low. Low water holding capacity and few nutrients in sandy soils influence composition. Hottest and driest areas. Range fires
Artemisia tridentata	*Festuca idahoensis*	Eastern areas with slightly higher precipitation and lower temperatures. Represented outside of state. Greater
Agropyron spicatum	*Poa secunda*	Occurs in Snake river drainage and Columbia Gorge. Wheatgrass and bluegrass dominate to near exlusion of other species. Scattered gray rabbit-brush, but other shrubs are non-existant.
Agropyron spicatum	*Festuca idahoensis*	Region divided by Snake River Valley. Shrubs and perennial herbs rare. Moderate moisture.
Festuca idahoensis	*Symphorocarpos albus*	Central position on eastern margin of Columbia Basin. Most common on dry southwesterly exposures. Low winter temperatures more limiting than summer drought. Recovery from fire rapid.
Festuca idahoensis	*Rosa nutkana*	North of Clearwater and Snake Rivers. Meadow-like community. Dwarf forms of rose represent the few shrubs. Wetter in winter but drier in summer.
Artemisia tripartita	*Festuca idahoensis*	Sagebrush barely rises above a continous herb layer. Shrub layers discontinuous.
Festuca idahoensis	*Hieraceum cynoglossoides*	Abundance of forbs but lacks shrubs.
Purshia tridentata	*Festuca idahoensis*	Could be classed as shrub-savanna because Purshia grows 1.5-2.0 meters tall.

Zootic Climaxes		Exotic annual grass communities. Disturbances by humans and grazing allows these communities to replace native communities.
Bromus tectorum		Replaces native communities in drier/hotter areas.
Poa pratensis		Replaces native communities in wetter/cooler areas.

Other Communities		
Festuca idahoensis	*Eriogonum heracleoides*	Found in meadow-like parks throughout the lower forests of the Okanogan Mountains.
Dune vegetation		Small dunes occur infrequently along Columbia River or in areas where glacier deposits are found. Plants like
Rock crevices		Cliffs found in river and dry canyon walls. Plants like *Cheilanthes feei, Woodsia oregana*, and *Pentstemon*
Talus slopes		Bases of cliffs. Usually bare except for mosses and lichens. Some shrubs can become established.
Pond vegetation		Multitude of ponds in areas that were covered by glaciers or felt their runoff. Distinctive family of water plants
Artemisia tridentata spp. *Vaseyana*		Cold adapted population found in parks high up in eastern Washington mountains.
Camassia marshes		Found in remaining remnants of marshes throughout the region.

Table 1a: Daubenmire Plant Communities

Data from Daubenmire 1988

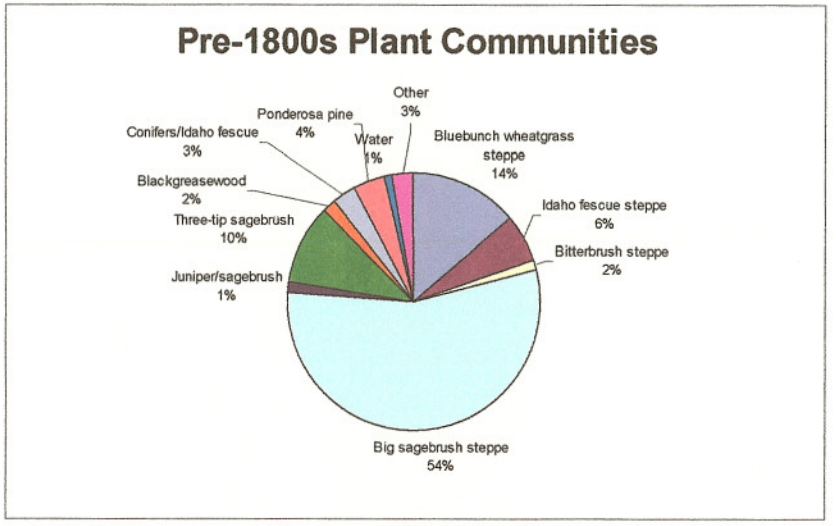
Edaphic Series Deep soils		Deep soils dominated by gravel, sand, or strongly weathered volcanic ash Gravel and sand soils have low moisture holding capability. Volcanic ash has high moisture content but are ecological equivalents. Lower soil fertility appears key in supporting needle and thread.
Artemisia tridentata	*Stipa comata*	Appears throughout big sagebrush zones.
Purshia tridentata	*Stipa comata*	Restricted to big sagebrush/bluebunch wheatgrass.
Stipa comata	*Poa secunda*	Occurs in bluebunch wheatgrass/Sandberg's bluegrass zones.
Artemisia tridentata	*Stipa comata*	
Shallow soils to bedrock (lithosols)		**Stony and extremely shallow to bedrock. Carpet of Sandberg's bluegrass and crust of lichens and mosses typifies this zone. Almost all have some shrub.**
Artemisia rigida	*Poa secunda*	Most widespread.
Eriogonum niveum	*Poa secunda*	
Eriogonum spaerocephalum	*Poa secunda*	
Eriogonum douglassi	*Poa secunda*	
Eriogonum compositum	*Poa secunda*	
Eriogonum thymoides	*Poa secunda*	
Eriogonum microthecum	*Physaria oregana*	
Aropyron spicatum	*Poa secunda*	
Saline-alkali soils		**Found throughout Washington steppe and commonly occur on poorly drained valley fill. All have Alkali saltgrass.**
Distachlis stricta		
Elymus cinereus	*Distichlus stricta*	
Sacobatus vermiculatus	*Distichlus stricta*	
Nonsaline soils that are more moist than zonal soils		**Deciduous forest and woodland or tall scrub within the steppe region. More abundant moisture leads to a higher variety of begtation.**
Crataegus douglasii	*Symphoricarpos albus*	Confined to Idaho fescue/snowberry and Idaho fescu/rose zones. Includes a phase with quaking aspen.
Crataegus douglasii	*Heracleum lanatum*	Confined to wetter parts of these zones on valley floors.
Populus trichocrapa	*Cicuta douglasii*	
Other special soils		
Purshia tridentata	*Agropyron spicatum*	Very stoney loam along eastern base of the Cascade Mountains.
Artemisia tripartita	*Agropyron spicatum*	Present in threetip sagebrus/Idahoe fescue areas with too much wind and sun exposure to support Idaho fescue
Artemisia tridentata	*Poa secunda*	Confined to the hottest and driest part of the big sagebrush/bluebunch wheatgrass zone
Grayia spinosa	*Poa secunda*	Located in the lowest and driest portion of big sagebrush/bluebunch wheatgrass zone
Eurotia lanata	*Poa secunda*	Highly calcareous regosols on the flanks of mountains
Sporobolus cryptandrus	*Poa secunda*	Sandy or gravelly soils in bluebunch wheatgrass/Sandberg's bluegrass
Aristida longiseta	*Poa secunda*	Snake, lower Grand Ronde, and lower Palouse River valleys
Rhus glabra	*Agropyron spicatum*	Colluvial and sandy alluvial soils in canyons.
Rhus glabra	*Agropyron spicatum*	Colluvial and sandy alluvial soils in canyons.
Rhus glabra	*Sporobolus cryptandrus*	Colluvial and sandy alluvial soils in canyons.
Celtis douglasii	*Bromus tectorum*	Zootic climax on colluvial cons and aprongs along major canyon walls

Table 1b: Daubenmire Plant Communities

Data from Daubenmire 1988

Plant Community	Pre-1800s*	1996*	Change**
Bluebunch wheatgrass steppe	13.8%	5.8%	-58%
Idaho fescue steppe	5.8%	1.6%	-72%
Bitterbrush steppe	1.6%	1.0%	-35%
Big sagebrush steppe	54.8%	22.2%	-59%
Juniper/sagebrush	1.5%	1.5%	-1%
Three-tip sagebrush	10.0%	0.0%	-100%
Blackgreasewood	1.8%	0.0%	-100%
Conifers/Idaho fescue	3.0%	0.0%	-100%
Ponderosa pine	4.1%	4.5%	11%
Water	1.0%	1.0%	0%
Urban	0.0%	0.3%	100%
Crop/hay/pasture	0.0%	59.4%	100%
Other	2.8%	2.7%	-2%

*% of land covered by the plant type or use
**Change in land covered by this plant type or use



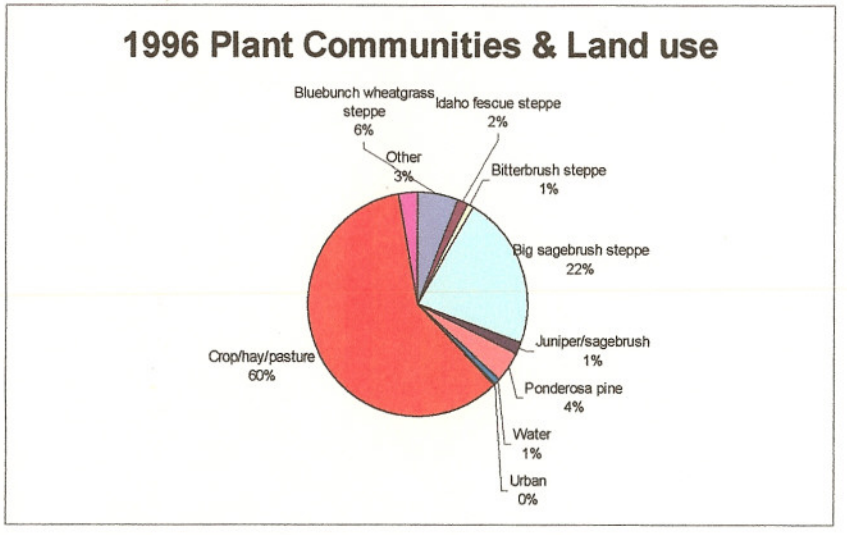


Table 2: Comparison of Historic and Current Plant Communities and Land Use

Data from O'Connor and Wieda 2001

Shrub-Steppe Ecoregion

Kane

WA shrub-steppe

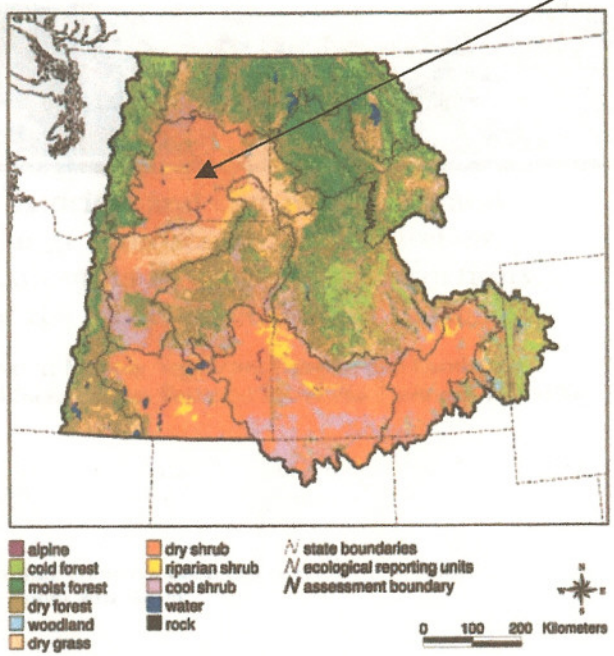
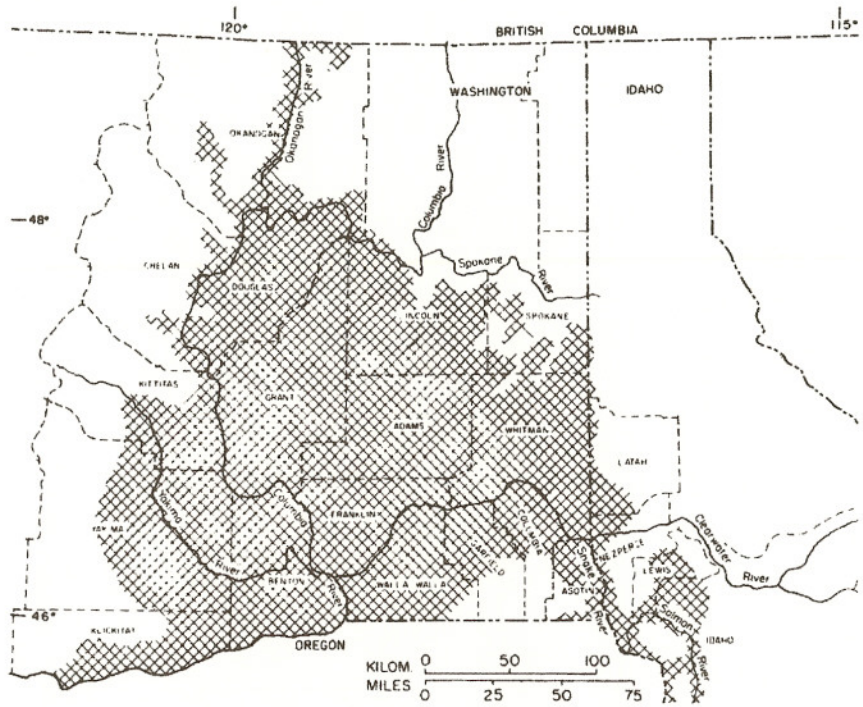


Figure 74—Broadscale (1-km² pixels) map of historical potential vegetation groups within the interior Columbia River basin assessment boundary. See Hann and others (1997) for map development procedures.

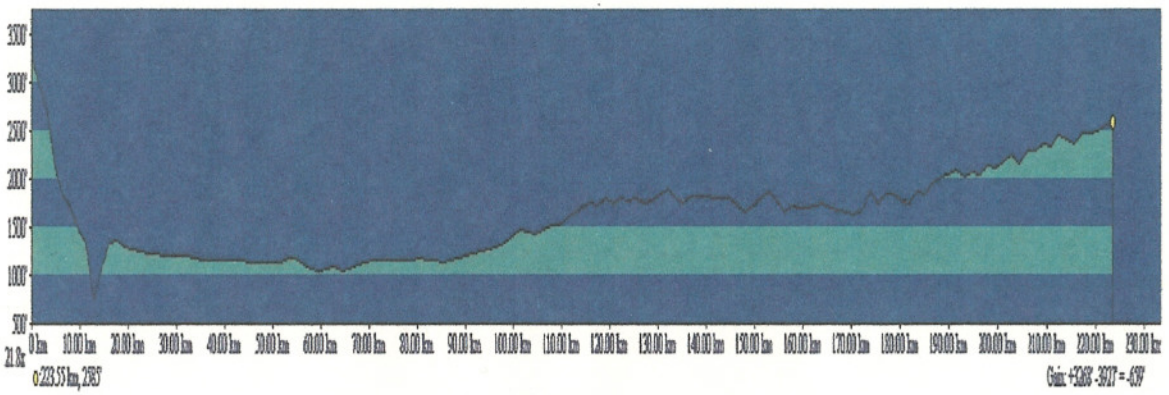


From Quigley 1999

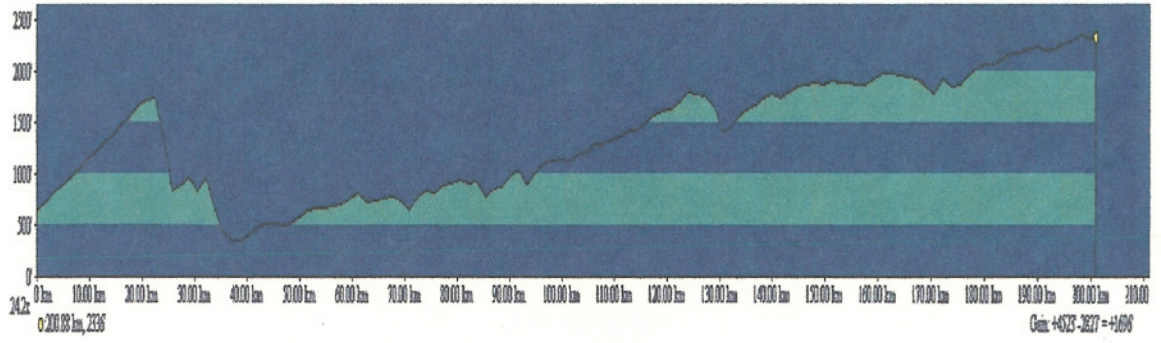
From Daubenmire 1988

Figure 1: Location of the Washington Shrub-steppe Ecoregion

Profile Locations
Printed from Topo! ©2000 National Geographic Holdings



East-west Elevation Profile
Printed from Topo! ©2000 National Geographic Holdings

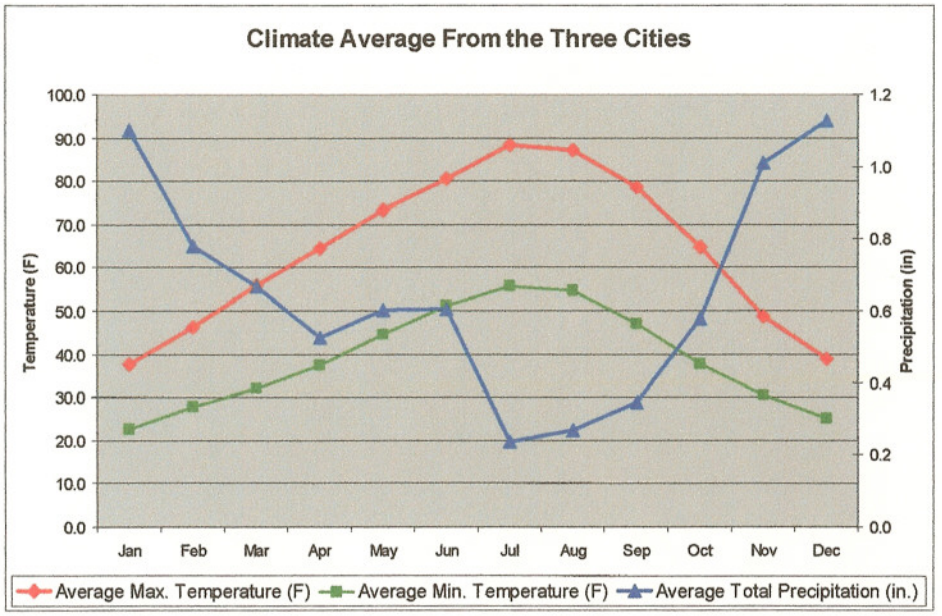


SW-NW Elevation Profile
Printed from Topo! ©2000 National Geographic Holdings

Would be helpful to draw approx. limits of your area on this map

Caption could help w/ barely readable y-axis scale!

Figure 2: Elevation Profiles of the Columbia Basin



Richland	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	40.5	48.5	57.9	66.8	75.4	82.7	90.3	89.3	80.7	67	51	41.9	66
Average Min. Temperature (F)	25.8	30.5	35	41	48.2	54.8	59.4	58.7	50.6	40.8	33.8	28.4	42.3
Average Total Precipitation (in.)	1.02	0.72	0.63	0.48	0.56	0.49	0.22	0.25	0.27	0.53	0.97	1.01	7.16

Othello	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annua
Average Max. Temperature (F)	35.8	44.3	54.3	63.3	71.9	79	87.5	86.1	77.4	63.6	46.8	37	62.2
Average Min. Temperature (F)	21.9	27.2	31.1	36.4	43.6	50.1	54.8	53.8	46.4	37.2	30	24.2	38.1
Average Total Precipitation (in.)	1.02	0.84	0.69	0.58	0.71	0.64	0.29	0.24	0.41	0.66	1.02	1.11	8.22

Yakima	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	37.1	45.8	55.3	63.8	72.6	79.7	87.3	86	77.7	64.1	48.2	38	63
Average Min. Temperature (F)	20.3	25.7	29.9	34.8	42.3	49	53.1	51.7	44.2	34.8	27.9	22.6	36.4
Average Total Precipitation (in.)	1.27	0.78	0.68	0.52	0.54	0.69	0.2	0.32	0.36	0.55	1.04	1.27	8.2

Figure 3: Climate of the Washington Shrub-steppe Ecoregion

Data from Western Regional Climate Center

http://www-k12.atmos.washington.edu/k12/grayskies/eastern/index.html

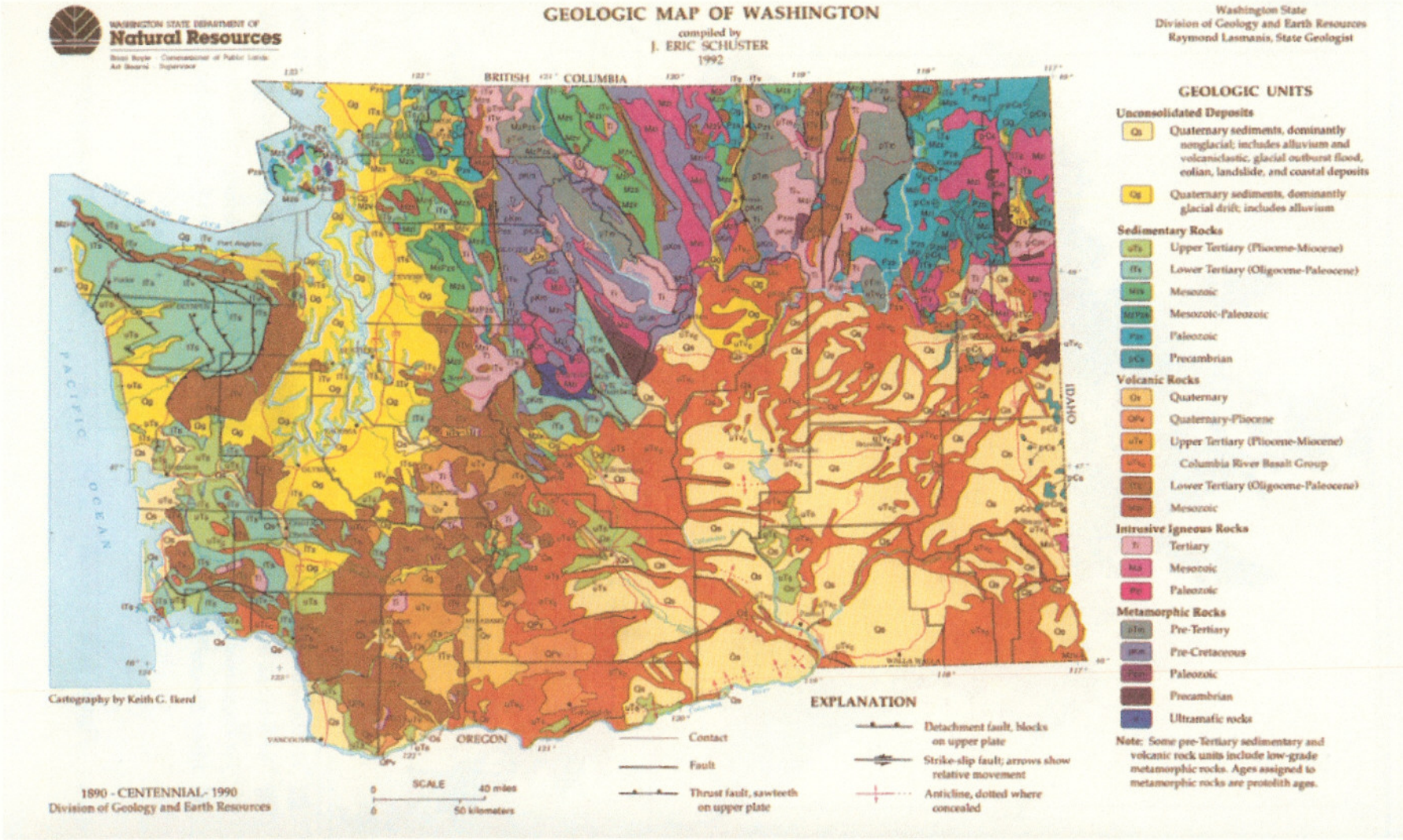


Figure 4: Geology of the Washington Shrub-steppe Ecoregion

From O'Connor and Wieda 2001

24

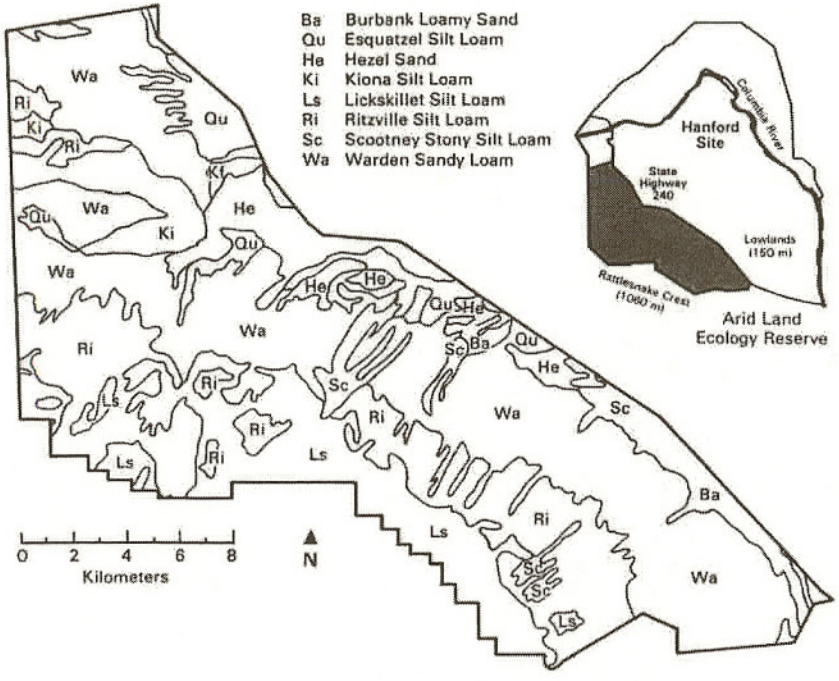


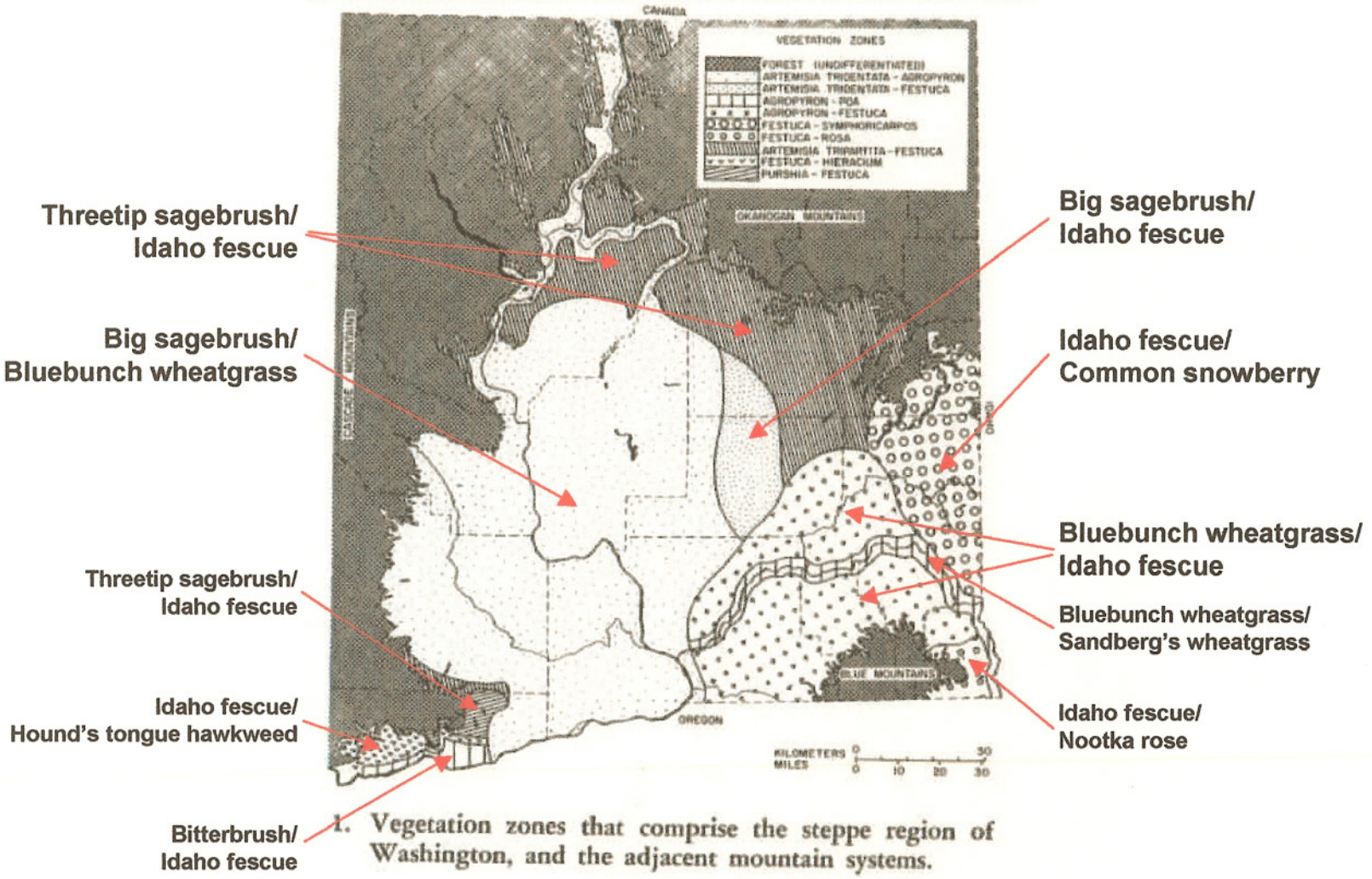
Fig. 3.1. Soil Distribution of the Arid Land Ecology Reserve (based on Hajek 1966)

From Wildung and Garland 1988

Burbank Loamy Sand	Dark-colored, coarse-textured soil underlain by gravel. Surface soil is usually about 40 cm (16 in.) thick but can be 75 cm (30 in.) thick. Gravel content of subsoil ranges from 20% to 80%.
Esquatzel Silt Loam	Deep dark-brown soil formed in recent alluvium derived from loess and lake sediments. Subsoil grades to dark grayish-brown in many areas, but color and texture of the subsoil are variable because of the stratified nature of the alluvial deposits.
Hezel Sand	Similar to Rupert sands; however, a laminated grayish-brown strongly calcareous silt loam subsoil is usually encountered within 100 cm (39 in.) of the surface. Surface soil is very dark brown and was formed in wind-blown sands that mantled lake-laid sediments.
Kiona Silt Loam	Occupies steep slopes and ridges. Surface soil is very dark grayish-brown and about 10 cm (4 in.) thick. Dark-brown subsoil contains basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments found in surface layer. Basalt rock outcrops present. A shallow stony soil normally occurring in association with Ritzville and Warden soils.
Lickskillet Silt Loam	Occupies ridge slopes of Rattlesnake Hills and slopes >765 m (2509 ft) elevation. Similar to Kiona series except surface soils are darker. Shallow over basalt bedrock, with numerous basalt fragments throughout the profile.
Ritzville Silt Loam	Dark-colored silt loam soils midway up the slopes of the Rattlesnake Hills. Developed under bunchgrass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically >150 cm (60 in.) deep, but bedrock may occur between 75 and 150 cm (30 and 60 in.).
Scootney Stony Silt Loam	Developed along the north slope of Rattlesnake Hills; usually confined to floors of narrow draws or small fan-shaped areas where draws open onto plains. Severely eroded with numerous basaltic boulders and fragments exposed. Surface soil is usually dark grayish-brown grading to grayish-brown in the subsoil.
Warden Silt Loam	Dark grayish-brown soil with a surface layer usually 23 cm (9 in.) thick. Silt loam subsoil becomes strongly calcareous at about 50 cm (20 in.) and becomes lighter colored. Granitic boulders are found in many areas. Usually >150 cm (60 in.) deep.

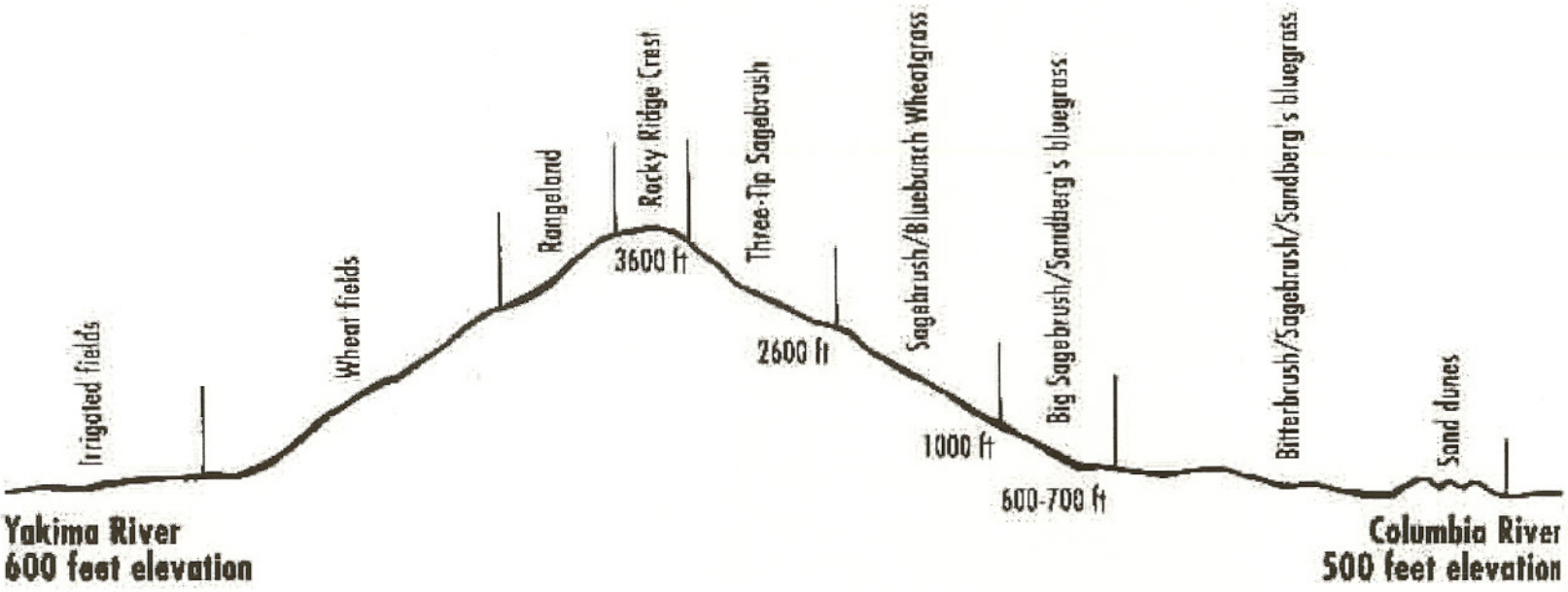
From O'Connor and Wieda 2001

Figure 5: Soils of the ALE Reserve



1. Vegetation zones that comprise the steppe region of Washington, and the adjacent mountain systems.

Figure 6: Location of Shrub-steppe Plant Communities
From Daubenmire 1988



Bitterbrush/Sagebrush/Sandberg's Bluegrass

Figure 7: Plant Communities and Topography

From O'Connor and Wieda 1991

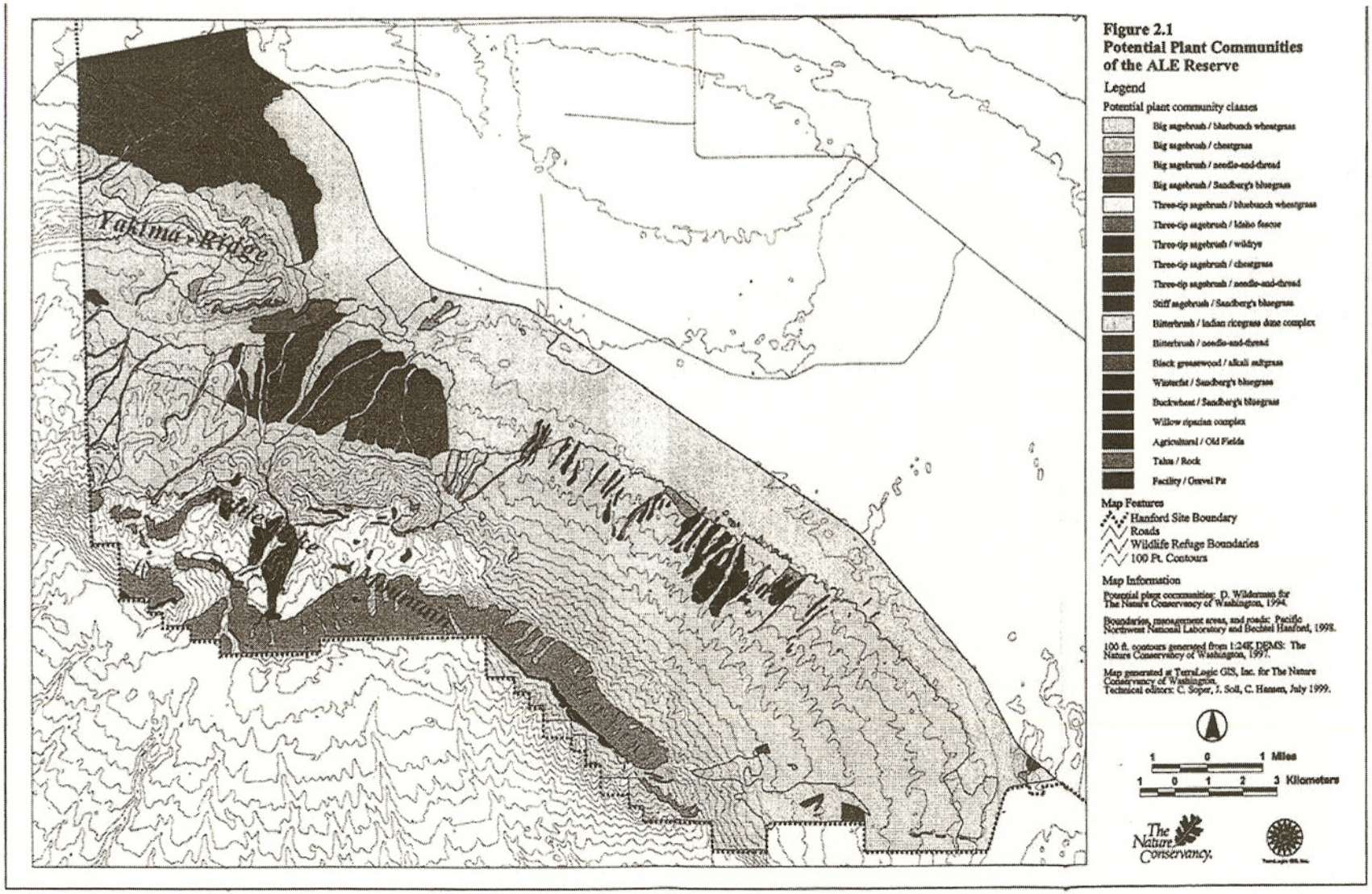


Figure 8a: Community Diversity at Hanford Site
From Soll *et al* 2000

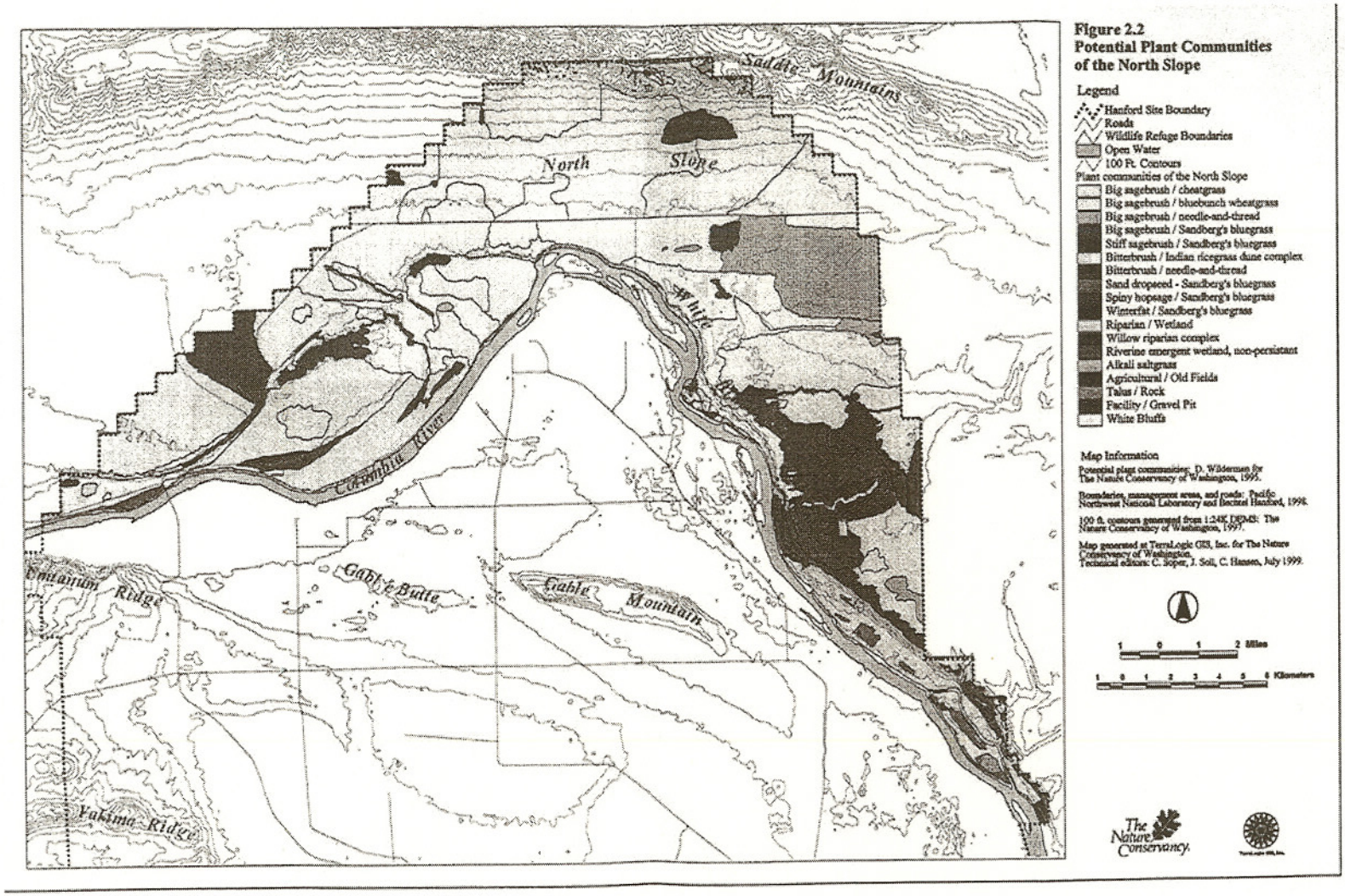


Figure 8b: Community Diversity at Hanford Site

From Soll *et al* 2000

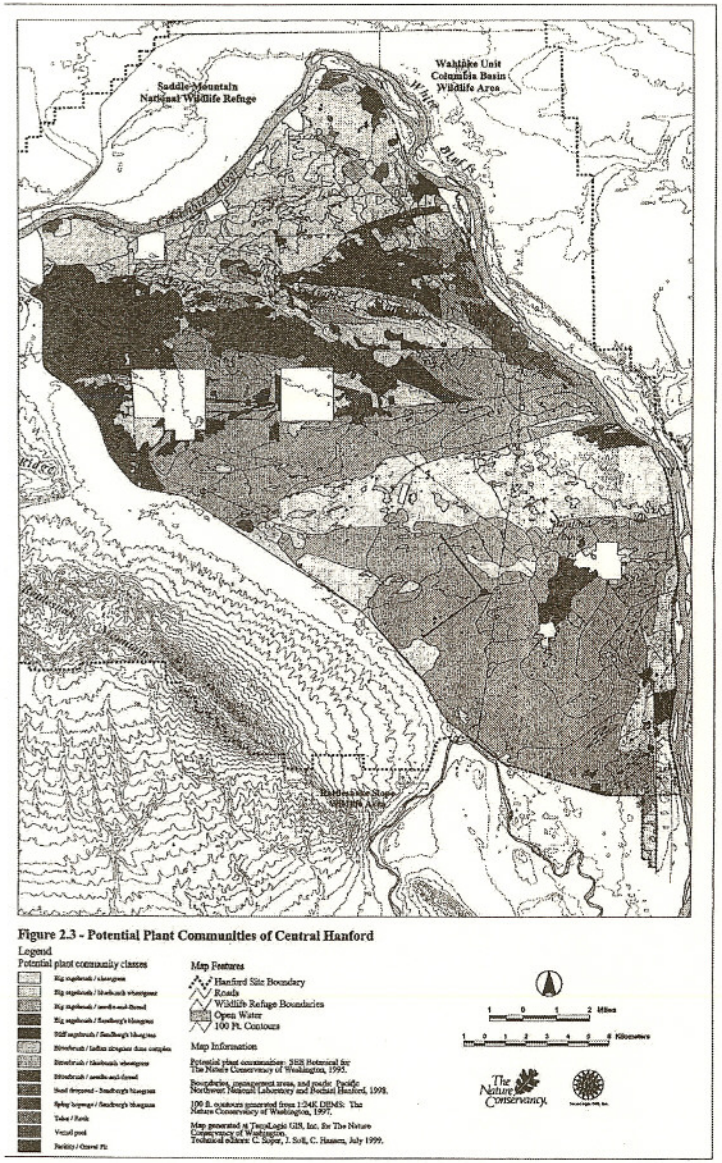


Figure 8c: Community Diversity at Hanford Site

From Soll *et al* 2000

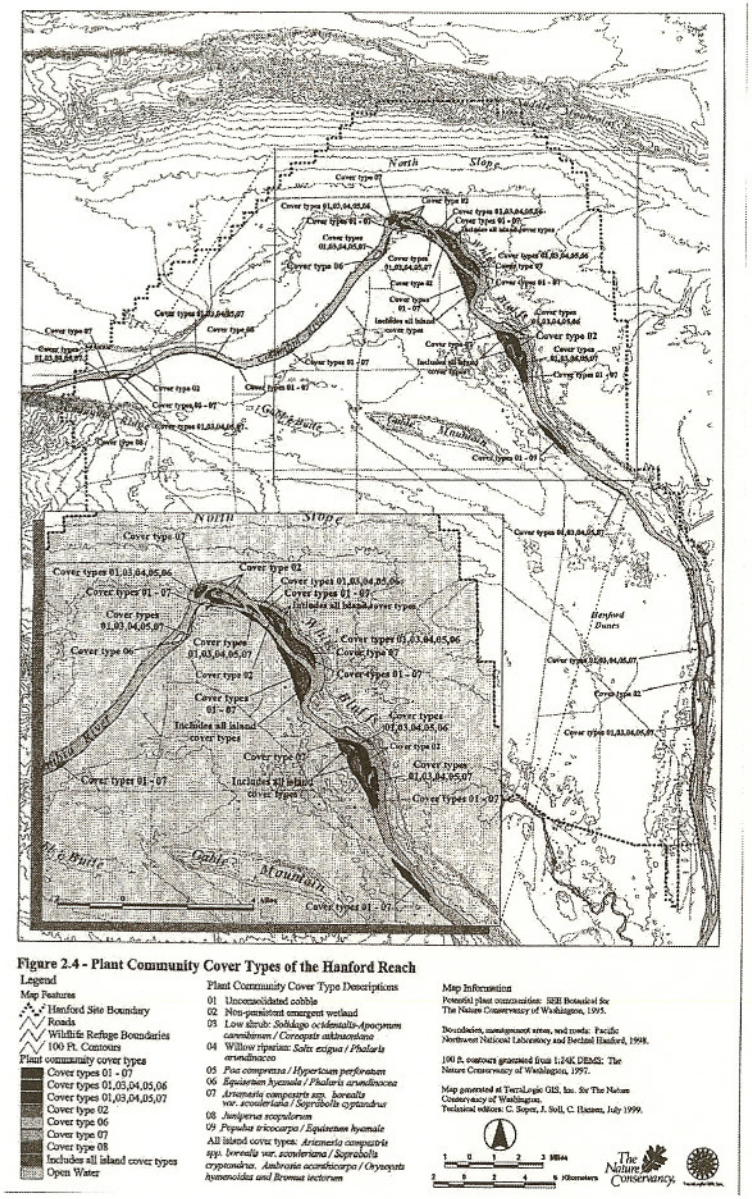


Figure 2.4 - Plant Community Cover Types of the Hanford Reach

Legend

Map Features
- Hanford Site Boundary
- Roads
- Wildlife Refuge Boundaries
- 100 Ft. Contours

Plant community cover types
- Cover types 01 - 07
- Cover types 01,03,04,05,06
- Cover types 01,03,04,05,07
- Cover type 02
- Cover type 06
- Cover type 07
- Cover type 08
- Includes all inland cover types
- Open Water

Plant Community Cover Type Descriptions

01 Unconsolidated cobble
02 Non-persistent emergent wetland
03 *Low shrub: Solidago occidentalis-Apocynum cannibinum / Coreopsis atkinsoniana*
04 Willow riparian: *Salix exigua / Phalaris arundinacea*
05 *Poa compressa / Hypericum perforatum*
06 *Equisetum hyemale / Phalaris arundinacea*
07 *Artemesia campestris ssp. borealis var. scouleriana / Sopribolis cryptandra*
08 *Juniperus scopulorum*
09 *Populus tricocarpa / Equisetum hyemale*

All inland cover types: *Artemesia campestris ssp. borealis var. scouleriana / Sopribolis cryptandra. Ambrosia acanthicarpa / Chrysopsis hymenoides and Bromus tectorum*

Map Information

Potential plant communities: SEH Botanical for The Nature Conservancy of Washington, 1995.

Boundaries, management areas, and roads: Pacific Northwest National Laboratory and Bechtel Hanford, 1998.

100 ft. contours generated from 1:24K DEMS: The Nature Conservancy of Washington, 1997.

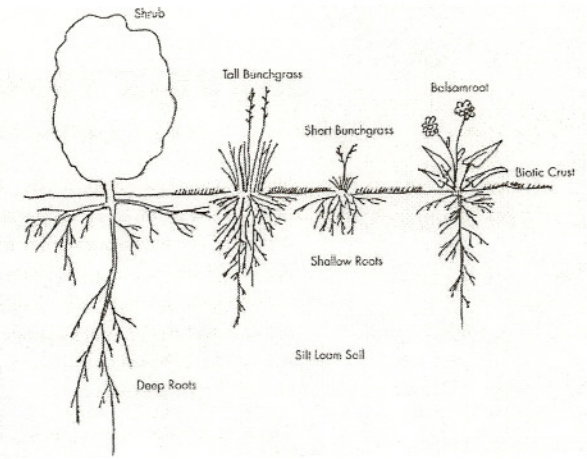
Map generated at TerraLogic GIS, Inc. for The Nature Conservancy of Washington.
Technical editors: C. Soper, J. Soll, C. Hansen, July 1999.

1 0 1 2 3 Miles
2 0 2 4 6 Kilometers

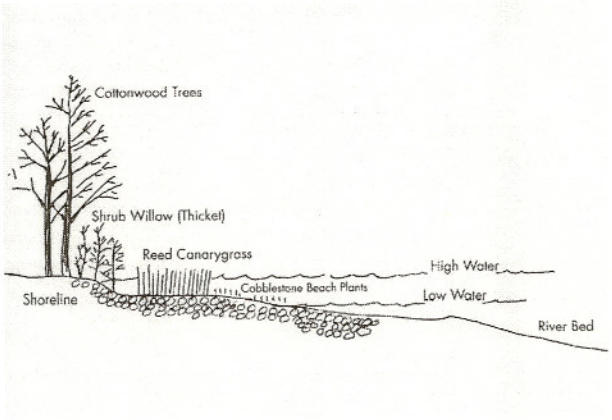
The Nature Conservancy

Figure 8d: Community Diversity at Hanford Site

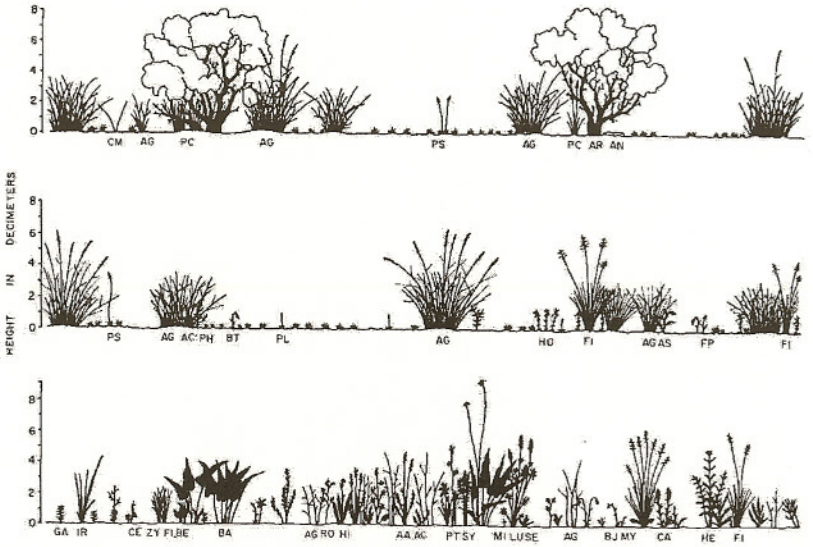
From Soll *et al* 2000



Simplified shrub-steppe profiles
From O'Connor and Wieda 2001



Simplified riparian-aquatic profile
From O'Connor and Wieda 2001



3. Representative physiognomic types in the zonal vegetation of the Washington steppe, as illustrated by profile drawings, to scale, of all vascular plants with any basal area impinging on a transect 2cm wide by 400cm long. Key to species symbols:

Ac *Achillea lanulosa*
Ag *Agropyron spicatum*
An *Antennaria dimorpha*
Ar *Artemisia tridentata*
Aa *Astragalus palousensis*
As *Astragalus spaldingii*
Ba *Balsamorrhiza sagittata*
Be *Besseya rubra*
Bj *Bromus japonicus*
Bt *Bromus tectorum*
Ce *Calochortus elegans*
Cm *Calochortus macrocarpus*
Ca *Castilleja lutescens*
Fi *Festuca idahoensis*
Fp *Festuca pacifica*
Ga *Galium boreale*
He *Helianthella uniflora douglasii*
Hi *Hieracium albertinum*
Ho *Holosteum umbellatum*
Ir *Iris missouriensis*
Lu *Lupinus sericeus*
Mi *Microsteris gracilis*
My *Myosotis micrantha*
Ph *Phlox longifolia*
Pl *Plantago patagonica*
Pc *Poa cusickii*
Ps *Poa secunda*
Pt *Potentilla gracilis*
Ro *Rosa spaldingii* or *R. nutkana*
Se *Senecio integerrimus exaltatus*
Zy *Zygadenus venenosus gramineus*

Above: shrub steppe represented by *Artemisia tridentata-Agropyron* stand 27. Middle: true steppe represented by *Agropyron-Festuca* stand 60. Below: meadow steppe represented by *Festuca-Symphoricarpos* stand 155.

Detailed shrub-steppe & meadow-steppe profiles
From Daubenmire 1988

Figure 9: Plant Communities Profiles

WA shrub-steppe ecoregion

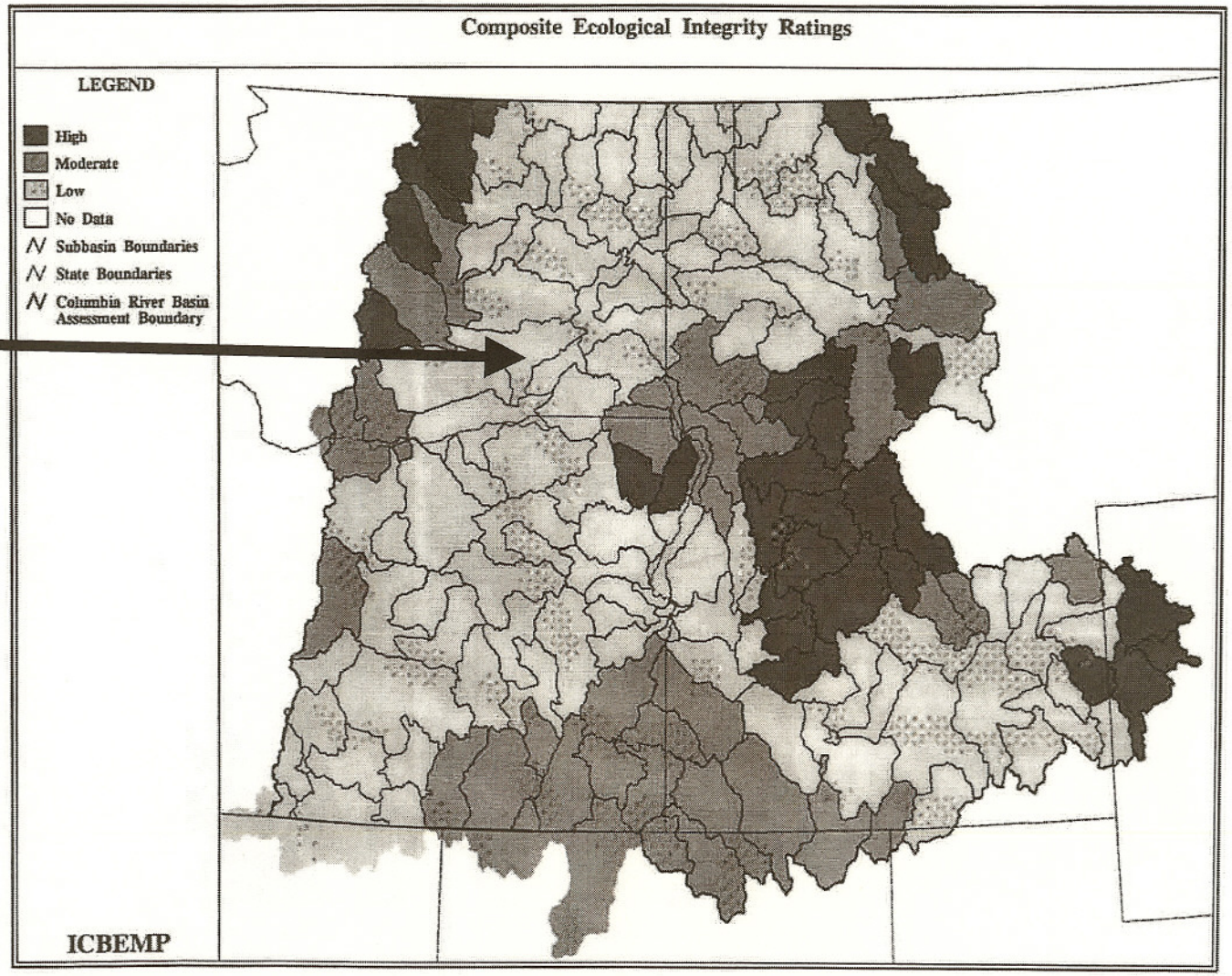
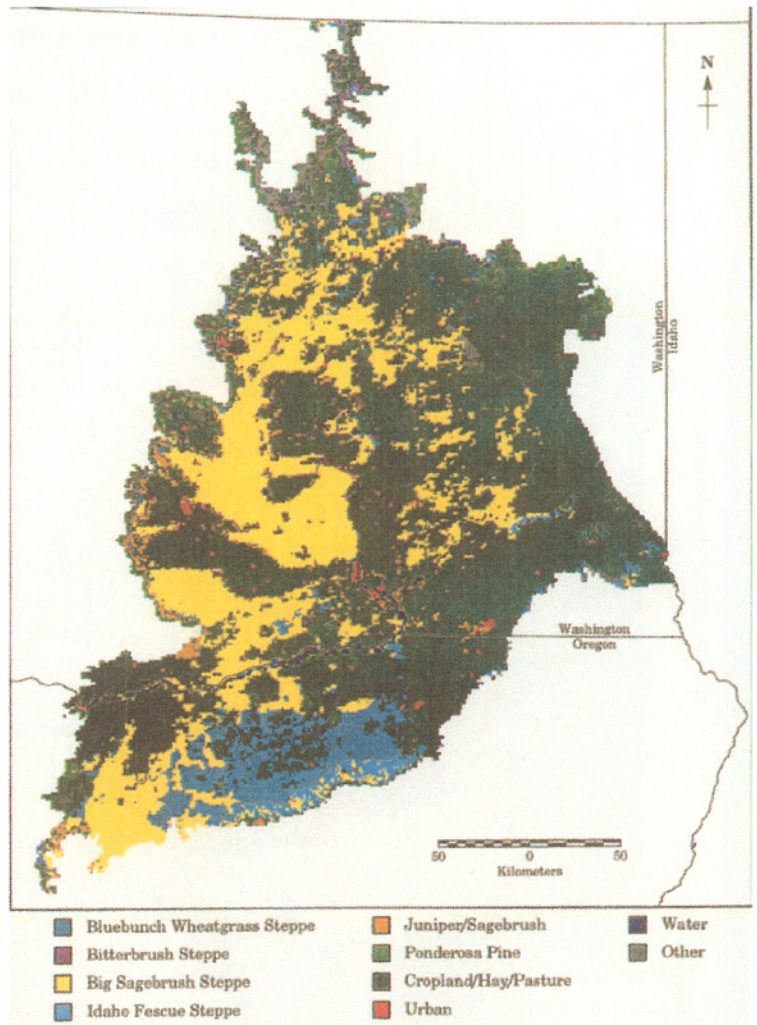


Figure 10: Ecological Integrity
From Quigley *et al* 1996

Pre-1800s



1996

Figure 11: Vegetative Cover and Land Use

From O'Connor and Wieda 2001

WA shrub-steppe ecoregion

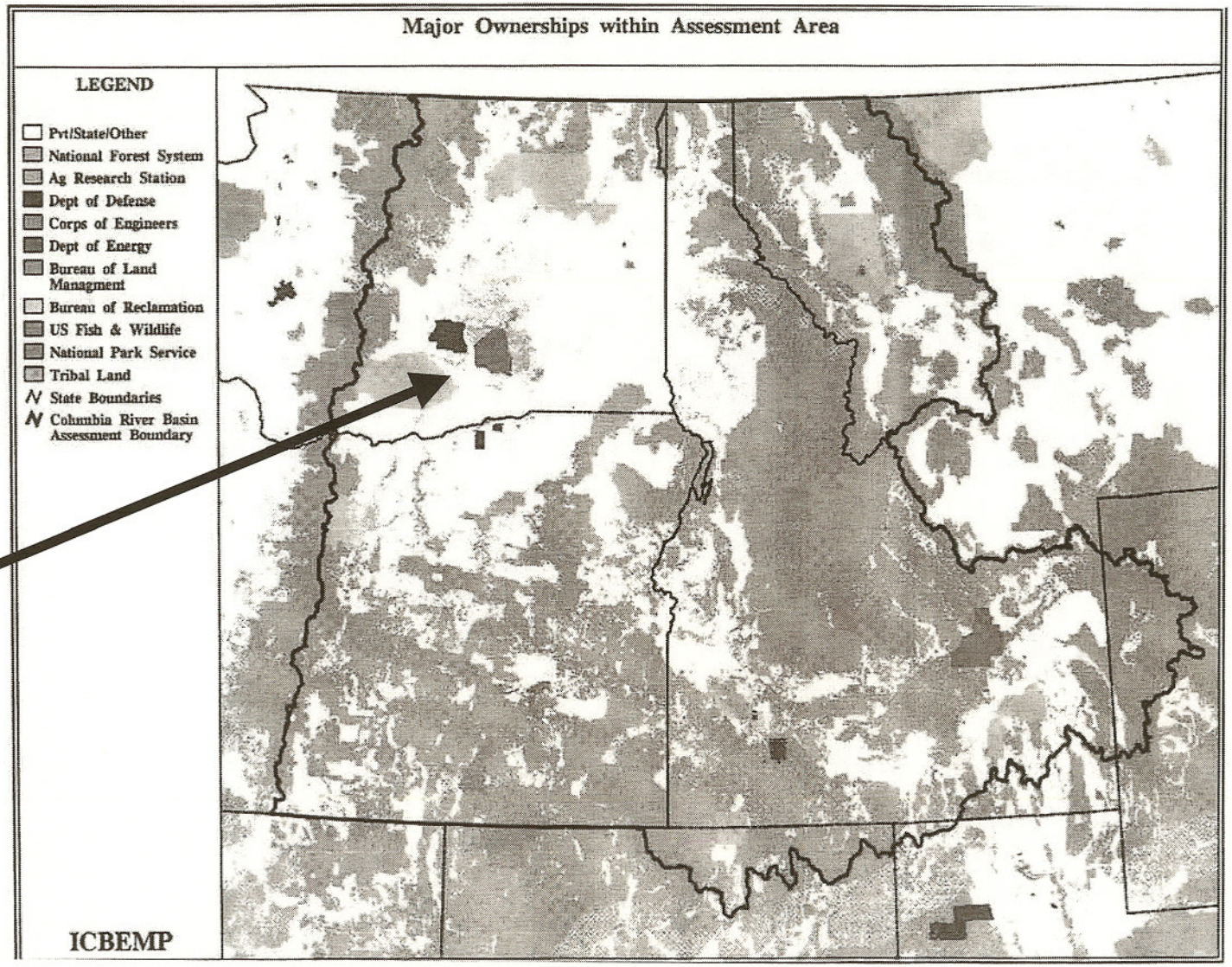


Figure 12: Land Ownership
From Quigley *et al* 1996