2.0 ENVIRONMENTAL OVERVIEW

2.1 Introduction

The proposed pipeline route traverses the state of Washington from the Puget Basin, over the Cascades, and into the Columbia Basin in eastern Washington. Because of the wide area covered by the pipeline, the environmental setting is best presented within the context of geomorphic regions defined by Franklin and Dyrness (1973). These regions include the Puget Basin, the West Cascades, the East Cascades, the Western Columbia Basin, and the Eastern Columbia Basin. They are defined by landform and vegetation. It is important to note that the regions defined by Franklin and Dyrness (1973), while based on physiographic and environmental criteria, are not internally homogeneous. Environmental variability obviously exists, but is less pronounced within regions than between.

This overview of the environmental setting includes a summary of the physiography, geology, hydrology, climate, flora, and fauna specific to each region.

2.2 Puget Basin

Physiography, Geology, and Hydrology

In overall structure, the Puget Basin is a tertiary downwarp between the Cascade and Coast Range uplifts. Hills within the lowlands are most frequently composed of Eocene basalts that are relatively resistant to erosion. On the eastern edge of the Puget Basin, the bedrock is primarily nonmarine andesitic and basaltic flows correlated with the Cascades. Sedimentary formations are interbedded with the flows and often contain fossils that are useful for dating and interpretation (McKee 1972).

The present topography of the Puget Basin is primarily a result of glaciation. During the Vashon Stade, which reached its maximum approximately 18,000 years ago (Pielou 1991), the Cordilleran ice sheet split into two lobes at the junction of the Puget Basin with the Strait of Juan de Fuca. The eastern lobe, known as the Puget Lobe, pushed into the area that is now Puget Sound and extended over the entire Puget Basin to a depth of 4,000 feet. As it advanced, the glacier extended to the northeast front of the Olympic Mountains and effectively dammed the entire lowland.

By approximately 14,000 years ago, the Puget lobe had retreated from its southern terminus just south of Olympia to the vicinity of Seattle. By 13,000 years ago the glacier had thinned sufficiently to allow marine water into the Puget Basin. The remaining ice floated, resulting in the eventual deposition of glaciomarine drift over an area of approximately 18,000 km^2. Glacial deposits range from very porous gravels and sands to a hard till in which clay and silt are mixed with coarser particles (Franklin and Dyrness 1973). A series of radiocarbon dates derived from shells and wood preserved in the drift indicate that it was deposited from berg ice over the entire region nearly simultaneously, as opposed to transgressively from a retreating, calving ice front (Blunt et al. 1987). Geologists now maintain that the Cordilleran ice sheet readvanced a short distance into the northern Puget Basin during the Sumas Stade approximately 11,500 years ago. Radiocarbon dates indicate that the Sumas ice had again retreated by 10,000 years ago.

The pipeline route lies within the Snohomish and Snoqualmie watersheds. The Snohomish River begins at the confluence of the Skykomish and Snoqualmie Rivers, approximately eight miles northeast of Woodinville. From there, the river flows northwest toward Everett, until it empties into Puget Sound. Upstream from its mouth, the Snohomish divides into a collection of sluggish streams that wander across Steamboat Slough.

The Snoqualmie River is composed of three major forks. From their respective headwaters at Lake Kanim, Lake Ivanhoe, and Snoqualmie Mountain, the North, Middle, and South Forks of the Snoqualmie River drain the Western Cascades, until they conflow above Snoqualmie Falls, near the communities of Snoqualmie and North Bend. Major tributaries include the Tolt River and Tokul Creek, which join the Snoqualmie River near Carnation and Spring Glen, respectively.

Climate

While an assessment of contemporary climates can be made by observation supplemented by historic records, attempts to reconstruct past climates and understand the changes that have taken place over the millennia must rely on proxy data (Bradley 1985; Lowe and Walker 1984). In recent years, advances in the analysis of proxy data such as ice cores, pollen and plant macrofossils, oxygen isotopes in marine sediments, and calcareous marine fauna, in addition to new dating techniques such as paleomagnetism, thermoluminescence, and fission-track dating, have increased our understanding of the complexity of climate change and the variability of climatic history between and within physiographic units. Such advances indicate a much more complex series of changes than previously hypothesized. Just over ten years ago, the common wisdom was that four major glaciations characterized the Quaternary. Recent studies of marine sediments now indicate more than 20 episodes of continental-scale glaciation occurred during the Pleistocene (Bradley 1985:409; Lowe and Walker 1984). Pielou (1991:12) suggests no fewer than 10 climatic shifts over the last 12,000 years and approximately 16 shifts over the last 20,000 years.

Since it is a commonly held view that humans did not populate the New World until the end of the Pleistocene, many studies of climate change in the archaeological literature concentrate on the last 12,000 years. There is some evidence that a single, very general climatic sequence for that time period might be applicable over a wide area. The standard scenario, supported by palynological studies (e.g., Hansen 1946, 1947; Heusser 1960, 1983, 1985; Barnosky 1981, 1985; Barnosky et al. 1987), is that the Northern Hemisphere has experienced broad climatic shifts since the late Pleistocene, summarized as follows: 1) late Pleistocene glacial to periglacial conditions (approximately 20,000 to 14,500 years ago); 2) early Holocene warming with generally cool and moist conditions (14,500 to 9,500 years ago); 3) mid-Holocene warming and drying period, known as the Hypsithermal (approximately 9,500 to 4,500 years ago); and 4) late Holocene (4,500 years ago to the present) return to cooler, more moist conditions, marking the beginning of the Neoglaciation.

Despite the wide acceptance of this scheme among archaeologists, there are difficulties associated with its general application. Mehringer (1985:174) points out that *within* each of the large subdivisions in the scheme outlined above, there may be more variation (as indicated in fossil pollen and macrofossils) than exists *between* the major subdivisions. A broad area like the Pacific Northwest can experience substantial local climatic variation that is suppressed in the larger scheme (Burtchard and Keeler 1991:34; Wright 1976:591). Thus, although the scenario of late Pleistocene and Holocene climatic change outlined above appears to adequately reflect broad-scale tendencies, caution must be exercised in applying the scheme to specific regions. This is a climatic model that simplifies a much more complex reality. The results of palynological studies of lake sediment cores at various locations in Washington (esp. Barnosky 1985; Heusser 1973, 1985; Ugolini and Schlichte 1973), and macrofossil and fossil foliar characteristics (Dunwiddie 1987; Wolfe 1993) should be consulted for a more detailed account of the climatic history of the Holocene.

Today, the Puget Basin has a maritime climate characterized by wet, mild winters and cool, relatively dry summers. Between 75 and 85 percent of the annual precipitation occurs between October 1 and March 31, mostly as rain (Franklin and Dyrness 1973:32). Most precipitation in the region is cyclonic, resulting from low-pressure systems that approach from the Pacific Ocean on dominant westerly winds. Storm tracks shift to the north during the summers, and at that time high pressure systems bring fair, dry weather.

Flora and Fauna

The distribution of plants across the landscape is commonly classified using a hierarchical system. Provinces are the highest level of the plant hierarchy and are based upon physiognomic and geographic criteria. In Washington, three (Frenkel 1993) or four (Franklin and Dyrness 1973:44) provinces are recognized. The three-province scheme divides the state into Forest Province, Shrub-Steppe Province, and Alpine Province. Although there is no one-to-one relationship between physiographic provinces and vegetation provinces, there is a high correlation. This is simply because plant colonization depends on the same variables that suggest the boundaries for the physiographic province divisions: elevation, geology, and climate.

Zones may be defined as the area in which one plant association is the climax community (Franklin and Dyrness 1973:46). They are the most useful division for this report because they ideally delineate an area of uniform macroclime and extend over broad regions. Although zonal divisions tend to reflect plant responses to strong gradients in temperature and moisture, they are generalizations and must be applied with caution.

The dominant vegetation province in the Puget Basin is the Forest Province (Franklin and Dyrness 1973; Frenkel 1993). A single zone is dominant in the Puget Basin: the Western Hemlock (*Tsuga heterophylla*) Zone. Douglas-fir (*Pseudotsuga menziesii*) is actually the dominant tree in this zone even though the zone is not named for this tree. Western red cedar (*Thuja plicata*) is the third tree that consistently occurs in the Western Hemlock Zone. Western white pine (*Pinus monticola*) and lodgepole pine (*P. contorta*) are common in the Puget Basin area of this zone, as they grow on glacial drift. Much of the Puget Basin has been heavily logged. In disturbed areas that are moist, Western red cedar is often replaced by red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*). In disturbed drier areas, Western hemlock gives way to Douglas fir and, at higher elevations, Pacific silver fir (*Abies amabilis*). Areas dominated by Western hemlock are characterized by an understory of vine maple (*Acer circinatum*), Western yew (*Taxus brevifolia*), and Pacific dogwood (*Cornus nuttalli*) (Franklin and Dyrness 1973:59). In areas dominated by Western red cedar, the understory is made up of swordfern (*Polystichum munitum*), Oregon oxalis (*Oxalis oregana*), devilsclub (*Oplopanax horridum*), and skunk cabbage (*Lysichitum americanum*). Dryer locations, where Douglas fir is common, contain an understory of oceanspray (*Holodiscus discolor*) and salal (*Gaultheria shallon*).

Terrestrial fauna common to the Puget Basin include deer (*Odocoileus* spp.), elk (*Cervus canadensis*), black bear (*Ursus americanus*), coyote (*Canis latrans*), fox (*Vulpes fulva*), mountain lion (*Felis concolor*), and bobcat (*Lynx rufus*). All of these large mammals have fairly extensive ranges and were at one time common in both bottomland and upland areas of the province. Mountain sheep (*Ovis canadensis*) and mountain goat (*Oreamnos americanus*), once common, still inhabit the higher elevation areas of the region. Marshy habitats in the region typically support a specialized but diverse array of fauna that includes raccoon (*Procyon lotor*), mink (*Mustela vison*), river otter (*Lutra canadensis*), beaver (*Castor canadensis*), and muskrat (*Ondatra zibethica*). In addition, a great variety of migratory waterfowl spend a portion of the year in the marshy areas of the Puget Basin (Blukis Onat 1987; Campbell 1981; Dalquest 1948; Thompson 1978).

The aquatic environments of the Puget Basin are varied and include freshwater lakes, streams, and rivers, and a variety of marine microenvironments. Estuarine tidal flats, characterized by sandy to muddy substrate, support native oyster (*Ostrea lurida*), basket cockle (*Clinocardium nuttalli*) and a number of species of clams. A variety of estuarine fish are common in the region.

Anadromous fish also pass through the estuarine and riverine microenvironments. These fish, primarily various species of salmon (*Oncorhynchus* spp.), were probably the most important staple for native people living in the Puget Basin during late prehistoric times. The relative abundance of different species of anadromous fish in the river channels and the timing of their passage is specific to each river drainage. Other fish that are permanent residents of the Puget Basin rivers, streams, and lakes include various species of trout (*Salmo* spp.) and Dolly Varden (*Salvelinus malma*) (Wydoski and Whitney 1979).

2.3 West Cascades

Physiography, Geology, and Hydrology

The West Cascades are primarily composed of Tertiary andesite and basalt flows and associated breccias and tuffs with only minor amounts of igneous intrusive, sedimentary, or metamorphic rocks (Franklin and Dyrness 1973:21,22). Dating to roughly 50 million years ago, limestone deposits in the vicinity of Snoqualmie Pass are remnants of the western coast of North America. Beginning in the late Eocene, vulcanism produced the majority of the current bedrock exposures (Alt and Hyndman 1984).

The volcanic history of the region has been divided into roughly four (Franklin and Dyrness 1973) or five (McKee 1972) chronological categories with associated geologic processes: 1) Eocene to early Miocene: deposition of volcanic strata; 2) Middle Miocene: folding, faulting, and granitic intrusions; 3) Middle to Late Miocene: lava flows of Columbia River basalts; 4) Late Tertiary: volcanism and initiation of range uplift; 5): Pleistocene to Recent: formation of the Cascade volcanoes, continued uplift of range, and glaciation. The last two stages in which uplift occurred involved secondary volcanic activity that deposited additional and more diverse rhyolites, andesites, and basalts and gradually built the composite cones of the modern Cascades (Harris 1988). By the end of the mid-Pleistocene, the major mountain-building period was ending and the general Cascade configuration of today was essentially complete.

During the Pleistocene, the West Cascades were extensively glaciated. The final Wisconsin glacial advance, the Vashon Stade, began wasting in the Cascades between 20,000 and 18,000 years ago. During that time, glacial ice retreated from most of the lower elevation peaks. Continuing terrain modification was limited largely to local-level effects of water erosion, mass sediment movements, and aeolian deposition of material from volcanic activity of windward peaks (Burtchard and Keeler 1991:15).

Processes of terrain modification have been active in the West Cascades throughout the Holocene up to the present day. An excellent example is the recent eruption of Mt. St. Helens and the drastic alterations to the landscape that resulted (Keller 1982). Less dramatic examples of contemporary modifications involve the erosional processes of high discharge and high gradient river systems within the Cascades, such as the Yakima River draining to the east and the Snoqualmie and Skykomish Rivers to the west. These rivers continue to erode more deeply into the basalts, andesites and other volcanic rocks that make up the Cascades and create new landforms such as benches and terraces. In addition, sediments are regularly deposited wherever river gradients decrease, creating floodplains and other depositional surfaces.

Climate

The contemporary climate of the West Cascades is characterized by sharp temperature and precipitation gradients. To a certain extent, the peaks create unique microclimates that correspond with variations in elevation, slope, and aspect (Jackson 1993). These sources of diversity make a characterization of general climate for the West Cascades difficult. Nevertheless, some generalizations can be drawn.

Precipitation is dominant during the winter months, as elsewhere in the Pacific Northwest, and rainfall levels are extremely high on the western slopes of the Cascades where they may reach up to 100 inches annually. Winter snowfall reaches a maximum on high elevation peaks between 5,000 to 7,000 feet where winter totals may average up to 600 inches with ground accumulation of 25 feet or more. In lower elevation areas, snowfields may last through the end of July, and on the highest peaks glaciers and snowfields last year round. Winter temperatures vary dramatically with elevation. On the lower western slopes of the Cascades, the mean minimum temperatures may be above 0 degrees C (Jackson 1993).

Summers in the West Cascades are also variable between the high mountains and the lower ranges. Temperature maximums may reach 20 to 28 degrees C during the day and may drop to freezing levels at night. Only a small percentage of the total annual precipitation (less than 8%) falls during the summer in this province.

Flora and Fauna

Encompassing a great range of elevations, the West Cascades physiographic province is divided into two vegetation provinces (Forest Province and Alpine Province) and five vegetation zones. The five vegetation zones can be described in an elevational gradient moving downslope from the Alpine Zone Complex. The Alpine Zone is not well-represented in Washington, occurring only above timberline on "recently dormant Pleistocene volcanoes of the Cascade Range where substrates are youthful and steep slopes help perpetuate them in that state" (Franklin and Dyrness 1973:284). Alpine heath communities of the subalpine parklands extend into this zone and grade into complete tundra vegetation with increasing elevation.

The Cascade Subalpine Forest Zone Complex begins at the timberline below the maximum low elevation extent of the Alpine Zone Complex. Subalpine forests are frequently dominated by mountain hemlock (*Pseudotsuga mertensiana*) and subalpine fir (*Abies lasiocarpa*), giving way to a Pacific Silver Fir Zone (*Abies amabilis*) at lower elevations (Frenkel 1993). In cleared forest openings, understory vegetation in the Pacific Silver Fir Zone may be dense, supporting such plants as huckleberry (*Vaccinium* spp.), *Rhododendron*, and cranberries (*Rubus* spp.). Meadow communities may also appear as openings in the tree cover of this zone. Precise floral composition of such communities varies with moisture and elevation, but they typically support a vast array of shrubs, herbs, and grasses (cf. Burtchard 1990:30).

Grand Fir and Douglas Fir Vegetation Zones are found in the West Cascades and most frequently occur as elevation decreases from the Pacific Silver Fir Zone. The dominant trees for which this zone was named characterize a zone of mesic coniferous forests with a broad distribution. Understory vegetation associations vary with moisture; however, Oregon boxwood (*Pachistima myrsinites*) and common snowberry (*Symphoricarpos albus*) are two predominant taxa. Western larch (*Laris occidentalis*) and lodgepole pine (*Pinus contorta*), termed "fire-responsive" by Frenkel (1993), are often among the early successional plants of the Grand Fir and Douglas Fir Zones.

The Western Hemlock Zone occurs on the western slopes of the Cascades and foothills. This zone was discussed in detail in the Puget Basin section above, so the characteristic associations will not be reviewed here. It is interesting to note, however, that this zone is analogous to the Ponderosa Pine Zone on the east side of the mountains. Due to the orographic barrier created by the mountain masses of the Southern Cascades, this zone supports moisture-tolerant species in contrast to the xerophytic vegetation associations of the Ponderosa Pine Zone.

Most of the fauna that inhabited the Puget Basin prior to American settlement also ranged into the Cascades (Burtchard 1990; Ellis et al. 1991; Hall 1981). A wide variety of avifauna frequent the region, some migratory and some permanent residents. Migrating water fowl, likely exploited to some extent by the native inhabitants of the province, include Canada goose (*Branta canadensis*), and a number of different kinds of ducks (e.g., mallard [*Anas platyrhynchos*], widgeon [*Mareca americana*]). Terrestrial mammals included elk (*Cervus canadensis*), black-tail deer (*Odocoileus* spp.), mountain sheep (*Ovis canadensis*), mountain goat (*Oreamnos americanus*), bobcat (*Lynx rufus*), mountain lion (*Felis concolor*), black bear (*Ursus americanus*), coyote (*Canis latrans*), lynx (*Lynx canadensis*), wolf (*Canis lupus*), raccoon (*Procyon lotor*), river otter (*Lutra canadensis*), mink (*Mustela vison*), beaver (*Castor canadensis*), mountain beaver (*Aplodontia rufa*), and snowshoe hare (*Lepus americanus*). Many of these species still inhabit the province today. Deer, elk, and small mammals such as beaver and hare were probably of significance to the aboriginal inhabitants of the Southern Cascades. Perhaps even more important were the runs of anadromous fish that migrate up the major rivers of the province. Even today, these include several species of salmon (*Oncorhynchus* spp.). Trout (*Salmo* spp.), mountain whitefish (*Prosopium williamsoni*), and Dolly Varden

(*Salvelinus malma*) are resident in many rivers and creeks that drain the West Cascades.

2.4 East Cascades

Physiography, Geology, and Hydrology

Geologically, the East Cascades share a similar history with the West Cascades. The orogenic processes that created the Cascade Range are discussed in Section 2.3 of this report. However, distinctions do exist between the eastern and western flanks of the Cascades, primarily as local variations of bedrock exposures and terminal moraine glacial drift deposits. Along the pipeline route, between Snoqualmie Pass and Cle Elum, sandstone and shale exposures are remnants of coastal beaches created during the early Eocene (Alt and Hyndman 1984). Widespread basalt flows during the late Eocene produced the Teanaway Formation, a series of agate-laden outcrops lying between Cle Elum and Ellensburg. Volcanic eruptions during this same time period also created the Naches Formation, which is characterized by interbedded sandstone layers within the basalt, located midway between Snoqualmie Pass and Cle Elum. Coal deposits interbed the Eocene-age rocks in the area surrounding Cle Elum (Alt and Hyndman 1984; Beikman et al. 1961).

During the Pleistocene, glaciers moved from the crest down both flanks of the Cascade Range. Ice originating at the summit above Snoqualmie Pass scoured out the Snoqualmie Valley, flowed down to sea level, and eventually merged with the Puget Lobe. Glaciers moving toward the east carved the Yakima River Valley, and were among the largest in the Cascades. The Lakedale Drift, thought to be roughly contemporaneous with the Vashon Drift, deposited moraine sediments west of Cle Elum. These sediments traveled up to 40km from their origin near Snoqualmie Pass (Alt and Hyndman 1984; Porter 1976).

The Yakima River is the major drainage of the East Cascades in the vicinity of the pipeline route. The modern river has its headwaters at Keechelus Lake, a reservoir created by the construction of Keechelus Dam. Neighboring Kachess and Cle Elum Lakes are also man-made reservoirs, and their outflow joins the Yakima River. The Teanaway River, its channel lying between the Cle Elum and Teanaway Ridges, is the final major tributary of the Yakima River in the East Cascades.

Climate

The north-south trend of the Cascades provides an effective orographic barrier to the movement of maritime and continental airmasses and contributes to sharp climatic contrasts between the east and west side of the mountains. The eastern slopes receive less precipitation than areas west of the Cascade crest. Portions of the East Cascades receive precipitation in excess of 60 inches, although 32 to 48 inches annually is typical for the region. Precipitation during the winter months usually arrives in the form of snow, and averages 200 inches per year, with an increase in accumulation with elevation (Franklin and Dyrness 1973; Jackson 1993). Precipitation totalling 2 millimeters or more within a 24-hour-period occur approximately 120 to 180 days out of each year (Jackson 1993).

Mean temperatures for the region range from a minimum of 10 degrees Fahrenheit (F) in January, to 80 degrees F in July (Franklin and Dyrness 1973; Jackson 1993). The onset of the killing frost in fall generally begins at the end of August. Frost and snow can last as late as the end of May in the East Cascades, resulting in approximately 120 freeze-free days per year (Jackson 1993).

Flora and Fauna

The East Cascades stretch of the pipeline route lies within the easternmost stretch of the Forest Province between the crest of the Cascades Range and the margin of the Columbia Basin. Two vegetation zones dominate this area: the *Pinus ponderosa* or Ponderosa Pine Zone, and the *Abies grandis/Pseudotsuga menziesii* or the Grand/Douglas Fir Zone. Major tree species in both of these zones are Ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and Douglas fir (*Pseudotsuga menziesii*). Scattered stands of Oregon white oak (*Quercus garryana*) may be present in the *Abies grandis/Pseudotsuga menziesii* Zone. The understory of these zones is comprised of low, deciduous shrubs. Common snowberry (*Symphoricarpos albus*), woods rose (*Rosa woodsii*), and Nootka rose (*Rosa nutkana*) are common understory constituents of both the Ponderosa Pine and Grand/Douglas Fir Zones. Soil moisture may vary with topography, resulting in small areas with more xeric or mesic habitats. Snowbrush ceanothus (*Ceanothus velutinus*), bluebunch wheatgrass (*Agropyron spicatum*), mallow ninebark (*Physocarpus malvaceus*), needle-and-thread grass (*Stipa comata*), and bitterbrush (*Purshia tridentata*) are common in drier tracts. Mesic environments may contain shinyleaf spirea (*Spirea betulifolia*), pinegrass (*Calamagrostis rubescens*), Oregon boxwood (*Pachistima myrsinites*), prickly currant (*Ribes lacustre*), and big huckleberry (*Vaccinium membranaceum*).

Carnivores found in relative abundance throughout the Eastern Cascades include black bear (*Ursus americanus*); raccoon (*Procyon lotor*); western marten and fisher (*Martes americana* and *M. pennanti*); weasels, ferrets, and minks (*Mustela spp*.); wolverine (*Gulo luscus*); spotted skunk (*Spilogale putorious*); skunk (*Mephitis mephitis*); red fox (*Vulpes fulva*); coyote and wolf (*Canus latrans* and *C. lupus*); lynx and bobcat (*Lynx spp*.) and cougar (*Felis concolor*). Four species of artiodactyl commonly inhabit the region. These include elk (*Cervus canadensis*), black-tailed deer (*Odocoileus hemionus*), mountain sheep (*Ovis canadensis*), and mountain goat (*Oreamnos americanus*) (Dalquest 1948).

Rodents comprise the largest group of mammal species within the Eastern Cascades. Yellow-pine chipmunk (*Eutamias amoenus*), golden-mantled ground squirrel (*Citellus lateralis*), red squirrel (*Tamiasciurus hudsonicus*), Douglas squirrel (*T. douglasii*), western gray squirrel (*Sciurus griseus*), deer mouse (*Peromyscus maniculatus*), bushy-tailed wood rat (*Neotoma cinerea*), heather vole (*Phenacomys intermedius*), long-tailed vole (*Microtus longicaudus*), big jumping mouse (*Zapus princeps*), and Boreal red-backed vole (*Clethrionomys gapperi*) inhabit the province. Other species, including hoary marmot (*Marmota caligata*), northern flying squirrel (*Glaucomys sabrinus*), and porcupine (*Erethizon dorsatum*) reside exclusively in high-elevation, timbered areas. Aquatic mammals such as beaver (*Castor canadensis*) and mountain beaver (*Aplodontia rufa*) reside near lakes, rivers, streams, and ponds (Dalquest 1948).

Other small mammals indigenous to the Eastern Cascades include the shrew mole (*Neurotrichus gibsii*), and several species of shrew (*Sorex cinerus, S. merriami, S. vagrans, S. obscurus, S. palustris,* and *S. bendii*). Lagomorphs include the pika (*Ochonta princeps*) and snowshoe rabbit (*Lepus americanus*) (Dalquest 1948).

2.5 Western Columbia Basin

Physiography, Geology, and Hydrology

The Columbia Basin is a narrow zone between the foothills of the Cascade Range and the Columbia Basin Flat. Elevations in this area range from 1,000 feet above sea level in the Cle Elum Ridge overlooking Ellensburg, down to 500 feet along the banks of the Columbia River.

The geologic history of this area combines elements of the orogenic processes that created the Cascades to the west, and the glacial outwash episodes that produced the topography of the Columbia Basin Flats to the east. Orogeny of the Cascades is discussed in detail in Sections 2.3 and 2.4 of this report, and Section 2.6 includes descriptions of subsidence and glaciofluvial action in the Columbia Basin. The bedrock within this region consists almost exclusively of Miocene-age Yakima Basalt Formation. The Ellensburg Formation, a sub-member of the Yakima Basalt, was deposited during the late Miocene and Pliocene, and consists of fluvial and lacustrine sediments interbedded between basalt flows (Alt and Hyndman 1984; Mackin 1961). During the late Cenozoic, these deposits experienced four types of deformation that resulted in the current topography of the area: folding, uplift of the Cascade Range, subsidence of the Columbia Plateau, and glacial outwash processes. Bedrock folding, which occurred during the late Tertiary, created the anticlinal arches and synclinal troughs of Manastash Ridge, Frenchman Hills, and Saddle Mountains south and east of Ellensburg (Alt and Hyndman 1984; Mackin 1961).

The major drainage of the Western Columbia Basin is the Yakima River which flows south from Ellensburg toward Yakima. Numerous small creeks crisscross the landscape and serve as tributaries for the Yakima or Columbia Rivers.

Climate

The Western Columbia Basin has a more temperate climate than that of the adjacent Flat. The higher elevations of the hills and the region's proximity to the Cascades produces a temperature range lacking the extremes of the central Columbia Basin; the mean January minimum temperature in the hills is 20 degrees F, and the mean July maximum is 80 degrees F. Annual precipitation ranges from 8 to 16 inches. Snowfall produces 24 to 60 inches annually, typically restricted between the end of September and late May (Franklin and Dyrness 1973; Jackson 1993).

Flora and Fauna

The vegetation of the Western Columbia Basin includes elements of both the Ponderosa Pine and Shrub-Steppe zones. Expression of zonal plant communities is dependent on localized variations in temperature, elevation, and moisture gradients. A discussion of the Ponderosa Pine zone is included in Section 2.4 of this report, and the Shrub-Steppe region is addressed in Section 2.6.

The animal populations of the Western Columbia Basin are typically defined by and contained within the ecological zones described above. However, a number of species are unique to this region. The coast mole (*Scopanus orarius yakimensis*); least chipmunk (*Eutamias minimus scrutator*); Townsend ground squirrel (*Citellus townsendii townsendii*); and local varieties of raccoon (*Procyon lotor excelsus*), skunk (*Mephistis mephistis notata*), yellow-pine chipmunk (*Eutamias amoenus affinis*), northern pocket gopher (*Thomomys talpoides fuscus* and *T. talpoides yakimensis*), and long-tailed vole (*Microtus longicaudus halli*) range within and between the Yakima and Columbia River valleys (Dalquest 1948).

2.6 Eastern Columbia Basin

Physiography, Geology, and Hydrology

The Columbia Basin is the largest physiographic province in Washington State, over 6,000,000 hectares in area (Franklin and Dyrness 1973; Rosenfeld 1993). The southern boundary of the province extends into Oregon west of the Blue Mountains. The western edge is bounded by the Cascades, and the northern boundary is the Columbia River and the Okanogan Highlands Province.

The Columbia River, originating in British Columbia and only partially contained in the Columbia Basin Province, is the largest river on the Pacific Coast of North America. It drains over 640,000 km^2 and flows over a distance exceeding 1900 km (Wilke et al. 1983). The Columbia drains virtually the entire province, directly or indirectly. The Yakima, Snake, Klickitat, and Walla Walla Rivers all flow into the Columbia.

Geologically, the Columbia Basin, sometimes referred to as the Columbia Plateau, is an irregular structural and topographic basin underlain by Tertiary basalt flows that have been depressed below sea level in some areas and upwarped on the flanks of the surrounding mountains in others. Overlying the basalts are sedimentary formations, derived from a variety of sources including fluvial, lacustrine, aeolian, and glacial depositions, and forming terraces and other subordinate landforms in the province (Rosenfeld 1993; Wilke et al. 1983). During late Pliocene and Pleistocene epochs, volcanic lava flows originating in the High Cascades were deposited. East-trending folding resulted in the formation of high elevation ridges that today rise above the intervening valleys.

While the area of the Columbia Basin is located south of the furthest extent of glacial ice during the last glaciation, much of the character of the landscape may be attributed to the effects of glaciation. In particular, the Channeled Scablands of the Columbia Basin are a vast erosional landscape that has a glacial origin and history. A hypothesis first advanced by J. Harlan Bretz (1925, 1928, 1969) explained the topography and sedimentary formations of the scablands as resulting from a catastrophic flood that occurred when an enormous ice dam in western Montana broke and released an estimated 500 cubic miles of water into Eastern Washington. The floodwaters scoured the landscape, cutting coulees and channels into the basalt bedrock and overlying loess of the region. This explanation, once extremely controversial, is now generally accepted (Alt and Hyndman 1984; Beckham et al. 1988; Easterbrook 1976; McKee 1972; Waitt and Thorson 1983; Wilke et al. 1983), and accounts for depositional features of the landscape as well. Stratigraphic analyses have revealed evidence for ponding of glacial floodwaters and the accumulation of thick deposits of sediment and loess islands. Shoreline benches provide evidence for as many as 40 previous flooding events during earlier advances and retreats of the Cordilleran ice sheet (Alt and Hyndman 1984).

Climate

Climatically, the Eastern Columbia Basin may be described as having an arid to semiarid climate with low precipitation, warm-to-hot, dry summers and relatively cold winters. The orographic barrier created by the Cascades to the west of the region is the principal reason this climatic situation exists. When air passes over the summits of the range, the airflow is diverted downward, compressed, and warmed, and precipitation is inhibited. In general, the result is large daily and seasonal temperature fluctuations, low relative humidity, and irregular rainfall (Lynott 1966).

Along the Columbia River east of the gorge, average temperatures range between 20 and 90 degrees F in January and July, respectively. Precipitation falls mainly between November and March, and averages about 8 to 16 inches. Winters in the Columbia Basin can be quite severe. Precipitation is usually in the form of snow. Strong winds blow across the plateau in response to pressure system movements. Although these statements about the climate of the basin are generally applicable, it is important to remember that this is a very large area (over 6,000,000 hectares) and local variations occur in response to differences in elevation and exposure.

Flora and Fauna

The Columbia Basin Province of eastern and southeastern Washington is a large, contiguous area of steppe and shrub-steppe vegetation (Daubenmire 1970; Franklin and Dyrness 1973:210). Nine different plant associations are recognized and vary depending on elevation, proximity to forested areas, precipitation, and a number of other interrelated variables. The four predominant associations, listed in order from more to less xerophytic and illustrating a general trend from the driest interior part of the province, east up the slope of the Columbia Plateau, and to the foothills of the Rocky Mountains, are: *Artemisia tridentata/Agropyron spicatum, Artemisia tridentata/Festuca idahoensis; Agrophyron spicatum-Poa sandbergii; Agrophyron spicatum-Festuca idahoensis.* Sagebrush and bunchgrass are the most common non-scientific descriptive terms for these associations. Idaho fescue (*Festuca idahoensis*), Sandberg's bluegrass (*Poa sandbergii*), and bluebunch wheatgrass (*Agropyron spicatum*) are perennial grasses easily damaged by overgrazing. *Artemisia tridentata* is a major shrub species, commonly known as sage, that is sensitive to fire. Recolonization after fire is difficult -- burning may result in a patchy distribution. The five other associations are found mainly on the periphery of the steppe region near its contact with forest vegetation. They are described as "lush, meadowlike communities with conspicuous amounts of large perennial grasses and broad-leaved forbs" (Franklin and Dyrness 1973:212).

Neither grazing by indigenous species of ungulates (deer, wapiti, antelope), nor fires are thought to have significantly impacted the vegetation of the province prior to settlement by early white ranchers and settlers, and their livestock. Cattle were introduced into the steppe region in the early 1800s and sheep around 1860. Intensive grazing, coupled with agricultural and reclamation activities, dramatically altered the indigenous vegetation associations and distributions. Large bunch grasses, not adapted to overgrazing by ungulates, were virtually eliminated in some areas. Big sagebrush was also temporarily eliminated by fire and the rapid succession of non-indigenous species like thistle, mustard, and grasses into over-grazed areas (Franklin and Dyrness 1973).

Currently, much of the province is under cultivation. Many of the areas lacking sufficient natural moisture to support agriculture have been reclaimed through irrigation. Some lands that were cropped now lie fallow. Range fires caused by people still occur in steppe areas, and heavy grazing continues today in much of the province. Thus, vegetation patterns observable today provide only a dim indication of the indigenous plant associations and distributions. Information on natural distributions and associations has been derived from historic accounts and records, observation of non-affected areas, and analysis of macrofossils and pollen cores.

Similarly, the fauna ranging the Columbia Basin today have changed in kind and number as a result of encroachment and destruction of habitat by settlers and developers. Early accounts suggest that elk (*Cervus canadensis*), deer (*Odocoileus* spp.), mule deer (*O. hemionus*), prong-horn antelope (*Antilocapra americana*), mountain goat (*Oreamnos americanus*) and mountain sheep (*Ovis canadensis*), are among the grazing animals that once inhabited the Columbia Basin. The small mammals observed historically and recently include beaver (*Castor canadensis*), fox (*Vulpes fulva*), rabbits (*Lepus* spp.), squirrels (*Citellus towsendii* and *C. washingtoni*) and badger (*Taxidea taxus*). Probably of less significance to aboriginal occupants of the region, were predatory animals such as cougar (*Felis concolor*), bobcat (*Lynx rufus*), timber wolf (*Canis lupus*), and coyote (*C. latrans*). Game birds, such as quail (*Colinus* spp.) and grouse (Family *Tetraonidae*), are still common in the Columbia Basin and were likely exploited by prehistoric human inhabitants (Wilke et al. 1983).