7. NATURAL RESOURCES IN THE GRAZING LEASE AREA

7.1. KEY SOURCES OF INFORMATION ABOUT THE FOX RIVER AREA

Managers need information specific to their planning area to implement goals, objectives, and policies on the ground. In the Fox River Flats area, such information comes from locals familiar with the area—such as Fox River cattlemen—and from professionals who work in the area, such as range specialists, soil scientists, and wildlife biologists. Hunters and recreationists who use the flats also often have local knowledge of particular resources. For example, the group "Kachemak Bay Birders" occasionally surveys shorebirds and waterfowl in the area (http://kachemakbaybirders.org).

Most of the site-specific information readily available about the Fox River Flats is contained in a handful of main sources. The first of these is the *Fox River Flats Critical Habitat Area (CHA) Plan* and its accompanying *Resource Inventory*. These were prepared by the ADF&G, Habitat Division, in 1993 and can be downloaded at: www.adfg.alaska.gov/index.cfm?adfg=foxriverflats.main). Because an Environmental Impact Statement (EIS) was completed in 1982 for the proposed Bradley Lake Hydro-electric Project, located on the Bradley River at the head of Kachemak Bay, ADF&G had access to this information in developing its plan. In addition, in 1985 the Federal Energy Regulatory Commission supplied supplemental information for the EIS, which was also available to the ADF&G. Much of the survey data collected for the EIS is provided in the *Resource Inventory* accompanying ADF&G's Fox River Flats CHA plan. The information is limited, however, in specifics, duration, and spatial coverage. Much of the information collected for the EIS centered on Bradley Lake and Bradley River. Little data was collected west of Sheep Creek.

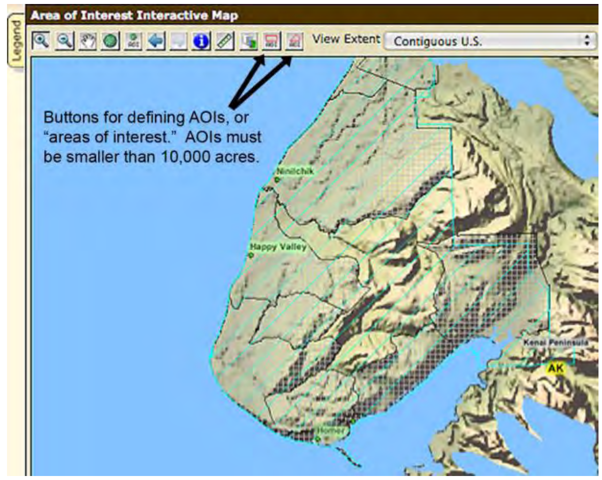
A second source of site-specific information is the Western Kenai Peninsula soil survey conducted by the Natural Resources Conservation Service (NRCS) and published online in 2005. The manuscript *Soil Survey of Western Kenai Peninsula Area, Alaska*, and accompanying map sheets, can be downloaded at http://soildatamart.nrcs.usda.gov/Manuscripts/AK652/0/. The flats are encompassed by Map Sheet 5. Additional information is available at an interactive online Web site called Web Soil Survey (WSS), which can be accessed at: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm or by searching for "web soil survey."

To get quickly to information about the Fox River Flats area at Web Soil Survey, including soils maps, ratings of soil suitability for various land uses, and plant community data (discussed below), click on the green "START WSS" button at the top of the WSS Web page (Figure 7-1). On the screen that loads next (which will have a map of the Lower 48), choose "Soil Survey

Figure 7-1. Web Soil Survey (WSS) showing green START button that leads to data.

Area" under Quick Navigation, then "Alaska" from the dropdown menu of states, and "Western Kenai Peninsula Soil Survey" from the dropdown menu under "Soil Survey Area." (You'll need to scroll down the list of soil surveys almost to the bottom.) Click the "View" button, and a map of the Kenai Peninsula Borough will load. You can then create zoom boxes to zoom in or choose "Set AOI" (AOI stands for "area of interest) to find your area of interest. You can navigate around the map of the Kenai Peninsula using the buttons along the top of the map, see Figure 7-2. Once you've defined your AOI, you can select the tab for soils data to get a soil map, or other tabs for other data.

Figure 7-2. Interactive map for defining "areas of interest" (AOIs) to access soil information from the Western Kenai Peninsula soil survey.



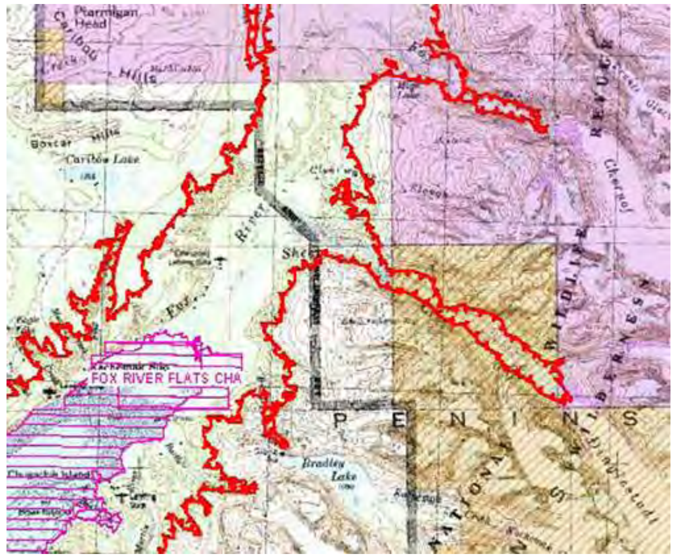
A third key source of site-specific information about the Fox River Flats area are the annual *Fox River Flats Grazing Evaluations* written by the NRCS each year since 2000. These provide detailed information about the condition and trend of grazed plant communities. These rangeland evaluations are discussed in more detail in Section 7.4. and Section 8.

A fourth source of information about the flats is the *Kachemak Bay Ecological Characterization* (KBEC), published by the Kachemak Bay Research Reserve on CD-ROM in 2001. The CD-ROM includes digital spatial data, images, and narratives based on knowledge available at the time information was compiled (from 1997 to 2001). Two years after KBEC was published, KBRR prepared a "site profile" summarizing "…the existing state of knowledge for research, monitoring, and education activities…" related to the Kachemak Bay watershed, including the Fox River Flats area. This document: *Kachemak Bay Ecological Characterization, A Site Profile of the Kachemak Bay Research Reserve: A Unit of the National Estuarine Research Reserve System*, was published in 2003. A pdf can be downloaded at: nerrs.noaa.gov/doc/pdf/**reserve**/kba_siteprofile.pdf. Two years later (October 2005), KBRR completed a management plan for the Kachemak Bay National Estuarine Research Reserve (see www.nerrs.noaa.gov/Doc/PDF/Reserve/KBA_MgmtPlan.pdf.) This in some cases supplemented information in the 2003 site profile. In recent years, KBRR has published annual summaries of research going on in Kachemak Bay, called *What's New in the Bay* (WNITB). Several of the projects summarized are being conducted in the Fox River Flats, including a study of the use of tidal channels by juvenile salmon. For the 2010 edition of WNITB, go to: http://www.guru.uaf.edu/kbay/2010%20KBAY%20Research%20Overviews.pdf.

A fifth source of information is provided in Environmental Sensitivity Index (ESI) Maps. Such maps provide a concise summary of coastal resources that are at risk if an oil spill occurs nearby. At-risk resources include biological resources (such as birds and shellfish beds), sensitive shorelines (such as marshes and tidal flats), and human-use resources (such as public beaches and parks). ESI maps are developed through NOAA's National Ocean Service, Office of Response and Restoration. In the following discussions, ESI maps are mentioned where appropriate.

Finally, *Kenai Peninsula Borough Coastal Management Program* [CMP]*, Final Plan Amendment, April 2007*, provides information relevant to management of resources in the coastal zone and includes a fairly extensive discussion of borough natural resources. The coastal zone extends inland from the coast to an elevation of 1,000 ft. All of the Fox River Flats grazing lease area is within the coastal zone boundary, see Map 7-1. The CMP plan's legal context and purpose is discussed in Section 4.

The rest of Section 7 provides an overview of natural resources within the Fox River Flats grazing lease area. Most of this information was compiled from the sources mentioned above. Where possible, ongoing research is also mentioned. Much of the information is provided here in tables to make scanning it easier.



Map 7-1. Coastal Zone boundary in the Fox River Flats area

7.2. Ecological Setting, inlcuding Topography

Most of the Fox River Flats grazing lease area lies within a relatively flat, steep walled valley bounded by the glaciated Kenai Mountains to the east and southeast and by bluffs and rolling uplands to the west and northwest (Map 7-2). In the lower flats, in the area of the river mouths, the valley is 2 to 4 miles wide. Near the middle of the flats, the channels of Fox River and Sheep Creek split. Upstream, each river emerges from narrow canyons carved by glaciers in the Harding Icefield to the east.

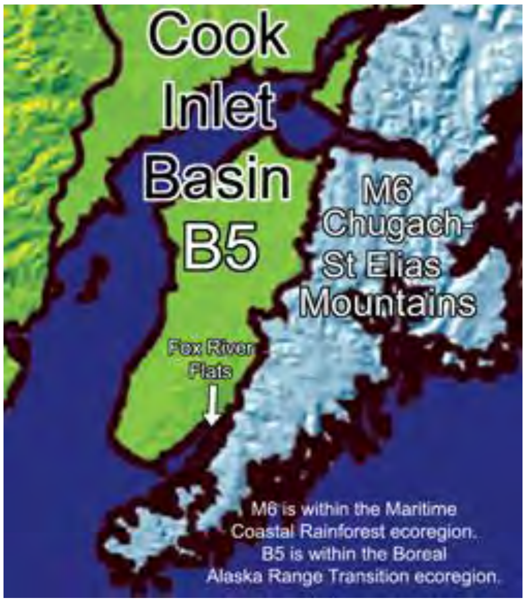
The valley floor consists of unconsolidated fluvial and glacial deposits. Shifting, braided river channels of Fox River, Sheep Creek, and Bradley River deposit a range of sediments, from coarse gravels to fine silts, across the valley floor. Particularly in the middle of the valley, areas of bare and thinly covered gravel from abandoned channels are interlaced with finer, less permeable deposits.

The entire Kachemak Bay area subsided on the order of 4 feet in the 1964 earthquake. However, rivers in the flats transport and deposit large amounts of material eroded by glaciers, water, and wind, so the area is aggrading relatively quickly back to pre-earthquake levels.

Map 7-2. General terrain of the Fox River Flats area and locations of USGS gauging stations on Bradley River.

Aggradation, isostatic rebound, and climatic warming may be contributing to the drying up of small lakes on the flats and invasion of herbaceous wetlands by woody species (see Section 8). This trend has been described for areas further up the peninsula by E. Berg in several articles (e.g., Berg 2006).

In the lower Fox River/Sheep Creek valley, an extensive tidal marsh has developed. The flats are by far the largest marsh in Kachemak Bay, comprising approximately 7,100 acres of coastal marsh and mudflats (see Wetlands discussion, below).



Map 7-3 (above). The Fox River Flats are located at the divide of two ecoregions (Nowacki et al. 2001).

Map 7-4 (below). Rivers draining into Cook Inlet (Cook Inletkeeper).

The Fox River/Sheep Creek valley is located on the divide between two different physiographic and geologic regions (ecoregions): to the east and south are found maritime montane coastal rainforests; to the west and north lies the Cook Inlet Basin—including the Kenai Lowlands (Map 7-3.) On the south and east, jagged, glaciated peaks of the Kenai Mountains are underlain by ancient igneous and metamorphic bedrock, some of it transported many hundreds of miles by tectonic plates shifting over the earth's surface. Deep, steep-sided fjords and long fingers of forest extend to the sea. Both Fox River and Sheep Creek emerge from such valleys in the Kenai Mountains (Map 7-2, see also Map 2-7). To the north and west lie rolling hills and lowlands underlain by sandstone and other sedimentary rocks of the Kenai Formation. These were deposited in an ancient delta formed by rivers flowing out of the Aleutian, Alaska, Talkeetna, and Chugach mountains to the north and west. A sense of this huge delta can be gained by looking at the river systems still flowing into Cook Inlet (Map 7-4). The thick Kenai Formation sediments are overlain by more recent glacial and windblown deposits. Near Homer, two main terraces left behind by advances of Naptowne glaciers form benches on the north side of Kachemak Bay (see Section 2-2). These benches are drained by streams that, like Fox Creek, cut steep, V-shaped channels.

The climates of the northern and southern sides also differ. The southern side is wetter, supporting coniferous rainforests dominated by Sitka spruce. (At its snow survey site below Nuka glacier, above Bradley Lake, the NRCS has in some winters measured over 20 feet of accumulated snow.) In comparison, the drier, flatter northern side supports a mix of deciduous and coniferous plant communities. On both sides, forests and shrublands transition to tundra at higher elevations. In the flats, as elsewhere on the peninsula, variations in elevation, aspect, topography, and wind exposure create a mosaic of different microclimates and habitats.

7.3. SWAPA

The NRCS looks at six kinds of resources when conducting inventories for comprehensive management plans: soils, water, air, plants, and animals. (The mnemonic "SWAPA" is used for short.) Information about each of these within the grazing lease area is provided below. Web links are provided for much information available online.

7.3.1. Soils

Soil surveys provide a range of information about soils in the survey area. Soil surveys also provide information about soil use and management that can be used to determine how best to use mapped soils for crops and pasture; as rangeland and forestland; as sites for buildings, sanitary facilities, highways and other transportation systems, and parks and other recreation facilities; and for wildlife habitat. This section provides information about soils in the grazing lease area, as well as some basic information that will help readers understand what a soil survey can offer.

Definition: A soil is a natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effects of climate and living matter acting on earthy parent material, as conditioned by landscape relief over periods of time. The upper limit of a soil is the boundary between the soil and air, shallow water, live plants, or plant materials that have not begun to decompose.

Basic terminology—soil surveys and soil maps (from *Soil Survey of Western Kenai Peninsula Area, Alaska*, and "From the Surface Down," at Web Soil Survey): A soil survey is an inventory and evaluation of the soils in the survey area. In preparing a soil survey, soil scientists and other professionals collect extensive field data about the nature and behavioral characteristics of the soils in the survey area. They collect data on erosion, droughtiness, flooding, and other factors that affect soil uses and management. Field experience and collected data on soil properties and performance are used as a basis in predicting soil behavior.

The objective of soil mapping is to separate the landscape into landforms or landform segments that have similar use and management characteristics.

Figure 7-3. Profile of Redoubt silt loam soil.

During soil survey fieldwork, soil scientists —often accompanied by botanists or ecologists—walk across the landscape looking for features that suggest a possible change in underlying soils (a slope break, for example, or change in vegetation or surface wetness). When they find a probable boundary between different kinds of soils, they dig holes (usually with an augur) to confirm that the landscape change reflects a change in soil conditions. As needed, they dig larger soil pits to expose soil "profiles" or "horizons" (Figure 7-3). These layers extend from ground surface down to the soil's "parent material" (underlying rocks and sediments not affected by soil-forming processes such as leaching, plant roots, and organisms). Information about these layers is recorded at each soil pit. By examining soil profiles, soil scientists determine various properties of the soil, such as texture, color, structure, and reaction of the soil, as well as the relationship and thickness of different soil horizons.

Each soil survey describes the properties of soils found and mapped in the survey area and shows the location of each kind of soil on detailed maps. The objective of mapping is not to delineate pure soil taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil taxonomy and "soil series" (from *Soil Survey of Western Kenai Peninsula Area, Alaska*): The system of soil classification used by the National Cooperative Soil Survey has six categories. Beginning with the broadest, these categories are soil order, suborder, great group, subgroup, family, and series. Taxonomic classification is based on soil properties observed in the field or inferred from those observations or from laboratory measurements. Soil taxons can reflect dominant soil-forming processes and the degree of soil formation (order and suborder); similarities in soil horizons, moisture, and temperature regimes (great groups); physical and chemical properties and other characteristics that affect management of soils (family), and similarities in color, texture, structure, reaction, consistence, mineral and chemical composition, and arrangement in the profile (series).

Photo 7-1. Cattle grazing on Typic Cryaquents (map unit 701) in the foreground, in the Fox River Flats. Tutka-Portgraham complex, hilly to steep (map unit 697), occurs on the mountain slopes in the background (from *Soil Survey Western Kenai Area, Alaska*, NRCS 2005).

Soils in the Western Kenai Peninsula soil survey area were mapped at a scale of 1:25,000. Each type of soil map unit was given a number, which corresponds to a soil series. Soil map units and corresponding series identified and mapped in the grazing lease area are listed in Table 7-1. The sum of acres mapped in the grazing lease area equals 15,251.8 acres.

Soil map unit delineations: A soil map unit delineation represents an area dominated by one or more major kinds of soil. A map unit is identified and named according to the taxonomic classification of the dominant soil. Areas of a single taxonomic soil class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor "components" that belong to taxonomic classes other than those of the major soils. Map units that consist of one major component are called ***consociations***. "Beluga silt loam, 0 to 4 percent slopes" is an example.

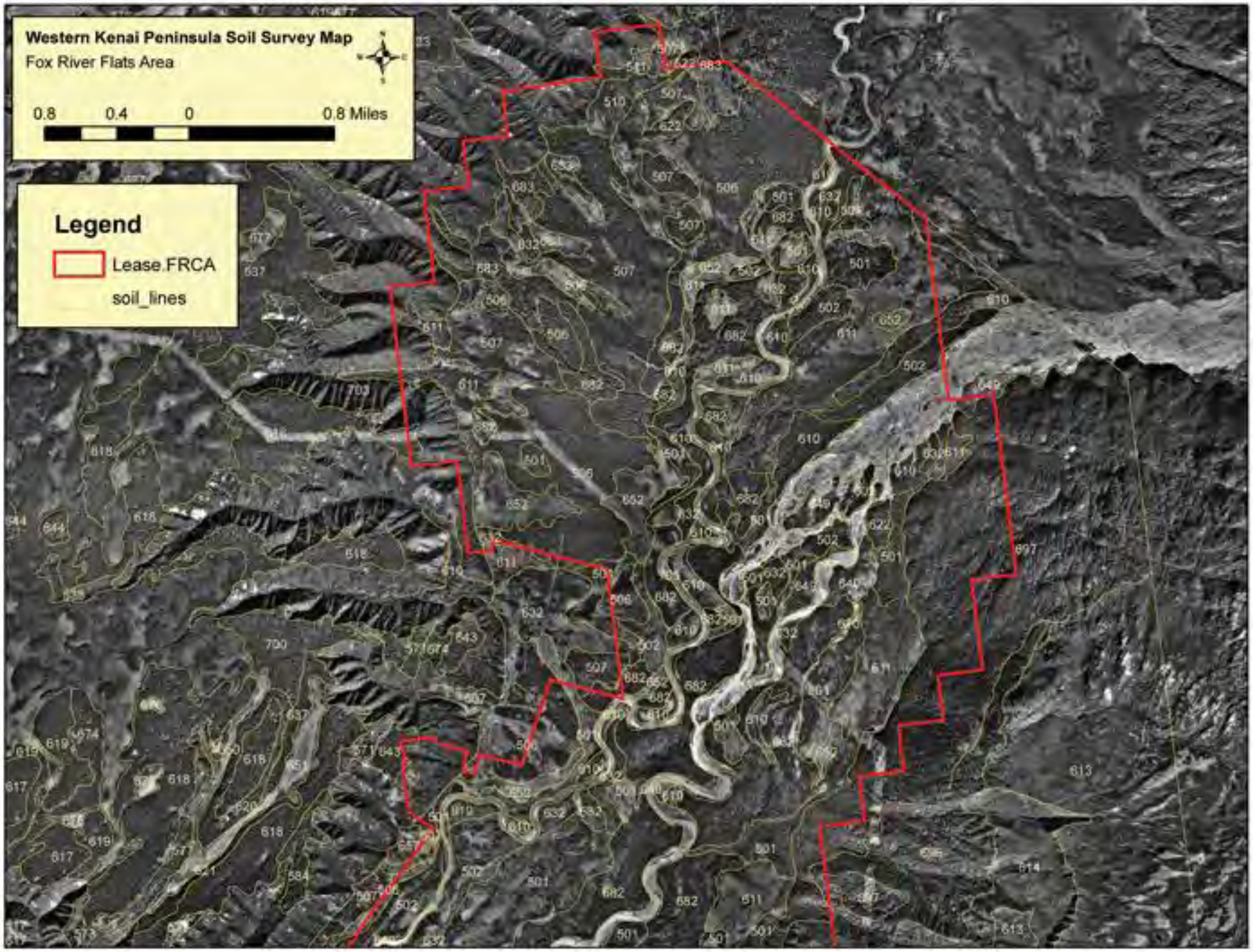
Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups. A ***complex*** consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. "Tutka-Portgraham complex, hilly to steep" is an example. An ***association*** is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. An ***undifferentiated group*** is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. ***Miscellaneous areas*** are areas that have little or no soil material and support little or no vegetation. Gravel pits is an example.

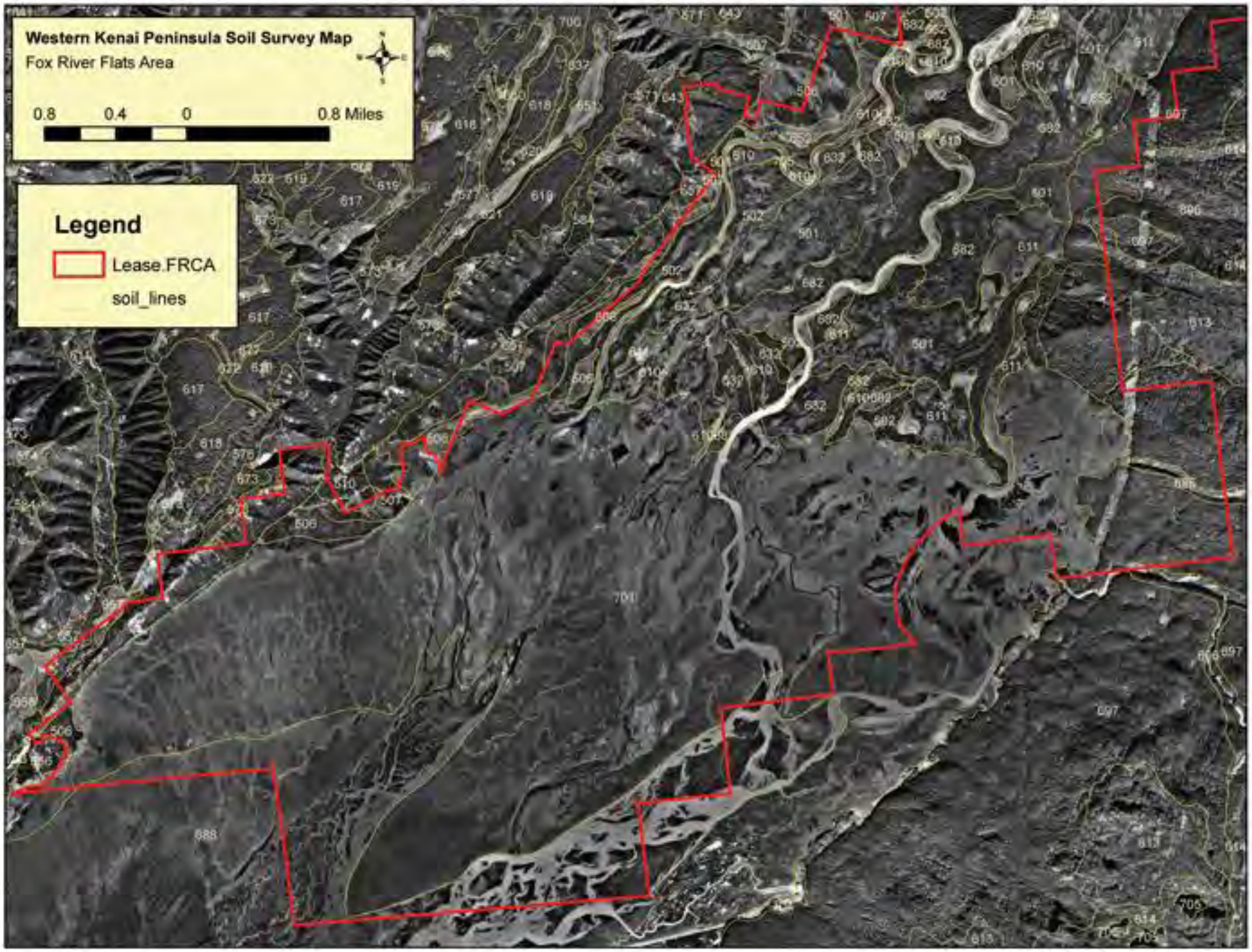
A **soil series** is group of soils having profiles that are almost alike, except for differences in texture of the surface layer. Series are given names like "Beluga silt loam." All the soils of a series have horizons that are similar in composition, thickness, and arrangement. Despite their basic similarities, soils within a given series can differ somewhat in slope, stoniness, surface texture, or other characteristics that may affect their use. Based on such differences, soil series are subdivided into soil "phases." Slope, in particular, is used in distinguishing different soil phases, such as Kachemak silt loam, nearly level, and Kachemak silt loam, strongly sloping. Soils within a single series and phase have similar suitabilities and limitations for particular land uses. Table 7-1 lists soil series and phases in the Fox River Flats grazing lease area. Map 7-5 shows soils mapped in the grazing lease area.

Table 7-1. Soil map units in the Fox River Flats grazing lease area, with acres and percent of lease area.

Soil map unit symbol and soil phases		Acres	%	Soil map unit symbol and soil phases		Acres	%
501	Aquic Cryofluvents, 0 to 2 percent slopes	1120.4	7%	**649**	Riverwash	115.0	1%
502	Aquic Cryofluvents, shallow, 0 to 2 percent slopes	438.7	3%	**652**	Slikok peat, 0 to 4 percent slopes	245.8	2%
506	Beluga silt loam, 0 to 4 percent slopes	1094.5	7%	**653**	Slikok peat, 4 to 8 percent slopes	62.1	0%
507	Beluga silt loam, 4 to 8 percent slopes	734.8	5%	**656**	Smokey Bay silt loam, 0 to 4 percent slopes	4.3	0%
510	Beluga-Smokey Bay complex, 4 to 8 percent slopes	71.9	0%	**657**	Smokey Bay silt loam, 8 to 15 percent slopes	13.8	0%
511	Beluga-Smokey Bay complex, 8 to 15 percent slopes	16.5	0%	**673**	Spenard peat, 0 to 4 percent slopes	0	0%
571	Island silt loam, 15 to 45 percent slopes	0	0%	**682**	Susitna silt loam, 0 to 2 percent slopes	1311.6	9%
573	Kachemak silt loam, 4 to 8 percent slopes	3.3	0%	**683**	Susitna silt loam, 4 to 8 percent slopes	162.9	1%
610	Kidazqeni silt loam, 0 to 2 percent slopes	680.2	4%	**688**	Tidal flats	351.9	2%
611	Killey and Moose River soils, 0 to 2 percent slopes	975	6%	**696**	Tutka-Kasitsna-Rock outcrop complex, very steep	175.5	1%
618	Mutnala silt loam, 4 to 8 percent slopes	6.0	0%	**697**	Tutka-Portgraham complex, hilly to steep	751.5	5%
622	Mutnala silt loam, 45 to 60 percent slopes	40.8	0%	**701**	Typic Cryaquents, 0 to 2 percent slopes	5094.5	33%
632	Niklason very fine sandy loam, 0 to 2 percent slopes	319	2%	**703**	Typic Cryorthents, 100 to 150 percent slopes	755.6	5%
643	Redoubt silt loam, 0 to 4 percent slopes	16.2	0%	**705**	Water, fresh	690.0	5%
Map unit acres and percent of area (per column)		5517.3	34%			9734.5	64%
Sum of map unit acres = 15,251.8 (100% of area).							

Map 7-5a. Soils mapped in the Fox River Flats grazing lease area, north section




Western Kenai Peninsula Soil Survey Map
Fox River Flats Area
0.8 0.4 0 0.8 Miles
Legend
Lease.FRCA
soil_lines

Soil properties (from *Soil Survey of Western Kenai Peninsula Area, Alaska*): Data relating to soil properties are collected during the course of the soil survey. Soil properties are ascertained by field examination of the soils and by laboratory index testing of some benchmark soils. During the survey, many shallow borings are made and examined to identify and classify the soils and to delineate them on the soil maps. Samples are taken from some typical profiles and tested in the laboratory to determine characteristics. Estimates of soil properties and soil features are based on field examinations, on laboratory tests of samples from the survey area, on laboratory tests of samples of similar soils in nearby areas, and on knowledge of the survey area. Tests verify field observations and properties that cannot be estimated accurately by field observation; they also help to characterize key soils.

Estimates of soil properties and features are shown in tables in the soil survey. These tables include physical and chemical properties and pertinent soil and water features. The kinds of soil properties ascertained for soils in the Western Kenai Peninsula soil survey area, including the Fox River Flats, are shown in Table 7-2. For more information about each of these, see the *Soil Survey of Western Kenai Peninsula Area, Alaska*. Alaskan soil survey manuscripts are available at http://soils.usda.gov/survey/online_surveys/alaska/. Section 7-1 provides instructions for using the soil survey online.

Table 7-2. Soil properties and features ascertained for soils in the Western Kenai Peninsula soil survey area, including the Fox River Flats grazing lease area (NRCS 2005).

Depth to the upper and lower boundaries of each layer is indicated.
Texture is given in the standard terms used by the USDA. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. Loam, for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. An appropriate modifier is added (for example, gravelly) if the content of particles coarser than sand is 15 percent or more. Textural terms are defined in the Glossary of the Western Kenai Peninsula soil survey.
Particle size is the effective diameter of a soil particle as measured by sedimentation, sieving, or micrometric methods. Particle sizes are expressed as classes with specific effective diameter class limits. The broad classes are sand, silt, and clay, ranging from the larger to the smaller. The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification. The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, permeability, plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earthmoving operations.
Classification of the soils is determined according to the Unified soil classification system (ASTM 2001) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO 2000).
Liquid limit and plasticity index (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination.
Rock fragments larger than 10 in (250 mm) in diameter and 3 to 10 in (75 to 250 mm) in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages are estimates determined mainly by converting volume percentage in the field to weight percentage.
Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 in (75 mm) in diameter based on ovendry weight.
Moist bulk density is the weight of soil (ovendry) per unit volume. Volume is measured when the soil is at field moisture capacity, that is, the moisture content at 1/3- or 1/10-bar (33kPa or 10kPa) moisture tension. Weight is determined after the soil is dried at 105 degrees C. In the soil survey table, the estimated moist bulk density of each soil horizon is expressed in grams per cubic centimeter of soil material that is less than 2 mm in diameter. Bulk density data are used to compute shrink-swell potential, available water capacity, total pore space, and other soil properties. The moist bulk density of a soil indicates the pore space available for water and roots. Depending on soil texture, a bulk density of more than 1.4 can restrict water storage and root penetration. Moist bulk density is influenced by texture, kind of clay, content of organic matter, and soil structure.
Permeability (Ksat) refers to the ability of a soil to transmit water or air. The term "permeability," as used in soil surveys, indicates saturated hydraulic conductivity (Ksat). The estimates in the soil survey table indicate the rate of water movement, in inches per hour, when the soil is saturated. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Permeability is considered in the design of soil drainage systems and septic tank absorption fields.
Available water capacity refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in inches of water per inch of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. Available water capacity is not an estimate of the quantity of water actually available to plants at any given time.

Linear extensibility refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. It is an expression of the volume change between the water content of the clod at 1/3- or 1/10-bar tension (33kPa or 10kPa tension) and oven dryness. The volume change is reported in the soil survey table as percent change for the whole soil. Volume change is influenced by amount and type of clay minerals in the soil. Linear extensibility is used to determine the shrink-swell potential of soils. The shrink-swell potential is low if the soil has a linear extensibility of less than 3 percent; moderate if 3 to 6 percent; high if 6 to 9 percent; and very high if more than 9 percent. If the linear extensibility is more than 3, shrinking and swelling can cause damage to buildings, roads, and other structures and to plant roots. Special design commonly is needed.
Organic matter is the plant and animal residue in the soil at various stages of decomposition. The estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 mm in diameter. The content of organic matter in a soil can be maintained by returning crop residue to the soil. Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms.
Erosion factors are shown as the K factor (Kw and Kf) and the T factor. Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of several factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and permeability. Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water. Erosion factor Kw indicates erodibility of the whole soil. The estimates are modified by the presence of rock fragments. Erosion factor Kf indicates erodibility of the fine-earth fraction, or the material less than 2 mm in size. Erosion factor T is an estimate of the maximum average annual rate of soil erosion by wind or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.
Wind erodibility groups are made up of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. Soils are grouped according to amount of stable aggregates more than 0.84 mm in size. Soils containing rock fragments can occur in any group. **Wind erodibility index** is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.
Cation-exchange capacity is the total amount of extractable bases that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. Soils having a low cation-exchange capacity hold fewer cations and may require more frequent applications of fertilizer than soils having a high cation-exchange capacity. The ability to retain cations reduces the hazard of ground-water pollution. **Effective cation-exchange capacity** refers to the sum of extractable bases plus aluminum expressed in terms of milliequivalents per 100 grams of soil. It is determined for soils that have pH of less than 5.5.
Soil reaction is a measure of acidity or alkalinity. The pH of each soil horizon is based on many field tests. For many soils, values have been verified by laboratory analyses. Soil reaction is important in selecting crops and other plants, in evaluating soil amendments for fertility and stabilization, and in determining risk of corrosion.
Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.
Wet soil refers to a saturated zone in the soil. The soil survey table indicates, by month, depth to the top (upper limit) and base (lower limit) of the saturated zone in most years. Estimates of the upper and lower limits are based mainly on observations of the water table at selected sites and on evidence of a saturated zone, namely grayish colors or mottles (redoximorphic features) in the soil. A saturated zone that lasts for less than a month is not considered a water table. Under water table kind, an apparent water table is one that generally corresponds to the regional ground water level.
A perched water table is one that is above an impermeable layer in the soil. The basis for determining that a water table is perched may be general knowledge of the area. The water table is proven to be perched if the water level in a borehole is observed to fall when the borehole is extended through the impermeable layer.
Ponding is standing water in a closed depression. Unless a drainage system is installed, the water is removed only by percolation, transpiration, or evaporation. The soil survey table indicates surface water depth and the duration and frequency of ponding.
Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding. Duration and frequency are estimated. The information is based on evidence in the soil profile, namely thin strata of gravel, sand, silt, or clay deposited by floodwater; irregular decrease in organic matter content with increasing depth; and little or no horizon development. Also considered are local information about extent and levels of flooding and relation of each soil on the landscape to historic floods.
A restrictive layer is a nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impedes movement of water and air through the soil or that restricts roots or otherwise provides an unfavorable root environment. Examples are bedrock, cemented layers, dense layers, and frozen layers. The soil survey table indicates the hardness and thickness of the restrictive layer, both of which significantly affect the ease of excavation. Depth to top is the vertical distance from the soil surface to the upper boundary of the restrictive layer.
Subsidence is the settlement of organic soils or of saturated mineral soils of very low density. Subsidence generally results from either desiccation and shrinkage or oxidation of organic material, or both, following drainage. Subsidence takes place gradually, usually over a period of several years. The soil survey table shows the expected initial subsidence, which usually is a result of drainage, and total subsidence, which results from a combination of factors.
Potential for frost action is the likelihood of upward or lateral expansion of the soil caused by the formation of segregated ice lenses (frost heave) and the subsequent collapse of the soil and loss of strength on thawing. Frost action occurs when moisture moves into the freezing

zone of the soil. Temperature, texture, density, permeability, content of organic matter, and depth to water table are the most important factors considered in evaluating the potential for frost action. It is assumed that the soil is not insulated by vegetation or snow and is not artificially drained. Silty and highly structured, clayey soils that have a high water table in winter are the most susceptible to frost action. Well drained, very gravelly, or very sandy soils are the least susceptible. Frost heave and low soil strength during thawing cause damage to pavements and other rigid structures.
Risk of corrosion pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel or concrete. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil.

Hydric soils: Some soils are associated with wetlands and, because of their saturation, present particular management issues. Hydric soils are defined as soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. These soils support the growth and reproduction of hydrophytic vegetation. (Wetlands are discussed in Section 7.3.4.)

Soils that are wet enough for long enough to be considered hydric exhibit certain properties that can be easily observed in the field. Visible properties—or indicators—used to make onsite determinations of hydric soils for the Western Kenai Peninsula soil survey area are specified in *Field Indicators of Hydric Soils in the United States*. A soil can be identified as a hydric soil if at least one of the approved indicators is present. Hydric soils are identified by examining and describing the soil to a depth of about 20 inches (50 centimeters). This depth may be greater if determining an appropriate indicator requires.

Those soils that meet the definition of hydric soils and, in addition, have at least one of the hydric soil indicators, are listed in Table 23 in the Western Kenai Soil Survey. Some map units consist almost entirely of hydric soils, other units consist primarily or entirely of non-hydric soils. Hydric soils may occur as minor inclusions even in map units listed without any hydric soils. Table 23 also lists the local landform on which each soil occurs, the hydric criteria code, and whether or not each soil meets the saturation, flooding, or ponding criteria for hydric soils.

Soils in the grazing lease area that include a hydric soil component of over 10% are: [add soil map unit names]. Those with a hydric component of between 1 and 10% are: 501, 502, . The rest of the soils mapped in the grazing lease area are listed as non-hyrdric. Map 7-14, under Wetlands, below, shows soil map units in terms of their percentage of hydric components.

Interpretive Ratings: A soil survey includes many interpretive tables. These rate the soils in the survey area for various uses, from urban to rural, from engineering to agronomic to forestry, from building sites to septic systems to trails. Many of the interpretive tables identify the limitations inherent in a soil that will affect specified uses and also indicate the severity of those limitations. Other tables indicate the suitability of the soils as source materials of gravel, sand, topsoil, and roadfill. Ratings in interpretive tables can be either narrative, numerical, or both.

Because map unit boundaries are digitized, maps can be developed showing where soils with particular properties occur, as well as maps showing interpretations of various soils for different purposes and land uses. Maps 7-6a and 7-6b provide two examples prepared for this CRMP by NRCS GIS staff in Palmer (as were many of the NRCS maps in this section.) Map 7-6a shows slope classes derived from soil map units; Map 7-6b shows depth-to-water table, also derived from soil map units. (See also maps in Section 7.3.4.)

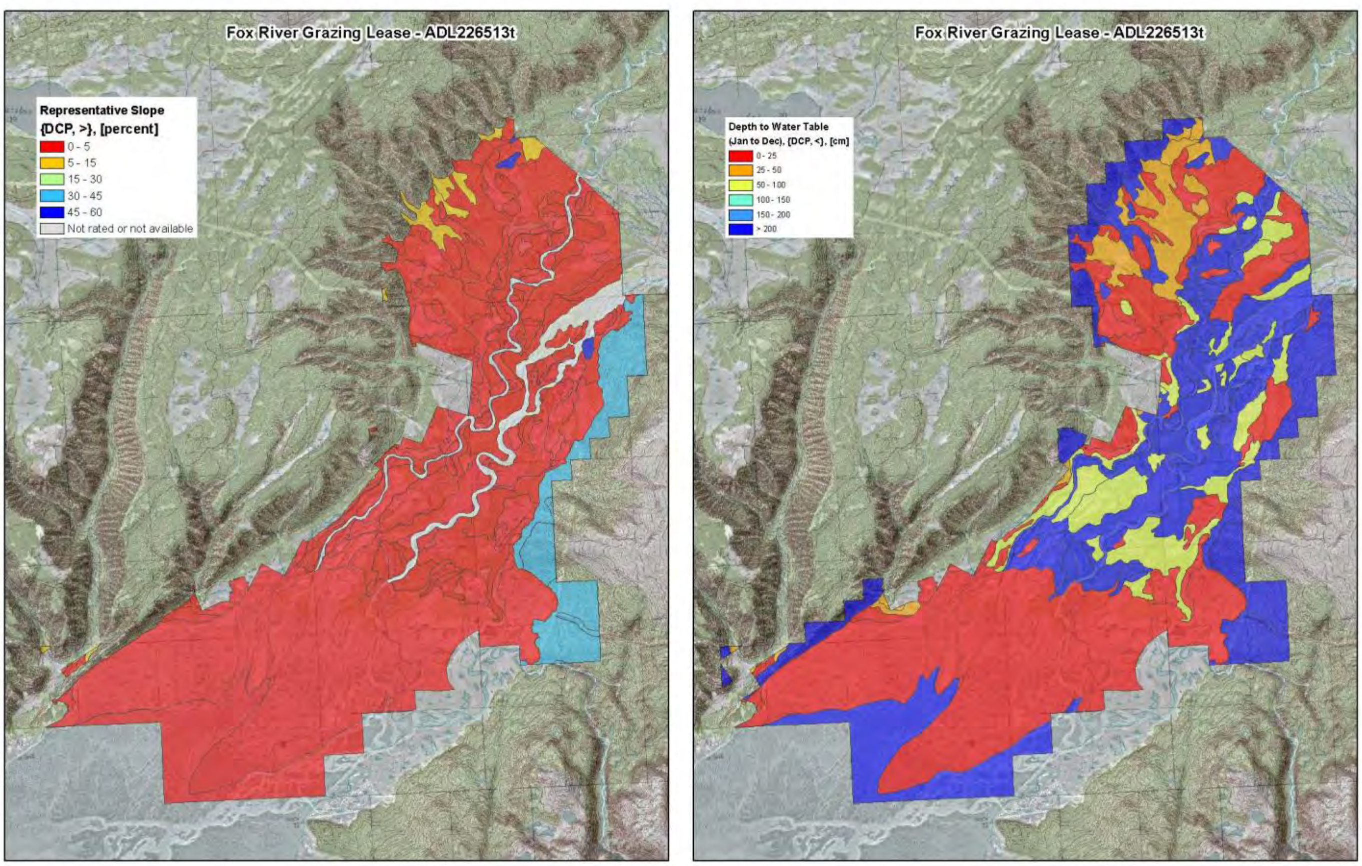
By reviewing what kinds of information have been collected about or ascertained for soils in the survey area (i.e., from Table 7-2), land managers of Fox River Flats resources can develop maps useful to them, for example, maps of trail routes on suitable soils, areas with soils highly susceptible to erosion, areas with particular fertility characteristics, etc. Additional such maps are included below as appropriate.

7.3.2. WATER

Water in the grazing lease area occurs as flowing (lotic) surface water—primarily flows in Fox River and Sheep Creek drainages; static (lentic) surface water—found in ponds, lakes, and wetlands; soil moisture; groundwater; and tidal flows. Wetlands are discussed in Section 7.3.4. Groundwater, soil moisture, rivers and streams, tidal water, and glacial meltwater are discussed in this section.

Groundwater: Groundwater is natural water that flows within aquifers (underground beds or layers of permeable rock, sediment, or soil that yield water). The groundwater table is the underground surface below which the ground is wholly saturated with water. Groundwater is replenished from surface water (rainfall, snowmelt, etc.) and eventually flows naturally to the ground surface, discharging into streams, ponds, lakes, wetlands, seeps, and other areas of surface wetness. Groundwater is often an important determinant of streamflows, particularly during dry periods with little precipitation. Unlike soil moisture (see below), groundwater is not tenaciously bound within soil pores and can, therefore, move in response to gravity or pressure. The water table is physically determined by the level to which groundwater flows into a porous pipe having a diameter large enough so that capillary forces do not affect the water level in the pipe. Groundwater movement, as a rule of thumb, generally parallels surface flows, but moves much more slowly.

Map 7-6a (left). Slope classes; Map 7-6b (right). Depth to water table, both in grazing lease area (NRCS).



Shallow groundwater (within about 6½ ft of the surface) was mapped during the Western Kenai Peninsula soil survey. Map 7-6b shows depth to water table as mapped in cm. (Depth-to-water table classes converted to inches are: 0-25 cm = 0-9.8 in, 25-50 cm = 9.8-19.7 in, 50-100 cm = 19.7-39.4 in, 100-150 cm = 39.4-59.1 in, 150-200 cm = 59.1-78.7 in, >200 cm = >78.7 in.) Groundwater quality has not been assessed in the grazing lease area, but would be largely a function of the chemistry of the rocks and sediments through which groundwater flows.

Soil moisture: Soil moisture is water that is held in voids or pores within the soil. Pores within a soil matrix are typically of various sizes. Water held as a film around soil particles and in the tiny spaces between particles is called capillary water. Surface tension is the adhesive force that holds capillary water in the soil. Soil pores act like capillary tubes. The diameter of the soil pore defines the capillary rise of the water column: the smaller the soil pore, the greater the capillary rise of water within that pore.

The capillary fringe is the zone of soil immediately above the water table. Like a sponge, soil pores in the capillary fringe "suck" water up from the underlying water table through capillary action. At the base of the capillary fringe—at the water table—most if not all of the soil pores are completely filled with water. At the top of the capillary fringe, only the smallest pores are filled with water. As a result, water content of the capillary fringe decreases with increasing distance above the water table.

Soils can be completely saturated with water while, at the same time, the water table is some distance below the point of complete saturation. This can happen during periods of heavy rainfall, when movement of water into and through the soil in response to gravity is slower than the rainfall rate. When this happens, precipitation begins to run off the soil surface, and this surface runoff can lead to flooding and/or erosion. Infiltration and permeability are measures of how quickly water moves into and through the soil. Infiltration rate is the rate at which water penetrates the surface of the soil at any given instant, usually expressed in inches per hour (see " hydrologic soil groups" below). The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied at the surface. Permeability is the quality of the soil that enables water or air to move downward through the soil profile. The rate at which a saturated soil transmits water is accepted as a measure of this quality. Permeability is measured in inches per hour. Permeability rates for soils in the Fox River Flats grazing lease are shown in Table 10 in the Western Kenai Peninsula soil survey. (Percolation is a related term, and means the movement of water through the soil.)

Hydrologic soil groups categorize soils according to their runoff potential. Soil properties that influence this potential (when soils are not frozen) are depth to a seasonal high water table, infiltration rate and permeability after prolonged wetting, and depth to a very slowly permeable layer. Slope and kind of plant cover are not considered but are separate factors in predicting runoff. Table 12 in the Western Kenai Peninsula Soil Survey shows the hydrologic group for each mapped soil series in the Fox River Flats grazing lease. The four hydrologic soil groups are:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes downward movement of water or of soils having moderately fine texture or fine texture. These soils have a slow rate of water transmission.
Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

The capacity of soils to hold water available for use by most plants is called "available water capacity" (available moisture capacity). It is commonly defined as the difference between the amount of soil water at field moisture capacity[1] and the amount at a plant's wilting point. It is commonly expressed as inches of water per inch of soil, either in a 60-inch profile or to a limiting layer. Table 10 of the *Soil Survey of Western Kenai Peninsula Area* shows available water capacity for soils in the Fox River Flats grazing lease area.

Rivers and streams: When considering a river or stream, a foundational piece of information is the boundary of the river's or stream's watershed—the area that contributes flows, physical matter, and plants and organisms to the water body in question. Map 7-7 outlines both the Fox River and Sheep Creek watersheds (or river basins, as they are also called), although the upper glacial reaches of the Sheep Creek watershed are not shown. The Fox River watershed is the largest of the two.

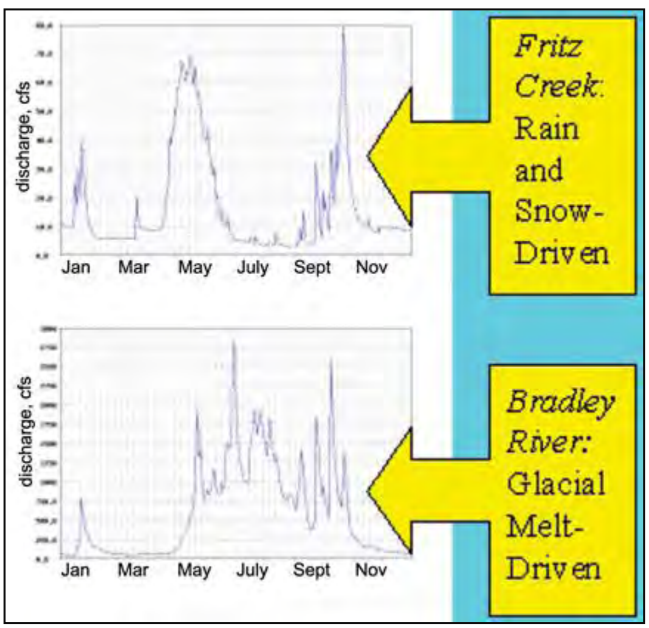
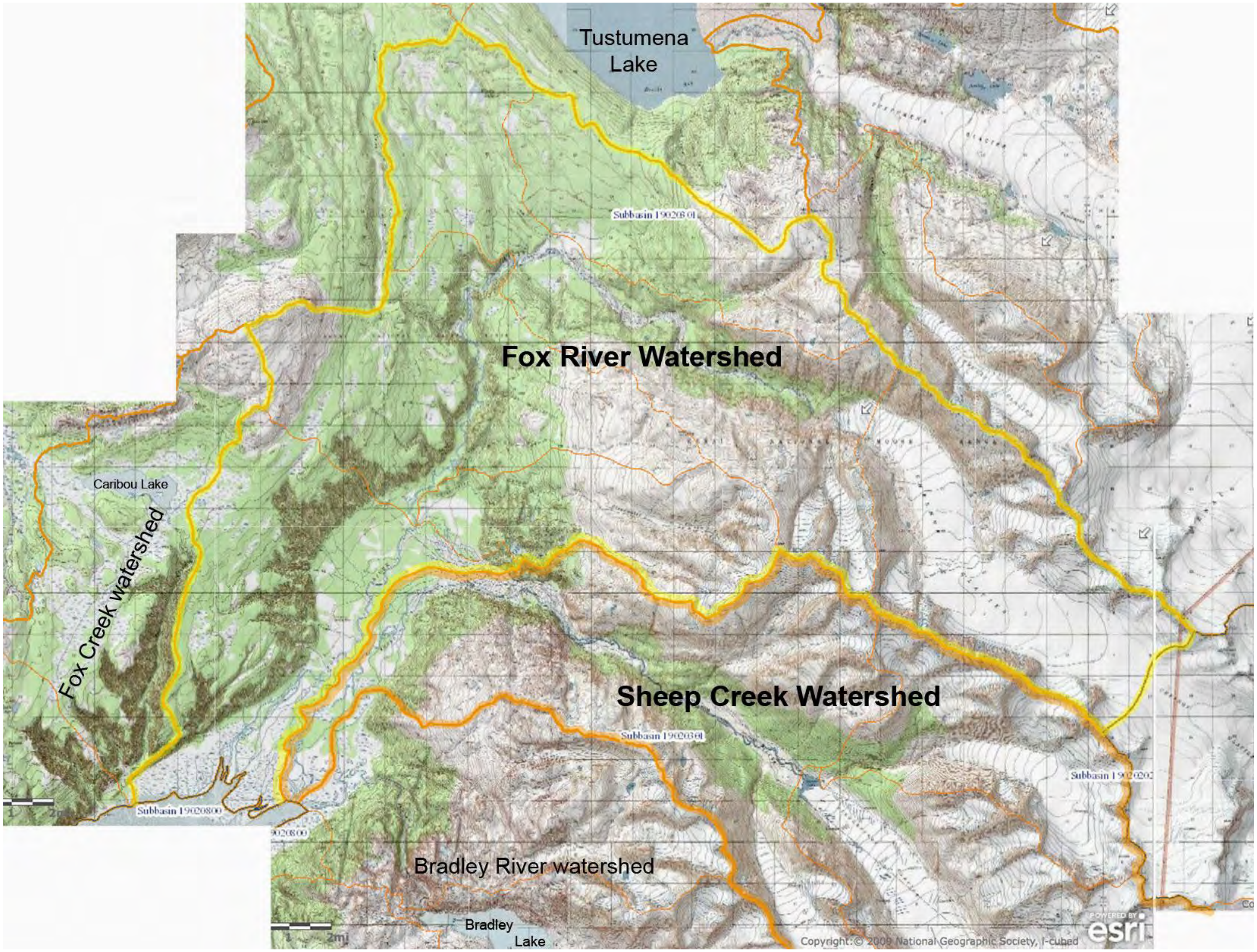


Figure 7-1. Hydrographs comparing seasonal flow patterns for precipitation-based streams and glacial meltwater streams (KBRR).

As noted above (Section 7-2), the Fox River Flats grazing lease area lies on the divide between two physiographic regions with differing geomorphological, geologic, climatic, vegetative, and soil characteristics. Melting snow and rain drive hydrologic systems flowing into the valley from the north or west, such as Fox Creek. On the southern and eastern side, snowmelt in early summer and glacial melt in mid-to-late summer drive hydrology, although heavy rainfall can also be significant. Because they are glacier-fed, Fox River, Sheep Creek (and Bradley River) have their highest flows during summer. Fox River, however, is also fed by numerous freshwater tributaries from the west, and so can have high flows in spring. In glacier-fed streams, peak flows correspond with warm summer temperatures. These patterns are illustrated in hydrographs shown in Figure 7-1. A hydrograph plots variations in stream discharge against time; discharge is the volume of water flowing past a location per unit time (usually expressed in cubic feet per second, or cfs).

[1] Field moisture capacity is the moisture content of a soil, expressed as a percentage of the ovendry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called *normal field capacity, normal moisture capacity, or capillary capacity* (from *Soil Survey of the Western Kenai Peninsula Area, Alaska*).

Map 7-7. Fox River and Sheep Creek watersheds (developed from arcgis.com.).



The volume of flow from glacial rivers can be many times greater than flows from non-glacial rivers. Summertime glacial melting brings a huge amount of freshwater into Kachemak Bay. This glacial meltwater has higher turbidities than do flows from snowmelt or rainfall. Fine sediments (clay and silt) suspended in the water column give glacial rivers their color and opacity.

Stream gauging stations nearest the Fox River Flats are on the Bradley River, which is also a glacial meltwater-fed stream. The USGS maintains four gauging stations on Bradley River:

- 15239050 MF Bradley R NR Homer (the farthest east of the four);
- 15239001 Bradley R BL DAM NR Homer (at the west end of Bradley Lake);
- 15239060 MF Bradley R BL NF Bradley R NR Homer;
- 15239070 Bradley R NR Tidewater NR Homer.

The locations of these four stations are shown on Map 7-2. USGS Waterwatch reports discharges at these stations in real time. (Go to: http://waterwatch.usgs.gov/index.php?m=real&w=gmap&regions=ak, click on the "Create Zoom Box" button in the lower left corner of the screen, draw a zoom box around the Fox River Flats/Bradley Lake area, and after the map zooms in, move the cursor over one of the gauging station dots to see current discharge there).

Hydrographs from Fox River and Sheep Creek can be expected to show patterns of high and low flows similar to Bradley River. If discharges in Fox River and/or Sheep Creek were correlated with those in Bradley River, real-time data from Bradley River gauging stations could be used as "proxies" for real-time flows in Fox River and Sheep Creek. This would allow individuals planning to cross the rivers in the flats to track flow heights and time their crossings accordingly.

Tidal water: Tidal water flows across intertidal areas of the Fox River Flats twice daily with the incoming tide. Because of the low slopes on the flats (see Map 7-6a) and the extreme tidal range of Kachemak Bay (and Cook Inlet) tides, large expanses of the flats are inundated during high tides and exposed during low tides. Extreme tides occur twice monthly, with the annual highest high tides exceeding plus 23 ft and the lowest low tides below minus 5 ft.

The salinity in Kachemak Bay varies by proximity to stream mouths and by time of year in relation to glacial melt. Salinities can approach zero near the mouths of freshwater streams. Surface salinity also decreases with increased rainfall and may be as low as 15 ppt[2] locally during periods of highest rainfall (generally in October). Salinities can be influenced by a number of other factors, including the force of the tidal surge, air and water temperatures (including temperature effects on glacial melting rates), and wind—which whips up waves that mix salty and fresh water. Salinities throughout Kachemak Bay average approximately 30 to 32 parts per thousand[3]. Figure 7-2 shows a hypothetical salinity gradient where a freshwater river meets a marine bay.

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[2] Absolute (or ideal) salinity is the mass fraction of salts in seawater. In practical terms, salinity is expressed as PSU (practical salinity units), which are based on water temperature and conductivity measurements. Salinity was formerly expressed in parts per thousand (ppt). For oceanic seawater, ppt and PSU are very close (www.ozcoasts.org.au/indicators/salinity.jsp).

[3] Mean salinities at six sites measured by ADF&G in 2001 during a study of juvenile groundfish habitat in Kachemak Bay during late summer, were: 30.51, 31.29, 31.56, 31.34, 31.11, 31.50 ppt (www.adfg.state.ak.us/pubs/afrb/vol8_n1/aboov8n1.pdf).

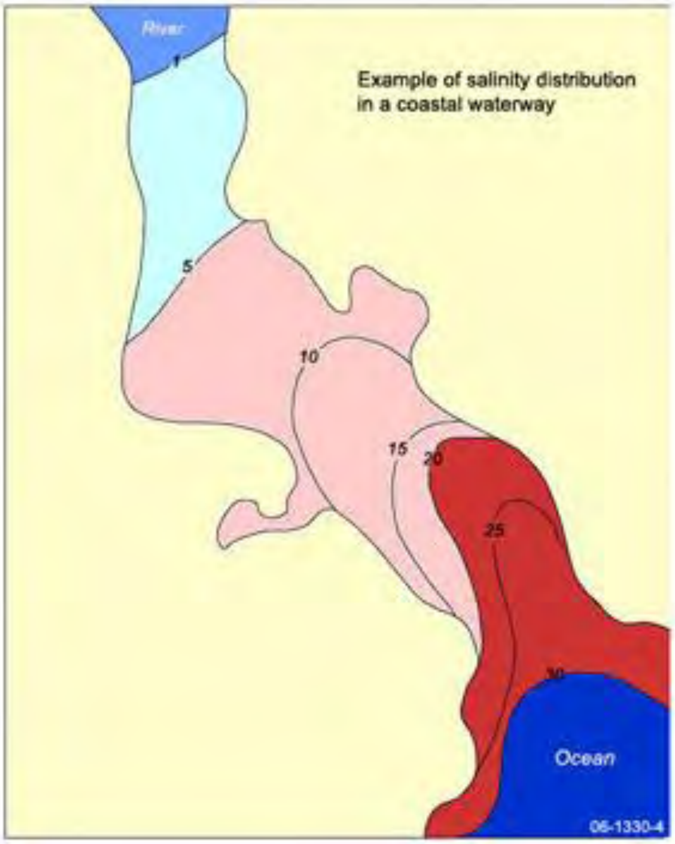


Figure 7-2. Plan view of the salinity distribution of a hypothetical estuary in which salinity increases away from the freshwater source (from www.ozcoasts.org.au/indicators/salinity.jsp).

Salinity is important because of how it affects invertebrate organisms that support estuarine food webs, which in turn support rearing salmon, migrating shorebirds, and other valued fish and wildlife. Daily, monthly, and seasonal changes in salinity in the Fox River Flats should be considered when attempting to understand patterns of fish and wildlife usage of the area. (Salinity effects on invertebrates are discussed briefly in Section 7.3.5 under Intertidal Invertebrates.) The bottom line is that, as a general rule, widely varying salinity regimes tend to select for a low-abundance and low-diversity suite of species, which are adapted to a broad range of ionic concentrations (e.g., "euryhaline" species).

Circulation patterns in Kachemak Bay determine how outflowing freshwater and inflowing saltwater mix. These patterns can be locally complex. As a general rule, however, inflowing saltwater—driven by tidal ranges of up to 28 ft—tends to hug the southern shore of Kachemak Bay, while waters flowing out of the bay, including discharges from Fox River and Sheep Creek, flow along the northwest shore of the inner bay. As inflowing saltwater moves up the bay, freshwater runoff from surrounding ice fields and watersheds dilutes salinities and increases sediment loads. The inflowing water, therefore, initially supports a marine system, while the outflowing water on the north side is more estuarine. KBRR instruments capture this difference along north and south shores (see: www.habitat.adfg.state.ak.us/index.cfm/FA/research.SWMP).

Glacial meltwater: As noted above, glacial meltwater contributes a large percentage of the volume of Fox River and Sheep Creek flows. As a result, glacial recession is an important factor that can alter the region's hydrology over time. Glaciers sequester vast amounts of water, and as they melt, this freshwater drains into the bay, changing salinity, turbidity, and possibly circulation patterns.

Glaciers in the Harding Icefield, which feeds Fox River and Sheep Creek (see Map 7-2) appear to be receding and thinning. By comparing recent (1998) data showing glacier elevations with glacier elevations as determined from 1950s USGS maps (and the photographs from which those maps were made), Echelmeyer and Adalgeirsdottir determined that the Harding Icefield had lost about 70 ft in elevation (that is, in the thickness of its glaciers) over the 48 years between 1950 and 1998 (www.gi.alaska.edu/ScienceForum/ASF13/1385.html). (Some of this reduction in elevation may have been caused by subsidence due to the 1964 earthquake.)

7.3.3. Air

There is little ongoing air quality monitoring in the Kenai Peninsula Borough, but air quality is generally considered to be good. Most of the land in the borough is classified as a Class II airshed by the Alaska Department of Environmental Conservation (DEC). Class II airsheds are generally pollution free. Currently, the only sources of negative impacts to local air quality consist of smoke from seasonal wildfires and emissions from internal combustion engines. Effects from both of these sources are infrequent and transitory. Temperature inversions, which could trap pollutants, are uncommon in this area.

Noise pollution is another component of the "air" resource. Except for the occasional plane or helicopter flying overhead or vehicle crossing the flats, the only sounds heard in the grazing lease area are those of nature, particularly the sounds of the wind and—near shore—the lapping of the tide. The profound wildness of the "soundtrack" of the flats is a quality that is easy to miss, but because sounds carry particularly well across water and mudflats, this quality can be quickly degraded by noise from engines and other disturbances. Noise pollution will increase as use of ATVs and other motorized vehicles increases in the grazing lease area.

7.3.4. Plant Communities, Ecological Sites, and Wetlands

NRCS categorizes natural plant communities in terms of ecological sites (ecosites). Plant communities dominated by trees are divided into forestland ecosites; communities dominated by shrubs and/or herbaceous species are divided into rangeland ecosites. Ecosites are correlated with soil map units. As a result, soil maps from the Western Kenai Peninsula soil survey can be used to develop maps of rangeland and forestland plant communities (Maps 7-9 and 7-10), as well as maps of rangeland plant productivity (Map 7-8). These plant community maps were developed for this CRMP by NRCS GIS staff in Palmer. The following discussion of ecological sites is largely excerpted from the *Soil Survey of Western Kenai Peninsula, Area, Alaska* and from introductory ecosite information found online at Web Soil Survey (see Section 7.1).

Ecological sites (ecosites): An ecological site, or ecosite, is an area where ecological conditions are sufficiently uniform to produce a distinct natural plant community (sometimes called the "hypothetical climax plant community" or HCPC). An ecological site is the product of all environmental factors responsible for its development, including climate, landform, hydrology, soils, vegetation, and other ecological properties and processes (such as nutrient cycling, vegetative succession, and productivity). An ecosite is typified by an association of plant species that differs in kind and/or proportion, or in total production, from associations on other ecological sites.

Ecological site classification is not oriented to any particular type of land or land use and is applicable to forestlands and rangelands, wetlands and uplands. Ecosites are identified as either forestland or rangeland depending on whether the potential natural plant community (PNC) is dominated by trees or by grasslike plants. Rangeland is land on which the

> *An ecological site is an area where environmental conditions (climate, soil, landform, etc.) are sufficiently uniform to produce a distinct natural plant community.*
>
> *An ecological site classification should be viewed as a landscape model… On the ground, the characteristics and properties within and between ecological sites are complex and variable, and usually overlap to some degree. Ecological sites provide a useful framework for correlating and compiling data and interpretations on multiple resources and landscape processes.*

potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing. Rangeland ecosites include natural grasslands, savannas, many wetlands, tundras, and areas that support certain forb and shrub communities. Forestland ecosites are dominated by tree species.

As suggested above, the primary emphasis of ecological site classification is usually the vegetation on a site. Vegetation is considered an indicator of the integrated factors of the environment. In addition, plant productivity, the response of the vegetation to various types of disturbances, and use and management of the vegetation are principal concerns of landowners and managers.

A secondary, but equally important, emphasis of ecosite classification is the relationships between landforms and soils. In general, landform/soil relationships across a landscape are fairly predictable. Natural disturbances caused by wildfire, wind, and flooding, to name a few, result in considerable variation in vegetation. In contrast, landforms and soils provide a more stable resource base by which ecological sites can be determined regardless of existing vegetative conditions. In addition, inferences based on landform and soil types can be made regarding site dynamics and stability, soil processes, and appropriate management systems.

While abrupt or distinct breaks between landforms, soils, and vegetation types occasionally do occur in nature, more often, such transitions are gradual and indistinct. In general, such transitions create edge zones or ecotones characterized by some conditions from each bordering area. This reflects the fact that influential environmental variables—such as precipitation, elevation, temperature and other climatic patterns, as well as micro-climatic variables—change gradually but in complex and interacting ways across the landscape. In response, on-the-ground characteristics and properties within and between ecological sites are complex and variable too, and usually overlap to some degree.

Furthermore, in some ecosystems the plant community is not predictable and is dominated by "opportunistic" plant species. For example, a peat bog can be dominated by several unique plant communities and site characteristics due to a natural, fluctuating water table, but peat bog functions remain the same. In this situation, ecological sites are grouped into an *ecological system*. Ecological sites within the ecological system function in similar ways but may support different plant communities. Landforms in which ecological systems rather than sites have been described include moraines, escarpments, and peat bogs. In the Fox River flats, "lower bench toe slopes" and "wetland complex" are ecological systems.

For the reasons mentioned above, ecological site classification should be viewed as a landscape model. Mapped boundaries between ecological sites are often approximate, and sometimes somewhat arbitrary. Nonetheless, ecological site classification provides a useful framework for correlating and compiling data and interpretations on multiple resources and landscape processes. Ecosite classification also provides a valuable framework for organizing, applying, and monitoring resource conservation systems for livestock grazing, forestry, wildlife habitat management, and other land uses.

Developing ecological sites based on soil-vegetation correlations: An ecological site classification is developed by grouping soils within known climatic zones based on similarities in landforms, soils, and vegetation characteristics and potentials. Soils that support similar vegetation, have similar productivity and ranges in physical characteristics, and whose known or expected ecological and management responses are similar, are grouped together into an ecological site. To achieve a high degree of correlation between the soils and vegetative potentials, soils usually are classified at the series or phase level, and occasionally the family level. At this level, an ecological site is correlated to a single potential natural plant community.

Tables 7-3 and 7-4 provide brief narrative descriptions of rangeland and forestland ecological sites (and ecological systems) in the Fox River Flats grazing lease area. Table 7-5 shows correlations between soil series and ecological sites for soils mapped in the grazing lease area. Ecosite categories described in these tables are shown on Maps 7-9 and 7-10.

Table 7-3. Brief descriptions of rangeland ecosites in the Fox River Flats grazing lease area.

Rangeland ecological sites	
Alpine ridges	Low growing dwarf shrubs dominate this alpine site, which is found on the tops of mountain ridges at elevations above 1,975 feet. Lichen communities make up a large part of this site's biomass; slopes are generally gentle, ranging from 0 to 10 percent.
Loamy slopes	This site is dominated by bluejoint reedgrass and fireweed and is found at elevations of 985 to 1,650 feet. Slopes range from 1 to 45 percent. With exposed soil and a nearby seed source, the site will support spruce trees as well.
Lower bench toe slopes	Located at low elevations (15 to 650 feet) east of Homer, this site has been manipulated by humans for many years. Homesteaders commonly burned this area to keep tree encroachment down for cultivating fields and grazing animals. Slopes are gentle, ranging from 1 to 20 percent, and the vegetation ranges from bluejoint reedgrass-dominated meadows to birch and spruce copses.
Ramensk's sedge	This herbaceous site is found on all aspects of nearly level tidal flats that are frequently inundated by tidewater. Ramensk's sedge is the dominant species, with a few other salt-tolerant forbs found in small amounts.
Shallow kettles	This unique site is found on all aspects in the form of meadows surrounded by forest. This site is primarily an herbaceous, diverse forb community, but is slowly being encroached upon by spruce trees. Slopes are generally level and range from 0 to 5 percent. Elevations range from 25 to 985 feet.
Wetland complex	Many different wetland plant communities can be found on this site, and differences are caused by varying factors including drainage, free water flow, and slight differences in elevation within the wetlands. Plant communities can vary from stunted black spruce forest to dwarf shrub to sedge-dominated fringes of open water. Slopes are most commonly nearly level, but can be gently sloping (0 to 5 percent).
Willow–grass (riparian)	This riparian site is dominated by Barclay's willow with an understory of bluejoint reedgrass. It occurs along small streams and large rivers on slopes from 1 to 20 percent and on all aspects. Elevations range from 15 to 1,300 feet.

Table 7-4. Brief narrative descriptions of forestland ecosites in the Fox River Flats grazing lease area

Forestland ecological sites
Betula papyrifera–Picea glauca/Alnus–Oplopanax horridus/Calamagrostis canadensis
The climax plant community on this site is composed of a white spruce and alder dominated community, located along streams and rivers in the low elevations of the Fox River Flats. When flooded, this site becomes dominated by balsam poplar with an understory of bluejoint reedgrass. This site occurs on all aspects on elevations up to 65 feet, and on nearly level slopes.
Picea glauca–Betula papyrifera/Calamagrostis canadensis–Equisetum arvense
This site is found on a wide range of elevations (from 0 to 1,975 feet) and on all aspects. The vegetation is either a spruce–birch forest found on elevations up to 1,065 feet, or a spruce–birch–willow community found at elevations above 1,065 feet. Slopes range from 0 to 45 percent.
Picea glauca–Betula papyrifera/Menziesia ferruginea/Gymnocarpium dryopteris
This site is found on a wide range of elevations (from 0 to 1,975 feet) and on all aspects. The vegetation is either a spruce–birch forest (found on elevations up to 1,066 feet) or a spruce–willow community (found at elevations above 1,066 feet). Slopes range from 0 to 45 percent.
Picea mariana/Empetrum nigrum–Betula nana
This forested site is found on wet soils and is dominated by black spruce with an understory of low shrubs that include crowberry and dwarf birch. Slopes are nearly level, ranging from 1 to 7 percent, with elevations ranging from 0 to 985 feet.
Picea × lutzi–Betula papyrifera/Gymnocarpium dryopteris–Rubus pedatus
This low elevation (15 to 985 feet) forested site is common south of Tustumena Lake and supports a mixed hardwood and conifer community with an understory of ferns and rusty menziesia on cooler microsites and five-leaf bramble on warmer microsites. Slopes are varied, ranging from 0 to 40 percent.
Picea × lutzi/Calamagrostis canadensis.
Bluejoint reedgrass is a dominant plant on this site. Undisturbed, the site will have an overstory of spruce, with early seral stages of birch. Elevations of this site range from 4 to 1,300 feet and slopes range from 1 to 10 percent. However, it is most commonly found at 165 feet on about a 3 percent slope
Picea × lutzi/Salix barclayi/Calamagrostis canadensis–Chamerion angustifolium

	This site is found south of Tustemena Lake and supports a Lutz spruce forest with a willow and bluejoint reedgrass understory. Elevations range from 130 to 1,150 feet, but the site is commonly found below 325 feet. Slopes are gentle, ranging from 0 to 30 percent.
Picea × lutzi/Salix barclayi–Empetrum nigrum/Equisetum arvense	
	This site is found at elevations from 825 to 1,300 feet in the hill slopes north of Homer. Slopes range from 1 to 35 percent and the vegetation is composed of a spruce forest with a willow and horsetail understory. When the spruce are first established after a disturbance, the understory may include bluejoint reedgrass and fireweed.

Table 7-5. Soil map units (series) and correlated ecological sites in the Fox River Flats grazing lease area.

Soil map unit symbol and soil series		Acres	Ecological site (ecosite) name	Ecosite type	Ecosite ID
501	Aquic Cryofluvents, shallow, 0 to 2 percent slopes	1120.4	*Betula papyrifera-Picea glauca/Alnus-Oplopanax horridus/Calamagrostis canadensis*	Forestland	F170XY004AK
502	Aquic Cryofluvents	438.7	None assigned		
506, 507	Beluga silt loam,	1829.3	Lower Bench Toe Slopes	Rangeland	R170XD424AK
510, 511	Beluga-Smokey Bay complex	88.4	Lower Bench Toe Slopes	Rangeland	R170XD424AK
571	Island silt loam	0	Shallow Kettles	Rangeland	R170XD407AK
573	Kachemak silt loam	3.3	Loamy Slopes	Rangeland	R170XY201AK
610	Kidazqeni silt loam	680.2	*Betula papyrifera-Picea glauca/Alnus-Oplopanax horridus/Calamagrostis canadensis*	Forestland	F170XY004AK
611	Killey and Moose River soils	975	Willow - Grass (Riparian)	Rangeland	R170XY408AK
618, 622	Mutnala silt loam	46.8	*Picea glauca-Betula papyrifera/Calamagrostis canadensis-Equisetum arvense*	Forestland	F170XD443AK
632	Niklason very fine sandy loam	319	*Betula papyrifera-Picea glauca/Alnus-Oplopanax horridus/Calamagrostis canadensis*	Forestland	F170XY004AK
643	Redoubt silt loam	16.2	*Populus balsamifera/Oplopanax horridus*	Forestland	F170XY445AK
649	Riverwash	115.0	None assigned		
652, 653	Slikok peat	307.9	*Picea mariana/Empetrum nigrum-Betula nana*	Forestland	F170XY412AK
656, 657	Smokey Bay silt loam	18.1	Lower Bench Toe Slopes	Rangeland	R170XD424AK
673	Spenard peat	0	*Picea glauca-Betula papyrifera/Menziesia ferruginea/ Gymnocarpium dryopteris*	Forestland |	F170XY018AK
682, 683	Susitna silt loam	1474.5	*Betula papyrifera-Picea glauca/Alnus-Oplopanax horridus/Calamagrostis canadensis*	Forestland |	F170XY004AK
688	Beaches, tidal flats	351.9	None assigned		
696	Tutka-Kasitsna-Rock outcrop complex, very steep	175.5	None assigned		
697	Tutka-Portgraham complex, hilly to steep	751.5	None assigned		
701	Typic Cryaquents, 0 to 2 percent slopes	5094.5	None assigned		
703	Typic Cryorthents, 100 to 150 percent slopes	755.6	Alpine Ridges	Rangeland	R169XY101AK
705	Water, fresh	690.0	None assigned		
	Total acres	15251.8			

Range potential: In addition to identifying the main species of range plants likely to be found on particular soils, some soil surveys also estimate forage yields that can be expected from particular range plant communities (i.e., rangeland ecosites). This is possible because forage yields depend in large part on soil properties (as well as on seasonal patterns of temperature and precipitation, which are generally reflected in ecosite classifications). Texture, depth, wetness, available water capacity, slope, and topographic position are among the important soil properties that affect range productivity and are ascertained during a soil survey. Grouping rangeland soils according to their potential productivity helps land managers identify conservation practices most likely to increase forage yields, as well as helps them estimate the likely benefits of particular practices. Map 7-8 shows potential productivity for different rangeland ecosites in the Fox River Flats grazing lease. While these numbers are preliminary, they provide useful comparative rankings of potential productivity.

Calculating range production: Total range production is the amount of vegetation that can be expected to grow in a "normal year" in a well managed area that is supporting the potential natural plant community. It includes all vegetation, whether or not it is palatable to grazing animals. It includes the current year's growth of leaves, twigs, and fruits of woody plants, but not the increase in stem diameter of trees and shrubs. In a "normal year," growing conditions are about average.

Total range production is expressed in pounds of vegetation (weighed when air-dry) per acre per year. Yields are adjusted to a common percent of air-dry moisture content. In the grazing lease area, the following soil map units were rated in terms of total range production and are shown on Map 7-8:

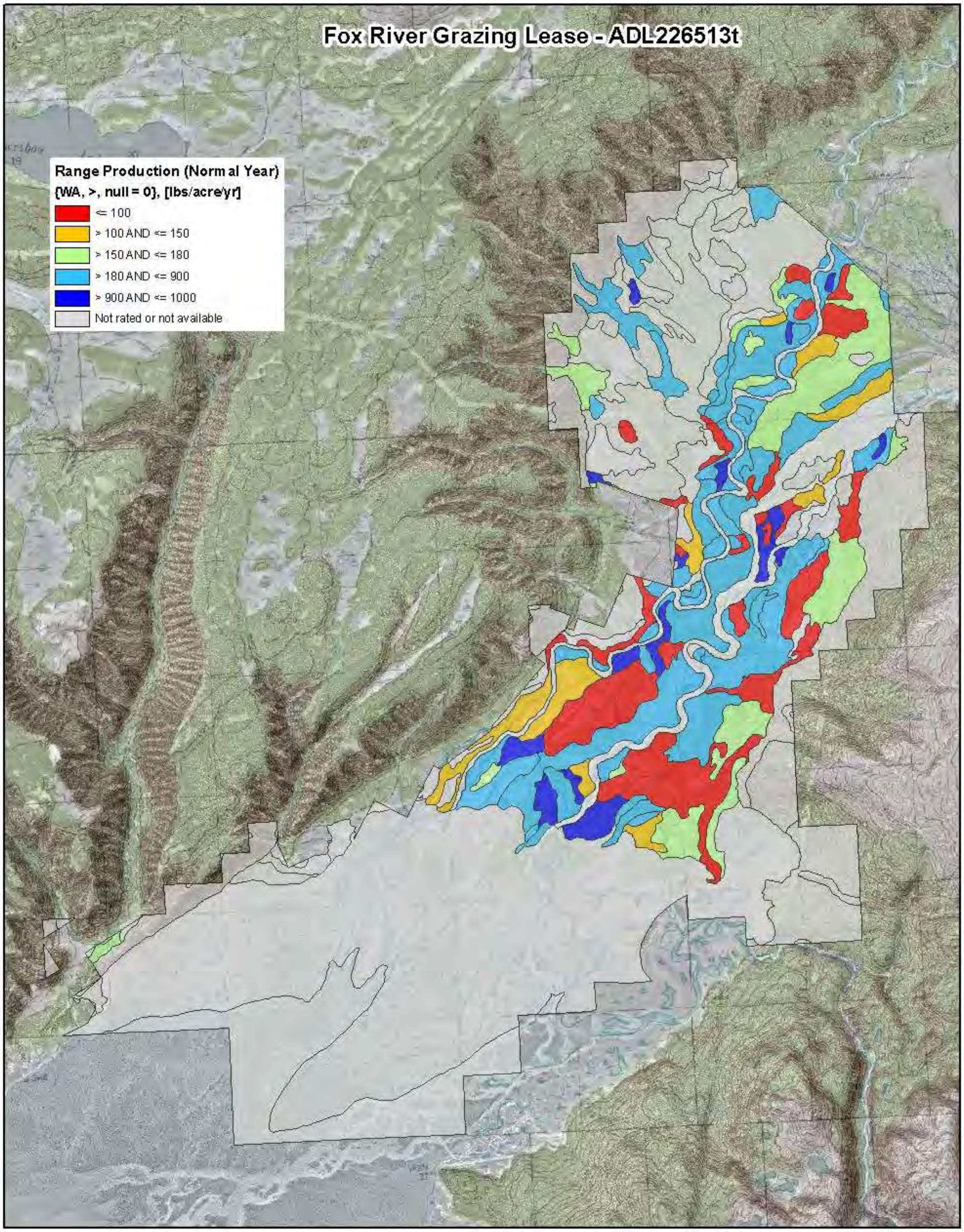
- 501 Aquic Cryofluvents, 0 to 2 percent slopes 100 lbs/ac/yr
- 502 Aquic Cryofluvents, shallow, 0 to 2 percent slopes 150 lbs/ac/yr
- 610 Kidazqeni silt loam, 0 to 2 percent slopes 900 lbs/ac/yr
- 611 Killey and Moose River soils, 0 to 2 percent slopes 180 lbs/ac/yr
- 632 Niklason very fine sandy loam, 0 to 2 percent slopes 1000 lbs/ac/yr
- 682 Susitna silt loam, 0 to 2 percent slopes 850 lbs/ac/yr
- 683 Susitna silt loam, 4 to 8 percent slopes 850 lbs/ac/yr

Weighted Average Aggregation Method: A map unit (e.g., 506, 673, 701) is typically composed of one or more "components." A component is either some type of soil or some non-soil entity, e.g., rock outcrop. The components in the map unit name (e.g., "Killey and Moose River soils, 0 to 2 percent slopes," "Susitna silt loam, 4 to 8 percent slopes") represent the major soils within a map unit delineation (i.e., a map unit "polygon" on a soil survey map). Minor components make up the balance of the map unit. For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Great differences in soil properties can occur between map unit components and within short distances. Minor components may be very different from the major components. Such differences could significantly affect use and management of the map unit. Aggregation is the process by which a set of component attribute values is reduced to a single value to represent the map unit as a whole. Aggregation is necessary because, on any soil map, map units are delineated but components are not. The aggregation method "Weighted Average" computes a weighted average value for all components in the map unit. Percent composition is the weighting factor. The result returned by this aggregation method represents a weighted average value of the corresponding attribute—in this case, total range production—throughout the map unit. (Percent composition is a critical factor in some, but not all, aggregation methods.) Once a single value for each map unit is derived, a thematic map for soil map units can be generated, such as Map 7-8.

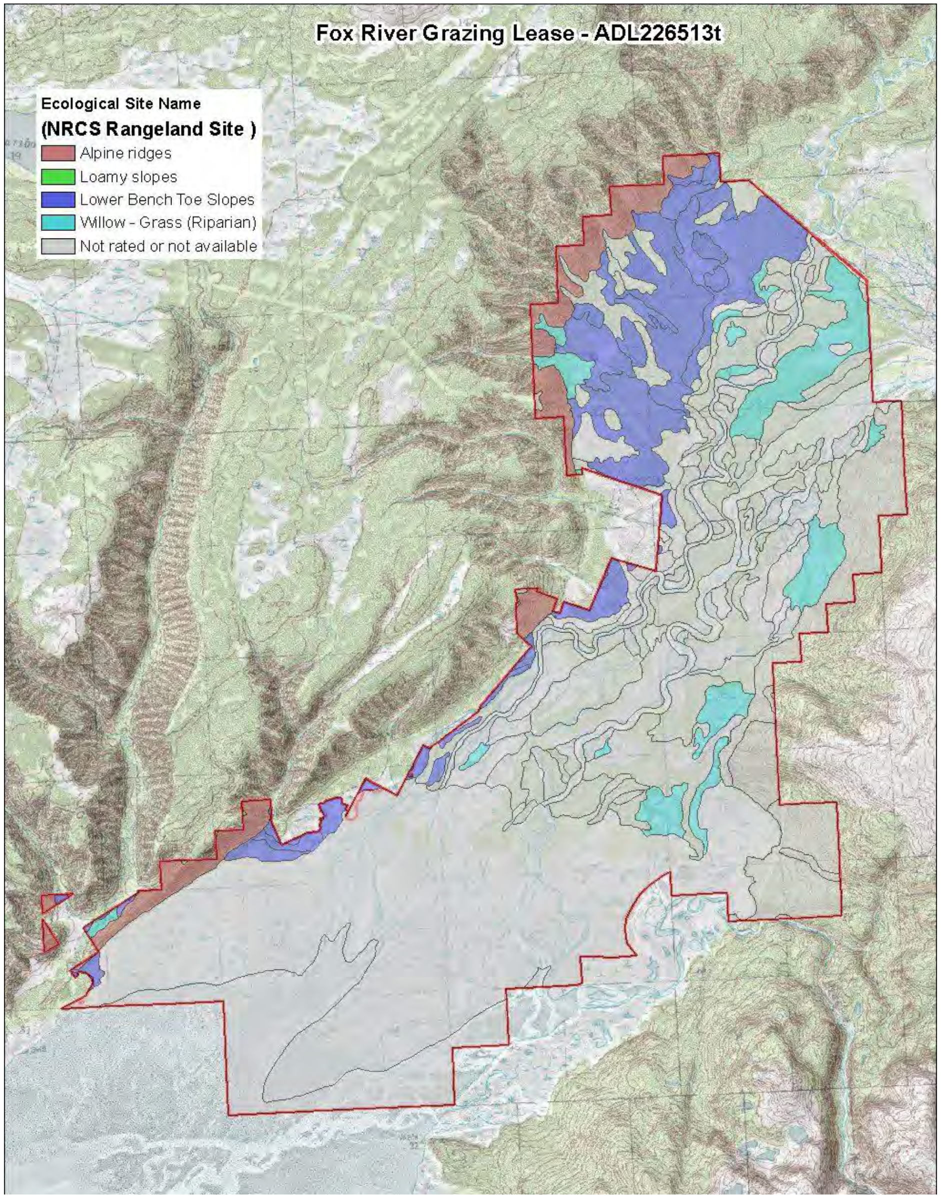
Aggregation also involves applying a tie-break rule, which indicates what value should be selected from a set of multiple candidate values, or what value should be selected in the event of a percent composition tie. In this case, ties go to the higher value. The “interpret nulls as zero” rule indicates that a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Minor components may or may not be documented in the database. The results of aggregation do not reflect the presence or absence of limitations of the components that are not listed in the database. An on-site investigation is required to identify the location of individual map unit components.

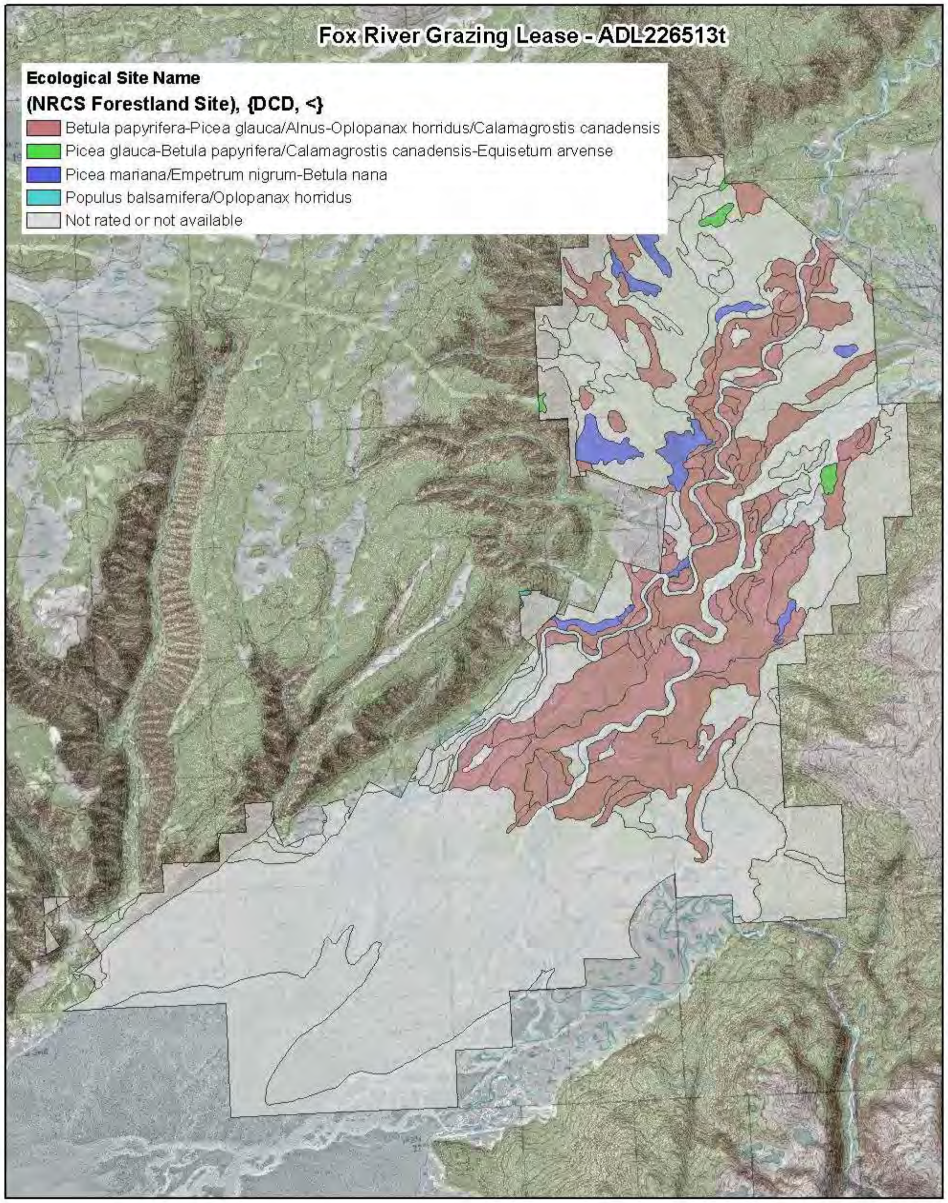
Map 7-8. Range production (in air-dry lbs/ac/yr for a "normal" year) in the Fox River Flats grazing lease.



Map 7-9. Rangeland ecosites in the Fox River Flats grazing lease area.

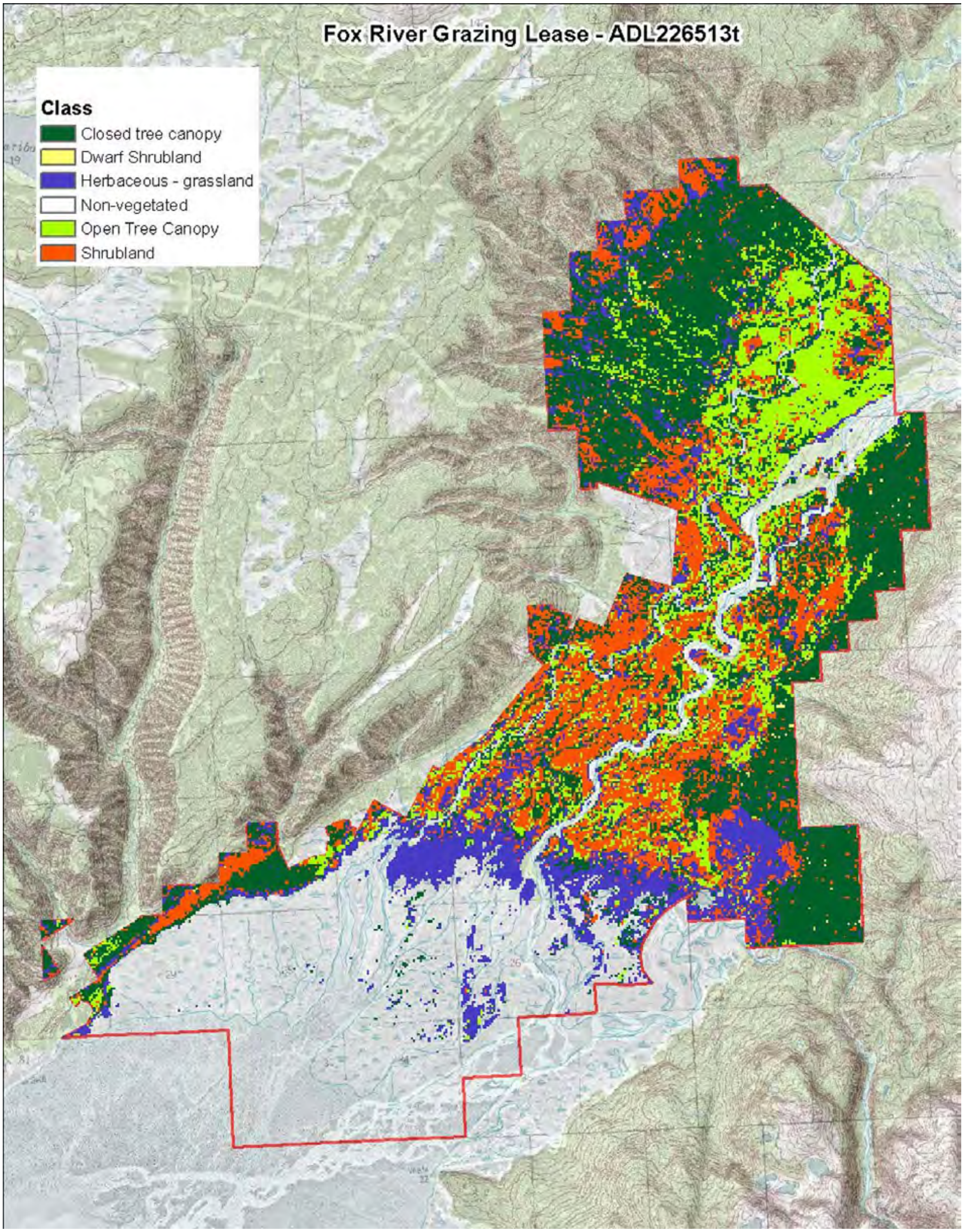


Map 7-10. Forestland ecosites in the Fox River Flats grazing lease area



Finally, soil plant community relationships can be mapped in terms of the growth form "class" of the dominant plants associated with the soil map unit—and, with forests, the degree of canopy closure. Map 7-11 shows plant communities in the Fox River Flats grazing lease area mapped in these terms.

Map 7-11. Growth form "class" of dominant plants found on soil map units in the grazing lease area (NRCS).



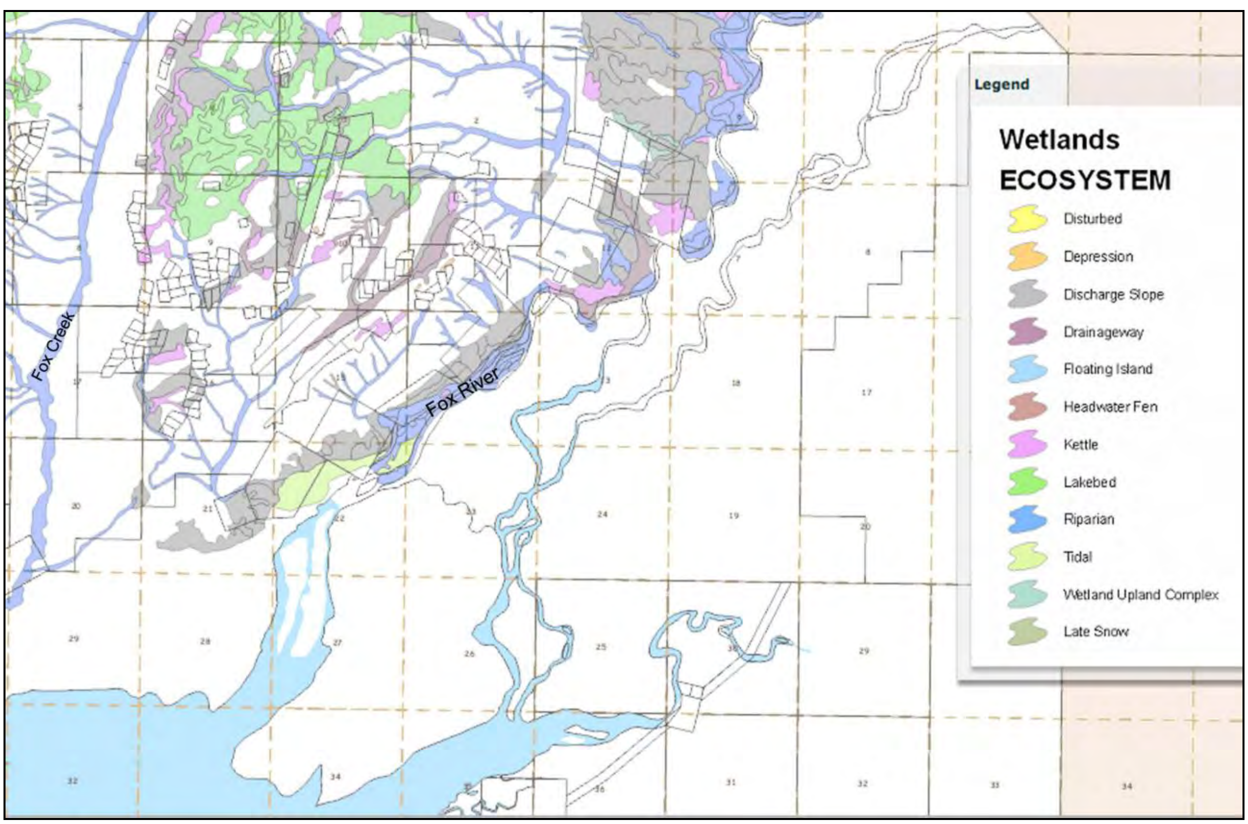
Wetlands: For regulatory purposes, the U.S. Army Corps of Engineers and Environmental Protection Agency (EPA) use the following definition of wetlands:

> Wetlands are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

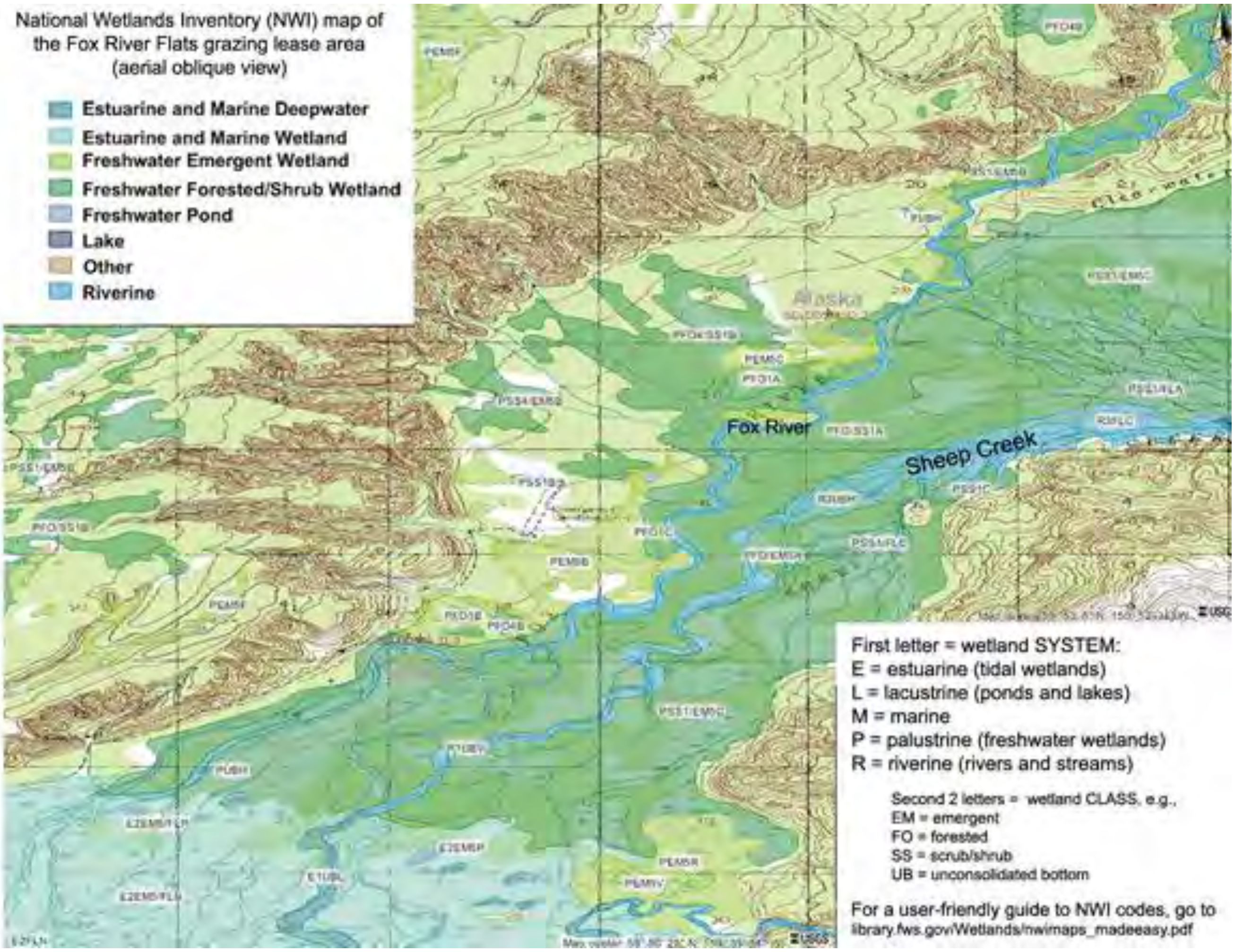
In other words, wetlands are areas where the frequent and prolonged presence of water at or near the soil surface largely determines how soils develop, which plants grow, and what fish and wildlife are likely to be present. Wetlands benefit humans in a number of ways. Examples include: storing stormwater flows (thus reducing flooding) contributing to "base flows" of streams and rivers (thus maintaining instream habitats for fish and wildlife during low flow periods), filtering water (thus maintaining water quality), and providing habitats for numerous fish and wildlife species.

A variety and large expanse of wetland types are found in the Fox River Flats grazing lease area, from tidal marshes to forested muskegs to riparian corridors. Wetlands on non-federal lands in the "Kenai Lowlands" were mapped at a scale of 1:25,000 (www.kenaiwetlands.net). This mapping extended up to the western bank of the Fox River, as shown on Map 7-12. East of Fox River, wetland maps are available only at a scale of 1:63,360 as part of the National Wetland Inventory (NWI) mapping conducted by the USFWS (http://wetlandsfws.er.usgs.gov/imf/imf.jsp?site=NWI_AK). Map 7-13 shows NWI-mapped wetlands in the Fox River Flats grazing lease area.

Map 7-12. Wetlands mapped at 1:25,000 scale up to the west bank of Fox River (www.kenaiwetlands.net). (Wetland plant communities listed in the map legend are described in detail in www.kenaiwetlands.net/.)



Map 7-13. NWI wetlands in the Fox River Flats grazing lease area (mapped at 1:63,360 scale).

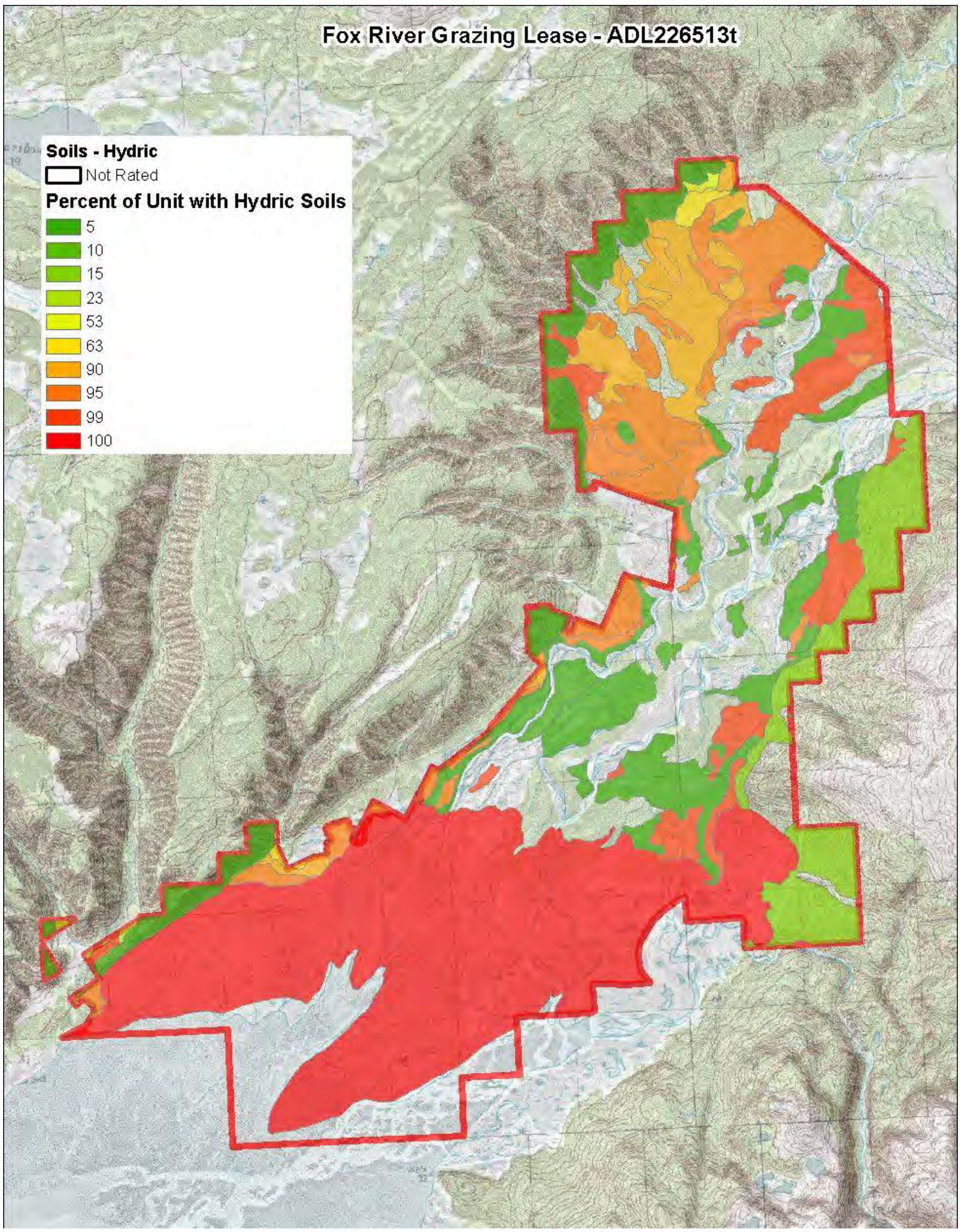


Hydric soils (see also discussion of hydric soils under Soils, above): Locations of wetlands in the Fox River Flats grazing area can also be approximated by mapping hydric soils using 1:25,000 soil survey data. As discussed under Soils and Total Range Production, each soil map unit delineation includes "components" that have not been delineated on the soil maps, and these may be similar to or different from the dominant component. As a result, some soil map units that are rated as "hydric" may include components that are not hydric, as well as components that are. Map 7-14 shows these relationships as derived from information about soils in the grazing lease area.

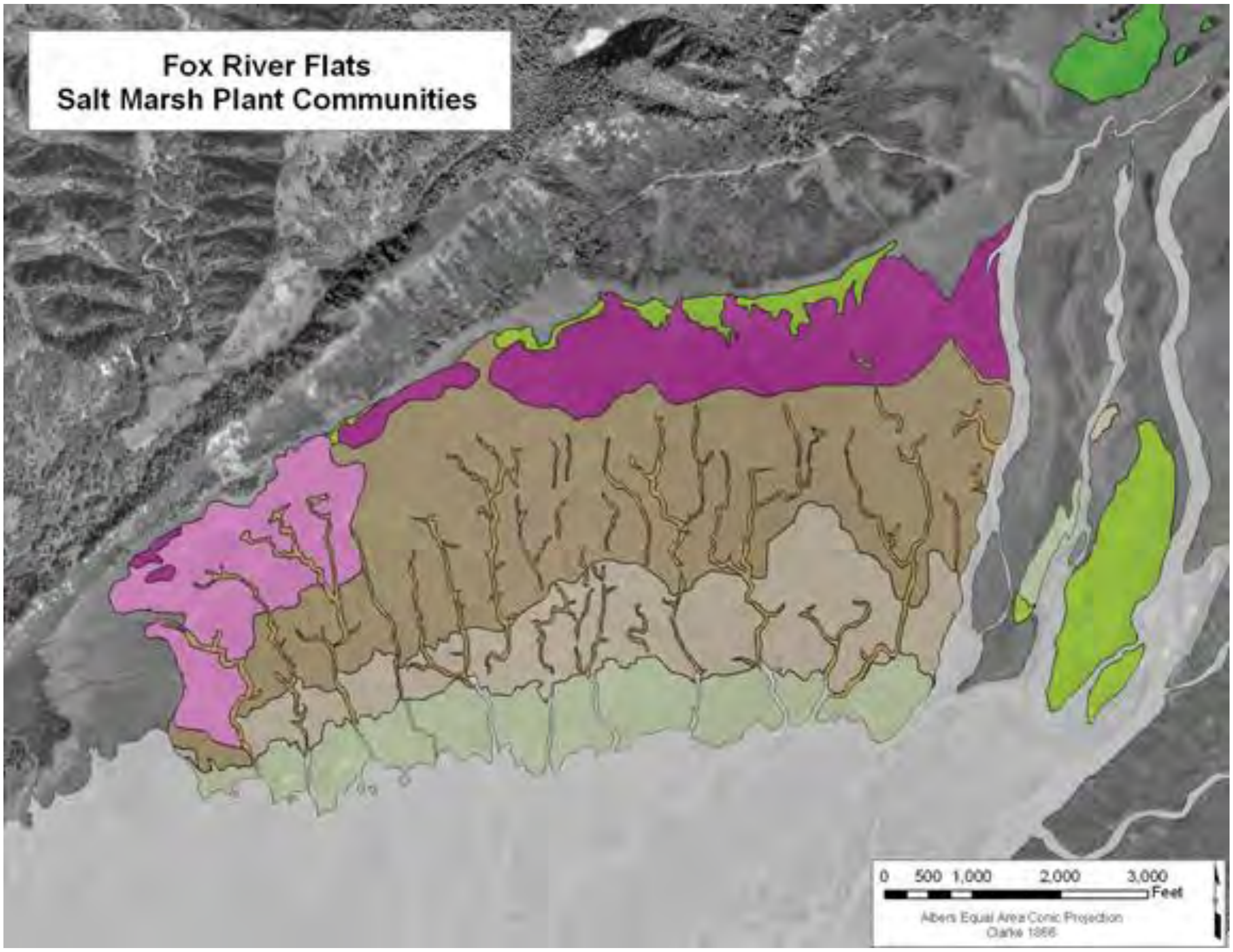
Tidal marsh: The Fox River Flats has one of the few large tidal marshes on the Kenai Peninsula. Although Alaska has a high percentage of the nation's wetlands, it has only 4 percent of the country's vegetated tidal marshes. Kachemak Bay supports two different tidal marshes: the Fox River Flats and China Poot Bay. Tidal marshes typically develop at river mouths (and behind barrier beaches and spits) that are protected from wave action. In these relatively low energy environments, fine sediments suspended in the water column can settle out, building up elevated areas on which marsh plants can establish themselves. In the Fox River Flats, large quantities of silt, clay, and sand are deposited by Fox River, Sheep Creek, and Bradley River to form an ever-shifting tidal delta.

Rising and ebbing tides rework marshland sediments and determine what plants grow where. While few terrestrial plants tolerate submersion in saltwater, halophytes (salt-tolerant plants), such as alkali salt grass (*Puccinellia hulteni*) and sedge (*Carex* spp.), flourish where estuarine influences prevent competition from less salt-tolerant plants. Spatial zonation of plant communities is common in tidal marshlands (Map 7-15 and Figure 7-4). In the Fox River Flats, for example, stands of Lyngbye's sedge (*Carex lyngbyei*) dominate upper tidally influenced zones, while Ramensk's sedge (*Carex ramenski*) is found just seaward. Intertidal plant communities mapped by KBRR clearly show tidally influenced zonation (Map 7-15). Figure 7-3 illustrates the extent of tidal variations to which marshland plants must adapt.

Map 7-14. Soil map units in the grazing lease area in terms of percent of hydric components (NRCS).



Map 7-15. Saltwater plant communities showing zonation along tidal gradients (from KBRR)



Plant community zonation is shaped by several environmental factors, including tide heights (which determine frequency and duration of inundation), other salinity/freshwater mixing patterns—both spatial and temporal, water and air temperatures, substrate texture and elevation, surface drainage patterns, microclimates, and soil type. Localized zonation can occur within a larger plant community pattern depending on the "resolution" of microhabitat variables.

Seaward, salinity is closest to that of seawater. Inshore, as seawater mixes with freshwater, salinity decreases (see Figure 7-2, above). Salinity gradients should be especially evident in the Fox River Flats tidal marsh. Here tidal ranges can be extreme due to relatively level topography, a tidal range of up to 28 feet, and the fact that Fox River and Sheep Creek seasonally provide large volumes of freshwater—especially when warm summer temperatures increase glacial melting.

Figure 7-3. Tidal range on Fox River Flats (tidal heights modeled with LiDAR data) (source: KBRR).

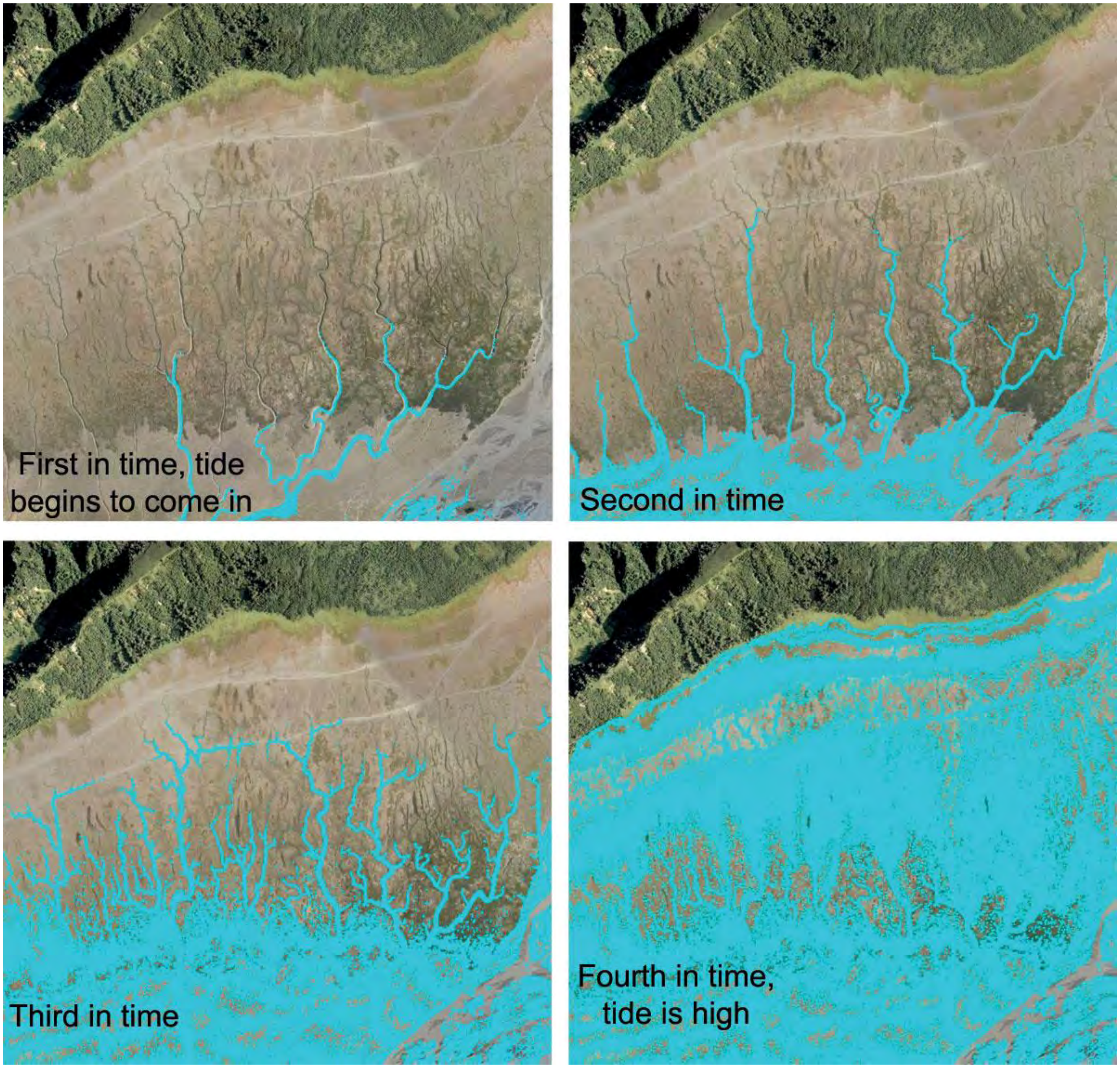
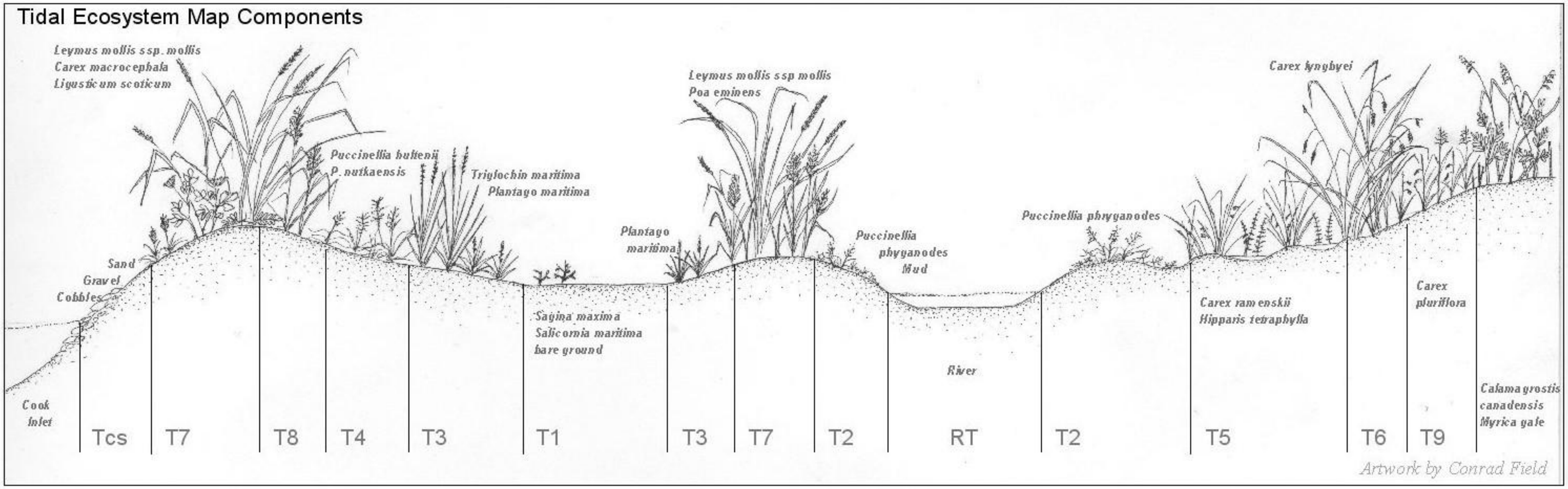


Figure 7-4. Plant relationships along gradients behind an idealized beach berm along Cook Inlet (from Gracz et al. 2008, www.kenaiwetlands.net/).



Key to tidal wetlands mapped in the Kenai Lowlands (partially edited) from Gracz et al. 2008, www.kenaiwetlands.net/.

T0- Bare mud

T1- saltpannes. Sparse, low glasswort (*Salicornia maritima*) and pearlwort (*Sagina maxima*).

T2- Mud with creeping alkaligrass (*Puccinellia phryganodes*). Inundated 26-46 times per summer (mean = 34).

T3- Bare ground with goosetongue (*Plantago maritima*) and seaside arrowgrass (*Triglochin maritima*). Inundated 6-13 times per summer (mean = 8).

T4- Alkali grass (*Puccinellia nootkaensis* and *P. Hultenii*) dominates, usually with a beachrye (*Leymus mollis* ssp. *mollis*) component. Inundated 10-20 times per summer (mean =15).

T5- Ramensk's sedge (*Carex ramenskii*) dominates with pools. Mare's tail (*Hippuris*), spikerush (*Eleocharis spp.*), saltmarsh starwort (*Stellaria humifusa*) found in and around the pools. Inundated 0-5 times per summer (mean = 3).

T6- Lyngbye's sedge (*Carex lyngbyei*) cover nearly continuous. Inundated 0-4 times per summer (mean = 2).

T7- Beachrye (*Leymus mollis* ssp. *mollis*) diverse plant community on storm berms. Inundated 0-2 times per summer (mean = 1).

T8- Pacific silverweed, largeflower speargrass (*Poa eminens*) and sometimes circumpolar reedgrass (*Calamagrostis deschampsioides*) dominate. Inundated 0-2 (mean = 1), and 8-13 (mean = 11) times per summer, respectively.

T9- Upper reaches of low gradient river mouths; dominated by manyflower sedge (*Carex pluriflora*). Inundated 0-2 times per summer (mean = 1).

RT- More than two non-consecutive units at a scale too small to map. Typically formed where gradients are steep, such as along larger tidal guts or at mouths of large streams.

(TL- Tidal Lagoon, one polygon in a lagoon, Mariner Lagoon, at the west side of the base of the Homer Spit.)

Tcs- Barren sand, gravel, cobbles, and some boulders, at the high storm line below bluffs.

Leaves, stems, and other parts of saltmarsh plants slow down flowing water, reduce erosion, and trap sediments. This builds up substrates and helps maintain elevational variation, creating microhabitats. Roots and rhizomes help bind marshland soils. (Rhizomes are horizontal, usually underground, stems that often send out roots and shoots from their nodes. *Carex* spp., for example, have rhizomes.)

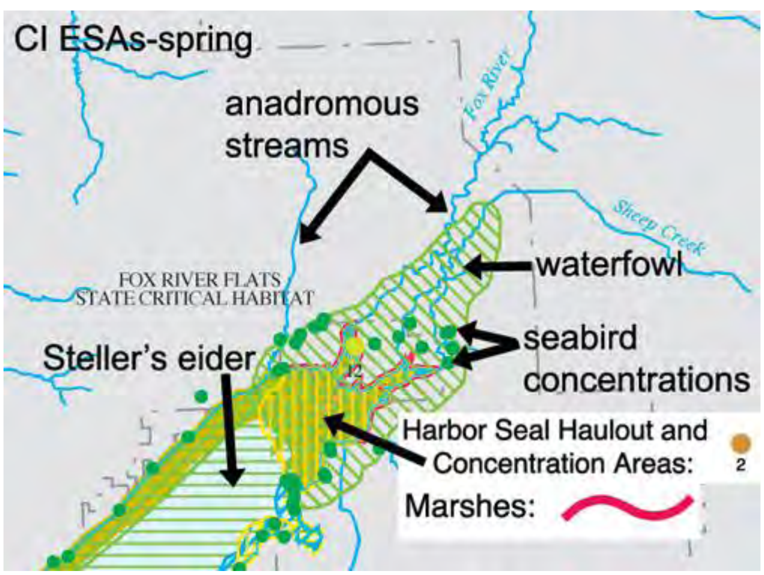
Tidal marshes form the basis of important estuarine food webs. The large quantities of plant material produced in tidal marshes support abundant communities of diatoms and invertebrates. Dead plant (and animal material) enters the detrital food chain, feeding microbes and invertebrates, which in turn become food for larger animals. Some plant litter washes out into the bay with the tides, some remains in the marsh, contributing to the organic content of marshland soils.

In Alaska, earthquake-caused land subsidence, on the one hand, and uplift due to isostatic rebound and tectonic processes, on the other, drastically affect marsh development and succession. During the 1964 earthquake, the Kenai Peninsula subsided by as much as 4 feet, substantially lowering Cook Inlet marshes. Despite subsidence, alluvial sediments from Fox River, Sheep Creek, and Bradley River have caused Fox River Flats marshlands to build up (aggrade) toward pre-earthquake elevations. An illustration of this is discussed in Section 8, for NRCS rangeland monitoring Site 4, *Carex lyngbyae*.

7.3.5. Animals

Species of birds, mammals, and fish that are highly valued by humans—both visitors and local residents, are supported in the Fox River Flats area. This section provides a brief overview of key species in the flats. As noted earlier, much of this information was obtained from ADF&G 1993 and KBRR 2003.

Map 7-16. Section of map: Cook Inlet "ESAs," Spring



When managing areas for fish and wildlife, identifying areas that are most productive or valuable for one or more species, as well as areas that are particularly vulnerable to damage, represents a useful process. Environmentally Sensitive Areas (ESAs) and Environmental Sensitivity Index (ESIs) maps have been developed for Kachemak Bay, including the Fox River Flats area. Map 7-16 shows the Fox River Flats area as depicted on a map of "Cook Inlet and Kenai Peninsula, Alaska, Environmentally Sensitive Areas: Spring (April-May)" (map labels were modified for this CRMP). This map is one of four seasonal maps showing Cook Inlet "environmentally sensitive areas" (ESAs). ESA maps were published in 1997 to provide a regional overview of Cook Inlet and Kenai Peninsula environmentally sensitive resources that would receive priority protection during oil spill planning and response[4].

Environmental resources depicted on the ESA maps were selected on the basis of their high sensitivity and/or vulnerability to spilled oil or their special management status. Several areas in Kachemak Bay were identified as "Most Environmentally Sensitive Areas," or MESAs. Maps 7-17 through 7-19 show MESA maps for the Fox River Flats. Original MESA maps can be found at: www.wc.adfg.state.ak.us/index.cfm?adfg=refuge.fox_river.

Birds

The Fox River Flats Critical Habitat Area is recognized as providing significant habitats for birds, particularly for migrating shorebirds and waterfowl. Fox River Flats/Kachemak Bay are designated as a "Site of International Importance" in the Western Hemisphere Shorebird Reserve Network (WHSRN). The basis for this designation is that this area supports more than 100,000 shorebirds annually (www.whsrn.org/western-hemisphere-shorebird-reserve-network)[5]. Numbers of birds using the Fox River Flats peak during spring and fall, when concentrations of migratory birds rest and feed in the flats on their way to breeding grounds (in the spring) and over-wintering areas (in the fall).

Kachemak Bay's tidal marshes are well known as seasonally critical nesting, resting, and feeding habitats. In the spring, Canada geese feed on goose tongue and other newly emerged vegetation. In spring, summer, and fall, mallards, pintails, American wigeon, and green-winged teal can be found feeding in brackish ponds, while scaup, scoter, goldeneye, and merganser feed in nearshore waters of the bay. Trumpeter swans are known to concentrate on the flats during migration. Gulls are usually present and, in the proper season, sparrows, warblers, and swallows can be observed. Several bald eagle nests have been found in cottonwood trees along the edge of the flats.

The birds of Kachemak Bay and Fox River Flats were studied during assessments of potential environmental impacts of the Bradley Lake Hydroelectric Project. These studies are summarized in the Resource Inventory section of the Fox River Critical Habitat Area plan (available online). Excerpts relevant to the Fox River Flats are included here in Table 7-4. Since these studies were completed, few (if any) additional systematic bird surveys of the Fox River Flats have been conducted (Matz, pers. commun.)

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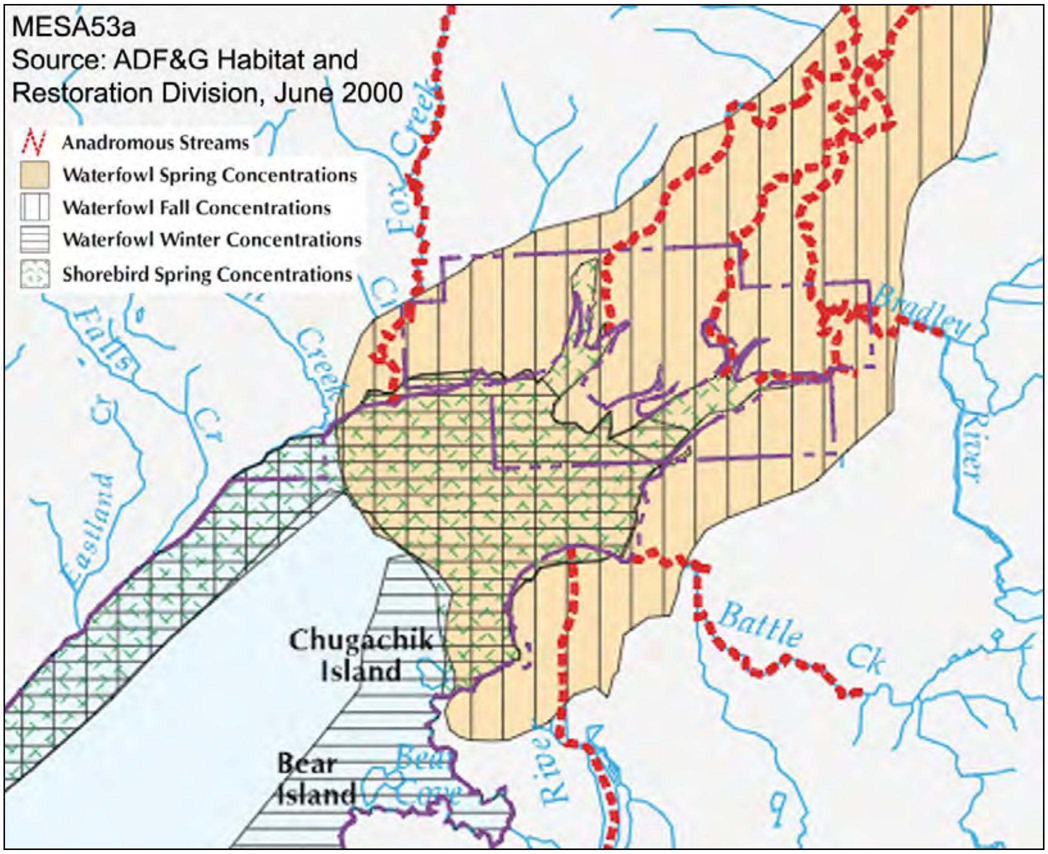
[4] The partnership that developed the maps was spearheaded by the Alaska Regional Response Team (ARRT), which is made up of US Coast Guard District 17; EPA, Region 10; and the Alaska Department of Environmental Conservation (ADEC), Division of Spill Prevention and Response, Prevention and Emergency Response Program. Mapping assistance was provided by Alaska State Geo-Spatial Data Clearinghouse (ASGDC). Funding for the project was provided by the US Coast Guard District 17, Cook Inlet Spill Prevention and Response, Inc., and Cook Inlet Regional Citizens Advisory Council. To obtain Cook Inlet maps online, go to: www.asgdc.state.ak.us/maps/cplans/subareas.html (Prevention and Emergency Response Subarea Plan Maps) and click on "3. Cook Inlet" under the Subarea Maps heading. ESI and MESA maps can be found in lists of available material.

[5] The Western Hemisphere Shorebird Reserve Network (WHSRN, pronounced "whissern") is a conservation strategy launched in 1986 by a consortium of organizations. The Network's mission and strategy are to identify and protect key habitats throughout the western hemisphere in order to sustain healthy populations of shorebirds.

Maps 7-17. Anadromous streams and waterfowl concentration areas in the grazing lease area.



Map 7-18. Seabird colony and seabird concentration areas in the grazing lease area.

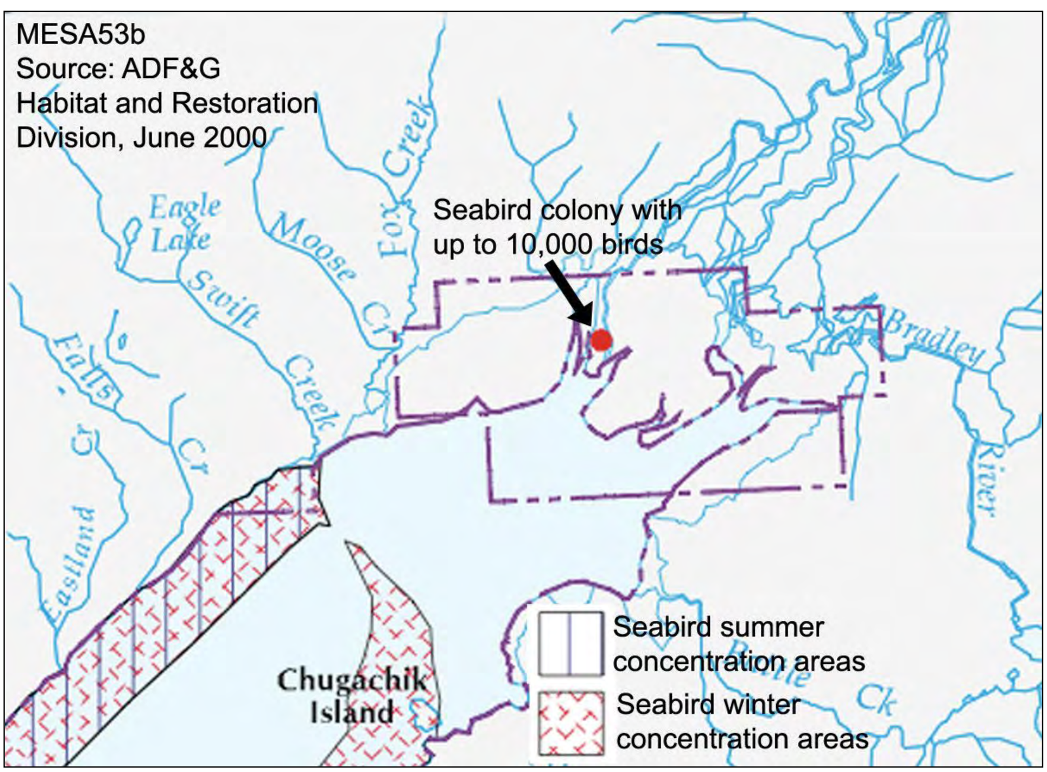


Table 7-4. Information on key bird species (compiled from ADF&G 1993 and KBRR 2003)

	Shorebirds
species	Thirty-one species of shorebird, many in significant numbers, occur regularly in Kachemak Bay. Thirty-six species have been recorded, including 4 plovers, 30 sandpipers, and the black oystercatcher. Three species predominate: western sandpipers (*Calidris mauri*) are by far the most numerous, followed by surfbirds (*Aphriza virgata*) and rock sandpipers (*Calidris ptilocnemis*). Dunlins and dowitchers are also present.
migration	Shorebirds make long-distance migrations between summer breeding and winter foraging areas, which requires great strength and endurance. Very significant proportions of the world population of both western sandpiper and surfbird stop over in Kachemak Bay every spring (West 1993, ADF&G 1993). Western sandpipers probably fly non-stop from Puget Sound to the Copper River Delta, depleting their energy reserves. Senner and West (1978) and Senner et al. (1981) hypothesized that small shorebirds, enroute from their Copper River Delta stopover to western Alaska breeding grounds, cannot store enough energy to fly all the way and, therefore, must make intermediary stops on the mudflats of Kachemak Bay. The spring migration north is generally a more focused and quicker activity than the fall migration south (Morris 1996). Shorebird migration peaks in early-to-mid May. Fox River Flats attracts the most migrating shorebirds of any area in Kachemak Bay and is a critical rest stop. A brief pulse of millions of migrating shorebirds each spring provides Kachemak Bay with its largest influx of shorebirds. An estimated 1-2 million small shorebirds were observed on an aerial survey of the Fox River Flats on May 11, 1976. Over 600,000 were counted in the Flats in the 1990s (ADF&G 1993), but those numbers appear to have declined recently. Shorebird surveys have identified no alternatives to the Fox River Flats and Mud Bay concentrated staging areas in Kachemak Bay, highlighting the need to protect these habitats from degradation (ADF&G 1993). Typically, each bird spends about 4 days feeding in the Bay before moving west and north to breed. The return, or southward migration, begins at the end of June with the non-breeders. Migration continues through July as unsuccessful breeders and parents not responsible for care of young make the trip. These are mostly females who spent the most energy producing eggs and, therefore, need greater time on staging areas to feed and replenish their reserves (West 1993). The rest of the adults, followed by juveniles of the year, move through the Kachemak Bay area between August and mid-October, with their numbers diminishing in September (West 1993). During migration, shorebirds use a succession of staging areas and a variety of habitats for resting and feeding. Generally, these are shallow wetlands with mudflats that are surrounded by short, sparse vegetation (WetNet 1999). Shorebirds are highly dependent on the resources found at the staging areas along their migrations (Environment Canada 1999). Many species concentrate together at these relatively limited staging areas along their extensive migratory routes (Morris 1996). This makes them very vulnerable to environmental change, particularly when large percentages of entire populations gather in one place at one time.
habitats	Most shorebirds are commonly found in tidal environments, where they spend roughly half their lives feeding. The rest of the time is spent in flight, on migration, or living in wet meadows or upland grassy fields (Terres 1991).
foods	During migration and on their wintering grounds, shorebirds feed mainly on invertebrates (Morris 1996), such as small clams, polychaete worms, and amphipod crustaceans (Thurston 1996). Most probe with their bills for invertebrates burrowing in intertidal sediments. Ten of fifteen western sandpipers collected at Fox River Flats in the late 1970s had eaten *Macoma balthica*; total numbers of this clam accounted for 30% of the birds' diet (Senner and West 1978). Shorebird species are distributed throughout the tidal zone, partitioning food resources largely on the basis of bill length and somewhat on the basis of leg length (Thurston 1996). As a result, mixed flocks of several different species can feed together in the same area, utilizing different food items without depleting the resources (Thurston 1996). On the summer breeding grounds, the abundant insect populations comprise the bulk of the shorebirds' diet (Morris 1996).
Population trends	Shorebird populations are decreasing worldwide due to wetland habitat loss and other impacts (Thurston 1996, West 1993, Harrington and Perry 1995). Soil erosion from deforestation, overgrazing, and other sources can alter sediment transport, thereby affecting the rich invertebrate populations on which the shorebirds feed. Pollution accumulating in wetlands from boats and runoff also can lead to chronic disturbance for resting, feeding, and nesting shorebirds. Shorebirds concentrated in on the Fox River Flats may be adversely affected by some human activities. Krasnow (1981) recommended limiting construction activities and low-level helicopter flights over Fox River Flats from April 30 to May 11.

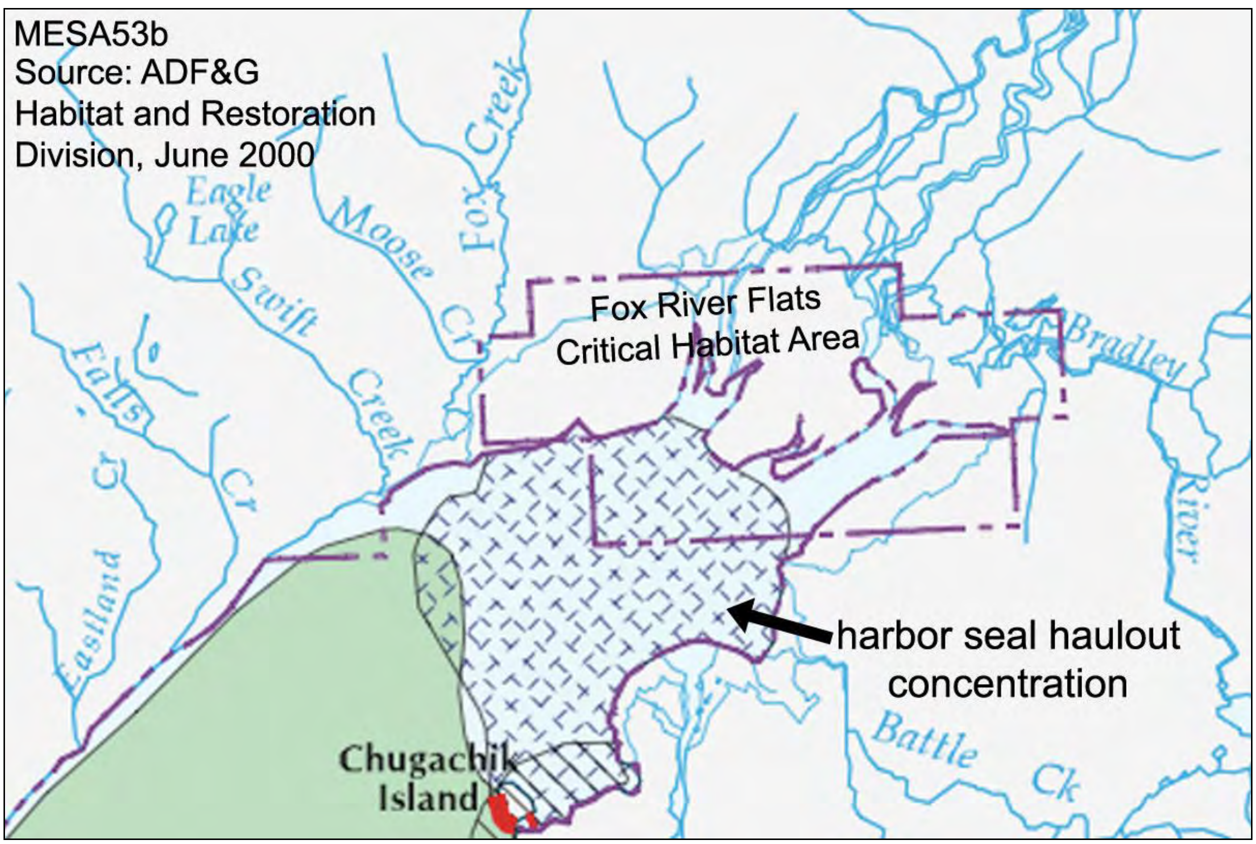
Gulls	Gulls are the most second most abundant bird group in Kachemak Bay. Gulls are most abundant along the northern shoreline of outer Kachemak Bay near Bluff Point and at the end of Homer Spit, where they feed on cannery waste (Erikson 1977). Concentrations of feeding gulls, kittiwakes, terns, and seabirds are attracted to the Bradley River-Sheep Creek estuary and mouth of the Martin River by runs of sandlance and smelt (USACE 1982). Parasitic, pomarine, and long-tailed jaegers are also present.
Terns	Arctic terns are known to nest in small numbers on… [the] Fox River Flats… In late July, arctic terns begin to congregate in Kachemak Bay. These terns presumably come from other areas in Cook Inlet as well as the Kachemak Bay area. They are joined by a few Aleutian terns, some probably from the breeding colony near Lampert Lake. Tern numbers begin to decrease after mid-August and by late August few are left in the bay (Erikson 1977).
Waterfowl	
species	Dabbling ducks, geese, and swans are the most common waterfowl on the Fox River Flats. The most common ducks on the Fox River Flats are mallards and common mergansers (Krasnow and Halpin 1981). Scoters are one of the most numerous ducks in spring, and this is reflected in their predominance in prehistoric middens on Chugachik Island. Canada geese are the most numerous geese. Snow geese, white-fronted geese, and brant have also been sited in the spring. Trumpeter swans are common on the Fox River Flats, primarily near the confluence of Bradley River and Sheep Creek, during spring and fall migration (ENTRIX and Stone & Webster 1985). Swans begin to stage in the Fox River Valley in mid-August. Densities during spring and fall average 2.6 swans/mi^2. Swans are only occasionally observed in summer and winter. The only area where nesting has been observed is on a pond near Clearwater Slough (Lensink 1980, Krasnow 1981).
migration	Fox River Flats is the major spring staging area for geese and ducks in Kachemak Bay (Erikson 1977). Geese feed primarily along the southern boundary of the Fox River Flats Critical Habitat Area and on the Martin River delta (Erikson 1977). Krasnow and Halpin (1981) found geese primarily in the intertidal marsh between Swift Creek and Bradley River. Mallards congregate on the southern edge of the Martin River delta as soon as ice melts (Krasnow and Halpin 1980). At high tide in both spring and fall, up to several thousand mallards, pintails, scoters, and mergansers congregate offshore between Swift Creek and Fox River. Trumpeter swans are known to concentrate on the flats during migration. During fall migration, large numbers of dabbling ducks begin arriving in Kachemak Bay in late July and early August (Erikson 1977, Lensink 1980). [One of the] …primary fall staging areas [is] Fox River Flats… Pintails are the most abundant fall migrants (Erikson 1977); typically by the end of August, most pintails have departed (Lensink 1980). Most sea ducks begin migrating slightly later than the dabblers. Major sea duck habitat in Kachemak Bay includes the entire shallow shelf from Homer Spit to Fox River Flats. Approximately 11,000 scoters were observed along the north shore of the bay in mid-August 1976 (Erikson 1977). In fall, geese stage primarily within the Fox River Flats CHA. Most white-fronted geese arrive and depart in August (Lensink 1980). The maximum number seen at any one time was 900 on the saltwater-influenced sedge flats between Sheep and Fox rivers. These wetlands contained preferred foods, such as *Puccinellia phryganodes*, P. hultenii, and *Carex ramenskii*. Canada geese arrive 1-2 weeks later than white-fronted geese and remain on the Flats through September (Lensink 1980).
foods	In the spring, Canada geese feed on goose tongue and other newly emerged vegetation. In spring, summer, and fall, mallards, pintails, American wigeon, and green-winged teal can be found feeding in brackish ponds, while scaup, scoter, goldeneye, and merganser feed in nearshore waters of the bay. Some birds, such as the trumpeter swans (*Olor buccinator*) can eat as much as 20 pounds of pondweed (P*otamageton* sp.) and sedges (*Carex* sp.) per day (Watson et al. 1981). Ducks, such as the northern pintail and green-winged teal, feed on Ramenski's sedge (*Carex ramenski*), creeping alkali grass (*Puccinellia phryganodes*), and alkali salt grass (*Puccinellia hulteni*) stems and seeds. Another alkali grass (*Puccinellia hultenii*) is also important for dabbling ducks such as the mallard, northern pintail, and green-winged teal. In Cook Inlet marshes, Carex, Scirpus, Potamogeton, and Hippuris comprise most of the vegetative matter eaten by mallards and pintails in summer and fall (Timm and Sellers 1979). Many ducks also hunt invertebrates, such as snail (*Littorina* sp). and euphausids that live in the tidal marsh and on the mudflats (Alaska Department of Fish and Game 1993). For example, forbs and snails (probably *Littorina*) are important for pintails, and euphausids are important for mallards.
breeding	Fox River Flats is also the major waterfowl breeding area in Kachemak Bay (Erikson 1977), primarily because nesting habitat is scarce along the fjords and eroding bluffs that border most of the bay. Waterfowl production on the Flats is

	poor probably because much of the available nesting habitat is flooded by monthly tides of 21 or 22 feet (Timm 1977)… Few, if any, Canada geese nest in the critical habitat area (Krasnow and Halpin 1981). Fox River Flats has the greatest proportion of diving to dabbling ducks among Cook Inlet marshes, probably due to the proximity of Kachemak Bay's productive marine environment. In 1976, the density of dabbling (mostly northern pintail and green-winged teal) and diving ducks on Fox River Flats was about 26 and 20 ducks/mi2, respectively (Timm 1976). Wigeon and green-winged teal are probably the most common nesting species in Fox River Valley (Dave Erikson, pers. commun.).
Bald Eagles	The most visible and best known raptor in Kachemak Bay is the bald eagle. Eagles congregate at river mouths on the Fox River Flats in April and May when eulachon [hooligan] return to streams and commonly roost on the Fox River tide flats (Krasnow and Halpin 1981, Krasnow 1981). Eagles nest all around the bay. Several bald eagle nests have been found in cottonwood trees along the edge of the flats, however, the highest densities of active and inactive nests occur along the southern shore.

Mammals

Marine mammals: Several species of marine mammals use the Fox River Flats. Harbor seals haul out regularly on the tide flats. Small pods of beluga whales can be seen near the head of Kachemak Bay feeding on herring and "hooligan" (eulachon) in the spring and on salmon in the summer. Map 7-19 shows harbor seal haulout areas identified during MESA mapping (see discussion above for explanation of MESA maps).

Map 7-19. Harbor seal haulout concentration area in the grazing lease area.



Land mammals: At least 21 species of terrestrial mammals are known to inhabit Fox River Flats and the intertidal zone of Kachemak Bay. Moose move down the valley from the hills during winter months, concentrating along the edges of the flats to feed on willows and other winter forage. Black and brown bears, coyotes, red fox, and wolves use the flats and adjacent valleys for hunting, reproduction, shelter, and other survival purposes. Mink, ermine, muskrat, and river otter are also present. Lynx and wolverine are occasional visitors. Snowshoe hares, voles, and shrews provide prey for larger predators, both birds and mammals. Use of the flats by selected species is summarized in Table 7-5. This information is largely derived from the ADF&G's Fox River Flats Critical Habitat Area Resource Inventory and KBRR's Kachemak Bay Ecological Characterization.

Table 7-5. Use of the Fox River Flats grazing lease area by selected mammals species.

Moose habitat use	Moose are highly mobile animals whose home ranges typically encompass a mix of habitats, including areas of abundant, high quality browse; shelter areas with access to food; aquatic feeding areas; isolated sites for calving; young forest stands with deciduous shrubs and forbs for summer feeding; mature forests for shelter from snow or heat; and mineral licks. Studies indicate that on the Kenai Peninsula moose have home ranges averaging 20 square miles. Most moose move between calving, summer feeding, rutting, and wintering areas. Use patterns often involve elevational change, e.g., use of higher elevations during summer and lower areas with less snow accumulation in winter; food availability is the principle driving factor. Deep, crusted snow can lead to malnutrition and subsequent death of many moose, also decreasing survival of the succeeding year's calves. Moose may travel from a few miles a day to as many as 60 miles during their seasonal transitions. Tendency to migrate and routes followed are learned by calves as they accompany their mothers in the first year of life. The Fox River Flats is a major moose calving area and a critical wintering area for migratory moose populations that summer in the Caribou Hills, near Eagle Lake, and in the lower Bradley Lake regions. Surveys suggest that Clearwater Slough and Sheep Creek are heavily used during fall rut, winter, and spring. The migratory population has been observed entering Fox River Valley from late November to early December and leaving from late February to mid-June.
behavior	Moose are active throughout the day with activity peaks during dawn and dusk. Their eyesight is poor but their hearing and sense of smell are excellent and so compensate. Due to a shortage of cones in their retinas, which provide color sensitivity, moose are color-blind. Their retina is composed mainly of rod cells, so they see the world as a spectrum of varying greys. Rods also provide excellent low-light and motion capability, but do not give moose the acuity or sharpness of detail typical of human visioin. They communicate through a variety of vocalizations, noises, body posturing, and odors. Although not normally aggressive, moose can be very aggressive when hungry, tired, or harassed by people, dogs, or vehicles. During the mating season, bull moose are often more aggressive toward people. Cows with young calves are very protective and will attack humans venturing too close. A moose is threatening a charge if the long hairs on its hump are raised and its ears are laid back. An aggressive moose may also lick its lips. Charges may only be "bluffs," however they should be taken seriously, and even a young calf can cause significant injuries given its size. When a moose does charge, it often kicks forward ("strikes") with its front hooves. Charging moose tend not to chase very far. Moose can run up to 35 miles per hour (55 km/h) for short periods and are good swimmers—able to sustain a speed of 6 mph (10 km/h).
reproduc-tion	The mating period (rut) for moose occurs between late September and early November. Gestation lasts about 230 days. Calves are generally born from mid May to early June, often as twins, sometimes as triplets. Moose cow milk is very high in fat and other nutrients, so calves grow quickly and can browse and follow their mothers at 3 weeks of age. Calves are generally weaned in the fall, at the time the mother is breeding again, but stay with their mother until she bears another calf the following spring. Cows aggressively chase their offspring from their immediate area just before giving birth to their next calves.
food	Moose are most abundant in recently burned areas that have propagated dense stands of willow, aspen, and birch shrubs, on timberline plateaus, and along major rivers, such as Fox River and Sheep Creek. Like cattle, moose are selective browsers rather than grazers; they are ruminants and chew their cud. In summer, moose feed on succulent, nutritious green vegetation, including horsetail, pond plants, other forbs, and grasses. They also eat lichens and leaves stripped with their bottom lip from willows, birch, aspen, and cottonwoods.

	In fall and winter, moose feed on woody plants, including large quantities of willow, birch, and aspen twigs, as well as peeled-off bark. In spring, they graze on a variety of green foods as soon as they become available, particularly sedges, horsetail (*Equisetum* spp.), pondweeds, and grasses.
population	Estimates of moose abundance differ, in part because the density and visibility of moose on the flats depends on winter conditions. Holdermann (1982), summarizing ADF&G aerial surveys of the entire Fox River drainage from 1964-1974, found an average of 155 moose (range 57-310) in November and December. Woodward-Clyde Consultants (1984) estimated 18-25 moose are permanent residents of the Fox River Valley; and that at least 70 were winter migrants from Caribou Lake and the Boxcar Hills that made their way to the valley between late November and mid-June. Most of the moose have been counted in the valley north of the critical habitat area. Data suggest densities of moose in the area range from 1.4 per square mile on the saltwater sedge flats to 1.9 per square mile on the edge of the freshwater sedge meadows and thickets. One intensive winter survey along Clearwater Slough that was conducted under good conditions with high visibility estimated a density of 40 moose per square mile (ADF&G 1993).
Black bear	Black bear are common at the head of Kachemak Bay. Most have been observed along the sedge flats between the Bradley and Martin Rivers (estimated at 8-12 bears) and in the Fox River Valley. Black bears are not common in the saltwater sedge flats of the Fox River Flats Critical Habitat Area, however, their use of this area appears to be highly seasonal. After emerging from dens in spring, bears are attracted to coastal flats to eat grass and early herbaceous plants. Bear numbers in the flats also increase from August to denning, when they appear to be attracted to lower elevations by berries.
Brown bear	Brown bear are generally not common on the flats. However increasing occurrences of brown bear predation on cattle suggest that their numbers may be increasing in the grazing lease area or, alternatively, that local populations are learning to take advantage of this seasonal food source. Like black bears, brown bears are also attracted to the flats by lush plant growth in spring. As many as three adult brown bears have been observed on the flats at one time in early May. Some brown bears are also attracted to the Fox River Valley by salmon, and perhaps by berries in fall. Brown bear on the Kenai Peninsula may be somewhat geographically isolated from other populations by the narrow isthmus (10 miles wide) that connects the peninsula to the Southcentral Alaskan mainland. Brown bear genetics may reflect this long-term isolation.
Coyote	Coyote tracks are often seen and calls heard in Fox River Valley.
Wolf	Wolves are rarely observed on the Flats; however, their tracks have been seen. They prey on moose in the flats and adjacent valleys, particularly following heavy snows at higher elevations.
Wolverine	Wolverine are opportunistic hunters and scavengers. They have been observed in the Bradley River drainage and can be expected to use the Fox River valley. In Alaska, resident males appear to have home range between 200-260 square miles. Resident females have home ranges as large as 115 square miles. Home range size and use patterns are thought to be a response to the availability of food or, for adult females, the presence of persistent snow cover for denning. Studies in Southcentral Alaska found that wolverines preferred higher elevations during summer and lower elevations during winter due to varying food availability. Data indicate that wolverines will move long distances in short periods to take advantage of food resources.
River otter	Observations suggest that river otter are relatively abundant along parts of Sheep Creek and Fox River, and they have been reported as abundant along the lower Bradley River.
Beaver	Beaver are not currently abundant in the Fox River Flats; however, evidence indicates that high populations occurred in the past along wooded margins near open water. Trapping may have eliminated local populations.
Small mammals	The common northern red-backed vole is probably the most abundant small mammal in grassy areas of the flats, as well as Sitka spruce forests and alder swamps. Tundra voles are also very common on the north side of Kachemak Bay. Snowshoe hare can be expected to use alder and willow shrublands intermixed with spruce forests. Their populations tend to exhibit cycles of abundance and sharp decline. Excellent climbers, porcupines use wooded areas and shrublands. Major winter foods are the inner bark (phloem and cambium layers) of spruce and birch, as well as spruce needles. Spring and summer foods are buds and young green leaves of birch, aspen, cottonwood, and willow (until tannin levels build too high for porcupines to tolerate).

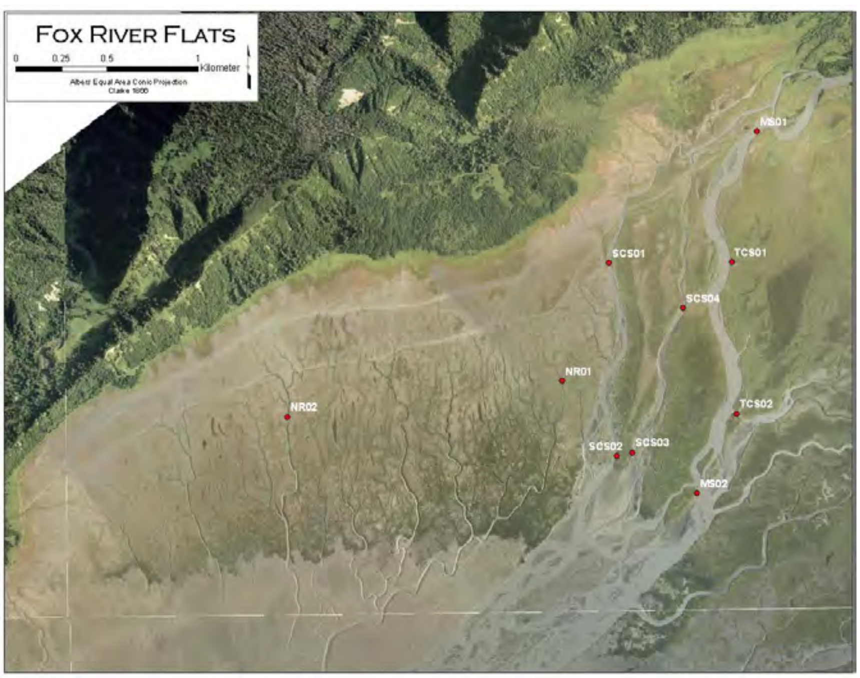
Fish

Fox River, Sheep Creek, Bradley River, and Fox Creek, are anadromous fish streams (see Map 7-17). They support coho (silver), chum, and pink salmon. Sockeye (red) salmon can be found in Fox River and Fox Creek. Chinook (king) salmon have been recorded in Fox River, as have Dolly Varden.

In 2009, KBRR initiated research on fish use of Fox River and its tributaries (Coowe et al.). Little research has been done on how juvenile salmon use estuaries. The Fox River Flats provides an accessible area suitable for such studies. In 2009, KBRR sampled a number of sites (Map 7-20) to determine where fish were present, compare potential sampling methods, and select methods to use in subsequent field seasons. Fish were found in all areas sampled, with the largest numbers found in Fox River tributaries. KBRR plans to continue this research annually, sampling fish populations, fish stomach contents, invertebrates present, and selected water parameters (discharge, temperature, salinities, etc.) throughout the summer field season (late May/early June to October/ November).

The KBRR study will focus on Fox River tributaries—especially the timing of fish movements into and throughout these drainages—as well as on the diets of juvenile fish. In 2009, the stomachs of about 30 fish were collected, revealing that chum salmon feed differently from silvers. (For example, silvers feed near the surface, so they concentrate on flying insects.) In 2010, KBRR began using "fallout traps" to collect flying insects (a soap layer traps the insects in the water). KBRR also took benthic cores to look at bottom-dwelling organisms and detritus collecting in bottom sediments.

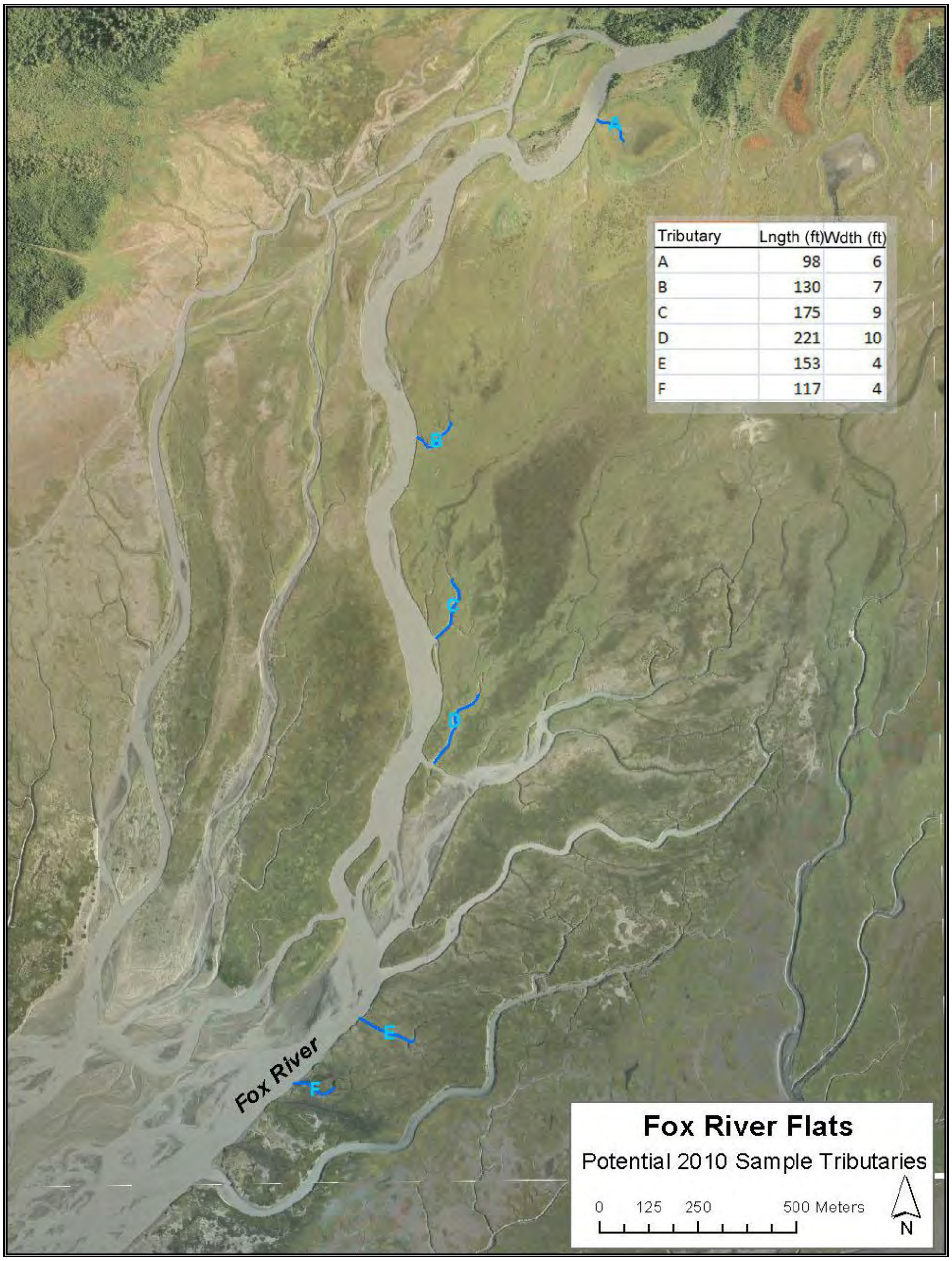
Map 7-20. Areas sampled for fish by KBRR in 2009.



In 2010, KBRR sampling efforts focused on tributary channels to the mainstem of the Fox River (Map 7-21). By late May, when sampling began, juvenile sockeye salmon were already abundant (at least two age classes), as well as juvenile coho (three age classes). Dolly Varden were also present, along with 3- and 9-spine sticklebacks and sculpin species.

Streambank conditions are being noted at fish- and water-sampling locations. Repeated photo documentation of stream-banks at consistent GPS locations/compass directions could be included in KBRR sampling activities at little additional cost. Such a photo record would provide "first-cut" but nonetheless useful information about streambank conditions. Sites at which bank degradation or other noteworthy changes are occurring could be visually identified from the photos. Because stream channel and bank characteristics are affected by numerous processes with high short- and long-term variability (e.g., day-to-day, week-to-week, month-to-month, and year-to-year changes in precipitation, temperatures, soil moisture, plant cover, animal and human impacts, etc.), and because this variability occurs in "patchy" patterns and intensities over the landscape, understanding the causes of streambank change observed at photo-documented sites would require careful analysis. [This section will be supplemented based on Coowe's report for the 2010 field season.]

Map 7-21. Fox River tributaries sampled for fish by KBRR in 2010.



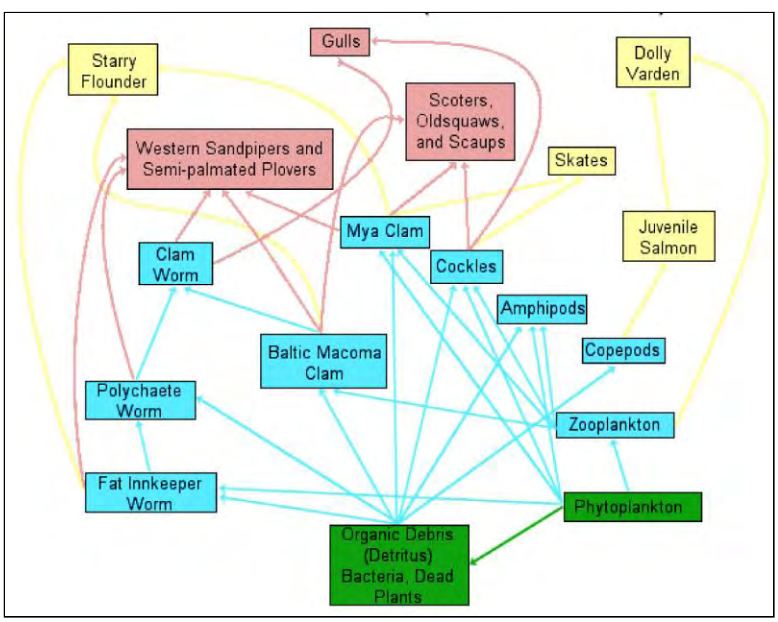
Intertidal Invertebrates

A brief word about intertidal invertebrates is warranted because of their significance to food webs in the Fox River Flats Critical Habitat Area, particularly intertidal areas where cattle regularly graze at low tides. This material is predominantly from *Ecological Characterization of Kachemak Bay* (KBRR 2001).

Intertidal habitats in the flats are extremely variable and dynamic: they are both deltaic—subject to ever-shifting alluvial deposition and redistribution of glacial sediments—and estuarine—subject to seasonally fluctuating freshwater flows mixing with saltwater brought in and carried out by ocean tides. (Kachemak Bay's 28-foot tidal range from low to high tide is the fourth largest in North America.) This local variability is in addition to the variability typical along coasts in southcentral Alaska, including seasonal temperature extremes and disturbances caused by storms and shifting sea ice (from slush ice to floes). Each intertidal habitat—from sheltered tidal flats with little wave energy to steep cobble beaches exposed to pounding surf—supports distinct invertebrate communities. Among the members of these communities are microscopic zooplankton and larger clams, polychaete worms, amphipods, and others. Of the unconsolidated habitats, mudflats support the greatest species diversity and biomass, and cobble beaches support the lowest. Among sheltered intertidal habitats, areas with relatively constant salinities support more diverse ("species rich") communities than areas with large variations in salinities.

Food webs in intertidal areas of the Fox River Flats are generally based on detritus and/or macrophytes (literally "big plants," meaning emergent, submerged, or floating aquatic plants other than microscopic algae). Figure 7-5 shows a conceptual model of an intertidal food web based on detritus. Most plant biomass in a saltmarsh or mudflat dies and enters the detrital food web, where the major consumers are bacteria and fungi. (One estimate is that less than 10% of the above-ground primary plant productivity in a saltmarsh gets grazed by birds, mammals, fish, or invertebrates.) Currents carry detritus to soft-bottom communities from adjacent habitats. The same slow currents that cause deposition of fine sediments also deposit detritus, much of which is then incorporated into the sediments. Bacteria and fungi are consumed by the smallest animals—worms, copepods, rotifers, larval stages of benthic invertebrates, in other words, by plankton. Bigger benthic invertebrates tend to be either scavengers (crabs, snails) or filter feeders (clams, mussels).

Figure 7-5. Simplified schematic of a detrital food web (from *Ecological Characterization of Kachemak Bay*, KBRR).



Most mudflat dwellers are deposit or filter feeders that live within the substrate and glean minute organic particles from the sediment or water column. There are also some predatory worms and gastropods. Filter-feeding clams and deposit-feeding worms convert the detritus into biomass. Because large macrophytes cannot attach to loose and shifting substrates, primary productivity can be limited in soft bottom areas. However, eelgrass and algae species, such as sea lettuce (*Ulva* spp.), do grow on the surface, and microscopic phytoplankton live on and between large silt and clay grains. The walls of extensive burrows created by species, such as fat inkeeper worms (*Echiuris echiuris alaskensis*) and softshelled clams, create oxygenated surface areas upon which microbial life can thrive, thus increasing primary productivity.

Trophic dynamics in mudflats are sensitive to shifts in productivity of “donor” communities. Changes in the productivity of phytoplankton, macroalgae, or marsh communities will affect mudflat residents, as well as shorebirds, flatfish, and other organisms that rely on mudflats for food, spawning, or nursery habitats. (www.ozcoasts.org.au/indicators/salinity.jsp).

Most aquatic organisms function optimally within a narrow range of salinity. When salinity changes to above or below this range, an organism may lose the ability to regulate its internal ion concentration, and “osmoregulation” may become so energetically expensive that the organism dies due to direct physiological effects or becomes more vulnerable to predation, competition, disease, or parasitism. As a result, shifting salinity distributions can affect the distributions of macrobenthos, as well as those of rooted vegetation and sessile organisms. In addition, the nature of the longitudinal salinity gradient (and the position of certain isohalines) is an important factor in the successful recruitment of larval and juvenile fish. Salinity is also an important control on the types of pathogenic organisms and invasive species that can occur in coastal waterways, on the types of species that can occur in algal blooms, and on the activity of nitrifying and denitrifying bacteria. As a general rule, widely varying salinity regimes tend to select for a low-abundance and low-diversity suite of species, which are adapted to a broad range of ionic concentrations (e.g., euryhaline species) (www.ozcoasts.org.au/indicators/salinity.jsp).